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NATIONAL ACADEMY OF SCIENCES.

VOL. VII.

FIRST MEMOIR.

ON THE BOMBYCINE MOTHS.

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MONOGRAPH

OF THE

BOMBYCINE MOTHS OF AMERICA NORTH OF MEXICO,

INCLUDING

THEIR TRANSFORMATIONS AND ORIGIN OF THE LARVAL MARKINGS AND ARMATURE.

PART I.

Family 1.—NOTODONTIDÆ.

BY

ALPHEUS S. PACKARD.

THE BOMBYCINE MOTHS OF AMERICA NORTH OF MEXICO.

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I.—INTRODUCTION.

For some years past the writer has been collecting materials for a general account, systematic and developmental, of our North American Bombycine moths. The leading object or motif of the essay has been to collect materials for working out the origin of the larval forms of the higher Lepidoptera.

The attempt has been made, so far as material and opportunity have allowed, to describe in as detailed a way as possible the transformations of our Bombycine moths, in the light of the recent very suggestive and stimulating work of Weismann, entitled Studies in the Theories of Descent (1882). Until within a few years the majority of descriptions of caterpillars have been prepared simply for the purpose of identification, or for taxonomical uses, and without reference to the philosophic or general zoological significance of these changes. The transformations of some of the European Sphingidæ have been very carefully worked out by Weismann, and also by Poulton, but it is believed that the life histories of the lower, more generalized families usually referred to the Bombyces, especially of the Notodontidæ, Ceratocampidæ, Saturniidæ, Hemileucidæ, Cochliopodidæ, and Lasiocampidæ, will bring out still more striking and valuable results, inasmuch as they, or forms near them now extinct, are believed to be closely similar to the stem forms from which many of the higher Lepidoptera have probably been evolved.

The aim therefore in such studies should be—

1. To treat the larvæ as though they were adult, independent animals, and to work out their specific and generic as well as family characters.

2. To trace the origin of mimetic and protective characters, and to ascertain the time of larval life when they are assumed, involving—

3. The history of the development of the more specialized setæ (hairs), spines, tubercles, lines, spots, and other markings.[1]

[1] Besides the work of Weismann, compare also the suggestive papers of E. B. Poulton, in Transactions of the Entomological Society of London, 1884–1888, and my papers: Proceedings of the Boston Society of Natural History, xxiv–v, 1890–91.

4. To obtain facts regarding the ontogeny of our native species and genera which, when added to what we know of the life histories of European, Asiatic, and South American Bombyces, may lead to at least a partial comprehension of the phylogeny of the higher Lepidoptera, viz, those above the so-called Microlepidoptera.

The transformations of the Bombycine moths are especially noteworthy and useful for the purposes we have indicated, since the group is rich in stem forms, because of its probable geological antiquity, and because of the remarkable and significant differences presented by the larvæ of many of the groups in the numerous successive stages of their larval life, these stages being characterized by distinctive and highly modified shapes, colors, markings, and armatures. These peculiarities, signalizing nearly each stage, were, we believe, evolved in direct response to the changes in their environment, in their mode of life, or to changes in their food plants, and the necessity of being protected through unconscious mimicry from the assaults of insects and reptilian and avian enemies.

The transformations also afford the clearest possible evidence of the action of what Darwin calls "inheritance at corresponding periods of life," and which Haeckel has tersely designated as "homochronic heredity."

This fact, moreover, of inheritance at corresponding periods of life throws light on the problem so much under discussion at the present day of the transmission of characters acquired at different epochs during the life of the individual. We have devoted a section to a discussion of this question, or rather to a review of some of the facts which strongly suggest the truth of this principle.

The characters, so unexpected and striking, as for those worked out in *Heterocampa biundata*, *H. guttivitta*, and *obliqua*, for example, as well as numerous other of the Notodontians and allied families, are plainly enough useless to the insect in the pupa or imago condition, and have evidently been inherited as the result of impressions or stimuli received from without at different periods in the life of the caterpillar alone.

Such cases occur in many other Arthropods, especially in the barnacles, and in the Decapoda, as well as in the parasitic worms, but the causes can nearly as well be investigated in these insects, which are so accessible.

Another series of problems is opened up by a study of the mouth-parts of the Bombyces and of their venation, which disclose facts intimately bearing on the genealogy of the Lepidoptera.

In no other Lepidoptera has the agency of use and disuse, particularly the latter, been more marked. While the mandibles are present in certain of the *Tineina* and *Pyralidina*, they have totally disappeared from the so-called Macrolepidoptera, or higher and less generalized and primitive groups. In the Bombyces, particularly the Saturnians, the maxillæ, owing to disuse, have undergone great reduction, with complete loss of their original function. In another direction, i. e., in the veins of the wings, there has been a reduction in their number, and this is correlated with their loss of power of taking food, the great but weak wings of these colossal moths being of no use in seeking for food, which they do not need; as, unlike the swift visitors of flowers, the butterflies, Sphinges, and Noctuids, they are too feeble of flight to sip the nectar of flowers, or too short lived to need any nourishment.

The geographical distribution of the Bombyces also tends to confirm the view that they are an ancient and generalized group, and to this subject we have given special attention.

In the systematic portion of the work I have endeavored to arrange the families, genera, and even the species, in accordance with the probable phylogeny of the group. I have begun my account of the entire superfamily with what I regard as the most primitive family. The seven subfamilies of Notodontians easily fall into this arrangement; it is not difficult to perceive that the Gluphisiinæ and Dataninæ are the most generalized, and that the Cerurinæ are the most specialized, whether we study the larvæ or imagines, though much the clearest light of course is thrown upon the subject by the larvæ. It is less easy to indicate the true succession of the genera, though the way is made very plain in the subfamily of Heterocampinæ.

The proper sequence of the species in a large genus is always difficult to make out. It is obvious, however, that the old, unphilosophic method of designating such and such a species as the type of a genus, and then arranging all the others under it, is a thoughtless procedure. Usually the type species is the most modified, that most unlike its congeners, unless, as is often the case, it happens to have been the first one of its genus to have been discovered and described.

We have thought it better and more philosophical to begin with that species whose larva is the most simple and generalized, and then arrange in their natural order those whose larvae are more and more specialized or modified, as regards the number and variety of their markings, or the complexity of their armature. In the genus Ichthyura, for example, the larva of *I. apicalis* (var.) is the most simple and generalized, not having the high tubercles and bright varied markings of *I. inclusa* and *albosigma*. I have therefore supposed this to have been the first species to have evolved, and this decision is supported by the wide distribution of the species and the rather large number of varieties and subvarieties into which the form has been broken up.

In the case of the imago, that species which has plain wings without complicated bars and spots is more primitive than those with more complex markings.

This course may at times lead to error and uncertainty, and involve more or less hypothesis or guesswork, but the simple attempt will lead to a more careful scrutiny of the larval characteristics, and to a profounder, more thorough, and better knowledge of the biology of the genus, and that of course is the aim in such work. Of course the systematic part of this or any other work of the sort is a necessary preliminary to all other higher endeavors to a complete history of the group from a morphological and biological point of view.

On this account it is, we think, a great pity that some of the compilers of our check lists of Lepidoptera and other insects, and of our zoological text-books and other works of the sort, still persist to cater to the tastes, rather than true needs, of amateurs and collectors by beginning at the wrong end, i. e., with the "highest" forms rather than with the "lower" or more primitive. Such lists and works would have a far higher educational value and lead to much better mental training if such compilers could have had some knowledge of the immense impetus given to the science and the new way of dealing with systematic zoology which has resulted from the labors of Darwin, Fritz Müller, Weismann, and others.

In describing caterpillars, particularly those of the Bombyces, I have been particular to distinguish between the three thoracic and the ten abdominal segments, because the former usually differ from the abdominal segments in the number, arrangement, and relative size of the tubercles, warts, and other markings. The warts or tubercles also are grouped into dorsal, subdorsal, and supraspiracular rows (though this latter may in some cases be the subdorsal row), and an infraspiracular row or series.

In order to obtain further material to finish and to perfect this monograph of the Bombyces, the author would like to obtain from collectors and students in all parts of the country, especially in the Southern, Western, and Pacific States, the egg, larvæ, or moths, in order to fill up gaps, as well as to afford material for illustration.

Should anyone rear any of these Bombyces, with a view to publication, I should be greatly obliged for alcoholic specimens of the eggs and different larval stages, which might be sent after such descriptions were published.[1] Such specimens would be carefully kept and returned. It will only be by such cooperation that we shall arrive at a fair knowledge of the transformations of this extensive group.

This monograph could not have been prepared without generous aid from friends and correspondents, as well as from those in charge of the several museums mentioned below, whose hearty cooperation I now acknowledge.

I am specially indebted to Prof. C. V. Riley for the opportunity of freely examining from time to time his extensive collections, so rich in preserved larvæ, both blown and alcoholic, the result of years of labor while residing in Illinois, St. Louis, and in Washington, D. C. After presenting them to the United States National Museum, he has continued to allow me to examine the Bombyces, and loaned me specimens of larvæ as well as moths for study and illustration. He has also permitted the use of numerous colored sketches, made by himself or his assistants under his

[1] It is earnestly hoped that anyone receiving this memoir will kindly reciprocate by sending the eggs and larvæ of any Bombycine moths not herein described, packed in tin boxes, to the author, at Providence, R. I., or during July and August, at Brunswick, Me. We still lack the eggs and young larvæ of Ellida, Lophodonta, Drymonia, and Notodonta.

direction, and has generously turned over to me all his notes on transformations, geographical distribution, etc., his contributions very much enhancing the value of this work.

I am also indebted to the authorities of the American Museum of Natural History, New York, for the opportunity of examining the types of the late Mr. Henry Edwards, and a few types of Mr. Grote. Other material and types in the Museum of Comparative Zoology at Cambridge, Mass., of the Boston Society of Natural History, particularly the Harris collection, and the collection of the American Entomological Society at Philadelphia, have been examined, and to the authorities in charge I am specially indebted. I should also acknowledge the frequent aid rendered by Mr. Henry Edwards before his death, and the labors of those who have in former years done much pioneer work in collecting and describing the Bombyces, especially of my friend, Mr. Aug. R. Grote, now of Bremen, Germany.

Mrs. Annie Trumbull Slosson, of New York, has generously given me valuable material, and given me free access to her collection, and in this and other ways laid me under special obligations.

Mr. H. G. Dyar and Mr. B. Neumogen have freely shown me their important collections, and generously loaned specimens for illustration and study. Mr. Dyar has in a number of ways rendered most efficient aid, and has my hearty thanks. We have together made a number of comparisons, and thus arrived at results which otherwise would have been less certain.

Dr. J. A. Lintner, State Entomologist of New York, has opened his collection to me, and loaned me several colored drawings of larvæ.

From Rev. E. D. Hulst, of Brooklyn, I have received by exchange many specimens.

Dr. R. Thaxter has permitted me to examine his very valuable collection of larvæ, now in the Cambridge Museum, and Professor French, of Carbondale, Ill., has also kindly helped me. I am much indebted to Miss Emily L. Morton, of Newburg, N. Y., for eggs, larvæ, and the use of several colored drawings of Datana larvæ, etc., and for notes on their habits. To Miss Caroline E. Soule also I am under obligations for a fine colored sketch of *Nerice bidentata*.

I am also indebted to the following entomologists who have aided me with larvæ, eggs, moths, local lists, etc.: Mr. O. S. Westcott, Chicago, Ill.; Mr. Tallant, Columbus, Ohio; Mr. Graef, Brooklyn, N. Y.; Mr. Trevor Kincaid, Olympia, Wash.; Mrs. Fernald, Amherst, Mass.; Mr. Charles Palm, of New York; Mr. William Beutenmueller, in charge of the collection of insects in the American Museum of Natural History, New York, and to others whose aid is acknowledged in the course of the work.

To Mr. Joseph Bridgham, who has made the drawings of the larval stages, I am under special obligations. Besides the work of drawing, he has secured many of the larvæ, and shown the utmost pleasure in aiding me to the extent of his ability. It is to be hoped that the work of the lithographer will bring out the delicacy of color and fidelity in drawing of the artist.

I have also had ten drawings of Walker's types in the British Museum, made by Mr. H. Knight, of London, with the permission of Dr. A. Guenther, superintendent of the zoological department, to whom my hearty thinks are due; also for his courtesy in allowing me, with the kind aid of Mr. A. G. Butler, assistant in entomology, to examine some of Walker's types.

I have also had copied in the plates a number of excellent colored drawings of caterpillars, made by the late Maj. John Eatton Le Conte, which were loaned me for such a purpose by his son, Dr. John Lawrence Le Conte, a few years before his death. They were made in Georgia, presumably at Sans Souci, on the Ogeechee River, about 16 miles south of Savannah.[1]

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[1] See Scudder's biographical sketch of J. L. Le Conte, Trans. Amer. Ent. Soc., Aug., 1884, p. 9.

II.—HINTS ON THE EVOLUTION OF THE BRISTLES, SPINES, AND TUBERCLES OF NOTODONTIAN AND OTHER CATERPILLARS.[1]

It is not improbable that, as a rule, all caterpillars at first lived on grasses, herbaceous and low-growing plants generally, and that gradually they began to climb trees, as the latter became developed, and in time became adapted to an arboreal station. As is well known, no deciduous trees or flowering plants appeared in such numbers as to form genuine forests before the Cretaceous period, and about that time in geological history began to appear the kinds of insects which visit flowers and trees that blossom.

The species of the great lepidopterous family Noctuidae, of which we have in the United States alone over a thousand species, are, as a rule, low feeders. Certain species of Mamestra and of Agrotis, ordinarily feeding on grasses and low herbs, will however, especially early in the spring, ascend trees and shrubs of different kinds and temporarily feed upon the buds; and in summer a species of Mamestra will ascend currant bushes in the night and cut off the young, fresh shoots.

In the group of forms represented by Catocala, Homoptera, and Pheocyma we have true tree inhabiting caterpillars, and, like the Notodontians and dendricolous Geometrids, their bodies differ remarkably from those of the low feeders, being variously spotted and mottled with shades of brown and ash, to assimilate them to the color of the bark of the tree they rest upon, and are, besides, provided with dorsal and lateral humps and warts, to further assimilate them, in outline as well as in color, to the knots and leaf-scales on the smaller branches and on the twigs among which they feed. And then there is the small group of Noctuo-bombyces, represented by species of Apatela, Platycerura, Raphia, Charadra, and their allies, which closely "mimic" the hairy, penciled, or spiny arboreal Bombyces.[2] It should, however, be observed that this is scarcely a case of mimicry, but rather of adaptation; the presence of hairs, pencils, spines, and bristles being apparently due to the caterpillars having changed their environment from herbs to trees, and being subjected to the same conditions as the Bombyces themselves.[3]

In the exclusively low feeding caterpillars of certain groups of butterflies the body is usually smooth and adorned with lines and spots, while the general feeders and many arboreal forms are often variously spined and tuberculated, yet many spined caterpillars of butterflies feed on low herbs.[4] The Sphingidae in part feed on low plants and in part on trees, and they do not, except as regards the caudal horn, exemplify our thesis.

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[1] This section is reprinted with some alterations from an article in the Proceedings of the Boston Society of Natural History, xxiv, 1890, pp. 482–515, 556–559.

[2] Of 34 species of North America Noctuo-bombyces, whose transformations are known, all except 1 feed upon trees. (See Edwards's catalogue.)

[3] It is hardly necessary for us to express our entire disagreement with the view of Mr. A. G. Butler, that these Noctuidae are really Notodontians, or in any way allied to them. It seems to us that the characters which he uses to remove them from the Noctuidae are superficial and adaptive. Nearly twenty-five years ago I satisfied myself, after an examination of the denuded head and wings, that the Noctuo-bombyces were true Noctuidae, and did not depart essentially from the typical genera.

[4] While many, though not all, butterfly larvae, as shown by Scudder and W. H. Edwards, have spine-like glandular hairs in the first stage, which may in some cases persist into one or two later stages, the body in many species, especially in those which are not general feeders, but select low-growing, herbaceous plants, becomes smooth and ornamented with stripes or spots. However, as a rule, butterfly larvae can not be divided, as the Bombyces, etc., into high and low feeders; yet from Scudder's "Classified list of food plants of American butterflies" (Psyche, 1889) the following facts and conclusions may be stated:

Hesperidæ.—Out of 45 species enumerated, all but 6 feed on herbs and especially on grasses, and those which feed on tall shrubs or trees, such as *Epargyreus tityrus* and 5 species of Thanaos, stand at the head of the group, which, as everybody knows, is the lowest family of butterflies and nearest related to the moths.

Papilionidæ.—Of the 6 species enumerated, 3 feed on trees as well as shrubs and herbs; 1 of these, however (*P. cresphontes*), feeds on trees alone. None of this family are hairy or spined when mature, except *P. philenor*, with its peculiar flexible, spike-like growths.

Pierinæ.—Of 10 species, all feed on herbs, rarely on low shrubs, and none are armed with hairs, bristles, or spines. The other two groups (*Lycænidæ* and *Nymphalidæ*) are general feeders, occurring indifferently on herbs, vines, and trees, except the striking case of the 8 Satyrinæ, which feed exclusively on grasses and herbs (*E. portlandia*, however, sometimes frequenting the Celtis). The very spiny Argynnis larvae feed on Viola. It should also be noted

Of the great group of Geometridæ many kinds are arboreal (Dendrogeometrids), and in such cases are almost invariably tuberculated in manifold ways. We know of no hairy or tufted caterpillars of this group or of any family below them, with the exception of the Pterophoridæ.

The arboreal Pyralidæ, Tortricidæ, and Tineidæ live in such concealment, between leaves, or in buds, or as miners, that they differ little in their surroundings from the low-feeding forms, and are thus scarcely ever tuberculated or spiny; in fact, we can not recall one of these groups which are s . The Pterophoridæ are, to be sure, spiny, but they are low feeders, and their peculiar excretory setæ (the Drüsenhärchen or glandular hairs of Zeller[1]) are similar, as Dimmock has observed, to the glandular or long hairs of plants; Miss Murtfeldt adding that "there is a very close imitation in the dermal clothing of the larvæ [of *Leioptilus sericidactylus*] to that of the young leaves of Vernonia, on which the spring and early summer broods feed." (Psyche iii, 390, 1882.)

Returning to the Bombyces, all the Notodontians, without any exception, known to us have trees as their principal, if not exclusive, food plants. Thus, of the 37 species of this group whose larval forms are known, and which are enumerated in Mr. H. Edwards's "Bibliographical catalogue of the described transformations of North American Lepidoptera," together with an additional species (*Ichthyura strigosa*) omitted from the catalogue, all are known to feed on trees, unless we except *Datana major*, which feeds on Andromeda. It is noteworthy that the only species found thus far on a herbaceous plant is the caterpillar of *Apatelodes torrefacta*, which Harris found on the burdock, though usually it is an arboreal insect. This apparently omnivorous feeder resembles the species of Halesidota, all of which occur more commonly on trees than on herbs, and thus differs markedly from the majority of the Lithosians and Arctians, unless we except the Nolidæ. Now the larva of Apatelodes is hairy, the long, white hairs having scattered among them black ones, with more or less black pencils, thus resembling the peculiar yellowish or white caterpillars of Halesidota, with their black tufts and pencils. Similar forms are some of the arboreal, hairy Noctuidæ, as *Charadra deridens*. It seems evident that the resemblance to each other in such different groups is the result simply of adaptation, brought about by two factors, the primary one being a change from a low feeding to an arboreal station, and consequent isolation or segregation, and the secondary one being natural selection, the latter further tending to preserve the specific form.

It will be seen by the following review that the North American Bombyces in general, with the exception of the Arctians and Lithosians, live on trees, and this will in general apply to the Old World species. In the group of Lasiocampidæ, represented by Tolype, Artace, Heterocampa, Gastropacha, and Clisiocampa, the station is an arboreal one, none being known to feed on herbaceous plants. All the Ceratocampidæ, all the Hemileucidæ and Attaci, the Platypterícidæ, all the Cochliopodidæ (Limacodes), including both the naked and spiny genera, as well as the Psychidæ, live exclusively on trees. Of our North American Liparidæ, all are arboreal in station, except the Californian *Orgyia vetusta*, which lives on the lupine. Finally we come to the Arctians and Lithosians, whose hairy, or rather setose, larvæ in general feed on herbaceous plants and sometimes on trees, being in many cases omnivorous, while those of the Nolidæ and Nycteolidæ whose history is known, are arboreal.

Of the Zygænidæ, including the Ctenuchidæ, the species are low feeders, living on lichens, grasses, and other low plants, or upon vines. The Dioptid genus Phryganidia feeds on the oak. Of the Agaristidæ, some are low feeders, *Euscirrhopterus gloveri* feeding on Portulaca, while the majority prefer vines (Vitis, etc.). As to the boring habits of the Hepialidæ and Cossidæ, which we now consider as independent groups, related to the Tineina, rather than belonging to the superfamily Bombyces, these seem to be the result of early adaptation.

An examination of the food plants of the British species of Bombyces, taken from Stainton's Manual of British butterflies and moths (1857), gives the same results for the Old World, as will be seen by the following statements:

that many moths, Notodontians among them, which in the Northern States feed on trees alone, in the Gulf States, according to Abbott, feed on shrubs, vines, and low plants, as well as trees.

In reply to an inquiry, Mr. W. H. Edwards kindly writes me: "I do not think that the butterfly larvæ which live on trees are under more favorable conditions than low feeders as to healthiness or ease of rearing."

[1] Revision der Pterophoriden. Linnæa entom., 1852, vi, 356. Mentioned by Dimmock.

Nolidæ.—Of the 3 British species, 2 feed on the oak and 1 on the hawthorn and sloe.

Liparidæ.—Of the 12 species, all feed on trees and shrubs, except *Lælia cænosa*, which lives on reeds and other water plants. It is tufted.

Notodontidæ.—Of 24 species, 1 (*Diloba cæruleocephala*, which is smooth, with no protuberances) feeds on the hawthorn and other plants.

PlatypterICidæ.—Of the 6 species, 5 feed on trees and 1 on a shrub.

Endromidæ.—The single species is arboreal.

Psychidæ.—The 2 species, whose larval habits were known, feed on trees and shrubs.

Cochliopodidæ.—The 2 species feed on trees.

Saturniidæ.—The single British species feeds on the heather, a shrubby plant.

Lasiocampidæ.—Of 11 species, 5 feed on trees, the others on shrubs and herbs.

Noctuo bombyces.—All the British species are reported as "living on trees and shrubs quite exposed."

Bombycoidæ.—All the species of Acronycta live on trees and shrubs.

Influence of a change from low to high feeding plants, i. e., from living on an herbaceous to an arboreal station.—It appears, then, that the more typical Bombyces, such as the Ceratocampidæ, Hemileucidæ, Attaci, Notodontians, Cochliopodidæ, and Liparidæ, are arboreal in their station, their bodies being variously protected by spines, spinulated tubercles, hairs, or tufts. The group is indeed particularly distinguished for the manifold modifications undergone by what are morphologically setæ, and it is an interesting inquiry whether the great development of these spines and hairs may not have originally resulted from some change in environment, such as that from low feeding to high-feeding or arboreal habits.

It may be objected that the setæ and spines were originally due to the stimulus arising from the attacks of parasitic insects, such as ichneumons and Tachinæ, or that, as hairy caterpillars are not usually devoured by birds, these hairs and spines have originated through natural selection, and are danger signals, indicating to birds that the wearers of such hirsute and bristling armature are inedible. But while the final purpose or ultimate use of such an armature may serve the useful purpose of protection, and while natural selection may have been the leading secondary factor in the preservation of varietal and specific forms of hairy and spiny caterpillars, this does not satisfactorily account for the initial causes of the growth of tubercles, spines, etc.

If spines and hairs form hedge-like guards against the attacks of parasitic insects, why are they not developed as well in the great multitude of low feeders as in the less numerous high feeders? It may be said, however, that *Euprepia caja* is more subject to the attacks of ichneumons than almost any other larvæ. (A. G. Butler in Ann. and Mag. Nat. Hist., 1891.) Everyone knows how efficacious any hairs or bristles are in deterring ichneumons and Tachinæ from ovipositing on caterpillars, and it is well known that naked or slightly piliferous larvæ are more subject to their attacks than those which are densely hairy or spinose.

The eruciform type of larvæ.—In endeavoring to account for the origin of the tubercles and spines, as well as the hairs of caterpillars, let us glance at the probable causes of the origin of the caterpillar form, and of the more primary colors and markings of the skin.

It was Fritz Müller who, in his Für Darwin (1864), maintained that "the so-called complete metamorphosis of insects, in which these animals quit the eggs as grubs or caterpillars, and afterwards become quiescent pupæ, incapable of feeding, was not inherited from the primitive ancestor of all insects, but acquired at a later period."[1]

In 1869 Dr. F. Brauer[2] divided the larvæ of insects into two groups, the campodea form and raupen form, and in 1871[3]–1873 we adopted these suggestive views, giving the name of eruciform to the larvæ of weevils and other coleopterous larvæ of cylindrical form, as well as to the larvæ of Diptera, Lepidoptera, and Hymenoptera, all of which are the result of adaptation, being derivatives of the primary campodea type of larva. Brauer's views on these two types of larvæ were also adopted by Sir John Lubbock in his Origin and Metamorphoses of Insects, 1873.

[1] Facts and Arguments for Darwin, with additions by the author. Translated from the German by W. S. Dallas, F. L. S., London, 1869.

[2] Betrachtungen über die Verwandlung der Insekten im Sinne der Descendenztheorie. Verh. K. K. Zool. bot. Ges. Wien, 1869.

[3] Embryology of Chrysopa. American Naturalist, Sept., 1871.

While the origin of the eruciform larvæ of the Cerambycidæ, Curculionidæ, Scolytidæ, and other wood-boring and seed-inhabiting and burrowing Coleopterous larvæ in general, is plainly attributable to adaptation to changed modes of life, as contrasted with the habits of roving, carnivorous, campodeiform larvæ, it is not so easy to account for the origin of the higher metabolous orders of Diptera, Lepidoptera, and Hymenoptera, whose larvæ are all more or less eruciform. We are forced to adopt the supposition that they have independently originated from groups either belonging to the Neuroptera (in the modern sense) or to some allied but extinct group.

Restricting ourselves to the Lepidoptera; as is well known the Lepidoptera are now by some believed to have descended from the Trichoptera or from forms allied to that group. We should, however, prefer the view that the Lepidoptera, Trichoptera, and Mecoptera had a common origin from some earlier, extinct group. The similarity of the imagines of certain of the lower Tineina and certain of the smaller Trichoptera is certainly very marked, the most significant feature being the fact that the mandibles in the two groups are either absent or minute and rudimentary.

We have attempted, however,[1] to show that the larvæ of the Panorpidæ, judging from Brauer's figures and descriptions, are much nearer in shape and ornamentation to caterpillars than to case worms. Hence, it seems to us probable that the ancestral or stem form of the Lepidoptera was probably a now extinct group, somewhat intermediate between the Mecoptera (Panorpidæ) and the Trichoptera.

The primitive caterpillar.—We would suggest that the earliest type of Lepidopterous larva was allied to some Tineoid which lived not only on land but on low herbage, not being a miner or sack-bearer, as these are evidently secondary adaptive forms. It is evident, when we take into account the remarkable changes in form of certain mining Tineoid larvæ described and figured by Chambers[2] and by Dimmock,[3] that the flattened, footless, or nearly apodous mining larvæ of the earlier stages are the result of adaptation to their burrowing habits. The generalized or primitive form of the first caterpillar was, then, like that of Tineoid larvæ in general, and was an external feeder rather than a miner. The body of this forerunner or ancestor of our present caterpillars (which may have lived late in Carboniferous times, just before the appearance of flowering plants and deciduous trees) was most probably cylindrical, long, and slender. Like the Panorpid larvæ, the thoracic and abdominal legs had already becom differentiated, and it differed from the larvæ of Panorpids in the plantæ of the abdominal legs being provided with perhaps two pairs of crochets, thus adapting them for creeping with security over the surface of leaves and along twigs and branches. The prothoracic or cervical shield was present, as this is apparently a primitive feature, often reappearing in the Noctuidæ, and sometimes in the Bombycina, and always present in the boring larvæ of the Hepialidæ and the Cossidæ.

As tactile hairs, defensive or locomotive setæ, and spines of manifold shapes occur in worms, often arising from fleshy warts or tubercles, it is reasonable to assume that the piliferous warts of lepidopterous larvæ are a direct heirloom of those of the vermian ancestors of the insects. In our primitive caterpillar, then, the piliferous warts were present, eventually becoming arranged as they now are in ordinary Tineoid, Tortricid, Pyralid, Geometrid, and Noctuid larvæ.

Origin of the green color of caterpillars.—The cuticle may at first, as in that of caseworms and Panorpid larvæ, have been colorless or horn colored. But soon after habitually feeding in the direct sunlight on green leaves, the chlorophyll[4] thus introduced into the digestive system and into the blood and the hypodermal tissues would cause the cuticle to become green. Afterwards, by further adaptation and by heredity this color would become the hue in general common to caterpillars. Moreover, some of the immediate descendants of our primitive caterpillars were probably lighter in hue than others; this was probably due to the fact that the lighter-colored ones fed on the pale-green underside of the leaves, this difference becoming transmitted by heredity.

[1] Third Report U. S. Entomological Commission. Genealogy of the Hexapoda, pp. 297–299, 1883. Also American Naturalist, Sept., 1883, 932–945.

[2] American Entomologist, iii, 1880, 255–262; Psyche, ii, 81, 137–227; iii, 63, 135, 147; iv, 71. Refers to the larvæ of the "Gracilaridæ" and "Lithocolletidæ" together with Phyllocnistis.

[3] Psyche, iii, Aug., 1880, 99–103.

[4] See the important and quite conclusive footnote by Professor Meldola on p. 310 of Weismann's Studies in the Theory of Descent, Vol. 1 ("I have already given reasons for suspecting that the color of green caterpillars may be due to the presence of chlorophyll in their tissues, Proc. Zool. Soc., 1873, 153.—R. M.").

Origin of the lines.—As Weismann has shown, the primitive markings of caterpillars were lines and longitudinal bands, the spots appearing from interruptions or what may be called the serial atrophy of the lines or bands. It is not difficult to account for the origin of the dorsal line, as this would naturally be due to the presence of the heart underneath. This dorsal line is, for example, wanting in the freshly hatched larvæ of *Spilosoma virginica* and *Hyphantria textor*, but after the first molt of *S. virginica* there is a slight, diffuse dorsal line of no decided color, though after the second ecdysis it is decidedly whitish, or at least much paler than the surrounding dorsal region. In pale caterpillars the dorsal line may be darker. In the first stages of the two moths in question there are no lines or bands; only the piliferous warts. Whether the subdorsal or the spiracular lines were the first to originate is uncertain, but probably, from what Weismann has concluded from his studies of the Sphingidæ, the subdorsal arose first. In the second stage of *Spilosoma virginica* the subdorsal lines are reddish lines extending between the two subdorsal rows of alternating subdorsal piliferous warts, the line becoming more decided, however, in the third stage of this species, there being as yet no signs of a spiracular or of any lateral line. In the freshly hatched larva of *H. textor*, however, what may be the first beginnings of the subdorsal line are elongated brownish linear spots inclosing the subdorsal row of larger piliferous dots, but not reaching the sutures between the segments. These patches, however, do not in the second stage unite to form continuous lines, but two rows of decided black elongated spots inclosing the black piliferous tubercles. In the freshly hatched larva of *Edema albifrons* each of the two subdorsal lines is a row of elongated black spots connected on the three thoracic segments, but separated by the sutures along the abdominal segments.

The spiracular line is seen in the same larva of the same stage to be a yellowish band inclosing the spiracles, and there seems to be a tendency in some, if not many, larvæ for the spiracles to be inclosed and connected by a parti-colored or bright line, and for this to have a darker (as in Edema) or lighter edging. Why the spiracles themselves are so apt, as in Bombyces and Sphinges, to be inclosed by a dark or conspicuous line remains to be explained.

To return to the subdorsal lines in the pale-reddish larva of Datana, probably *D. integerrima*, these lines before the first molt are also inclosed by the two rows of subdorsal piliferous spots, and in both the first and second stages there are pale spiracular lines, which appear to be contemporaneous with the subdorsal line. In the third stage a new dark-red line is interpolated between the subdorsal and spiracular. In the fourth stage the spiracular line has disappeared, and there is a supra and an infra-spiracular pale line on the now brown, dark skin of the caterpillar. Seen from above there are four pale lilac lines, but after molting two of them disappear, and in the last stage there are only two subdorsal lines to be seen, if my colored drawings, very carefully made by Mr. Brigham, are correct. We thus see that after the subdorsal and spiracular lines are formed, others are rapidly introduced—and some may as rapidly vanish, as necessary features of certain stages—which, when they become useless are discarded.

The admirable and most suggestive work of Weismann has placed on a sound basis the theory of the origin of the lines, bands, and spots of the Sphingidæ. The additional notes by Professor Meldola and the beautiful researches of Mr. Poulton have added to the strength of the arguments of Weismann. The lines, bars, stripes, spots, and other colorational markings of caterpillars, by which they mimic the colors and shadows of leaves, stems, etc., have evidently been in the first place induced by the nature of the food (chlorophyll), by the effects produced by light and shade, by adaptation to the form of the edge of the leaf, as in the serrated back of certain Notodontians, by adaptation to the colors of different leaves and to the stems, often reddish, shades of greens, yellows, reds, and browns being as common in the cuticle of caterpillars as on the surface or cuticle of the leaves and their stems or in the bark of the twigs and branches. We (and probably others) have observed that the peculiar brown spots and patches of certain Notodontians do not appear until late in larval life, and also late in the summer or early in the autumn contemporaneous with the appearance of dead and sere blotches in the leaves themselves.

Now, to say that these wonderful adaptations and marked changes in the markings of caterpillars are due to "natural selection," and to let the matter rest there, is quite unsatisfactory. Natural selection may account for the elaboration of these larval forms with their markings after they have once appeared, but we want to discover, if possible, the original causes of such ornamentation, i. e., the primary factors concerned in their evolution. Weismann in his earlier work repeatedly asserts that these changes are due to the direct action of external conditions together with natural selection. Within a few years past many naturalists have returned to a more profound study of the causes of variation along some of the lines vaguely pointed out by Lamarck.[1] It is noteworthy that Darwin changed his views somewhat in his Variation of Animals and Plants under Domestication, and laid more stress on the influence of the surroundings than in his Origin of Species.

Neither Weismann nor other authors, however, so far as we know, have formally discussed the probable mode of origin of humps, horns, tubercles, spines, and such outgrowths in larvæ. They are so marked and so manifold in their variations in form, and so manifestly related, and in fact have so evidently been directly developed by adaptation to changes in the habits of the Notodontian caterpillars and tree-feeding larvæ in general that this group affords favorable material for a study of the general problem.

Spines and prickles in animals, like those of plants, serve to protect the organism from external attack, and also to strengthen the shell or skin; they are adaptive structures, and have evidently arisen in response to external stimuli, either those of a general or of a cosmical nature, or those resulting from the attacks of animals. It is almost an axiomatic truth that a change of habit in the organism precedes or induces a change of structure.

What has caused the enlargement and specialization of certain of the piliferous warts? As remarked by Sir James Paget, "Constant extrapressure on a part always appears to produce atrophy and absorption; occasional pressure may, and usually does, produce hypertrophy and thickening. All the thickenings of the cuticle are the consequences of occasional pressure, as the pressure of shoes in occasional walking, of tools occasionally used with the hand, and the like, for it seems a necessary condition for hypertrophy, in most parts, that they should enjoy intervals in which their nutrition may go on actively." (See Lectures on Surgical Pathology, I, p. 89, quoted by Henslow, who remarks in his suggestive work, "The origin of floral structures through insect and other agencies," that "the reader will perceive the significance of this passage when recalling the fact that insects' visits are intermittent."[2])

It is now assumed by some naturalists that the thorns, spines, and prickles of cacti and other plants growing in desert or dry and sterile places are due either to defective nutrition or to "ebbing vitality" (Geddes), or by others, as Mr. Wallace, to the stimulus resulting from the occasional attacks or visits of animals, especially mammals. It should be borne in mind that the great deserts of the globe are of quite recent formation, being the result of the desiccation of interior areas of the continents, late in the Quaternary epoch, succeeding the time of river terraces. Owing to this

[1] Herbert Spencer says: "The direct action of the medium was the primordial factor of organic evolution" (see The Factor of Organic Evolution, 1886). Claude Bernard wrote: "The conditions of life are neither in the organism, nor in its external surroundings, but in both at once" (quoted from J. A. Thompson's Synthetic Summary of the Influence of the Environment upon the Organism, Proc. Roy. Phys. Soc., ix, 1888). Sachs remarks: "A far greater portion of the phenomena of life are [is] called forth by external influences than one formerly ventured to assume" (Phys. of Plants, 1887, 191, English translation). Semper claims "that of all the properties of the animal organism, variability is that which may first and most easily be traced by exact investigation to its efficient causes" (Animal Life, etc., preface, vi). "External conditions can exert not only a very powerful selective influence, but a transforming one as well, although it must be the more limited of the two" (Ib., 37). "No power which is able to act only as a selective, and not as a transforming, influence can ever be exclusively put forward as the proper efficient cause—*causa efficiens*—of any phenomenon (Ib., 104).

[2] Henslow also adds that "atrophy by pressure and absorption is seen in the growth of embryos, while the constant pressure of a ligature arrests all growth at the constricted place. On the other hand, it would seem to be the persistent contact which causes a climber to thicken."

It may here be noted that the results of the hypertrophy and overgrowth of the two consolidated tergites of the second antennal and mandibular segments of the Decapod Crustacea, by which the carapace has been produced, has resulted in a constant pressure on the dorsal arches of the succeeding five cephalic and five thoracic segments, until as a result we have an atrophy of the dorsal arches of as many as ten segments, these being covered by the carapace. Audouin early in this century enunciated the law that in articulated animals one part was built up at the expense of adjoining portions or organs, and this is beautifully exemplified by the changes in the development of the carapace of the embryo and larval Decapod Crustacea, and also in insects. For example, note the change in form and partial atrophy of the two hinder thoracic somites of some beetles, as compared with the large prothorax, due probably to the more or less continual pressure exerted by the folded elytra and wings.

widespread change in the environment, involving a drying up of the soil, much of it alkaline, the direct influence on plant life must have been profound, as regards their protective defenses, and after spines began to develop one can well understand how their shapes should have been regulated for each species and preserved by the set of minor factors which pass current under the term "natural selection."

Animals may also, in some cases, have developed spines in response to a change of environment. If we glance over the epochs of paleontological history we shall see that at certain periods trilobites, brachiopods, ammonites, and perhaps other groups showed a tendency to become tuberculated, spiny, or otherwise excessively ornamented. These periods must have been characterized by great geological changes, both of the relative distribution of land and water and perhaps of climate and soil. Among the brachiopods, more spiny species occur in the Carboniferous period than in the earlier Paleozoic times.[1] Among the trilobites, although in Paradoxides and in other genera the genæ and sides of the segments are often greatly elongated, we only find forms with long dorsal spines at the close of the Silurian and during the Devonian.[2] There are no such spiny forms of ammonites as in the uncoiled Cretaceous Crioceras,[3] etc.

These types, as is well known, had their period of rise, culmination, and decline, or extinction, and the more spiny, highly ornamented, abnormal, bizarre forms appeared at or about the time when the vitality of the type was apparently declining. Geddes claims that the spines of plants are a proof of ebbing vitality. Whether or not this was the case with the types of animal life referred to, whether the excess of ornamentation was due to excess or deficiency of food, it is not improbable that the appearance of such highly or grotesquely ornamented forms as certain later brachiopods, trilobites, and ammonites was the result of a change in their environment during a period when there were more widespread and profound changes in physical geography than had perhaps previously occurred.

If the tendency to the production of spines in past geological times was directly or indirectly due to a change in the milieu, and if plants when subjected to new conditions, such as a transfer to deserts, show a tendency to the growth of thorns, or if those which are constantly submerged tend to throw out ascending aerial roots,[4] or if, like epiphytes, when growing in mid-air, they throw out descending aerial roots, I have thought it not improbable that tubercles, humps, or spines may have in the first place been developed in a few generations, as the result of some change in the environment during the critical time attending or following the close of the Paleozoic or the early part of the Mesozoic age, the time when deciduous trees and flowers probably began to appear.

I have always regarded the Bombyces, or the superfamily of silkworm moths, as a very ancient one, which has lost many forms by geological extinction. We thus account for the many gaps between the genera. Both the larvæ and the moths differ structurally far more than the genera of Geometrids and of Noctuidæ, and the number of species is less. The two latter families probably arose from the great specialization of type in Tertiary times; while evidently the great

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[1] Although there are spiny brachiopods in the Silurian, they become more common in the Devonian (e. g., *Atrypa hystrix, Chonetes scitula, C. coronata, C. muricata, Productella hirsuta, P. hystricula, P. rarispina,* and *Strophalosia productoides*), and are apparently more numerous in the Carboniferous formation (e. g., *Productus longispinus, P. nebrascensis, Chonetes ornata, C. mesoloba, C. variolata, C. salmaniana, C. setigerus* (also Devonian), *C. fischeri*, etc., *Productella newberryi*, besides the Permian *Productus horrida*.

[2] Besides Paradoxides, there are such forms as the Cambrian *Hydrocephalus carens*, the Silurian *Dalmania punctata, Cheirurus pleurexanthemus*, and *Eurycare brevicauda*, while the spiny species of Acidaspis seem to be more abundant in the Devonian than in the Silurian strata, but those which bear dorsal spines, such as *Deiphon forbesii* and *Arges armatus*, are Devonian.

[3] Quite long spines occur in the Cretaceous species of Crioceras and *Ancyloceras matheronianum* of Europe, but none, so far as we are aware, in earlier times.

[4] See N. S. Shaler: Notes on *Taxodium distichum*, Mem. M. C. Z., xvi, 1, 2, and W. P. Wilson: The production of aerating organs on the roots of swamp and other plants, Proc. Acad. Nat. Sci. Phil., April 2, 1889, quoted in Garden and Forest, Jan. 1, 1890. Shaler conjectures that the function of the "knees" is in some way connected with the aeration of the sap. Mr. Wilson shows that "besides the cypress, other plants which habitually grow with roots covered with water (the water gum, *Nyssa silvatica*, var. *aquatica*, *Avicennia nitida*, and *Pinus serotina*) develop similar root processes; and what is still more suggestive, Mr. Wilson has induced plants of Indian corn to send roots above the surface of the soil by keeping it continually saturated with water." It is to be observed that the aerial roots of the latter develop in a single generation.

group or superfamily Tineina and allied forms, in some of which the mandibles still persist,[1] and which in other features (besides having, as in Nepticula and Phyllocnistis, nine pairs of abdominal legs[2]) show their affinity to the Trichoptera and Mecoptera, originated at an earlier date. As is well known, the Cretaceous land was covered with forests of oaks, liquidambars, maples, willows, sassafras, dogwood, hickory, beech, poplar, walnut, sycamore, laurel, myrtle, fig, etc., at or soon after the close of the Laramie epoch, and this may have been the time, if not earlier in the Mesozoic, when in all probability the low feeding caterpillars of that time began, perhaps through overcrowding, to desert their primitive herbaceous food plants and to ascend trees in order to feed on their leaves.

Darwin[3] has made the significant remark "that organic beings, when subjected during several generations to any change whatever in their conditions, tend to vary." Further on he refers to the general arguments, which appear to him to have great weight, "in favor of the view that variations of all kinds and degrees are directly or indirectly caused by the conditions of life to which each being, and more especially its ancestors, have been exposed" (p. 241), and he finally concludes: "Changes of any kind in the conditions of life, even extremely slight changes, often suffice to cause variability. Excess of nutriment is perhaps the most efficient single exciting cause" (p. 258).

When, in Mesozoic or possibly still earlier times, caterpillars began to migrate from herbaceous plants to trees, they experienced not only some change, however slight, in the nature of their food, but also a slight climatic change, so to speak, involving a change in the temperature. Insects

[1] Dr. A. Walter has discovered the presence of minute rudimentary mandibles in the European *Micropteryx caltella*, *Tinea pellionella*, *Tineola biseliella*, *Argyresthia nitidella*, *Crambus tristellus*, and two genera of Pterophoridæ (Sitzungsb. Jena, Ges. für Med. u. Naturwiss., 1885). I have also detected them in *Coleophora coruscipennella* and in another Tineid of a genus as yet undetermined.

[2] The larvæ of Phyllocnistis have no thoracic legs, but have eight pairs of membranous retractile abdominal legs and an anal pair. (American Entomologist, III, 256.) Mr. H. T. Stainton kindly informs me that the larvæ of Nepticula have no thoracic legs "but possess nine pairs of abdominal legs," which, however, bear no hooks; "they look like so many fleshy prominences."

[3] The Variation of Animals and Plants under Domestication, second edition, revised, London, 1888. In the same work Darwin says: "Nathusius states positively (pp. 99, 103), as the result of common experience and of his experiments, that rich and abundant food, given during youth, tends by some direct action to make the head [of the pig] broader and shorter, and that poor food works a contrary result."

Darwin also states that "the nature of the food supplied during many generations has apparently affected the length of the intestines, for, according to Cuvier, their length to that of the body in the wild boar is as 9 to 1, in the common domestic boar as 13.5 to 1, and in the Siam breed as 16 to 1" (Ib., 77). See also the cases mentioned by Semper in his Animal Life, etc., pp. 60–62, and Neumayr's Stämme der Thierreichs, 1889, 123. Virchow claims that the characters of the skull depend on the shape of the jaw, this being due to differences in food; and here might be quoted the witty remark of Brillat-Savarin, "Dis-moi ce que tu manges, je te dirai ce que tu es."

The most remarkable case, and one directly applicable to our subject of the probable cause of the growth of spines, is that cited by Prof. J. A. Ryder: "Even certain species of fishes, when well fed and kept in confinement, not only spawn several times during a season, instead of only once, as I am informed by Dr. W. H. Wahl, but also when kept from hibernating, as he suggests, tend to vary in the most astounding manner. The wonderful results of Dr. Wahl, attained in the comparatively short period of six years, show what may be done in intensifying the monstrous variations of Japanese goldfishes, through selection, confinement in tanks and aquaria, with comparatively limited room for swimming, plenty of food, etc., all of which conditions tend to favor growth and metabolism, and the expenditure of energy under such wholly new and restricted conditions as to render it almost certain, as he thinks, that these factors have something to do with the development of the enormous and abnormally lengthened pectoral, ventral, dorsal, double anal, and caudal fins of his stock. Some of the races of these fishes have obviously been affected in appearance by abundant feeding, as is attested by their short, almost globular bodies, protuberant abdomens, and greedy habits, as I have observed in watching examples of this short-bodied race living in Dr. Wahl's aquaria. In these last instances we are brought face to face with modifications occurring in fishes under domestication which are infinitely in excess, morphologically speaking, of anything known among any other domesticated animals. That the abundant feeding and exposure to a uniform temperature during the whole year and confinement in comparatively restricted quarters have had something to do with the genesis of these variations, through an influence thus extended upon the metabolism affecting the growth of certain parts of the body, which have tended to become hereditary, there can scarcely be any doubt" (American Naturalist, Jan., 1890).

Darwin states that in India several species of fresh-water fishes "are only so far treated artificially that they are reared in great tanks; but this small change is sufficient to induce much variability" (Variation of Animals and Plants under Domestication, ii, 246).

living in trees or shrubs several or many feet above the ground are certainly exposed to a more even temperature, as it is colder at night even in midsummer within a few inches of the ground, say about a foot, the usual height to which grasses and herbs grow. The changes, therefore, by day and night are greater at the surface of the ground than among the leaves and branches of a tree. Moreover, forests, not too dense for insect life, with glades and paths to admit the sunlight and heat, must necessarily have a more even temperature and be less exposed to cool winds, and less subject to periods of drought than grassy fields. There is also a less free circulation of air among grasses and herbs, which may be more or less matted and lodged after heavy rains, than among the separate and coarser leaves of trees, such as the different species of oak, which in North America, at least north of Mexico, harbors a far greater number of species of insects (over 500) than any other plant known. On the whole, forest trees support a far larger number of kinds of phytophagous insects than grasses or herbs, and may this not be due to better air and a freer circulation, to a more equable temperature, perhaps of a higher average, and thus lead insects to eat more? May not the plump bodies of the larger silkworms, as the larval Attaci, the Ceratocampids, and especially the Cochliopodidæ (Limacodes), be in some way due to their strictly arboreal environment?[1]

When the ancestors of the present groups became fairly established under these changed conditions, becoming high feeders, and rarely wandering to low herbaceous plants, we should have a condition of things akin to geographical isolation. The species would gradually tend to become segregated. The females would more and more tend to deposit their eggs on the bark or leaves of trees, gradually deserting annual herbs.

For example, the females of the Attaci and their allies, as well as the Cochliopodidæ, may have at first had larger wings and smaller bodies, or been more active during flight than their descendants. Their present heavy, thick bodies and sluggish habits are evidently secondary and adaptive, and these features were induced perhaps by the habit of the females ovipositing directly upon leaving their cocoon, and cocoon-spinning moths are perhaps as a rule more sluggish and heavy-bodied than those which enter the earth to transform, as witness the Ceratocampidæ compared with the cocoon-spinning silkworm (*B. mori*) and the Attaci. Spinning their cocoons among the leaves at a period in the earth's history when there was no alternation of winter and summer and probably only times of drought, as in the dry season of the Tropics at the present day, the females may have gradually formed the habit of depositing their eggs immediately after exclusion and on the leaves of the trees forming their larval abode. The females thus scarcely used their wings, while (as in *Callosamia promethea*) the males, with their larger wings, lighter bodies, broadly pectinated antennæ, and consequently far keener sense of smell, could fly to a greater or less distance in search of their mates.[2] The principal of segregation[3] so well worked out by Mr. Gulick, to which Mr. Romanes' theory of physiological selection is a closely allied factor, if not covering the same ground, would soon be in operation, and the tendency to breed only among themselves, rather than with the low feeders, would more and more assert itself, until, as at present, arboreal moths, as a rule almost, if not wholly, oviposit exclusively on the leaves or bark of trees.

[1] The fat, overgrown slugworms (Limacodes) may be compared to the overfed, high-bred pig, which eats voraciously, has little need of rooting, and takes but little exercise. Where, as among cave animals, there is a deficiency of food, we have a constant tendency to slimness, to an attenuation of the body. This is seen in the blind cave arthropods, such as the blind crayfish, blind beetles, blind Cæcidotæa, etc., compared with their allies which live under normal conditions. (See the author's memoir on the Cave Fauna of North America, etc., Mem. Nat. Acad. Sciences, iv, 21, 1889.)

[2] The secondary sexual characters so marked in Bombyces are perhaps the result of their peculiar arboreal habits; so also the apterous tendency of Orgyia and a few other forms, especially the arboreal Psychidæ (*Œceticus* and *Thyridopteryx*), as well as *Anisopteryx* and *Hibernia*. The larvæ of the *Nyssia* feed on trees or low plants. It may be questioned whether any wingless female Lepidoptera live on herbaceous plants. Contrast with them the grass-feeding species of Noctuidæ, as those of *Agrotis*, *Leucania*, etc.

[3] In fact nearly the whole group of insects is an example on a vast scale of the principles of segregation, geographical isolation, and physiological selection. As soon as the ancesters of insects acquired wings their *milieu* was changed. The air rather than the earth became their habitat; the acquisition of wings introduced them to a new world of existence, and free from the attacks of creeping enemies and other adverse conditions to which the terrestrial Myriopods and Arachnids were subjected; the winged insects living a part of their lives, and the most important part, above the surface of the soil, multiplied prodigiously, the number of species being estimated by millions when we take into account the fossil as well as the living forms.

Coming now to the origin of humps, fixed or movable, and of spines, the change from herbaceous to arboreal feeding grounds doubtless affected not only the shape of the body, causing it in many cases to be thick and fleshy, but also led to a hypertrophy of the piliferous warts common to all lepidopterous larvæ. The change was probably not necessarily due to the stimulus of the visits and attacks of parasitic insects, because the low feeders are, if anything, at the present day at least, more subject to injury from them than arboreal caterpillars. The cause was probably more pervasive and a result of a change of the environment, such as is seen in the growth of thorns on desert plants, or the knees of the cypress and other water plants, or the aerial roots of ochids and other epiphytes; and that they may have originated with comparative suddenness seems probable when we bear in mind the aerial roots of corn artificially produced in the lifetime of a single individual; though it should be taken into account that plants are far more plastic than animals.

If the reader will look at the recapitulations we have given at the end of the detailed life histories of certain Notodontians, it will be seen that not only are there different adaptive characters in the larval, pupal, and imaginal stages, but that the larva itself in its different stages is wonderfully adapted to different surroundings.

1. At first some, indeed most, species live socially on the underside of the leaves near where they were born, and thus concealed from observation. Many have glandular hairs, while the tubercles are more or less uniform.

2. Toward the end of Stage II and in Stage III they feed in exposed situations on the upper side of the leaves, and at the same time appears the showy style of ornamentation both as regards colors, hairs, and tubercles, approximating to that of the mature caterpillar, whose life apparently is conditioned by its bright colors and bizarre trappings.

The smooth-bodied, green larvæ of Gluphisia, Nadata, Lophodonta, etc., are the primary forms.[1] Their shape, coloration, and retired habits ally them biologically to the larvæ of the European *Panolis piniperda* and other smooth-bodied, green caterpillars with reddish or yellowish stripes, which feed on trees. These smooth larvæ are, however, rare and exceptional, especially in North America.

But now, owing to a change in the environment, there arose a tendency to the hypertrophy of the normal piliferous warts, and in the actual life history of the caterpillar the tendency manifests itself in the third stage of larval life. We are inclined to believe (1) that the hypertrophy of certain of the tubercles was effected in a comparatively sudden period in consequence of a comparatively sudden change from herbs to trees, and (2) in response to a sudden exigency; (3) that the spines and stiff, dense spinulated hairs were immediately useful in preventing the attacks of parasitic insects, while (4) the poison glands at the base of the tubercles (in the Attaci, etc.) served to render them distasteful to birds, (5) the bright colors serving as danger signals.

The Lamarckian factors (1) of change (both direct and indirect) in the milieu, (2) need, and (3) change of habit, and the now generally adopted principle that a change of function induces change in organs[2] and in some or many cases actually induces the hypertrophy and specialization of what otherwise would be indifferent parts or organs; these factors are all-important in the evolution of the colors, ornaments, and outgrowths from the cuticle of caterpillars.[3]

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[1] I am however inclined, since writing the above, to regard Datana and Pygæra as the most primitive forms of Notodontians, the smooth-bodied larvæ of Gluphisia being secondary and adaptive forms.

[2] R. Marey: Le transformisme et la physiologie expérimentale, Cours du Collége de France. Revue scientifique, 2e Série, iv, 818. (Function makes the organ, especially in the osseous and muscular systems.)

See also A. Dohrn: Der Ursprung der Wirbelthiere und das Princip des Functionswechsels, Leipzig, 1875.

[3] It is possible that the close resemblance of the warts, projections, and spines of certain arboreal caterpillars which so closely mimic the spines, leaf scars, and projections of the branches or twigs or plants, has been brought about in a way analogous to the production of spots and lines on the body of caterpillars. Darwinians attribute this to the action of "protective mimicry," but this expression rather expresses the result of a series of causes to which we have endeavored to call attention. The effect of dark and light shades and the light and shade in producing the stripes and bars of caterpillars are comparatively direct and manifest; but how can thorns and other projections on trees and shrubs affect caterpillars directly? Given the origination by hypertrophy of warts and spines, and it is then easy to see that by natural selection caterpillars may have finally become adapted so as to mimic similar vegetable growths. Our object is to endeavor to explain the causes of the primary growth and development of such projections, i. e., to lay the foundation for the action of natural selection.

The following table is an attempt at a classification of some of the structures arising from the various modifications of the primitive piliferous warts or tubercles common to nearly all, if not all, smooth-bodied lepidopterous larvæ. As is well known, the term "hair" does not properly apply to the bristles or hair-like structures of worms and Arthropoda, as morphologically they are not the homologues of the hairs of mammals, but arise, as Newport first showed, through a modification and hypertrophy of the nuclei of certain cells of the cuticle. Hence the word seta, as suggested by Lankester, is most applicable.

A.—TUBERCLES.

a. Simple and minute, due to a slight thickening of the hypodermis and a decided thickening of the overlying cuticle; the hypodermis contains a large unicellular gland, either for the secretion of the seta or for the production of poison.

1. Minute piliferous warts. (Most Tineid, Tortricid, and Noctuid larvæ.)
2. Enlarged smooth tubercles, bearing a single seta. (Many Geometrid and Bombycine larvæ.)
3. Enlarged spherical tubercles, bearing a number of setæ, either radiated or subverticillate. (Arctians, Lithosians Zygænidæ, including some Glaucopinæ.)
4. High, movable, smooth tubercles, having a terrifying function. (*Schizura*, *Nylinodes*, *Notodonta*, *Nerice*.)
5. Low and broad, rudimentary, replacing the "caudal horn." (Chœrocampa, the European *Thyosia dictæa*, and *dictæoides*.)

b. More or less spinulose or spiny (disappearing in some Sphinges after Stage I).

1. Long and slender, usually situated on top of the eighth abdominal segment, with microscopic spinules in stage I. (Most Sphingidæ and *Sesia*.)
2. Smooth subspherical warts. (Zygænidæ, e. g., Chalcosia, East Indies); or elongated, but still smooth. (*Attacus atlas*, and a species from Southwestern Territories, U. S. A.)
3. Subspherical or clavate spiny tubercles of many Attaci; the spinules usually short.
4. Spinulated spines or elongated tubercles of Ceratocampidæ and Hemileucidæ. (*H. io* and *H. maia*, etc.)
5. Spike-like hairs or spines. (*Samia cynthia*, Anisota, East Indian Hypsa, Anagma.)
6. Antler-like spines. Early stages of *Heterocampa biundata*, *guttivitta* and *obliqua*.)

B.—SETÆ ("HAIRS," BRISTLES, ETC.).

1. Simple, fine, short or long, microscopic or macroscopic setæ, tapering hairs, scattered or dense, often forming pencils. (Many Bombyces, Zygænidæ, Noctuo-bombyces, Apatelæ.)
2. Glandular hairs, truncate, spindle-shaped or forked at the end, and secreting a more or less viscid fluid. (Many in Stages I and II of Notodontians, many butterfly larvæ, and in the last stages of Pterophoridæ.)
3. Long, spindle shaped hairs of Apatelodes, *Apatela americana*, figured in Harris Corr., Pl. III, fig. 2; also Packard's Guide, fig. 236, and the European *Tinolius eburneigutta* Walk.
4. Flattened, triangular hairs in the tufts or on the sides of the body of *Gastropacha americana*, or flattened, spindle-shaped scales in the European *G. quercifolia*.[1]
5. Spinulated or barbed hairs. (Most Glaucopides, etc., Arctians, Lithosians, and Liparidæ, and many other Bombyces.)

C.—PSEUDO-TUBERCLES.

1. The filamental anal legs (stemapoda) of Cerura and *Heterocampa marthesia*.
2. The long suranal spine of Platypterididæ.

THE USUAL POSITION OF THE MORE SPECIALIZED WARTS, HUMPS, OR HORNS.

Everybody has noticed that the horn characteristic of larval Sesiæ and Sphinges is uniformly situated on the back of the eighth abdominal segment and no other, and that when it is absent, as in Chœrocampa, etc., it is replaced by a small, low, and flattened tubercle, the segment itself being somewhat swollen. The larval Agaristidæ (Alypia, Eudryas, Copidryas, Psychomorpha, etc.) have a prominent, gibbous hump on this segment, or at least this segment is more or less prominent and humped, not only in this family, but also in certain smooth-bodied Noctuidæ, as Amphipyra, and *Olygia versicolor*, etc.

In many Notodontidæ the first abdominal segment bears a conspicuous hump, sometimes forked, often ending in a seta.

In the larval Ceratocampidæ, either the prothoracic segment or the second and third thoracic segments bear high conspicuous horns and spines. They may be roughly classified as follows:

[1] See my article in Annals and Magazine of Natural History. Ser. 6, ix, pp. 372–375. 1892.

Prothoracic segment.—With a large subspherical tubercle on each side bearing numerous radiating hairs (Lasiocampidæ of first stage) or pencils of hairs (Parorgyia); two antlers (*H. guttivitta, biundata* and *H. obliqua*).

Second thoracic segment.—Two high slender spines. First stage of *Anisota senatoria, A. stigma*, and *Dryocampa rubicunda*.

Third thoracic segment.—Two spinulose pappose flaps, *Empretia stimulea*.

First, second, and third thoracic segments.—Each with a pair of high spines, *Citheronia regalis* and *Eacles imperialis*.

Second and third thoracic segments.—Each with a pair of long horns, *Sphingicampa bicolor*.

First and third thoracic segments.—In Stage I of the European *Aglia tau* (Poulton).

First abdominal segment.—Movable tubercle in Schizura and Xylinodes.

Eighth abdominal segment.—The caudal horn of Sesia and most Sphingidæ, Pheosia, and Endromis, *Bombyx mori*, and other species—Sphingicampa, Eacles, Citheronia, and *Aglia tau* (Stage I).

So far as I am aware no one has suggested why these horns and high tubercles, and often pencils of hairs, are restricted to these particular segments. As a partial explanation of the reason it may be stated that the presence of these high tubercles, etc., is correlated with the absence of abdominal legs on the segments bearing the former. It will also be noticed that in walking the apodous segments of the caterpillar are more elevated and prominent than those to which the legs are appended. They tend to bend or hump up, particularly the first and the eighth abdominal, the ninth segment being reduced to a minimum, and the tenth simply represented by the suranal and paranal plates, together with the last pair of legs.

As is well known, the loopers or geometrid worms, while walking, elevate or bend up the part of the body situated between the last thoracic and first pair of abdominal legs, which are appended to the seventh uromere. Now, in the larva of *Nematocampa filamentaria*, which bears two pairs of remarkable filamental tubercles rolled up at the end, it is certainly very suggestive that these are situated on top of the loop made by the caterpillar's body during progression, the first pair arising from the second and the hinder pair from the fourth abdominal segment.

It seems, therefore, that the humps or horns arise from the most prominent portions of the body, at the point where the body is most exposed to external stimuli; and the force of this is especially seen in the conspicuous position of those tubercles which are voluntarily made to nod or so move as to frighten away other creatures. Perhaps the tendency of these segments to loop or hump up has had a relation of cause and effect in inducing the hypertrophy of the dermal tissues entering into the composition of the tubercles or horns.

Analogous positions are in the vertebrates utilized, as in spiny, osseous fishes, or the sharks, the horned Amphibia, or horned reptiles and horned mammals. The prominence of the foundation parts, from which the tubercles arise, may lead to a determination of the blood toward such places, and thus in well-fed or overfed (possibly underfed) individuals induce a tendency to hypertrophy, which once set up in early generations led to the production of incipient humps which became more developed as they proved useful and became preserved in this or that form by natural selection. On the other hand, the hypertrophy of certain piliferous warts would tend to cause an arrest of development or a tendency to atrophy in the piliferous warts of adjoining segments. And in like manner may the simple setæ have become hypertrophied on account of their great utility as deterrent organs, and become wonderfully modified in this and that direction in such and such forms, until they became in recent geological times the common and normal inheritance not only of scattered species but of certain genera in scattered families, and even of entire families.

It is to be observed, as one will see by referring to the special larval histories and the recapitulations which we have appended, that in the species of Schizura the evolution or hypertrophy of the movable or nutant tubercles begins in the third stage at about the time when the young caterpillars leave their common birthplace on the underside of the leaf and seek more conspicuous feeding grounds on the outer edge or on the upper side of the leaf, where they are exposed to the visits of ichneumons, or Tachinæ, or carnivorous Hemiptera, or to the onset of open-mouthed insectivorous birds. At the same time arise the bright colors, spots, and stripes, the very peculiar V-shaped silver or yellowish-white mark characteristic of the species of Schizura—these are perhaps danger signals—though later in life the brown shades and green tints, so like the green leaf with its serrated, blotched, sere patched edges, would often deceive the most observant of birds.

In regard to the nutant or movable tubercles, it may be observed that a slight motion of these appendages may suffice to scare off an approaching ichneumon or Tachina. If most insects have, as supposed by Exner and by Plateau, more imperfect vision than has formerly been attributed to them, so that they are extremely nearsighted and only clearly perceive bodies when in motion, then even slight movements of these tubercles, while the caterpillar itself was immobile, would probably be sufficient to frighten a parasitic insect and deter it from laying its eggs on the caterpillar.

GROUPING OF NOTODONTIAN LARVÆ ACCORDING TO THEIR AFFINITIES AND ALSO THEIR ADAPTATION TO ARBOREAL LIFE.

As is well known, the larvæ of this family vary greatly in form and ornamentation for a group of such moderate numbers; and the following synopsis has been prepared in order to show this great variety in as graphic a manner as possible:

1. Body smooth, not hairy, with red and yellow spots. *Gluphisia.*

2. Body smooth, moderately hairy. *Datana.*

3. Very hairy, the body almost totally concealed. *Apatelodes.*

4. Body smooth, hairless; with no humps or tubercles, of a noctuid shape; anal legs never elevated; color green, with yellow lines, the latter sometimes edged with reddish; feeding less conspicuously than any others of the family. *Nadata, Lophodonta,* etc.

5. Body with two dorsal tubercles; also hairy. *Ichthyura.*

6. Body smooth, polished; a single hump, surmounted by a horn on the eighth abdominal segment. *Pheosia.*

7. Back 2–8-humped, serrate, body smooth, not brightly striped. *Notodonta, Nerice.*

8. Body smooth, gayly striped, eighth abdominal segment gibbous. *Edema, Dasylophia.*

9. Body smooth, with nutant tubercles on first and eighth abdominal segments; end of body uplifted. Colors green with brown patches simulating dead blotches on leaves. *Hyparpax, Schizura,* and *Xylinodes.*

10. Body with stout spines and with spiny tubercles on first and eighth abdominal segments. *Schizura unicornis.*

11. Body smooth, tapering; anal legs normal, often with two prothoracic tubercles, enormous in early stages. *Heterocampa guttivitta, biundata,* and *obliqua.*

12. Body smooth, striped; anal legs normal. *Heterocampa manteo.*

13. Body with two dorsal prothoracic tubercles; anal legs filamental; each ending in an eversible flagellum. *Macrurocampa marthesia.*

14. Body with two lateral prothoracic tubercles; anal legs filamental, each ending in an eversible flagellum. *Cerura.*

15. Body doubly humped on the abdominal segments; filamental anal legs. The Old World genus *Stauropus.*

So far as I have gone in the examination of the structure of the moths, this succession of genera roughly corresponds with the classification of the family. Judging by the moths alone, Datana stands at one end of the series and Cerura at the other.

Perhaps Cerura has generally been placed at the end of the group because of its fancied resemblance to the larva of Drepana, but this is deceptive, because the long caudal filament of the latter genus is simply a hypertrophy of the suranal plate, and the anal legs themselves are atrophied, while in Cerura they are enormously hypertrophied, probably owing to their active use as deterrent appendages.

SUMMARY.

One would suppose that the two genera Nadata and Lophodonta, with the Old World genera Pterostoma, Ptilophora, Drymonia, Microdonta, and Lophopteryx[1] (of the two species *L. cucullina*, which is humped on the eighth abdominal segment, connects with the plain-bodied *L. carmelita*

[1] The first larval stages of the following genera are still unknown, and the author would be much indebted for eggs or alcoholic specimens of the larvæ of the first and later stages: Ellida, Lophodonta, Drymonia, Notodonta,

and the above-mentioned group, Pheosia, Leiocampa) should properly, by their smooth, noctuiform shape, stand at the bottom of the family, as being nearest related to the primitive form of the group. But until we know more of the earliest stages it is best to suspend our judgment.

1. The more prominent tubercles and spines or bristles arising from them are hypertrophied piliferous warts, the warts with the seta or hair which they bear being common to all caterpillars.

2. The hypertrophy or enlargement was probably primarily due to a change of station from herbs to trees, involving better air, a more equable temperature, perhaps a different and better food.

3. The enlarged and specialized tubercles developed more rapidly on certain segments than others, especially the more prominent segments, because the nutritive fluids would tend to more freely supply parts most exposed to external stimuli.

4. The stimuli were in great part due to the visits of insects and birds, resulting in a mimicry of the spines and projections on the trees; the colors (lines and spots) were due to light or shade, with the general result of protective mimicry or adaptation to tree life.

5. As the result of some unknown factor several of the hypodermic cells at the base of the spines became in certain forms specialized so as to secrete a poisonous fluid.

6. After such primitive forms, members of different families, had become established on trees, a process of arboreal segregation or isolation would set in, and intercrossing with low feeders would cease.

7. Heredity, or the unknown factors of which heredity is the result, would go on uninterruptedly, the result being a succession of generations perfectly adapted to arboreal life.

8. Finally the conservative agency of natural selection would operate, constantly tending toward the elaboration and preservation of the new varieties, species, and genera, and would not cease to act in a given direction so long as the environment remained the same.

9. Thus, in order to account for the origin of a species, genus, family, order, or even a class, the first steps, causing the origination of variations, were in the beginning due to the primary (direct and indirect) factors of evolution (Neolamarckism), and the final stages were due to the secondary factors, segregation and natural selection (Darwinism).

III.—ON CERTAIN POINTS IN THE EXTERNAL ANATOMY OF BOMBYCINE LARVÆ.

Homology of the "flagellum" of Cerura, etc., with the planta of the other abdominal legs.—We have in a former[1] article, in describing the larvæ of *Macrurocampa marthesia* and of certain species of Cerura, called attention to the nature of the *stemapoda*[2] or filamental legs of those caterpillars, and their generally undisputed homology with the anal legs of other Notodontians. Pl. XXXVII, fig. 9, represents the anal legs of *Dasylophia anguina* in its first larval stage. It is intermediate in form between the normal leg and the stemapod. It has no crochets, but the planta, of which the "flagellum" of Cerura and *H. marthesia* seems to be the homologue, is retracted and the retractor muscles, one of which is divided, are much as in the filamental legs of Cerura, etc.

Note on the modifications in the tenant or glandular hairs of the thoracic feet.—As is well known, the thoracic feet of caterpillars are five jointed and end in a single claw, with apparently a rudimentary one at the base. Usually, besides the unguis or claw, there is a tenant hair, which is generally spine like, but besides these appendages there are sometimes more or less flattened, lamellate setæ, which are curious and worthy of notice. In *Parorgyia parallela*, besides the unguis

[1] Proceedings Boston Soc. Nat. Hist., xxiv, 1890.

[2] The term "tails" or caudal filaments is too vague for these highly modified anal legs; hence we propose the term *stemapoda* or stemapods for those of Cerura and Macrurocampa. The derivation is Gr. *στημα*, filament, *πους*, *ποδος*, leg or foot. Mr. J. Hellins, referring to these organs in Buckler's Larvæ of the British Butterflies and Moths (Roy. Soc., ii, 138), remarks: "But now through Dr. T. A. Chapman's good teaching, I regard them as dorsal appendages, somewhat after the fashion of the anal spines of the larvæ of the Satyridæ." This, I am satisfied, is an error. After repeated comparisons of the filamental anal legs of Cerura with those of *Macrurocampa marthesia*, and comparing these with the greatly elongated anal legs of young *H. unicolor* as figured by Popenoe, and taking into account the structures and homologies of the supraanal and paranal flaps, one can scarcely doubt that those of Cerura are modified anal legs.

and the spine-like tenant hair, there is a lamellate, flattened hair. Pl. XXXVII, fig. 10, represents the end of a thoracic leg of *Heterocampa manteo*. Besides the unguis and tenant hair at the end, there are two singular, thin, flattened, oval leaf-like setæ arising near the middle of the joint. The use of the claw and tenant hair as grappling organs is quite apparent, but the function of the singular lamellate hairs is a matter of conjecture.

Hints on the origin of the prothoracic or cervical shield.—Not only in the wood-boring Lepidoptera, such as the larvæ of the Hepialidæ, and the Cossidæ, as well as the Sesiidæ, is there a well marked cervical shield, but also in the grubs of Cerambycidæ, and some other Coleopterous families whose larvæ bore in hard substances, and in such groups this hard, chitinous plate serves to protect the base of the head and adjacent parts of the body most exposed to injury. Developed in the borers of widely different orders, and obviously of direct use to the animal, it has probably arisen in response to an external stimulus, an extra quantity of chitin having been developed by the hypodermal cells of the tergal arch of the prothoracic segment, which by friction has become thickened, just as the skin of the sole of the foot in savages becomes thick and horny in those accustomed to go barefoot in dry, rough places.

In the lower lepidopterous families, as the Tineina, Tortricidæ, Pyralidæ, as well as in the low-feeding Noctuidæ, which hide under stones, such as the cutworms, a well developed cervical shield is generally present.

In the Bombyces, which feed exposed both on trees and on herbaceous plants, the cervical shield is rarely even well developed, but there are sporadic cases of its development, and especially of its appearance in the early stages and of its suppression in later larval life, which are of interest and merit notice.

In the Notodontian genus Cerura, the prothoracic segment is unusually broad and flat above, although it is not smooth, chitinous, or polished; whether its use is to support the large lateral tubercles or to resist pressure and friction is a question.

In the first stage of *Dasylophia anguina* there is a small cervical shield (Pl. XXXVII, fig. 11*c*), which bears four glandular setæ on each side of the median red dorsal line.

In *Datana integerrima*, a small, transversely oblong, conspicuous black cervical shield is present in the freshly hatched larva and in the subsequent stages. There is, however, no shield or rudiments of one in *Edema albifrons* or in Heterocampa and Macrurocampa.

In the other Bombyces there is no genuine shield, but in the first stage of some forms the two dorsal piliferous warts on the prothoracic segment are more or less enlarged and sometimes coalesced so as to indicate that the shield may have been formed by the enlargement and coalescence of these warts.

The supraanal or suranal plate.—This plate, the *podex* of Kirby and Spence, in Bombycine and Geometrid larvæ, both as to its shape and ornamentation, affords excellent characters for distinguishing species, and we have found it of great use, especially in describing Geometrid caterpillars. It varies much in shape and ornamentation in Notodontidæ, also in Attacidæ and Ceratocampidæ. In Noctuidæ it is not, so far as we know, very characteristic. It seems to be especially developed in those larvæ which constantly use the anal legs for grasping, while the front part of the body is more or less raised. It is thus correlated with enlarged anal legs.

Morphologically this plate appears to represent the dorsal arch of the tenth or last abdominal segment of the body,[1] and is the "anal operculum" or *lamina supraanalis* of different authors.[2] This suranal plate is in the Platypterícidæ remarkably elongated, forming an approach to a flagellum-like terrifying appendage, and in the larva of *Aglia tau* forms a long, prominent sharp spine. Its shape also in Cerura caterpillars is rather unusual, being long and narrow. In the Ceratocampidæ, especially in Anisota, Dryocampa, Eacles, and Citheronia, this plate is very large, the surface and edges being rough and tuberculated, while it seems to attain its maximum in Sphingicampa, being triangular, ending in a bifid point.

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[1] See my note, "The number of abdominal segments in Lepidopterous larvæ." American Naturalist, March, 1885, pp. 307, 308.

[2] Compare E. Haase, "On the constitution of the body in the Blattidæ." Ann. and Mag. Nat. Hist., March, 1890, 227-231. Translated from Sitzungsb. Ges. Naturf. Freunde zu Berlin, Jahrg., 1889, 128-136.

The ninth abdominal segment is unusually well developed in the Attacidæ and the Ceratocampidæ, sometimes, as has been previously stated, bearing a true "caudal horn," which takes the place of that usually growing on the eighth segment. In the Rhopalocera, the suranal plate is in general, especially in Hesperidæ and Papilionidæ, small and rounded, much as in the Noctuidæ, but in the Nymphalidæ it is more or less specialized, and remarkably so in the larva of *Neonympha phocion* and other satyrines, where it is greatly elongated and forked. (See figures in Scudder's "Butterflies of New England;" also W. Müller's figures of larva of Prepona.)

The paranal lobes.—These are the homologues of the two anal valves (*valvulæ* of Burmeister, "the podical plates" of Huxley) observed in the cockroach, and occurring in nearly all, if not all, insects. In Geometrid larvæ they are full, fleshy, lobe-like, or papilliform, bounding the areas on each side, and appear as if projecting backward from the base of the anal legs.

In the Ceratocampidæ these paranal lobes are not well developed. In the larva of Cerura they are much as in Geometrid caterpillars, where they end each in a seta.

The paranal forks.—We have already called attention to these two bristles in our description of the larvæ of Cerura. (Proceedings Boston Soc. N. H. xxiv, p. 553.) They are well developed, arising from the end of a papilla projecting directly backward. Their use has been indicated by Mr. John Hellins,[1] who refers to a pair of sharp points underneath the anal flap, "which are used to throw the pellets of frass to a distance." Occurring in Notodontian and other arboreal caterpillars, notably the tree-inhabiting Geometrids, they are wanting in Noctuidæ (including Acronycta and Catocala), Sphingidæ, and Rhopalocera, as well as the lower Geometrids and the Microlepidoptera, and are not developed in the Sphingidæ. In Ichthyura (Clostera) they are slightly developed. In the European *Urapteryx sambucata* (received from M. P. Chrétien) these lobes are very large, papilliform, and setiferous, and in our Chœrodes, etc., they are similarly developed and the use of the two setæ or the fork is undoubtedly the same as in Cerura.

The infraanal lobe.—My attention was first called to this lobe or flap while examining some Geometrid larvæ. It is a thick, conical, fleshy lobe or flap, ending often in a hard chitinous point, and situated directly beneath the vent. In appearance it is somewhat like the egg-guide of the Acrydii, though the latter is thin and flat. Its use is evidently to aid in tossing the pellets of excrement away so as not to allow them to come in contact with the body. In a large not identified Geometrid worm, which lives on the ash, this flap is large and conical, ending in a blunt chitinous point. In a large geometer belonging to another genus, the tip is sharper and harder, and in what is probably a larva of Endropia, while the paranal forks are well developed, the infraanal lobe ends in a stiff bristle. Whether this infraanal lobe is the homologue of the ninth urosternite or ventral plate I will not at present undertake to say.

Glandular setæ.—Among the Notodontidæ the freshly hatched larvæ of several genera are provided with glandular hairs of various shapes. In *Datana integerrima* they are clavate; in *Dasylophia anguina* they are clavate, somewhat flattened, and are dark, but clear at the tip,[2] while in all the other caterpillars we have observed that the glandular hairs are confined to the body, those on the head tapering to a point, and apparently not fitted for secreting a fluid; those on the head of Dasylophia are glandular, all ending in a slight transparent bulb.

Other genera of this group will probably on further investigation be found to possess glandular setæ in their first larval stages. They occur in the freshly hatched larva of what is probably a species of Heterocampa, also in *Nadata gibbosa*, *Ichthyura inclusa*, and *Pheosia rimosa*.

It is to be observed that the freshly hatched caterpillars of *Ceratosia tricolor* Smith are provided with glandular hairs. They are flattened at the tip, which is slightly tridentate, with

[1] The use of these I find explained by Mr. Hellins in his description of the larva of *C. bifida* in Buckler's Larvæ of British Butterflies and Moths, ii, p. 142, as follows: "At the tip of the anal flap are two sharp points, and another pair underneath, which are used to throw the pellets of frass to a distance." Similar dungforks are very generally present in Geometrid larvæ, the paranal papilliform tubercles being well developed, though we have not seen them in use.

I have noticed a caterpillar of *C. borealis* in the process of defecating, and with the forceps pulled off a pellet which was held by the two spines of the paranal tubercles. Mr. Dyar tells me he has both seen and heard the caterpillars casting their pellets with the aid of their spine against the side of a tumbler.

[2] Pl. XXXVII, fig 11. Glandular hairs of Dasylophia; *a*, of body; *b*, of the head; *c*, of prothoracic shield.

grooves passing down the shaft from the notches between the teeth. They occur not only on the back and sides of the body segments, but also on the sides of the abdominal legs. The occurrence of such hairs in this genus is interesting from the fact that they have not yet been observed in Arctians, to which this moth has been referred, nor in the Noctuidæ, among which it should be placed, since no Arctians have when hatched smooth glandular hairs.[1]

IV.—ON THE INCONGRUENCE BETWEEN THE LARVAL AND ADULT CHARACTERS OF NOTODONTIANS.

As is well known to zoologists, from the writings of Fritz Müller and later students, in groups of animals which generally undergo a metamorphosis, two or more species of the same genus may differ remarkably in respect to their early life, one species passing through a complicated metamorphosis while a closely allied form has a direct development, hatching in the form of the adult. The embryo, however, in the latter case rapidly passes through a series of changes, constituting a premature, abbreviated, or condensed metamorphosis, epitomizing the ordinary early stage of its metamorphic allies. Thus the lobster differs from the other marine macruran crustacea in having a condensed metamorphosis before hatching from the egg, rapidly passing through a nauplius and a zoëa phase. It is so with some crabs. All the fresh-water Decapoda, notably the crayfish, have no postembryonic metamorphosis. The fact that the embryo exhibits a condensed metamorphosis shows their origin from metamorphic forms.

These are perhaps the most remarkable cases of incongruence between what may be closely allied genera and even species.

Also two allied species of Gammarus may differ in toto as regards the mode of segmentation of the yolk, total cleavage occurring in one marine species (*G. locusta*) and partial or peripheral cleavage in two fresh-water forms (*G. pulex* and *fluviatilis*).

Examples of such great divergences in larval or early life, or in the condition in which the animal is hatched, in species closely similar in adult life, are not uncommon in worms, Echinoderms, Molluscs, Crustacea, besides insects, and the phenomenon is with little doubt due to the changed conditions of the environments to which forms with such exceptional modes of development have been exposed.

The principle, then, of divergence or incongruence of larval characters in forms whose adults are closely allied has been established in the lower classes of Metazoa. The most remarkable and puzzling case, perhaps, is that of Balanoglossus, whose Tornaria larva is so much like that of Echinoderms, while the adult is a protochordate animal.

As a matter of fact this does not affect the classification of these animals. Zoologists have not thrown forms with a direct development into distinct groups where the adults have not shown any differences; at the same time no one would unite the two species recognized as such which presented no easily observed differences if one had a direct and the other a metamorphic development. In the present state of our knowledge it may be well to at least provisionally mark the differences between the two forms, so divergent in their early life, by giving them distinct names, and thus emphasizing the fact that of the two closely allied forms one has diverged from the other through having been subjected to a different set of external influences, whatever such conditions may have been.

Systematic zoology has undergone within the last thirty years an entire change. Our present systems of classification are now attempts to arrange animals in the order of their probable appearance, i. e., phylogenetically, and as the subject is yet in its infancy, and our attempts provisional and tentative, we are obliged to give great weight to any differences in the larval conditions of animals with a metamorphosis, because such differences were undoubtedly due to differences in the environments of their parents. Indeed if it had not been owing to changes in the physical and biological environment, animals would never have risen beyond the dead level of the lowest Protozoa.

Such reflections as these and a knowledge of the mode of development of the lower classes of invertebrates are all-important to the students of insects, especially of the metamorphic orders,

[1] Pl. XXXVII, fig. 12. Glandular hairs of *Ceratosia tricolor*, *a*, from the second thoracic and first abdominal segment; *b*, those on the first and second abdominal legs.

Neuroptera, Coleoptera, Mecoptera, Trichoptera, Lepidoptera, Diptera, and Hymenoptera, where there are so many and perplexing cases of incongruence or divergence in larval forms whose parents are very closely allied.

It is worthy of notice that in respect to Diptera the veteran dipterologist, Baron R. von Osten Sacken, remarks of the nemocerous flies: "An arrangement of the imagoes based upon such principles will of necessity be justified by a more or less tangible correspondence in the characters of their larvæ. This structural correspondence, this parallelism of larvæ and imagoes among the *Nemocera*, suffers, as far as I know, but one exception, *Mycetobia pallipes* and Rhyphus. In both almost identical larvæ produce flies belonging to different families." (Berliner entomolog. Zeitschrift, Bd. xxxvii, 1892, Heft iv, p. 418.) In the copy kindly sent me by the author a second case of Anopheles and Dixa is mentioned in the printed copy, but struck out by the author in the emended copy.

Everyone is familiar with the fact that there is a nearly similar incongruity between the larvæ of the Muscidæ and the flies. Many new facts bearing on this subject appeared in Portchinsky's article on the habits of the necrophagous and coprophagous larvæ of Muscidæ, of which an English abstract by Baron R. von Osten Sacken appeared in the Berliner ent. Zeitschrift for 1887. After speaking of the wonderful power of adaptation of these larvæ to their environment, he states:

> Distinctly related species belonging to different genera issue from larvæ almost indistinguishable from each other. And again closely related and almost indistinguishable imagoes, species of the same genus, differ in their oviposition (size and number of eggs), and their larvæ follow a different law of development (as to the degree of maturity the larva reaches within the body of the mother and the number of stages of development it passes through).
>
> In one case even (*Musca corvina*) larvæ of the same species were found to have a different mode of development in northern and southern regions of Russia.

Here also it is evident that the cause of the incongruity is due to the fact that the larvæ, for the time being different animals from the adult, are modified by their environment, the similar surroundings and habits of the larvæ of quite different genera causing the larvæ externally at least to closely resemble each other. Whether they are so similar in their internal organs remains to be seen. Dr. C. W. Stiles, who has studied so carefully by microscopic sections tapeworms of externally similar form, and which can not be separated by external characters, tells me that the internal organs seem to afford excellent specific and generic characters.

Lepidopterists in general do not hesitate to base their systems of classification on the larval as well as adult features. They in general regard their systematic arrangements of the imagines as more or less provisional, and all acknowledge that it is immensely satisfactory, even after they are pretty well satisfied with their arrangement of the adults of a group, whether a genus or family, to work out the larval stages and to check their classifications based on adult features by the larval characters. In many cases they may be led to change the position of a species or genus, or to split up a genus or species.

But, after all this, the fact that so many larvæ, even in the same group, are hatched with such different shapes and characters; the fact that some are so much more simple and primitive than others, opens up most perplexing yet interesting questions and problems. We may, however, be able to solve these, and in the present group of Bombyces it seems to us that the different larval forms, some primitive and generalized and others more or less modified or specialized, give clues to the phylogeny of the groups which we confess we had not expected.

And in this memoir we have endeavored, though often it is mere guesswork, to drop the old-time method of putting the type species first and then ranging the others after it in an ill-assorted group, and have attempted to begin with what has seemed to us to be the ancestral form of the group, following with the later forms. This can be best accomplished by taking into consideration the caterpillar, beginning with the generalized forms and ending with the later more modified or specialized forms. In such a large genus as Heterocampa this is not difficult to do. For example, as we shall see hereafter, the larva of *H. manteo* is as simple and generalized as any, while that of *H. unicolor* is the most modified, with its semi-stemapoda, from which Macrurocampa, with its fully formed stemapoda, may have descended. And then, while Cerura, with its stemapoda alike in all the species, is often or generally placed first in the group, it is evident that it was descended from some Heterocampa-like form through Macrurocampa. Aided by our knowledge of the larval forms, especially of the earliest stages, it is not difficult to construct a genealogical tree of the subfamilies Heterocampinæ and Cerurinæ. When taking into account the larval stages of the entire family, even with our present imperfect knowledge, it is easy to see that Datana stands at the base, is the more generalized primitive form, and was perhaps the first to diverge from the stem-form of the family.

The first author to call attention and at the same time to treat in a philosophic way of what he has called "the incongruence of form relationship, between larvæ on the one hand and imagines on the other" is Weismann, in his well-known work entitled Studies in the Theory of Descent. In Chapter II of the second volume, entitled "Does the form relationship of the larva coincide with that of the imago?" he points out certain incongruences between the larval and adult characters. He claims that "neither the group of Microlepidoptera nor those of the *Noctuina*, *Bombycina*, *Sphingina*, and *Rhopalocera* can be based systematically on larval characters," adding the qualification, "Several of these groups are indeed but indistinctly defined, and even the imagines present no common characteristics by which the group can be sharply distinguished." Within the families, however, he states: "There there can be no doubt that in an overwhelmingly large majority of cases the phyletic development has proceeded with very close parallelism in both stages; larval and imaginal families agree almost completely. On the other hand, "in the butterflies a perfect congruence of form relationship does not exist, inasmuch as the imagines constitute one large group of the higher order, whilst the larvæ can only be formed into families." But in this case Weismann does not seem to be aware that the imaginal Rhopalocera as such is quite an artificial group, and that the imaginal families recognized by Bates, Scudder, and others have perhaps more equivalent, congruent, or nondivergent larval forms than his remarks would seem to imply.

But without attempting to enter into an exposition or criticism of Weismann's general statements, his whole discussion being most suggestive and stimulating, we will turn to what he says of the Notodontidæ:

> An especially striking case of incongruence is offered by the family *Notodontida*, under which Boisduval, depending only on imaginal characters, united genera of which the larvæ differed to a very great extent. * * * In fact, in the whole order Lepidoptera there can scarcely be found associated together such diverse larvæ as are here placed in one imago family.

He then refers to the short cylindrical caterpillars of *Cnethocampa*, which, however is not a Notodontian, but a Lasiocampid. He then briefly refers to the larvæ of Harpyia (Cerura) and the caterpillars of Stauropus, Hybocampa, and Notodonta. Without giving further attention to the family, he returns to the butterflies. This family, then, presenting "an especially striking case of incongruence," we will briefly discuss, referring the reader for fuller details to the figures on the plates.

In the first place, as a matter of fact, the more one becomes familiar with the Lepidoptera and their larval forms the easier it is to distinguish the larvæ by their "family" characteristics, premising, however, that the term family is of very uncertain meaning, and that different authors differ as to what to call a family as much as they do what to designate a species. But no one, we think, need to err in correctly picking out or identifying any Bombycine larva except, perhaps, a few Notodont larvæ, which are liable to be confounded with certain Thyatiridæ, and the hairy Noctuidæ, but even then a careful examination will show family differences even when adaptation and modification have nearly bridged over the fundamental differential characters.

In this work I have divided the family into seven groups, which may be for convenience regarded as so many subfamilies. I was first led to do so by the larval characters alone, but found that this classification would also apply in general to the moths, so that there proved not to be so much incongruity as was expected. There appear to be, then, seven larval subfamilies and seven imaginal subfamilies. Others may not agree with this view, but it is the most rational classification I have been able to make.

Beginning with the most simple forms of larva, those of the *Gluphisinæ*, which, both as regards those of the Old and New World, are tolerably constant, the adults certainly differ notably from those of other subfamilies, as also do the larvæ and pupæ.

The remarkably woolly and penciled larvæ of Apatelodes are congruous with the very distinct imagines of the subfamily *Apatelodinæ*, which are so well defined by their structural characters.

The hairy and brightly banded larvæ of the *Pygærinæ*, so unlike those of other Notodontians, are paralleled by the general appearance and structure of the moths, so much so that the group was regarded as a distinct family (Pygæridæ) by Duponchel. The larvæ of the European Pygærinæ are hairy and gaily striped, and related in much the same way to our larval Datana as the imago is to our imaginal Datana.

The larvæ of the subfamily *Ichthyurinæ*, represented by only a single genus, need not be confounded with those of any other division of the family, though there is a great deal of plasticity within the limits of the group. The most generalized species is the larva of *I. apicalis* (*vau*) and its allies *brucei* (*multnoma*), since it has no large specialized tubercles like those of *inclusa* and *albosigma*, and the latter species differs, both as regards larva and imago, from *I. inclusa*. The incongruence in this group is not greatly emphasized.

But in the two next subfamilies there is a striking lack of congruity between the larva and moth, both in the genera and species.

Among the Notodontinæ we have Hyparpax, whose imago is so different, in the shape of the wings and in the color of the body and wings, compared with any other genus of the group or even of the family; yet the larva is very nearly allied to those of *Xylinodes* and of *Schizura*.

A remarkable case of incongruence is the larva of *Schizura concinna*. This well-known caterpillar, with its formidable armature of long hobnail-like spines and its gay head and swollen coral-red dorsal hump, would seem to be the type of a distinct genus, and yet from a study of its adult character it is not separable from the other species of *Schizura*, and we have dropped the genus *Œdemasia* we originally proposed for it from the lack of stable differential characters. The freshly hatched larvæ, however, is undistinguishable from that of other Schizuræ yet known, and perhaps we have done violence to the principles of classification in not allowing it to remain in the genus we originally proposed for it. At all events, it with other Schizuræ evidently had a common parentage, and it has diverged since it first molt farther away from the stem than others of its cospecies and may be regarded as an incipient genus. It is also plain that the causes which have acted upon this organism have from the first been of a quite different nature from those which have been efficient in causing fixed variations in other directions, resulting in the fixation of the other species of the genus. As the change takes place after the first molt, this may have been produced in the Tertiary period. Its larval stages are discussed at some length under the head of the species in the systematic portion of this work.

On the other hand, in the genus *Seirodonta* we have a remarkable case of congruence in its larva as compared with that of *Heterocampa manteo*. It is almost impossible until after repeated and careful comparisons to distingush the caterpillars of *Seirodonta bilineata* and *H. manteo*, though the imagines differ somewhat, perhaps generically. At times I have united *Seirodanta* with *Heterocampa*, but for the present conclude to keep them apart, as others have done, but really the genus is not so "good" a one as Œdemasia.[1]

In the genus *Heterocampa*, as the name implies, there is a remarkable degree of diversity between the caterpillars of the different species, and our knowledge of them, especially of their early stages, has greatly extended since the days of Doubleday.

If we take account of the fully grown caterpillars, it seems quite evident that there are several, perhaps three, "larval" genera in the group. In *H. manteo*, *guttivitta*, *biundata*, *obliqua*, and *astarte*, the body in the fully grown larva is smooth and unarmed, but in *pulverea*, which has a pair of small tubercles on the prothoracic segment, we have a notable persistance of early larval features. Unfortunately we are not yet familiar with the early stages of this caterpillar. Possibly this species is the stem form of the group.

In *H. unicolor* we have a transfer of the differential generic characters from the prothoracic region to the anal legs. Though the high prothoracic tubercle appears in the first stages and perhaps, as in *Macrurocampa*, in all except the last stage, when the larva is on a level with the fully

[1] I have some sketches made by Mr. Bridgham of a larva in its first three stages which is Schizura-like, and as it feeds on the elm it is probably Seirodonta. Should it prove to be such, this genus is a Schizura in the early stages and a Heterocampa in the last.

grown *pulverea*, it outstrips that form, and the new forces of variation are concentrated at the other end of the body, resulting in the hypertrophy of the anal legs.

This tendency once initiated, it became accelerated, until in the larva of *Macrurocampa* it culminated in a pair of anal filaments with their evertible flagella as fully finished as in Cerura, the larva using these in the same manner as deterrent structures; and yet nature holds on to the prothoracic armature, rudimentary to be sure, through all the stages of larval development up to and including the fourth or penultimate stage. Without doubt by very careful and close observations in the past geological times of the Tertiary, the courses of the variation along this line would have been worked out had there been an eye and trained mind behind it to observe.

Attention should also be called to the remarkable incongruence in the first larval stages of this subfamily, the presence of nine pairs of antlers in *H. guttivitta* and of but a single pair, restricted to the prothoracic segments, in *H. biundata*, though the moths are very closely allied.

In the succeeding and what we regard as the latest and most highly modified or specialized group, taking the larvæ into account, are the Cerurinæ.

The imago of Cerura is structurally quite distinct from Macrurocampa, but apparently the sluggish habits, the infrequent, weak, and more or less curtailment of the power of flight common to the entire family of Bombyces have led to a lack of variation in form and structure which does not obtain in the larvæ themselves.

The larva of Cerura is evidently a derivation from *Macrurocampa* or some lost ally, at least some member of the subfamily Heterocampinæ. The prothoracic horns of the young larva of Cerura, owing to the great development and specialization of the first segment succeeding the head, are thrown wide apart and project out laterally. These horns are yet perhaps an heirloom from the dorsal horns of *Heterocampa*.

The Cerura larva varied in the direction of the enlargement of the prothoracic segment to form a sort of hood to admit the head, serving to make a visage calculated to frighten away any assailant. It is the puff adder among the Bombycine caterpillars, as the larva of *Chærocampa* is among Sphingid larvæ. The stematopoda, which seemed to have proved very useful in *Macrurocampa*, were retained in Cerura, being apparently too useful to be lost.

While the Cerura caterpillars assume a defensive and offensive attitude in order to frighten away other animals, they do not mimic the appearance of other animals; but in the singular caterpillar of Stauropus there is such a mimicry, the thoracic legs being much longer than in any other known lepidopterous larva and the stemapods being thickened and shortened, so that when the creature throws itself into a sprawling, grotesque attitude, with the tail up in the air, as remarked by Hermann Müller, it resembles a great spider. At the same time the style of coloration is changed; it has not the green and red tints of Cerura, but is tinted light and dark horn-brown, like the bodies of many large spiders.

In the case, then, of Stauropus, variation has gone on in a novel and determinate direction, the process of natural selection ending in a result not to be observed in the case of any other lepidopterous larvæ, the initial cause of variation being apparently the result of protection due to a resemblance to members of another class of arthropods.

THE PROBABLE CAUSES OF VARIATION, LEADING TO INCONGRUOUS LARVAL CHARACTERS.

We have seen that the moths of the Bombyces are far less active, have a weaker flight, are more sluggish, and hence are more uniform in color and markings than any other superfamily of Lepidoptera. The females remain stationary on the bark of trees and in similar situations, while the males seek and find them, not so much by virtue of swiftness of flight as by their unusual power of scent, as evidenced by their well-pectinated antennæ. Variation, then, is the result more of disuse of the wings and of the maxillæ than any other cause, these suffering more or less reduction. The very short or vestigial maxillæ of the Saturnians and the reduction in the number of veins of the wings in that group is the result of disuse; but, on the whole, variations in details of structure, in the specialization of the scales, of the parts and appendages of the legs, of the palpi, and other parts so striking in the Noctuina are very noticeable.

On the other hand, from causes potent though obscure, the degree of variation in the larval forms is most striking. We have every reason to believe that this great degree of modification and specialization of larval forms in the Bombyces is due to changes in their environment after they had effected their descent from their Lithosian ancestry. It was from adaptation to totally new surroundings which at once broke up the old simplicity of shape of their early ancestry and induced a striking plasticity of form and of structural features.

Such changes as these could not have been brought about so recently as the Quaternary period, but must have been most active during the late Mesozoic and throughout the Tertiary. Probably the date of the appearance of the Bombycine phylum was coeval with the appearance of the Cretaceous forests.

We have always maintained that the Bombyces are a very old type, which have lost a great many forms by geological extinction. In number of species the type is at present far less numerous than the Noctuina. The ranks of the latter have not been thinned by the ravages of geological time; on the contrary, there are few and unimportant gaps in their numbers—few links which are missing.

We would suggest, then, that the plasticity of the larval forms of the Bombyces, especially in the "lower," or to speak more correctly, the more primitive and in a degree generalized, families, is due to the great changes in their environment during the Cretaceous and Tertiary periods.

This is indicated by the facts in geographical distribution to be stated in more detail further on. When species are widely distributed this is to be taken as an evidence that they have had a high antiquity. When, for example, a group like the Heteroeampinæ is entirely wanting in Europe and the western portion of North America, such great gaps in distribution are naturally to be attributed to geological extinction.

It will be recalled that the opossum and other marsupials are extinct in Europe, though existing at present in Australia and America. Lingula was once abundant all over the globe; it now only lives along portions of the American and Asiatic and Australian coasts. Limulus was represented by several species in the Jurassic of Europe but now only occurs on the northeastern shores of North America and the eastern shores of Asia from the Malaysian Peninsula to Japan, having become extinct in other parts of the world.

In like manner the great gaps in the genera of our existing Bombyces are probably due to geological extinction, and also to the great plasticity or marked difference in the larvæ, as compared with the homogeneousness of the imagines, these being due to the widespread changes in the environment which took place during the later Mesozoic and Tertiary periods, and which reacted on the insects in their early rather than later stages.

This incongruity between the larval and adult stages, then, was probably most marked in the periods before the Quaternary, while since then there has been divergence. We have some reason to suppose that the families of Noctuidæ and Geometridæ, so numerous in species, were largely evolved during the Pliocene and Quaternary.

Where a family or subfamily is equably developed both in the Old and New worlds, we are inclined to suppose that it was a recently evolved group.

It is well known that America has lagged behind Europe, geologically speaking, although America is the older continent as such; the process first of specialization and then of extinction has gone on more rapidly in the Old World, or at least the western portion of it.

Were fossil Bombyces ever to be found in Europe, we should expect to discover among them representatives of the Cochliopodidæ, of the Attacine Saturniidæ, Ceratocampidæ, and Notodontidæ, now characteristic of North and South America or of the tropical regions of Asia and perhaps of Africa.

Among the Notodontidæ the Heterocampidæ, for example, now confined to eastern North America, Central America, and western South America, may have flourished in Europe contemporaneously with the sequoia, magnolia, liquidambar, gum tree, and other existing types of vegetation now extinct in Europe. Although Macrurocampa is an American genus, some form like it may have existed in Europe, from which the European *Cerurinæ* may have evolved, unless the type migrated from Asia. There is a species of Stauropus in India, though there are few Notodontians in that country, and southeastern Asia is evidently the center of development of the bulk of the European genera of Bombyces, geological extinction in these moths having gone on very extensively in Europe, perhaps as the result of the cold of the Glacial epoch.

V.—ON THE INHERITANCE OF ACQUIRED CHARACTERS IN LEPIDOPTERA.

Perhaps in no other group or order of animals may we study the subject of the inheritance of acquired characters with more success than in the Lepidoptera. In these insects the four stages of existence—the egg, larva, pupa, and imago—are definite and fixed, and during each of the three last periods the organism is, so to speak, a different creature, with distinct and separate shape and structure, external and internal, and during each leads a different life. Family, generic, and specific characters are inherited at each of these stages, and at each there is a combination of congenital and acquired characteristics, some of both classes of which, i. e., those least marked, are difficult to separate from each other.

The following is an attempt at a rough grouping of such features at the last three stages. We omit the egg stage, for though they more or less vary in shape and ornamentation, this is perhaps due more to difference in the structure of the lining of the oviduct of the female than to the action of external circumstances on the egg after it has been laid. Yet this should be said with some reservation, because we are not aware that any one has discussed the probable mode of origin of the specific differences in the shape and color of the eggs of birds or the shape and markings of the eggs of insects, though undoubtedly the agency of external causes, together with natural selection, has had something to do with the variation.

It has seemed to us that the relation of specific and generic characteristics in the eggs of insects is a most difficult problem. Yet it should be observed that while the differences in ornamentation and shape are primarily due to the impression on the shell received from the lining of the oviduct, yet the wonderful diversity we see in the eggs of insects is often readily seen to be correlated with the external conditions in which they exist after having been deposited by the parent. In birds the thick, solid shell and the oval shape of the murre's egg seem due to the unprotected manner in which they are left on the rocks and shelves, from which they are liable to fall.

We may contrast with such an egg that of the robin, in which the shell is thin and uniform in color, since it is protected from harm by being contained in a nest; so also the color of the murre's eggs may be due to the action of protective mimicry, the spots assimilating them to lichen-grown rocks, by which they escape the observation of their natural enemies, the fox, the mink, and other egg devouring animals. So the eggs of Chrysopa, of many bugs, etc., are in shape and mode of attachment beautifully adapted to prevent them from being seen by egg-devouring animals.

In the larval histories given in this work we have endeavored, where they have been observed with sufficient completeness, to discriminate between the congenital and the acquired characters.

1. Larval state.—A. In this state we have the inheritance of congenital characteristics.

B. Inheritance of what were originally acquired characters, the results of attacks of enemies: Examples are the tubercles armed with spines and sometimes with caltrops (Empretia, etc.) and stripes, all apparently inherited at different periods of larval life, the least important specific and varietal characters probably having been acquired during the life of an individual.

2. Pupa state.—A. Cocoon: The absence or presence of a cocoon was doubtless originally due to differing external conditions, while the dense, perfect cocoon is characteristic of the spinning moths (Attacidæ, Lasiocampidæ, etc.); the Ceratocampidæ make none at all, but, like the Sphinges, the larvæ simply bury themselves in the earth before pupation. In the Arctiidæ and the Liparidæ the cocoon is chiefly composed of the barbed larval hairs, with a little silk to fasten them more firmly together; in the Geometridæ certain larvæ spin a loose, thin web. In such cases the spinning of a cocoon is intimately associated with a change of larval habits, and is, with little doubt, an acquired habit, originally formed by a single individual.

B. The shape of the pupa is often dependent on the presence or absence of a cocoon. In the Notodontidæ the cremaster is often absent in genera such as Gluphisia, which spins a very slight cocoon, and Lophodonta, which spins no cocoon, and is closely allied to those which do. In Cerura there is no spine on the rudimentary cremaster, because the pupa lies in a very dense cocoon fastened to the bark of trees, etc., and being in no danger of being shaken out no cremasterial spine or hooks are developed. The cremaster affords excellent generic and specific characters. In the subterranean pupa of Datana it is present, and is of use in aiding the pupa to reach the surface of the ground. It is very large and acute in the subterranean pupæ of Ceratocampidæ and Sphinges. It is evident that in the presence or absence of the cremaster, and in its shape and in the number of hooks and their shape, we have a set of very plastic characters (though excellent for distinguishing genera and species) whose variability and plasticity is due to the varying habits of the pupa, whether living above or under ground, whether protected by a very thin, loose, net-like cocoon or by a solid double one like that of Cerura or of the silkworms. Also whether the thread is continuous and can be readily reeled, as in *Bombyx mori*, or whether the thread is often interrupted at the anterior end, as in *Platysamia cecropia*, is a feature which was probably the result of a slight change of circumstances and may have been inaugurated as the result of variation in a single individual during a single lifetime, afterwards in succeeding generations becoming fixed by homochronic inheritance.

3. *Imago state.*—It is easier to select what may have been acquired characters in caterpillars than in butterflies and moths, and yet the latter have a complicated series of what may originally have been acquired characters. It should be borne in mind that while caterpillars live for weeks and even months, are subject to frequent molts, are active, and are dependent on a proper supply of their food, usually this or that plant, butterflies and moths perish, as a rule, directly after mating, taking little or no food. Of course acquired characters are most marked in the parts which are most used, as the maxillæ, wings, and external genital armature.

The absence of maxillæ or their very rudimentary condition in Bombycine moths is, with little doubt, a recently acquired character. The very arbitrary distribution in Lepidoptera of scent organs (Androconia, etc.) are apparently characters recently acquired. The wonderful variations in the markings of the wings, due to a variety of slight causes, may often arise during an individual's lifetime and become a matter of inheritance, the result of sudden changes in temperature, moisture, or dryness, and changes in food of the larva. By subjecting individual pupæ to prolonged cold, or *vice versa*, varieties and a greater or less number of broods may be produced artificially, and this may illustrate how seasonal varieties have arisen in nature.

Many species are only separated by differences in the male genital armature. These, as is well known, are subject to great individual variation, and why should not the characters peculiar to a distinct variety, or even species, arise during the lifetime of two individuals when mated? An unusually vigorous polygamous butterfly may have some new congenital extra development of hooks and processes, and by frequent use develop the muscles controlling these to the extent of providing an acquired character, which may be, if useful, inherited in the next and succeeding generations.

But an especially interesting and fruitful field of investigation would be a study of wingless Lepidoptera, such as the cankerworm, the autumn moths allied to it, the tussock moths (Orgyia), and especially the sack bearers or Psychidæ.

The loss of wings in these cases seems to be due to disuse in individuals more sluggish than others, and with little doubt has been the result of inheritance of what were originally acquired characters. It is easy to imagine how this has been induced by a study of a series of forms, beginning with certain European genera, in which the wings of the female are very small, and passing to those in which they become simple pads, as in Orgyia, and ending with those such as Anisopteryx, in which their reduction is still further carried out. And then Lepidoptera should be compared with certain of the Ephemeræ, whose hind wings are so much reduced; with Pezzotettix and other Orthoptera with aborted wings, and certain Hemiptera in which the wings are aborted, ending with the great order of Diptera, comprising a vast number of species, in which the hind wings have not only undergone a great reduction, but have been transformed through change of function into balancers, with their extraordinary sense organs. It is not difficult to see that the disuse of wings may have begun in the life of a single individual, which, losing its wings and having perhaps inherited a tendency to this lesion through corpulency and other bodily changes, became inactive, averse to flight, and finally transmitted the peculiarity to its offspring.

In a paper in the Proceedings of the Boston Society of Natural History (xxiv, 482), on the life history of *Drepana arcuata*, I have described the different stages of this moth, and at the end recapitulated the congenital characters, and finally given a synopsis of the chief steps in the evolution of the adaptional characters, which appear after the first exuviation. It seems very probable that these later features were the result of the action of external stimuli, both physical and biological, and that they were acquired not only during the lifetime of the larva, but at certain distinct stages or periods during the growth of the creature. The changes are both colorational and structural, and during the different stages the larva was adapted for different surroundings, and thus at each important stage was virtually for the time being a distinct animal.

During the pupa stage special and unusual structural adaptations arose, the cremaster being unusually developed, and also a pair of cephalic hooks, seeming to entangle the head in the web of the cocoon, so that the pupa can not be thrown out of the curled leaf, which remains in the first brood on the trees. These I regard as characters acquired by the insect after birth and in response to the exigencies of life at different stages. I will here add the conclusions given in that paper.

RECAPITULATION OF THE SALIENT FEATURES IN THE ONTOGENY OF DREPANA ARCUATA.

A. CONGENITAL CHARACTERS OF THE LARVA.

1. Anal legs obsolete: suranal plate already ending in an elevated rod-like spine in Stage I.

2. Glandular hairs (split at the end) present only in Stage I.

3. Piliferous warts well developed but of uniform size on all the segments in Stage I.

4. Head and body dark brown, but the warts pale; uromeres 1 and 7, pale yellowish in Stage I.

5. Crochets of abdominal legs more numerous than usual, forming an incomplete circle, compensating for the lack of anal legs and crochets.

6. These congenital characters are of generic value, the specific characters appearing at and after Stage III.

B. EVOLUTION OF LATER ADAPTATIONAL CHARACTERS.

1. Reduction in size and length of hairs after Stage I, glandular hairs being replaced by ordinary tapering ones.

2. At the beginning of Stage III the body becomes yellowish-green, and the dorsal region, previously dark, becomes broken up into pale yellowish-green spots. Head distinctly banded with yellow.

3. In Stages IV and V the greenish portions of the body become darker, like that of the food plant, and the reddish-brown parts are assimilated to the hue of the leaf stalks and twigs.

4. In Stage III the prothoracic dorsal warts degenerate, and those of the two succeeding stages slightly progress in development.

5. The ninth uromere becomes as large as, if not slightly larger than, the eighth, and separated by a distinct suture from the tenth—a very unusual feature in caterpillars.

6. The chief adaptational features are: (1) colorational, to enable the partly or fully grown caterpillar to escape observation, and (2) structural, the unusually large ninth and tenth abdominal segments being upraised, with the upturned threatening suranal rod or spine fitted to frighten away ichneumons or Tachinæ, and possibly insectivorous birds.

C. A SPECIAL ADAPTATION IN THE PUPA.

The pair of cephalic stout hooks serving to entangle the head in the web of the cocoon, the cremaster also being unusually well developed, so that the pupa, which in the first brood remains on the tree, is slung by its head and tail, and can not be thrown out of the curled leaf.

D. PROTECTIVE COLORATION OF THE MOTH.

When I first noticed the moths, with their broad wings outspread and resting on the upper side of the leaves, I mistook them for pieces of dead, dry, yellowish leaves which had fallen upon and become fastened to the surface of the fresh leaf.

ACQUIRED CHARACTERS IN THE NOTODONTIDÆ.

In the succeeding systematic portion of this work I have given a number of life histories of the family, and with more or less detail pointed out the later adaptional as distinguished from the congenital characters. I have on pages 21–23, called attention to the varying shapes of the tubercles and setæ in the larvæ of the Bombyces and other of the higher Lepidoptera and to their probable mode of origin and why they appear on certain segments in preference to others. The attention of the reader is called to the summary or recapitulation of changes especially in the life history of *Datana integerrima*, *Apatelodes torrefacta*, *Symmerista albifrons*, *Macrurocampa marthesia*, and of three species of *Cerura*, while there is a summary of the steps in the assumption of the adaptive characters at the different larval stages of several species of Schizura. The steps in the evolution of what may be regarded as acquired characters in Schizura, and in *Dasylophia anguina*, Hyparpax, Heterocampa, etc., are readily seen by an examination of the plates.

The Notodontians are remarkable in general for the humps, tubercles, and spines of their larvæ, some of which are congenital, while others appear at different stages after birth. Still some larvæ of this group are entirely without them and remain so throughout their larval life. And this is an argument that the various processes of the cuticle or outgrowths of the entire integument are characters originally acquired during the postembryonic life of the young insect.

Take for example the larval *Nadata gibbosa*: this, like the caterpillar of Gluphisia and of Lophodonta, is a smooth bodied larva, ornamented with lines, but entirely unarmed. The life history of *N. gibbosa* shows that it is born with a smooth body, without any traces of tubercles or enlarged bristles, while no traces of the yellowish subdorsal lines appear until at the end of the second stage, the only ornamentation being coloration. This form is therefore a primitive one, and this fact would seem to demonstrate that the humps, tubercles, and spines so frequently observed in the group arose within recent geological times, and were acquired during the postembryonic stages of the larvæ of different genera in response to various changes in the surroundings of different species, these finally becoming fixed and regularly transmitted along various lines of development, resulting in a series of forms constituting the present genera of the family.

One of the most notable cases in the family is that of the loss at about the middle of the larval life of the remarkable antlers of *Heterocampa biundata*. During the three earliest stages the larva bears on the prothoracic segment a pair of enormous antlers with four tines. At the second molt these are discarded, and in the two last stages are represented by a pair of conical, rounded, polished, piliferous knobs. The rest of the partly grown body of the larva is smooth. After casting its horns the larva assumes a new set of coloration markings, so that in its last two stages it is a totally different creature in appearance from the earlier stages.

One of the plates represents a series of colored drawings, by Mr. Bridgham, of the still more wonderful changes undergone by the caterpillar of *Heterocampa guttivitta*, representing five stages, nearly each of which presents notable differences. In the first, directly after hatching, the reddish larva has not only a pair of enormous antlers with four tines on the first thoracic segment, but a pair of long antler-like spines on abdominal segments 1 to 6 and also 8 and 9, those on segments 1 and 8 being about three times as large as the others. It is certainly one of the most singular larvæ of the family.

Now this bizarre armature is entirely discarded at the first molt, with the exception that the prothoracic antlers are represented by a pair of knob-like tubercles, the other segments, however, showing no trace of the former existence of spines. Also, while the body was not striped in Stage I, it is now paler red, with a more brownish tint, and is marked with four yellowish stripes. At the end of this stage the lines become effaced and the body grows more yellowish on the sides. In the third stage the tubercles still persist, but the markings differ very much, as reddish dorsal patches appear in the middle and near the end of the body, and there are anticipations of the markings of the fully grown caterpillar. In the present stage the insect closely resembles the mature larva, having bright crimson markings on the thoracic segments and on the third and fourth and on the fifth and sixth abdominal segments, these bright spots becoming somewhat less decided and conspicuous in the final stage.

Fig. 1 (p. 37) represents the first larval stage of *H. obliqua*, its horns being like those of *H. guttivitta* (111*a*), and also dropped at the first molt.

Now, it seems natural to suppose that the disappearance of the armature of this insect with the first molt was due to the lack of need for it by the caterpillar, which gradually became adapted to a life on the underside of an oak leaf, where it assumed a simple spindle-shaped body extended when at rest along the midrib, in which position we have found the older caterpillar, its body glaucous-green and so marked with yellowish lines and reddish spots, as well as with dashes and lines, as to be wonderfully assimilated to the greenish, reddish, and whitish lines of the leaf under which it was sheltered.

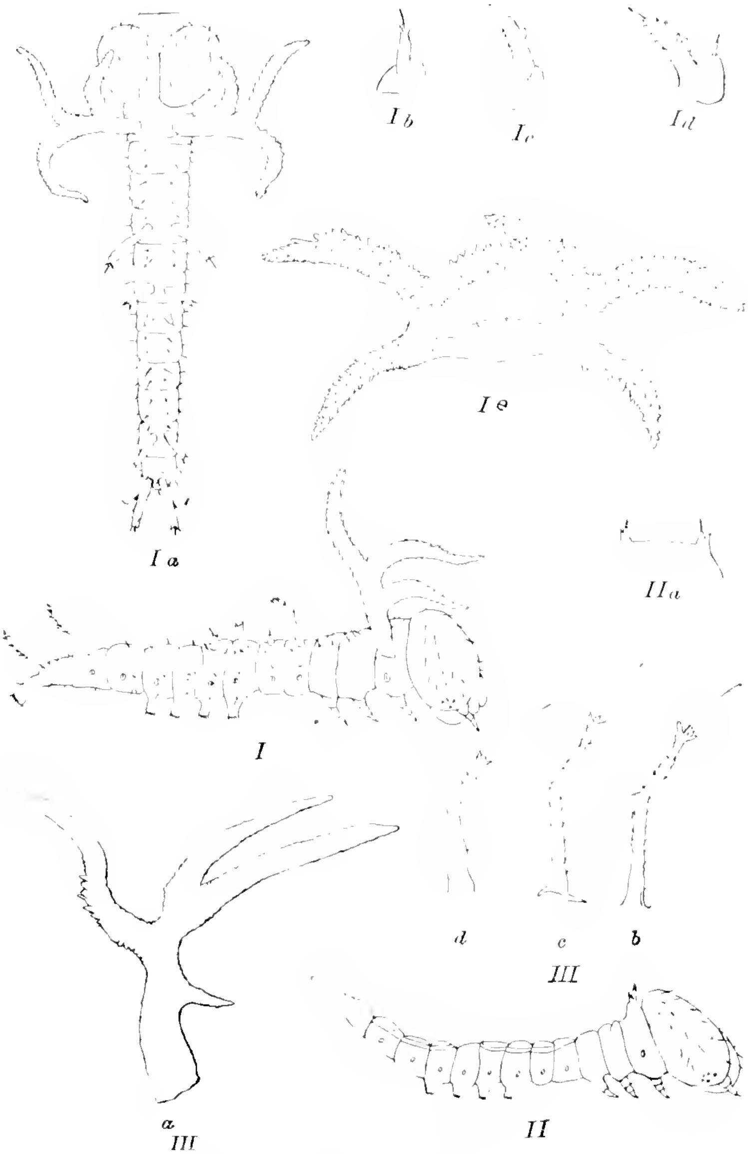

FIG. 1.—Early stages of *Heterocampa obliqua* and *H. guttivitta*.—I. *Heterocampa obliqua Pack.*—Freshly hatched larva; *Ia*, dorsal view; *Ib*, spine on third; *Ic*, spine on eighth; *Id*, spine on ninth abdominal segment; *Ie*, prothoracic horns of stage I, enlarged. II. Heterocampa obliqua *Pack.*—Stage II; *IIa*, horns on first prothoracic segment. III. *Heterocampa guttivitta Walk.*—Horns in stage I *a*, prothoracic horn; *b*, one on second abdominal; *c*, one on third to fifth, and *d*, on ninth abdominal segment. (The setæ are in some cases omitted).

It also seems reasonable to suppose that these adaptational, colorational features were acquired by the ancestors of the present forms during the different stages succeeding the first ecdysis. And thus we are warranted in assuming that this and multitudes of other cases of adaptation to the change in habits and modes of life and special situations were acquired originally, at different periods after birth, during an earlier geological period than this, when the ancestors were fewer in number and more plastic than now. Otherwise, how can we have the differentiation of a few ancestral forms into the present series of genera, subfamilies, and families represented by such a great number of species?

Indeed, it seems difficult to account for the evolution of the vast hordes of existing species of insects, unless we assume that there was going on throughout the entire process the rise and gradual perfecting of postnatal acquired characters, such characters becoming fixed by heredity and reappearing with unerring certitude at different stages in the life of the individual, while in some animals whose postnatal metamorphosis became suppressed we have the more salient stages epitomized during the life of the embryo.

The reddish and russet spots developed in the three, and especially two, last stages of the larva of these Notodontians are, as shown by the experiments of Wood, and especially of Poulton, the result of the environment, being due to the action of the color of the spots of the leaves on the sensitive portions of the skin or cuticle of the caterpillars. It seems to be fundamentally due to the action of both physical and physiological processes. The skin is spotted and painted by the reflection of the red and russet tints of the leaves on the sensitive skin of the living organism.

The results are inherited at a corresponding period of life, just as the tubercles, spines, horns, and other kinds of armature. Hence for thousands of generations we have had such spotted caterpillars. Now if, as is quite obvious, the spots are thus suddenly produced, since light and dark hues were so produced in Mr. Poulton's laboratory, at a certain time in the life of the caterpillars observed by him, as we know by his experiments the colors were produced in the individuals of a single generation, it would seem to follow that in nature the characters were thus acquired in the larva at a certain stage in the life of the individual, and have been transmitted by homochronous inheritance. Moreover, this appears to be a case where the characters have been produced by the direct action of the environment.

At the time, the last of summer, when the leaves are fully mature, preparing to fall off and beginning to be variously spotted and tinted, there is made ready the peculiar environment of these leaf-feeding larvæ, and so long as these conditions of red and russet spotted or tinted leaves exist we shall continue to have similarly spotted caterpillars; should the leaves remain green, we should not expect to have such spotted larvæ. Now, these changes in the larvæ are due to the primary factors of organic evolution, i. e., to changes in the environment, to the reflection of these bright or russet colored patches on the cuticle of the animal. By the neo-Darwinian, the organization and production is attributed to "natural selection," as if it were the main and only efficient cause of evolution, but really it is not so at all. It may act as a subordinate factor after the colors are produced, and serve to preserve those individuals most distinctly marked, those less so more readily falling a prey to birds and insects. Natural selection does not originate, but after the new structures or markings have appeared, as the result of the operation of the primary factors of organic evolution (the views of neo-Lamarckians), natural selection comes in as a late and quite subordinate factor to preserve the organism.

Family Ceratocampidæ.—It is easy to believe that this group might have evolved from such a thoroughly armed caterpillar as that of *Heterocampa guttivitta*, whose ontogeny we have just outlined, as all the Ceratocampidæ bear spines which vary in degree of complexity. We are now acquainted with the life history of each important genus of this interesting group. We will select the case of *Sphingicampa bicolor*, a creature of marvellous beauty of ornamentation, which feeds on the Gleditschia or spiny locust. After a detailed study of the larva through its first larval stages to its maturity, we have drawn up the following summary of the more salient features in its ontogeny, dividing the characters into those which are congenital and those which we believe to have been acquired during the stages succeeding the first:

SUMMARY OF THE SALIENT FEATURES IN THE ONTOGENY OF SPHINGICAMPA BICOLOR.

A. CONGENITAL CHARACTERS OF THE LARVA, ALL APPEARING IN STAGE I.

1. The two pairs of enormous spines of second and third thoracic segments one-half as long as the body and ending in a two-spined, large, flattened, dark bulb, freely movable and plainly defensive in function.

2. The large, reddish, spiny "caudal horn" on the eighth uromere ending in two bristles.

3. The double piliferous tubercle on the ninth uromere becoming obsolete in Stages IV and V.

4. The abdominal region is longitudinally striped with dark and whitish bands, but there are no transverse marks in Stage I or in later stages.

B. EVOLUTION OF LATER ADAPTATIONAL CHARACTERS.

1. The head slightly angular, face subtriangular, with a light-brown or greenish lateral stripe (Stages II–V).

2. Appearance of a transverse row of dorsal granulations on the hinder end of each segment in Stage II, persisting through larval life.

3. The eight thoracic spines lose their bulbous tips and become simply slightly forked in Stage III and later.

4. The two dorsal spines of uromeres 1–7 are in Stage II larger than the others; in Stage III they become ivory white externally and in Stage IV larger and silvery white on the outside.

5. In the last two stages the eight thoracic spines become very much shorter in proportion to the size of the body and become less movable; as they decline in size and functional importance, the metallic, silvery, dorsal spines on the abdominal segments become conspicuous and apparently useful to the larva.

The following summary of a better-known caterpillar, that of *Eacles imperialis*, will bring out more clearly, perhaps, the point we wish to make, i. e., that the later adaptational characters have been acquired during the lifetime of either one or of a series of ancestral forms leading up to the present one.

SUMMARY OF THE CHIEF ONTOGENETIC FEATURES OF EACLES IMPERIALIS.

A. CONGENITAL CHARACTERS.

1. In Stage I there are three pairs of very long dorsal deeply forked thoracic horns, nearly half as long as the body.

2. A similar median spine on the eighth abdominal segment, with one half as long on the ninth.

3. The abdominal segments are transversely banded with black.

4. The lateral spines on the abdominal segments bifid and nearly as large as the subsimple dorsal ones.

5. Body pale chestnut brown; head light reddish.

6. The spiracles minute and difficult to detect, as they are situated in one of the transverse black bands.

B. EVOLUTION OF LATER ADAPTATIONAL CHARACTERS.

1. The forks of the larger dorsal spines disappear at the end of Stage III.

2. The dorsal thoracic spines become recurved in Stage III.

3. The dorsal thoracic and caudal horn become much shorter and stouter in Stage IV, when the characters of Stage V (and last) are nearly assumed.

4. In Stage II the dorsal spines on the prothoracic segment begin to grow shorter and stouter.

5. In Stage II the large horns begin to be less deeply forked.

6. The transverse black stripes disappear at the end of Stage II.

7. The dorsal and lateral spines on abdominal segments 1–7 are much smaller in proportion in Stage III than in Stage II.

8. Toward the end of Stage III the colors of the body become more conspicuous and variable.

9. In Stage III the spiracles become parti-colored and very conspicuous.

10. The dorsal thoracic and the "caudal horn" become much shorter in Stage IV and not forked at the tip.

11. The hairs become long and abundant in Stage IV.

12. The body in Stage IV becomes much stouter and heavier than before, while the head has not greatly gained in size proportionately.

The European *Aglia tau* appears to be the sole representative in the Old World of the American group or family Ceratocampidæ, though with the larval, pupal, and imaginal characters it seems to be the type of a distinct subdivision of the Ceratocampidæ (the subfamily *Agliinæ*), as we have named the group. This form is a connecting link between the genuine Ceratocampidæ and the Saturniidæ. As originally shown by Duponchel and more recently by Mr. Poulton, before the last molt the caterpillar wholly discards the congenital characters, viz, its spinous armature, characters common to the Ceratocampidæ, and assumes an entirely and strikingly different shape. It is now destitute of any spines at all, its body is rather short and thick, the segments full convex, and it closely approximates the general appearance of a Saturnian larva, though the majority of these are armed with more or less spinose tubercles; the caterpillar of the Brazilian *Attacus betis* Walker, however, is figured and described by Burmeister as being smooth-bodied. The Aglia is now quite a different creature from what it was in its earlier stages; its conditions of existence have somewhat changed, and in adaptation to such changes its means of defense are of a different nature. It now feeds passively on its food plant, and is dependent on its colors, various delicate shades of green and yellow, to escape the observation of its vertebrate and insect enemies, and if discovered it appears to rely on its large, terrifying eye-spot and somewhat sphinx-like attitude to frighten away its aggressors.

Now, it seems most natural to suppose that the features of the last stage were in the ancestors of this insect acquired wholly or in part during a definite epoch in the lifetime of one or perhaps of a few generations. The mature characters were not originally congenital and would have perhaps been useless in the early stages of the caterpillar. They may have suddenly appeared in a single individual and then have become transmitted by heredity and fixed by natural selection, or this process may have extended through several, though not very many, generations.

The chief factors in the origination of such a striking change in shape and ornamentation after the last molt appear to have been the atrophy of the spines and tubercles by disuse, the larva, by a change in its mode of life, with more sluggish habits and perhaps feeding in less exposed conditions, not needing them, the same change resulting in a transfer of the nutritive fluids and bringing about the deposit of pigment in definite places, as in the eye-spots.

Whether one accepts the view of the transmission of acquired characters or not, it must be conceded that the remarkable changes exhibited by Aglia in the last stage must have been induced with more or less suddenness; that the tendency, at least, to the change was probably originated during the lifetime of perhaps a single individual. The case seems to us to almost amount to a crucial one, and if it can be explained by any other mode of reasoning than the one suggested it will be a matter of interest. Certainly the congenital characters show a remarkable contrast with what we assume to be acquired characters, and we know of no better example which could be cited to prove the fact of the transmission of acquired characters.

Family Saturniidæ.—In the larval stages of this regal family we have great contrasts between the first and later stages, both in armature and coloration, as summarized below, each stage differing remarkably from the others:

RECAPITULATION OF THE MORE SALIENT ONTOGENETIC FEATURES OF PLATYSAMIA CECROPIA.

A. CONGENITAL CHARACTERS.

1. The setæ in Stage I blunt, slightly bulbous, and glandular.
2. The tubercles are all of the same size.
3. Body in Stage I dark, almost blackish green; head jet-black; tubercles yellowish green.
4. The homologue of the "caudal horn" shows plainly its double origin.
5. The difference between the colors of the larva of the first and last stages very marked.

B. EVOLUTION OF LATER ADAPTATIONAL FEATURES.

1. The thoracic dorsal tubercles in Stage II and onward are longer than the abdominal ones.

2. Five rows of indistinct black spots along the body in Stage II, not so distinct as in *S. cynthia*, the body being still dusky green. (These do not originate from lines.) At the end of Stage II the larva is more like *cynthia* of the same age, the body being more yellow and the black spots more distinct. The spots disappear at the end of Stage IV.

3. The thoracic dorsal tubercles deep orange; their homologues on the abdominal segments amber yellow.

4. The tubercles at the end of Stage II and in Stage III spotted on the sides with black.

5. In Stage III the dorsal tubercles of second and third thoracic segments showy coral red. The subdorsal and infraspiracular tubercles tipped with pale blue; in Stage II the same tubercles are almost entirely pale blue.

6. The head becomes green in Stage IV, with a black spot on the side.

7. The larva is most gaudily colored and conspicuous in the last two stages, while in *S. cynthia* there are not such marked differences between the different stages, though the last is the most variegated, owing to the beautiful turquoise-blue trappings.

In *Callosamia promethea* the freshly hatched caterpillar is most remarkably banded, and all its marks and tubercles are in striking contrast with the fully grown larva. The differences may be epitomized as follows:

RECAPITULATION OF THE MORE SALIENT ONTOGENETIC FEATURES OF CALLOSAMIA.

A. CONGENITAL FEATURES.

1. Hatched with heavy black transverse bands on a yellow body, and the head black, banded with yellow; the bristles moderately long; thus the larva is already a rather conspicuous object.

2. The dorsal thoracic tubercles already differentiated in size and color from those on abdominal segments 1 to 7. The differences between the freshly hatched larva and the last stage very marked; more so than in Platysamia or Samia.

B. EVOLUTION OF LATER ADAPTATIONAL FEATURES.

1. In Stage II the body becomes paler, and thus the black bands more conspicuous. The second and third thoracic dorsal tubercles and those on abdominal segments I to 8 are now all yellowish and of the same size.

2. Disappearance in Stage III of the transverse black bands. The abdominal tubercles all become blackish.

3. In Stage IV the head becomes yellow, being less conspicuously marked, and the dorsal abdominal tubercles are about half as long and large as those on the second and third thoracic segments.

4. The body becomes in the last stage much smoother than before, the dorsal prothoracic and abdominal tubercles being much shorter than in Stage IV. This reduction of size and inconspicuousness of the dorsal abdominal tubercles is carried out to excess in *C. angulifera*, where they become obsolete, and the larva is simply a large green caterpillar with inconspicuous markings, and simply protected by its green color, like the majority of lepidopterous larvae, not being so strikingly marked as in the fully fed *Samia cynthia*.

It is not improbable that the reduction and atrophy of the dorsal tubercles in question is also accompanied by a great reduction, if not total abolition, of the poison glands at the base of these spines. However, having lost the power of resisting or avoiding attack by this means, it, by the action of the law of correlation, also loses its bright markings or danger signals, and having become harmless to its enemies it is preserved from extinction by passively relying on its smooth, glaucous-green body to escape the observation of its natural enemies.

A tendency to the same end is seen in the larva of *Samia cynthia*, which is paler, less gaily ornamented with bright markings, and also is much less heavily intercalated than the caterpillar of *Platysamia cecropia*.

It is evident that of the two species of Callosamia, *C. promethea* is the more primitive form and *C. angulifera* a derivation from it; the former is what systematists call a "higher" species and *C. angulifera* a "lower," but many "lower" species are simply a set of those individuals which have undergone some degree of modification or degeneration, and are later in point of origin.

Likewise the Asiatic genus, *Samia* (*S. cynthia* being an introduced form), with little doubt, is a form which has undergone more or less modification and indeed a slight degree of reduction or atrophy, and is thus a later form, the genus *Platysamia* being an earlier type, since it has probably been envolved from *Saturnia*, which is the most primitive genus of the family.

The terms "high" and "low" are expressions much misused and misapplied; the terms generalized, or early or primitive; and modified, specialized, or later, are perhaps truer to nature.

It is not always the highest—i. e., most specialized—forms which are furthest removed from the ancestral forms. For example, the Diptera, especially the Muscidæ, are the most modified of insects, i. e., the furthest removed structurally from the winged ancestral forms; but the Hymenoptera, especially the wasps and bees, when we take into account the adult stage, are the "highest"—i. e., the most specialized—of all insects.

The life histories of the colossal moths, *Telea polyphemus* and *Actias luna*, are of much interest in connection with this topic, and our remarks should be illustrated by elaborate detailed descriptions and colored figures, but the essential points may be indicated by the following epitomes. It should be premised that the shape of the tubercles and the glandular setæ they bear differ greatly in the freshly hatched larva from their appearance after the first molt:[1]

RECAPITULATION OF THE MORE SALIENT ONTOGENETIC FEATURES OF TELEA POLYPHEMUS.

A. CONGENITAL FEATURES.

1. The setæ (bristles) of Stage I but little longer than the tubercles, and both truncate and distinctly bulbous at tip.

2. A slight but distinct differentiation in size and color of the dorsal tubercles, those of the third thoracic and ninth abdominal segments being of the same size, and larger than those on uromeres 1–7, and of a deeper yellow shade. (Stage I.)

3. The homologue of the "caudal horn" is distinctly double and more deeply divided than in any other American genera of Attacinæ; each fork about as long as thick. (Stage I.)

4. Abdominal legs each with 24 crotchets—a larger number by 6 to 8 than in the other genera. (Stage I.)

5. Each abdominal segment (uromere) with a lateral pair of transverse black slashes in Stage I.

6. The two tubercles in Stage I on the suranal plate slender, papilliform, and approximate.

B. EVOLUTION OF LATER ADAPTATIONAL CHARACTERS.

1. The lateral pair of black transverse stripes on each uromere nearly or quite disappear in Stage II.

2. The segments more convex and angular in Stage III.

3. Appearance of a yellowish lateral oblique stripe connecting the lateral tubercles of the lower and upper row in Stage III.

4. Appearance of the pale purplish edging of the suranal plate and anal legs in Stage III.

5. Appearance in Stage IV of the pearly spot on the outside of the dorsal tubercles.

The generic characters are mostly assumed in Stage III.

RECAPITULATION OF THE MORE SALIENT ONTOGENETIC FEATURES OF ACTIAS LUNA.

A. CONGENITAL FEATURES.

1. Setæ tapering to a point, not bulbous, and finely barbed. (Stage I.) Most of them are three or four times as long as the tubercles.

2. Some larvæ in Stage I with a very broad lateral dark band along the side of the body, some without it; no transverse stripes present, but the head in front is twice banded with dark brown.

3. The second and third dorsal thoracic tubercles differentiated in Stage I, being slightly larger than the abdominal ones.

4. On the suranal plate are two rudimentary tubercles, each bearing a tuft of bristles.

5. The dorsal median tubercle on uromere 8 does not show such marked traces of its double origin as Stage I of *C. promethea* or *T. polyphemus*, but it is more duplex than in *P. cecropia*.

[1] See Proc. Amer. Acad. Arts and Sciences. Boston, xxviii, p. 80. 1893.

B. EVOLUTION OF LATER ADAPTATIONAL CHARACTERS.

1. Dorsal tubercles in Stage II higher than before.

2. The lateral dark band disappears in Stage II.

3. In Stage III the dorsal thoracic tubercles become nearly twice as long and thick as the abdominal ones.

4. The head is not banded in Stage IV.

5. The tubercles brightest (pink or dark carmine) and most conspicuous in the last stage.

6. A distinct infraspiracular yellow line in Stage IV, and the suranal plate and anal legs lined with yellow, and the surface of the suranal plate and sides of the anal legs amber colored.

Family Cochliopodidæ.—The slug-like larvæ of the Bombycoid family Cochliopodidæ, so remarkable from their snail like mode of locomotion, their abdominal legs being entirely atrophied, in their life history offer strong circumstantial evidence in favor of the primitive rapid acquisition of striking characteristics at the first molt. These larvæ, as we have elsewhere stated, are born without traces of abdominal legs, are nearly colorless, and with bodies more cylindrical than in the full grown caterpillar. In the more specialized tuberculated and spiny genera Adoneta and Empretia (and probably Euclea) the tubercles are already differentiated in Stage I, much as in the last stage, but otherwise the change from the first to the second stage is very great, so that the set of congenital characters is very different from the assemblage of acquired characters, especially the addition of great numbers of bristles on the tubercles, and the gay varied colors and markings of the body. This sudden change, after but a single molt, shows that these characters are suddenly acquired. The larvæ from being minute, pale-yellowish worms, hatching from almost invisible scale-like transparent eggs, after the first molt undergo a striking change, the result of feeding in a more exposed situation and of consequent successful adaptation to prevent recognition on the part of hostile insects and birds. The armature of poisonous glandular spines and the development of bright warning colors are evidently characters acquired late in larval life, when the creatures are large enough to attract notice.

In illustration of the changes due to adaptation undergone by members of this family, I have selected the following examples, copied from a previous paper:[1]

RECAPITULATION OF THE MORE SALIENT ONTOGENETIC FEATURES OF EMPRETIA STIMULEA.

A. CONGENITAL FEATURES.

1. The tubercles on the second and third thoracic and the first, seventh, and eighth abdominal segments three times the size of those on abdominal segments 2–6, these tubercles being already differentiated at birth and more markedly so than in Adoneta.

2. Head not capable of being withdrawn into and concealed by the prothoracic segment.

3. The tubercles each bear only three two-forked glandular setæ.

4. The body is more cylindrical than in the later stages and colorless.

B. EVOLUTION OF ADAPTATIONAL FEATURES.

1. In Stage II the form and general colors of the full-fed larva are assumed.

2. The tubercles are now armed with numerous poisonous spinules.

NOTE.—From what we now know of the congenital as compared with the later acquired adaptational characters of Cochliopods, it is evident that the latter are acquired at an earlier stage than in most other caterpillars.

RECAPITULATION OF THE MORE SALIENT ONTOGENETIC FEATURES OF ADONETA SPINULOIDES.

A. CONGENITAL FEATURES.

1. No tubercles on the prothoracic segment.

2. The dorsal tubercles on the second and third thoracic and first, fourth, seventh, and eighth abdominal segments double the size of those on the other segments, the tubercles being already differentiated at birth.

[1] Proceedings Amer. Philosophical Society, Phil. xxxi, pp. 83–108, 1893.

3. The prothoracic segment not yet forming a hood, the head not retracted within it so readily as in the last stages.

4. The tubercles each bear only three three-forked glandular setæ.

5. The segments are more distinct than in the later stages.

6. The body is pearly white, slightly purplish on the back.

B. EVOLUTION OF ADAPTATIONAL FEATURES.

1. The body in Stage II assumes nearly the form and colors of the last stage, the tubercles being armed with numerous spines and some of them tinted with red.

2. In Stage III the colors and appearance of the full-fed larva are assumed.

RECAPITULATION OF THE MORE SALIENT ONTOGENETIC FEATURES OF LITHACODIA FASCIOLA.

A. CONGENITAL FEATURES.

1. The larva is hatched without any tubercles.

2. The glandular hairs are of the same size and shape in the dorsal and subdorsal rows, being short, with a tine at the middle and forked at the truncated end.

3. The body is more cylindrical than in the last stages and not skiff-like, and the segments are distinct and simple.

4. The body is at first colorless.

B. EVOLUTION OF ADAPTATIONAL FEATURES.

1. The body becomes skiff-like when 5.5 mm. in length.

2. The color is pea green, like that of the leaf it feeds on, with straw-yellowish marks and spots.

3. The skin becomes rough and granulated and the plateau distinctly marked in Stage III or IV.

4. In the last stage the minute spines disappear.

VI.—GEOGRAPHICAL DISTRIBUTION OF THE AMERICAN NOTODONTIDÆ.

MAPS I–X.

The Lepidoptera are, as regards the higher groups, from the Bombyces to the butterflies, very largely tropical, the number of species diminishing as we pass from the equator to the poles.

Mr. Wallace[1] states that the distribution of butterflies corresponds generally with that of birds in showing a primary division of the earth into eastern and western rather than into northern and southern lands. From his studies on the distribution of butterflies and "Sphingina" (including, however, the Ægeriidæ, Castniidæ, Agaristidæ, Zygænidæ, Uraniidæ), he concludes that "the neotropical region is by far the richest and most peculiar."

The Zygænidæ or day-flying moths are usually restricted to the Tropics, as we have seen in a striking manner when descending from the temperate zone of Mexico to Cordova, which is situated in the tropical zone (tierra caliente), and it is easy to recognize the fact that our United States species of this family have been derived from the tropical regions of Central and South America and the Antilles.

It would be premature for us to enter into even a provisional account of the distribution of the Bombyces as a whole until we have completed our survey of the members of the entire superfamily, and our remarks at present will be therefore confined to the Notodontidæ.

It may, however, be well to bear in mind some general results which are quite obvious to one who has paid even slight attention to the Bombycine moths.

While the Notodontidæ appear to be both tropical and temperate forms, though it should be borne in mind that we know but little of the tropical forms, and few species are known from India or southern Asia in general, certain other families are largely tropical.

[1] The Geographical Distribution of Animals, 1876, ii, p. 483.

Upon the whole, the *Ceratocampidæ* are tropical, many more species occurring in Brazil and Central America than in North America, and this may be said of the family Hemileucidæ.

The family *Saturniidæ* is a tropical group, only a single genus occurring in Europe, while in North America north of Mexico there are six. In tropical America, Africa, and southeastern Asia, including China, the species and genera are far more numerous and form a characteristic feature of the fauna.

Another family richly developed in the tropics of South America, Africa, and Asia is the extensive family of *Lasiocampidæ*, many of them rivaling in size the colossal Attaci, and judging from a collection of Central African caterpillars of this group in the museum of Brown University, collected on the Upper Congo, their armature of spines is the most formidable of any of the Bombyces. And here it may be observed that the most spiny forms appear to be tropical, and this tends to prove that originally nearly all our spiny caterpillars appeared in warm regions, while the densely hairy forms, like Arctian larvæ, predominate in cool temperate regions.

The *Psychidæ*, though so richly developed in Europe, appear on the whole to be widely distributed over the tropical regions, including Australia.

The group of *Cochliopodidæ* or slug caterpillars is richly developed in Central and South America, as well as in India, but is entirely wanting in western North America, while in Europe there are only two species, this paucity or absence of species being probably due to geological extinction in the western portions of the Old and New Worlds.

The small family of *Megalopygidæ* (Lagoidæ) is confined to the New World. One genus (*Lagoa*) occurs in the eastern United States, but the species are most numerous in the forest regions of eastern South America.

The family *Liparidæ* appears on the whole to exist in greater force in the Tropics of America and Asia than in the temperate regions to the northward.

On the other hand, the extensive group of *Arctiidæ* and *Lithosiidæ* predominate in the temperate regions, and its species, in rare cases—a few of Arctia—extend to the Polar Regions, only one other genus, Laria, a Liparid, sharing the regions of the Arctic Circle, a species of each genus, Arctia and Laria, also being Alpine in Europe and North America.

We will proceed to analyze the Notodontian fauna of North America.

The animals of our American continent south of the Polar Region may roughly be divided into three grand assemblages, i. e., (1) those inhabiting the northern moist and forest-clad regions; (2) those inhabiting the elevated, dry plateau region of the Cordillera mountain ranges, extending southward over the Mexican plateau, and which may be called the Plateau Province (it is Allen's Arid Province); (3) those inhabiting the tropical portions of southern Florida and the low tropical shores of southern Texas and of Central America.

In our essay on the geographical distribution of the Geometrid moths,[1] published in 1876, we called attention to the elements from which our present insect fauna has been formed, and claimed that the tropical elements in our fauna originally migrated from Central America by three avenues, i. e., the Pacific Coast, the central plateau of the Cordilleras, and the Atlantic Coast, and we have always been of the opinion that the Mexican fauna had strongly influenced the Pacific Coast fauna, as well as the fauna of New Mexico, Utah, and Nevada.

As to the Arid province, or Plateau province as it might also be designated, it may be observed that within the limits of the United States it comprises the Central province of Agassiz, together with the Pacific Coast or California province, and to which Dr. Allen gives the name of Campestrian subprovince. The southern equivalent of the Campestrian is the Mexican subprovince. We very much prefer the word Mexican to the term "Sonoran" of Dr. Merriam.[2] Originally the term "Sonoran" was applied by Cope to a restricted portion of northwestern Mexico known politically as Sonora.

But Dr. Merriam has, somewhat unwarrantably it seems to us, extended the term "Sonoran" to include not only the elevated portions of Mexico, but also almost the whole of the United States

[1] A monograph of the Geometrid moths or Phalænidæ of the United States. Report U. S. Geological Survey, F. V. Hayden, geologist in charge, Vol. X, 1876.

[2] The Geographic Distribution of Life in North America, with special reference to the Mammalia. Proc. Biological Society of Washington, vii, pp. 1–64, April, 1892. With a map.

south of the Great Lakes and New England, his Upper Sonoran being the equivalent of the Carolinian of other writers, and his Lower Sonoran corresponding to the Austroriparian subprovince of Allen. Such an enormous extension of the term Sonoran seems unfortunate, and it is to be hoped that it will not be generally adopted.

The word Mexican, being far more general in its application, is obviously a more natural and general term, and means more to the general student than the restricted word "Sonoran." Sonora is but a small district or portion of Mexico, and while we might perhaps retain the name Sonoran for the fauna of northeastern Mexico in the sense originally intended by Professor Cope, to give it the very great extension now proposed is at least inadvisable.[1]

Another consideration is the probable origin of the fauna of this Arid or Plateau Province. The region covered by the fauna and flora of the Great Plains of the United States (Campestrian) and of the Mexican Plateau is entirely distinct from the northern or cold-humid and the southern warm-humid subregions of our continent.

It is possible that it is in a large part made up of the remnants of the Pliocene fauna, which underwent great modifications during the process of desiccation of the treeless, elevated western portion of our continent (originally the Mesozoic Pacifis of Clarence King). Doubtless during the period of elevation and of drainage, resulting in the formation of the extensive desert tracts of the United States and Mexico, when the surface became deforested, owing to the lack of sufficient rainfall, the present assemblage, or at least the immediate forerunners of the plants and animals of this vast plateau region, formerly inhabitated by the lacustrian life of the Eocene, Miocene, and Pliocene Tertiary epochs—times of tropical humidity and heat—was gradually brought into existence.

The general name "Arid province" applied by Dr. Allen to this plateau region seems appropriate, and for the two quite distinct subprovinces Dr. Allen's term Campestrian is well selected, and for the southern we hope the term Mexican will be reserved, especially since the tropical portions of Mexico seem, so far as our present knowledge extends, scarcely distinguishable from that of Central America in general. We shall venture in this work to use the word Mexican in the sense in which the term Sonoran has been employed by Dr. Merriam.

The maps published by Dr. Allen in his most recent essay on the geographical distribution of North American mammals (Bulletin of the American Museum of Natural History, iv, pp. 199–243, 1892) will, with a few minor changes, serve our purpose in illustrating the distribution of the insects and in a more restricted way of the Bombycine moths (see Map I). We may have in our former essay contrasted too sharply the Central province and the Pacific Coast district.

We will first contrast our North American assemblage of Notodontidæ with that of Europe, including northwestern Asia (the "Palæartic" region of Sclater) and inclusive of the tropical portions of southeastern Asia (Wallace's Oriental Region). We purposely omit any reference to the term Nearctic, believing it an unfortunate appellation, neither philosophical nor true to the fact that America is zoologically an older continent than Eurasia, its plants and animals having lagged behind in development that of the flora and fauna of the Old World, geological extinction having gone on more rapidly in Europe than in America, at least in northwestern America, while the ending Arctic is quite inapplicable to an assemblage of north temperate animals.

The Notodontian fauna of America is naturally richer than that of Eurasia, because of the greater extent and diversity of surface of the continent over which it is spread.

In Staudinger's Catalogue of European Lepidoptera of Notodontidæ there are enumerated 14 genera and 42 species; in America, north of Mexico, we have 21 genera and about 78 species.

The following lists will present in a graphic way the resemblances and differences between the Notodontian fauna of the two hemispheres, it being understood that by Eurasia we mean Europe and Asia, without the Oriental region; and by North America, that continent less Mexico and Central America.

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[1] In his valuable essay entitled "Laws of temperature control of the geographic distribution of terrestrial animals and plants," Nat. Geogr. Mag., vi, Dec., 1894, Dr. Merriam divides the United States into three regions: the Boreal, Austral, and Tropical. The Austral region is divided into three zones: the Transition, Upper Austral, and Lower Austral. The Upper Austral zone comprises two principal subdivisions: an eastern or Carolinian area and a western or Upper Sonoran area. The Lower Austral zone comprises two principal subdivisions: an eastern or Austroriparian area, and a western or Lower Sonoran area (p. 277).

The Notodontidæ of North America are in this work divided into seven subfamilies; of these the *Gluphisinæ*, *Pygærinæ*, *Ichthyurinæ*, and *Notodontinæ* occur both in Eurasia and North America, while two of the seven, the *Apatelodinæ* and *Heterocampinæ*, are peculiar to North America, and extend through Central into the eastern forest-clad tropical region of South America.

Genera common to Eurasia and North America.

Lophopteryx.	Pheosia.
Gluphisia.	Notodonta.
Ichthyura.	Nerice. (China and Nepaul.)
Lophodonta.	Cerura.
Drymonia.	

Genera peculiar to North America.

Apatelodes.	Hyparpax.
Datana.	Euhyparpax.
Nadata.	Xylinodes.
Ellida.	Schizura.
Dasylophia.	Seirodonta.
Symmerista.	Heterocampa.
	Macrurocampa.

Of this assemblage several genera extend into Central and South America (the Brazilian subregion), and, besides those enumerated, Nadata, Hyparpax, and Schizura will perhaps eventually be found to exist in the Brazilian subregions. I have included Apatelodes, as it is so closely allied to Parathyris, and may be found to be identical with it. Cerura is of doubtful occurrence in South America.

Genera common to North and South America.

Apatelodes.	Heterocampa.
Dasylophia.	Macrurocampa.
Symmerista.	

It appears from these facts that our Notodontians have originated in North America, the species of those genera ranging into tropical South America having perhaps migrated from the northward, and their ancestors may have formed the Notodontian fauna of Miocene and Pliocene North America.

Within the limits of the United States there are profound differences in the Arid Plateau province and the humid or eastern province.

American genera not occurring in the Campestrian subprovince, including the Pacific Coast district (south of Oregon).

Apatelodes.	Symmerista.
Datana (only 1 species).	Hyparpax.
Lophodonta.	Xylinodes.
Drymonia (occurs in Colorado).	Seirodonta.
Ellida.	Heterocampa. (Except H. plumosa from Arizona.)
Nerice.	
Dasylophia.	Macrurocampa.

Excepting three species of Schizura and Euhyparpax, the entire group of Heterocampinæ is wanting in western America, and it is significant that the *Heterocampinæ* are entirely wanting in the Old World, as is also the group *Apatelodinæ*.

Now, confining our attention to the United States and British America, we will give a tabular view of the species of the forest-clad, humid, northeastern portion of North America, adding in a parenthesis after the name of each species either (1) for the Appalachian subprovince or (2) showing its residence in the Austroriparian subprovince. Where a species ranges through both subprovinces both numbers are inserted.

Species inhabitating the Cold Temperate subregion and Humid province (Allen) (i. e., the northern or boreal and the eastern or forest-clad province).

Subfamily I.—GLUPHISINÆ.

Gluphisia septentrionis (1). G. lintneri (1). G. severa (1).

Subfamily II.—APATELODINÆ.

Apatelodes torrefacta (1, 2). A. angelica (1).

Subfamily III.—PYGÆRINÆ.

All the (13) species of the genus, except *Datana californica*.

Subfamily IV.—ICHTHYURINÆ.

Ichthyura apicalis (van) (1).
inclusa (1, 2).
strigosa (1).
Ichthyura albosigma (1).
brucei (1).

Subfamily V.—NOTODONTINÆ.

Nadata gibbosa (1, 2).
Lophodonta angulosa (1, 2).
ferruginea (2).
basitriens (1).
Drymonia georgica (1, 2).
Lophopteryx elegans (1).
camelina (1).
Pheosia dimidiata (1).
Notodonta stragula (1).
simplaria (1).
Ellida caniplaga (1).
Nerice bidentata (1).
Dasylophia anguina (1, 2).
interna (1).
Symmerista albifrons (1, 2).
packardii (1).

Subfamily VI.—HETEROCAMPINÆ.

Hyparpax aurora (1, 2).
perophoroides (2).
Xylinodes lignicolor (1, 2).
Schizura ipomeæ (1, 2).
leptinoides (1, 2).
apicalis (1).
unicornis (1, 2).
badia (1).
eximia (1).
concinna (1, 2).
Seirodonta bilineata (1).
Heterocampa manteo (1, 2).
biundata (1, 2).
guttivitta (1, 2).
pulverea (1, 2).
obliqua (1, 2).
astarte (2).
belfragei (2).
subrotata (2).
hydromeli (2).
unicolor (1).
Macrurocampa marthesia (1, 2).

Subfamily VII.—CERURINÆ.

Cerura borealis (1, 2).
occidentalis (1).
scolopendrina (1).
Cerura cinerea (1, 2).
scitiscripta (1, 2).

It will be seen from the foregoing list that out of 52 species 25 are, so far as yet known, restricted to the Appalachian subprovince, though extending westward in some cases to the Pacific Coast, a few, notably *Gluphisia septentrionis*, *Ichthyura apicalis* (van), and a species of Cerura, extending to the northern limits of the Hudsonian district. None of the family are peculiar to the Alpine summits of this or any country.

Species inhabiting the Arid province (Campestrian) and Pacific Coast district.

Those from the Great Basin and Rocky Mountain region (including Oregon and Washington) are marked (1); those from the Pacific Coast district (including California and Arizona), (2).

Subfamily I.—GLUPHISINÆ.

Gluphisia wrightii (2).
form ridenda (1).
rupta (1).
Gluphisia albofascia (1).
formosa (1).
severa (2).

Subfamily III.—PYGÆRINÆ.

Datana californica (2).

Subfamily IV.—ICHTHYURINÆ.

Ichthyura apicalis (1, 2).
var. ornata (1, 2).
var. astoriæ (1).
var. bifiria (2).
inornata (2).

Ichthyura brucei (1).
var. multnoma (1).
albosigma (1).

Subfamily V.—NOTODONTINÆ.

Nadata gibbosa (1, 2).
Pheosia dimidiata (1, 2).

Notodonta stragula var. pacifica (2).

Subfamily VI.—HETEROCAMPINÆ.

Schizura ipomeæ (1, 2).
perangulata (1).
unicornis (2).

Schizura concinna (salicis) (2).
Heterocampa plumosa (1, 2).

Subfamily VII.—CERURINÆ.

Cerura scolopendrina (1, 2).

Cerura cinerea (1, 2).

This list shows in a very striking way that not only is there not a genus of Notodontinæ as far as we yet know peculiar to the vast Campestrian subprovince, but also, with perhaps the exception of one species (*Heterocampa plumosa*), there is not throughout the whole of western North America any of the family widely distinct from eastern forms. All of the species and varieties of *Gluphisia* appear to be but climatic varieties of the eastern *G. septentrionis* and *severa*; the single species of Datana (*D. californica*) may prove to be a local variety of *D. ministra*. The only distinct species of Ichthyura is *I. inornata*, whose specific rank is quite doubtful, since I have been inclined to regard it as only a climatic variety of *I. apicalis*. *Schizura perangulata* is, however, quite distinct, and yet it is closely allied to *S. eximia*.

In fact, the greater part of the number of Campestrian species are really inhabitants of the humid, wooded mountains and elevated valleys which rise out of the dry, rainless plains and plateaus, and the species found there are truly members of the Appalachian fauna, the areas which they inhabit being simple outliers on the western and Pacific slopes of the Appalachian subprovince (Canadian and Alleghanian fauna), which extends southward along the elevated ranges of the Rocky Mountains of the Cascade Range and the Sierra Nevada.

The Notodontians are peculiarly tree-inhabiting forms, and in a region so destitute of forests and of deciduous trees as the Plains, the Great Basin, and California we should not expect good material for characterizing faunæ. Hence the distribution of this restricted group of moths presents very different results from that of insects in general and of mammals and birds, and it is difficult to separate on such slender evidence the Californian or Pacific Coast district fauna from the Campestrian, though when we take into account other groups of insects, especially Coleoptera, we seem warranted in such a differentiation of the faunæ of western North America.

From what we know of the life histories of the Californian and Campestrian Notodontians their principle food plants in that region are the poplars and willows which flourish along the river courses of that dry area, others feeding on the scrub oaks of the plains and foothills.

This interdigitation of Campestrian (dry) and humid forest-clad mountain tracts, with the outliers from the Boreal (Arctic, Hudsonian, and Canadian) and Alleghanian ("Transition" Merriam) faunæ is well shown on Dr. Merriam's map.[1]

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[1] In our zoogeographical map published in 1883 (Vol. XII, Hayden's Annual Report) we believe we were the first to represent on a colored map the southward extension along the Rocky Mountain range and Sierra Nevada, as well as along the Appalachians and Adirondacks of the Boreal (Canadian) province. Having visited those mountains and studied the Alpine fauna of those regions, and from general knowledge, it is somewhat surprising to read on page 226 of Dr. Allen's article the following statement:

"Dr. Packard, in his otherwise excellent zoogeographical map of North America, failed, however, to recognize the southward extension of the Cold Temperate subregion along the principal mountain systems of the continent." On the contrary, as anyone will see on examining my map, I have carried down along the Rocky Mountain range a long loop of the isotherm of 40° as nearly far south as Santa Fé, N. Mex., and colored the mountain ranges and spurs within the loop pale blue, the same hue as that used in coloring the Boreal province.

The distribution of most of the genera and nearly each species of Notodontians is shown on the nine plain maps accompanying this memoir. It is believed that by having a number in conspicuous type, representing a distinct species, the map will both show at a glance the known localities where they were found and also the distribution. When the entire group has been discussed, we hope to present a final colored map showing the general distribution of insect life in North America.

SEASONAL VARIATION.

Almost nothing has been done on this subject, except for the butterflies by Mr. W. H. Edwards, whose able investigations are well known. The only facts known as regards the Bombyces are those stated to us by Mr. Beutenmüller, who, in breeding *Ichthyura apicalis*, has found that the summer and winter broods of this species are different in hue, the pale individuals belonging to the summer brood and the darker ones to the earlier winter brood.

We[1] have also called attention to the cases of *Drepana arcuata* and *Dryopteris rosea*, first noticed by the late S. Lowell Elliot. Mrs. Slosson tells us that in Franconia, N. H., the early May brood of the Geometrid moth, *Selenea kentaria*, is darker and richer in hue than those of the later or summer brood.

CLIMATIC VARIATION IN THE NOTODONTIDÆ.

In an essay on the general subject of climatic variation in our Monograph of Geometrid Moths (pp. 584-589) we called attention to the changes in the size of the body, in the shape of the wings, and in the coloration, observed in Colorado and on the Pacific Coast, in individuals of species ranging across the continent. We gave a list of 27 species of Geometrid moths which attain a larger size as we go west, and which in some cases have longer, more pointed wings than individuals from the Atlantic Coast.

Our observations on individuals of the present family have been very scanty from the lack of material, none of the collections I have been able to consult being rich in number of individuals; also from deficiency on the labels of exact localties, and of information as to whether captures were made on the plains or among the mountains in a State like Colorado, and whatever is stated here should be regarded as merely tentative and suggestive, rather than final and conclusive.

Notodontidæ which attain a larger size in the Campestrian subprovince, including the Pacific Coast, than in the Atlantic or Appalachian and Austroriparian subprovinces.

Ichthyura inornata.
Pheosia dimidiata.
Schizura unicornis var. conspecta.
Cerura cinera and var. cineroides.

Species which have longer wings in the Campestrian subprovinces than in the Appalachian and Austroriparian.

Schizura concinna (salicis).
Cerura nivea.

Species which tend to bleach out or to become paler than eastern individuals, and to lose their dark markings in the Arid or Campestrian subprovinces (including the lowlands of California).

Gluphisia wrightii.
severa.
var. formosa.
var. albofascia (Utah).

Ichthyura apicalis.
var. astoriæ.
Schizura unicornis.
var. conspecta.
Cerura cinerea.
and var. nivea.

It is not improbable that the Campestrian (Colorado and Utah) species of *Gluphisia*, such as *G. ridenda*, *G. rupta* and *albofascia* are climatic varieties of *G. septentrionis*.

[1] Proc. Bost. Soc. Nat. Hist., xxiv, p. 491, 1890.

MELANISM IN THE WHITE AND ROCKY MOUNTAIN AND PACIFIC COAST MOUNTAIN REGIONS.

Without at present entering into the discussion of the general causes of melanism, we will draw attention to such cases as have fallen under our notice in the present group.

It seems generally recognized, however, that melanism is due to elevation (not necessarily a high latitude) united with an excessively humid or wet climate. We have such elevated areas over which the rainfall is excessive in the White Mountains, in the Adirondacks, in the mountains of British America, the Cascade Range and its spurs in British Columbia, Washington, and Oregon, and in the elevated portions of the Sierra Nevada and of the Rocky Mountains, with their subordinate ranges and spurs. In such a cool and moist climate we also have much cloudy weather and far less direct sunlight than on the drier and more sunny lowlands. This does not exclude the fact that melanism may occur in a low and wet region, as the west coast of Africa.

Mrs. Slosson, who has spent numerous summers in Franconia, N. H., and has had wide experience in collecting Lepidoptera in that region, as well as in Florida, informs me that it is almost invariably the case that the White Mountain moths are darker and richer in hue than southern individuals of the same species.

The following facts bear on this point:

"But it is also a known fact that many species of animals, especially of insects, which are found at a high level on mountains have a darker coloring than their allies at a lower level. Thus there are remarkably dark species and varieties of beetles occurring at high levels." (Eimer's Organic Evolution, p. 96.)

The late Dr. Weinland, who lived some years in the United States, remarks, as quoted by Eimer, "that darker pigment is always produced on mountains, as in *Vipera prester*, the Black Mountain variety of *Vipera berus*, as in the black rattlesnake of the White Mountains in North America" (Ibid., p. 98).

Eimer thinks only two causes, apart from moisture, aid in the production of dark hues in Alpine animals, i. e., "either light or decreased atmospheric pressure." But is not the cloudiness and dullness of the skies about mountain summits, i. e., the absence of sunlight as compared with the bright sunny days of the lowlands, sufficient, with moisture, to account for the increase in dark pigment? Though, to be sure, the heat and moisture of the west coast of Africa cause the greatest extreme of melanism in the negro races.

Cases of melanotic forms, both in the Rocky Mountains and on the humid, cool portions of the Pacific Coast, and on the Atlantic Coast regions.

Gluphisia severa var. slossoniae (White Mountains).
Ichthyura brucei var. multnoma (Oregon and Washington).
Pheosia dimidiata var. portlandia (Oregon and Washington).
Notodonta stragula var. pacifica (California).
Heterocampa guttivitta. Franconia, N. H.
Cerura multiscripta. In the Northeastern States.

It should be noted that *Cerura scitiscripta* is represented in New England by the dark form *C. multiscripta*.

It is greatly to be desired that hereafter collectors working in the Rocky Mountain regions, as well as anywhere in the Campestrian region, including the Pacific Coast, should carefully state on their labels the exact locality, with date (at least the month), of their captures.

VII.—ON THE PHYLOGENY OR CLASSIFICATION OF THE LEPIDOPTERA.

It hardly need be said that the classification of the Lepidoptera is in a very unsatisfactory state. This is due largely to the fact that the group is so homogeneous, that the habits and environment of the species are so uniform, and that the adaptive modern characters have hidden the slight primitive or ancestral characters which crop out in certain forms; hence the phylogeny of the order is difficult to unravel. It is now perhaps generally supposed that the Lepidoptera have originated from the Trichoptera, or from forms very much like them, the most generalized Tineina being closely similar to the caddis flies, though we shall endeavor to show that this view is not well founded, since it is more probable that both Trichoptera and Lepidoptera have had a common parentage. On the other hand, all agree in placing the butterflies at the head of the series as the most specialized modern group of families. But as regards the natural sequence of the groups between these two assemblages there are wide differences of opinion. Certainly the division of the order into Rhopalocera and Heterocera is amateurish and artificial, as is the separation of the order into the divisions of Macrolepidoptera and Microlepidoptera.

The principles which it seems to us should be kept in view in working out the relations of the groups are the following:

1. We should keep constantly in mind that a true classification of the Lepidoptera is, like that of any other group of organic beings, an expression of the phylogenetic development of the members of the group.

2. The mouth-parts and particularly the highly modified and specialized maxillæ, being diagnostic of adult Lepidoptera, as also the absence of functional mandibles, these characters, together with the pupal ones, are of great phylogenetic importance and of primary taxonomic value in the establishment of suborders.

3. As in the case of the Diptera, which were divided by Brauer into *Diptera cyclorhapha* and *orthorhapha*, the pupa serving for a division of the order into suborders, the larval and imaginal characters agreeing with those drawn from the pupa, so the pupal characters of Lepidoptera, as first employed by Chapman, are, it seems to us, of fundamental importance in the classification of the order into subdivisions of suborders, i. e., of superfamilies and families. Owing to the adaptive characters of the imago and also of the larva we have hitherto been very much in the dark as to the most fundamental features, such as will be of permanent value in the establishment of the minor groups named. Yet it will be seen that in general the imaginal characters agree with the pupal ones.

Thanks to the labors of Walter[1] on the mouth-parts of the imago of Eriocephala, and to Dr. T. A. Chapman's[2] paper on the pupæ of Heterocera, a truly epoch-making one, we now have clews to the arrangement of the order which promise the most valuable results. Inspired by the labors and suggestions of these two authors, I have endeavored, after studying the structure of Eriocephala and Micropteryx and what pupæ of other forms could be collected, to work along the lines laid out in these papers.

Those entomologists who disbelieve in the importance of the transformations of insects in taxonomy should bear in mind the value of larval as well as pupal characters in the Trichoptera, Mecoptera, Siphonaptera, Neuroptera, and Hymenoptera. As regards the Coleoptera, it is evident that their classification thus far as based on adult characters is quite unsatisfactory, the more generalized forms having been placed at the head of the order and the extremely modified weevils (Rhyncophora) regarded as the "lowest" group, and that we shall have to depend on the larvæ for the clew which will lead to a revision based on scientific evolutional principles. In 1883[3] the writer attempted to show that the campodea-form larva of the Meloidæ and Stylopidæ were the most generalized coleopterous larvæ, that the primitive Coleoptera were carnivorous forms, and that the scavenger and phytophagous families were derived from them; the weevils and Scolytidæ, instead of being the lowest, proving to be really the most modified and, therefore, recent groups.

4. The older, more generalized groups of moths are much less numerous in number of species than the more modern and specialized groups; such are the generalized Tineina and the Bombyces as compared with the Geometridæ and Noctuidæ, as well as the butterflies, this being probably in part due to geological extinction.

5. While the peculiar shape of caterpillars, with their round heads, reduced cephalic appendages, three pairs of jointed thoracic feet, and abdominal legs, not exceeding five pairs, is diagnostic

[1] Zur Morphologie der Schmetterlingsmundtheile, Sitzungsb. Jena. Ges. Med. und Naturwissens., 1885. Beiträge zur Morphologie der Schmetterlinge, Jena. Zeit., 1885, pp. 751–807.

[2] On some neglected points in the structure of the pupæ of Heterocerous Lepidoptera and their probable value in classification, etc. Trans. Ent. Soc. London, 1893, pp. 97–119.

[3] Third Report U. S. Entomological Commission, 1883, p. 299. This view has been adopted and extended by M. C. Houlbert, who has published a new classification of the Coleoptera. See Rapports naturel et phylogénie des Coléoptères. Bulletin des Sciences nat. de l'Association des Eleves de la Faculté des Sciences de Paris, iv, May, 1894, pp. 62–171.

of Lepidoptera, only the larvæ of the Trichoptera, Panorpidæ, and Tenthredinidæ approaching them, they do not seem to afford salient features of value for subordinal characters. Yet there are some archaic features, such as the arrangement of the hooks on the abdominal legs, the presence of eversible coxal glands on the under side or on the sides of the body; and in the larva of Eriocephala we have subordinal characters in the absence of a functional spinneret, also in the extraordinarily large size of the antennæ, and of the maxillary palpi of that genus.

The process of specialization in the larva has effected not so much the general form of the body as the armature of the abdominal legs and of the body. Chambers, and also Dimmock, (Psyche, iii, 99, 1880) has shown in Lithocolletis and in Gracilaria, especially, the changes which take place in the head and mouth parts as well as feet of the larva after the first molt, in adaptation from a mining to a free existence. But in free-feeding forms it is difficult to distinguish a normal Tineid larva from a Tortricid or Pyralid larva, and as yet no characters diagnostic of them and other families have been indicated. With the exception of the larvæ of certain Tineina, of the Cochliopodidæ (Limacodidæ), of the Psychidæ, those of the Hesperians and the onisciform caterpillars of Lycaenidæ, lepidopterous larvæ are remarkably homogeneous in form, as they are in habits. The only reliable larval characters for distinguishing families are the differences in the piliferous tubercles, the number of hairs or setæ arising from a tubercle, or the shape and size of the tubercles themselves, and even within the limits of any family there is great variation in these, as seen in the Saturniidæ, or the Ceratocampidæ, or Arctiidæ, etc.

The resemblance between the larvæ of the Trichoptera and the Lepidoptera is remarkably close, their internal and external anatomy being nearly the same, the Lepidoptera differing chiefly in the presence of abdominal legs; these, however, being absent in Micropteryx.

Supposing that the Lepidoptera did spring from some neuropterous group allied to the stem form of the Trichoptera, the type at once after the primitive lepidoptera ceased to live in the water, if its ancestors were aquatic, assumed abdominal legs, hooks developed on them, at first a pair, then more until two complete rows appeared, and the larva was fitted to climb the stems of plants in order to feed on the leaves. Eventually we may imagine that the larvæ, owing to the attacks of insect parasites, sought shelter by mining leaves, seeds, twigs, stems, trunks, and even roots of plants. In adaptation to these novel surroundings, the mining forms by disuse lost their legs, their bodies became flattened and otherwise modified as in certain Tineina, or the sack bearers were modified in adaptation to their peculiar habits. This great diversity in the mode of obtaining their vegetable food and their exposure to varying surroundings resulted in manifold special adaptations in ornamentation and armature, hence the groups most successful in the struggle for existence became very numerous in genera and species.

The generalized forms may be detected by the larvæ having one-haired warts, with minute tubercles without spines, but other primitive forms have large tubercles, warts, humps, or highly colored lines, bands, or spots. While the larval characters are useful in distinguishing genera or families, they do not appear to present salient subordinal characters, as they do in Coleoptera, Diptera, and Hymenoptera.

6. The generalized pupal forms are those nearest to the *pupa libera* of Trichoptera and the Neuroptera, etc.; such is that of Micropteryx. Those pupæ with more or less free abdominal segments, the *Pupæ incompletæ* of Chapman, are plainly more archaic or generalized than those belonging to his division, *Pupæ obtectæ*, which comprise the modern or specialized forms. Where the ends of the maxillary palpi appear externally under the eyes; where the labial palpi are visible; where what we call the paraclypeal pieces are present, we have survivals of the characters of the *pupa libera* of Micropteryx. When these features have been by modification lost, we have the uniform obtected pupa of the Neolepidoptera, and these characters are so persistent that they are of high taxonomic value.

7. The pupa, then, is of the greatest importance in defining the larger groups of the haustellate Lepidoptera, and chiefly for the reason that the lepidopterous pupa, with its so-called wing and appendage cases, appears to represent not only what may be called a subimaginal condition, but a still earlier, lost, or extinct imaginal type, a type perhaps midway between the ametabolous and metabolous series. This is suggested by the wing cases which are as in ametabolous nymphs, such as those of Dermaptera, Termitidæ, and Psocidæ, as well as of Hemiptera; and, as shown by Spuler, the venation of the lepidopterous pupa is almost identical with that of the Blattidæ

and Fulgoridæ. The wings of the lepidopterous pupa may be said to be in the nymph stage of the ametabolous insects mentioned, since they are direct outgrowths from the tergites of the segments from which they arise. If the wing-cases of any lepidopterous pupa, together with the meso- or metathorax, are, before its larval skin is molted, removed and spread out, they bear, as Spuler shows, a striking resemblance to those of a beetle, Termes, Psocus, or any Hemipterous nymph. There are no traces in the pupa of any of the isolated chitinous pieces in the membrane connecting the wings with the trunk, which are seen in the imago. If the wing of the immature imago is removed from the pupal wing case, it will be seen to differ greatly in shape and venation from that of the pupa. The pupal venation is ancestral and phylogenetic; that of the imago is more specialized, showing the results of a long process of adaptation and modification. So it is with the appendages; those of the maxillæ, labium, and of the legs differ greatly, as anyone has observed who has studied fresh pupæ, as compared with those from which the imago is ready to emerge. Those of the pupa show important differences; they are not simply cases, but differ in structure, and possibly represent the appendages of an ametabolous ancestor, a progenitor which may have descended from the campodeiform ancestor of the class of insects.

The importance of the pupa is also seen when we compare those of the generalized Lepidoptera with the more primitive generalized dipterous families Bibionidæ, Cecidomyiidæ, Tipulidæ, Mycetophilidæ, etc. The close resemblance between the orthoraphous Dipterous pupa and Tineid pupa affords strong evidence that the two orders are not only closely allied, but even that they may have originated from a common ancestry, the loss of thoracic and of abdominal limbs and the reduction of the head and its appendages of dipterous larvæ, as well as the reduction of the hind wings, being due to modification from disuse. In the Dipterous pupa (Culex, etc.) the hind pairs of wings are nearly as well developed as those of lepidopterous pupæ.

8. The imaginal features in the haustellate Lepidoptera will in general be found to correspond with the pupal characters, though they are not so salient and striking as the latter after these have been once observed and appreciated. In the moths (Heterocera) especially, the adaptative characters have concealed the more fundamental or primitive characters. What we regard as adaptative or secondary characters are the absence of vestiges of mandibles and of maxillary palpi, coupled with the great development of the maxillæ themselves, the usually broad frenate wings, and the difference in shape of the two pairs, besides the specialization of the scales, not only of the wings, but of those forming the vestiture of the legs (in Noctuidæ, etc.).

9. What we regard as generalized or ancestral characters in the haustellate Lepidoptera are those which have proved of especial service in studying the phylogeny of the order. These are the retention of neuropteroid characters, such as the square head, the small eyes, the vestigial mandibles; in the Eriocephalidæ, the retention of the lacinia and galea, the retention of the maxillary palpi; in the higher moths the elongated thorax, the large metathorax, with separate scuta, the exserted large male genital armature of Micropteryx and of the Psychidæ, the small narrow wings of both pairs, and the trichopteriform venation of the more generalized Tineina and of the Eriocephalidæ (Protolepidoptera); also as respects the markings of the wings, the absence of highly colored spots, and even of bars crossing the wings. When, as in the highly colored Tineids, the wings are spotted, they are often barred, this style of markings seen in Adela, having been possibly handed down from or at least reminding us of certain beautifully ornamented and barred trichopterous genera.

It will be seen, then, as we pass up from the Protolepidoptera to the butterflies, that there has been more or less extinction of neuropteroid features and an increasing specialization of the parts of the thorax, of the maxillæ, of the shape of the wings, including their scales and markings in general, spots succeeding bands and bars, brighter and more varied markings the dull uniform hues of many micros and Bombyces.

THE STEM FORMS OR PROGENITORS OF THE LEPIDOPTERA.

It seems to us that in the discovery of two-lobed maxillæ in Eriocephala, and other anatomical features we have new data for discussing this subject, or at least for critising the view perhaps quite generally held that the Lepidoptera have directly descended from the Trichoptera or from forms more closely resembling them than other neuropteroid orders.

The first author to suggest the derivation of Lepidoptera and the Trichoptera from a common stem form was A. Speyer.[1] He speaks of the great similarity of the venation of the trichopterous wings to those of the Hepialidæ, Cossidæ, Micropterygidæ, and to the hind wings of the Psychidæ, though allowing that there is no Trichopteron whose venation entirely agrees with that of any Lepidoptera. He points out the fact that there are certain moths whose pupæ have free limbs, as Heterogenea, Adela, and Micropteryx, and that members of both orders spin a cocoon. He refers to the dissimilarity in the mouth-parts of the two orders, the maxillæ and labium, but does not specially refer to the distinction in shape between the maxillæ of the two orders. Speyer does not believe that the Lepidoptera directly descended from the Trichoptera, but that they had a common origin, the latter being the earlier to appear, their remains occurring in lower geological strata.[2] He thinks this common stem-form in the imago state had through disuse slightly developed biting mouth parts; that they took little or no nourishment, like the moths. The duration in the adult life was probably short, and the ancestors of the Lepidoptera were in the larval state aquatic, like caseworms. He suggests that the outer lobe of the maxillæ were at first simple in shape, but in the course of time by adaptation to the slowly increasing depth of the corollas of flowers, became a hollow sucking organ. This view was also held by H. Müller in 1869, who claimed that "There is the closest affinity between the Phryganeidæ and Lepidoptera, and the Phryganeidæ have the buccal organs precisely in that rudimentary state which we should presuppose appropriate to the primordial race or type of Lepidoptera." Müller also claimed that both Lepidoptera and Phryganeidæ proceeded from a common stock. (Amer. Nat., v, 288, 1871).

In a review entitled "The position of the caddis flies" (Amer. Nat., v, 707, 1871) we pointed out that in the trunk characters, especially the thoracic, these insects were fundamentally much less allied to the Lepidoptera than has been supposed.

But in the mouth parts also we have a character of fundamental importance which still further separates the two orders, notwithstanding the fact that both orders in the imago state lack mandibles. This is the presence in the maxilla of Eriocephala of a lacinia, and of a true galea, while the maxilla of Trichoptera entirely differs, having not only no lacinia, but a much reduced, almost vestigial, galea,[3] the maxillary palpi being very large.

In respect, then, to the maxillæ, the Lepidoptera are nearer the ametabolous, mandibulate insects than the Trichoptera, while some genera of the former order (Eriocephala) have well-formed mandibles, and many others (Tineidæ, Pyralidæ, and Crambidæ) have vestigial ones.

In fact the venation of Eriocephala and of Micropteryx is in general remarkably like that of Amphientomum, a generalized Psocid, and it is not altogether impossible that these insects with their reduced prothorax and concentrated or fused meso and metathorax, together with their maxillary fork, may have had some extinct allies which were related to the remote ametabolous ancestors of the Lepidoptera.

Here might be recalled the suggestion of Hermann Müller in the same address from which we have just quoted, that there is a close relationship between the Tipulariæ and the Lepidoptera, in the similar venation of the wings in many Tipulariæ (Limnobia, Ctenophora) and the Phryganeidæ, "and, finally, the circumstance that it is far easier to deduce morphologically the proboscis of the Tipulæ from the buccal organs of the Phryganeidæ than from those of any other order of insects." By this statement he probably means the strong resemblance of the haustellum (rather a lapping organ than a sucker) of the Trichoptera to the lapping organ or proboscis of the Diptera. This is a point which needs further examination. The close similarity of the pupa of the more generalized Diptera and of the more generalized Lepidoptera also needs to be emphasized, for it is suggestive of an early close relationship between the two orders.

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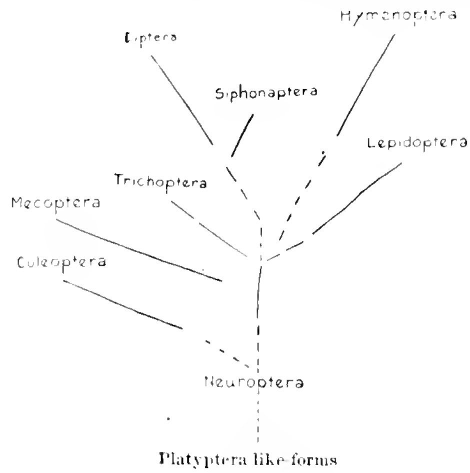
[1] Ent. Zeitung, Stettin, Jahrg. 31, p. 202, 1870.

[2] The cases of a trichopterous insect have recently been discovered by Dr. Anton Fritsch in the Permian beds of Bohemia. K. böhm. Gesellschaft der Wissenschaften, November 23, 1894. The earliest Lepidopterous remains, referred to a sphinx and to Pterophorus, occur in Jurassic strata.

[3] See our figure of the maxilla of Limnephilus, fig. 4, Pl. LIX (*lac* should be *galea*), Third Report United States Entomological Commission, 1883; also the much more detailed figures of R. Lucas in his Beiträge zur Kenntniss der Mundwerkzeuge der Trichoptera, 1893.

The conclusion seems to be with our present knowledge that the Lepidoptera, Trichoptera, and Diptera may possibly have had a common ancestry, and that it may be found that the Lepidoptera was the first to be differentiated, and the Diptera the last, since they are more highly modified. The line of descent of the metabolous orders might tentatively be thus expressed:



VIII.—ATTEMPT AT A NEW CLASSIFICATION OF THE LEPIDOPTERA.

The first step toward a scientific classification of the Lepidoptera was taken by Dr. Chapman in his suggestive paper on neglected points in the pupæ of Heterocerous Lepidoptera. His division of the groups based on pupal characters is the following:

LEPIDOPTERA-HETEROCERA.

A. OBTECTÆ. Pupa smooth and rounded, externally solid, inner dissepiments flimsy. Free segments in both sexes fifth and sixth (abdominal). Never emerges from cocoon, or progresses in any way. Dehiscence by irregular fracture.

1. *Macros.* Larva with hooks of ventral prolegs on inner side only. (Exposed feeders.) *Sphinges, Bombyces, Nolidæ, Nycteolidæ, Noctuina, Geometra.*

2. *Pyraloids.* Larva with complete circle of hooks to ventral prolegs. (Concealed feeders.) *Pyrales, Phycidæ, Eudoridæ, Crambidæ, Gelechidæ, Plutellidæ, Œcophoridæ.* (*Epigraphiidæ, Alucitidæ.*)

3. ——— ?. Doubtful whether Pyraloids or of separate (classificatory) value. *Hyponymeutidæ, Argyresthidæ, Coleophoridæ.* (Perittia?), (Elachistidæ?).

B. INCOMPLETÆ. Pupa less solid and rounded, appendages often partially free. Free segments may extend upward to third (abdominal). Seventh always free in male, fixed in female. Dehiscence accompanied by freeing of segments and appendages previously fixed. (Except in 1) pupa progresses and emerges from cocoon.

1. Pupa attached by cremaster. Free segments. 4 5 6 7. 4 5 6. *Pterophorina.*

2. Pupa free to move and emerge from cocoon.

a. Larva concealed feeder, often a miner, and usually rather active when not cramped by the mine.

1. Free segments. 5 6. 5 6 7. *Lithocolletidæ, Gracilariidæ.*

2. Free segments. 4 5 6. 4 5 6 7.

a. TINEÆ (*Tineidæ, Psychidæ, Sesiidæ*).

b. TORTRICES (*Tortricina, Cossus, Exapate, Simaethis*). (Castnia.)

3. Free segments. 3 4 5 6. 3 4 5 6 7.

a. ZEUZERA and HEPIALUS tend to lose third as a free segment (are gaining it as a fixed segment).

b. TISCHERIA.

c. ADELIDÆ. Ovipositor (of imago) formed for piercing plant tissues.

d. NEPTICULIDÆ. Antennæ separate from head in dehiscence.

b. Larva exposed feeder. Slug-like in form and movement, head very retractile. Free segments. 3 4 5 6 7. 3 4 5 6.

1. MICROPTERYGIDÆ.[1] Eight pairs abdominal legs, curious appendages, moss feeders.

2. COCHLIOPODIDÆ. Legs evanescent, but traces of extra pairs and of curious appendages. *Max. palps large in pupa*, not in imago.

3. ZYGÆNIDÆ. Legs of Macro type. Max. palps evanescent in pupa.

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[1] I have only seen a portion of a pupa of these and of Psychids. I have had none of my own, and have not been able to examine them freely.—T. A. C.

C. ——?. Pupa with no free segments, appendages adherent to all abdominal segments. *Lyonetia*, *Cemiostoma*, *Bedellia*.

NOTE.—Eriocephala (Micropteryx purpurella, etc.) appears by imaginal characters to belong to Adelidæ. But the pupa is truly incomplete, not semiincomplete, as all the other Incompletæ are; that is, the appendages are all absolutely distinct and free, and all the abdominal segments are "free;" moreover, it possesses working jaws.

Apparently a few months after the publication of Dr. Chapman's paper Professor Comstock's[1] able and suggestive paper appeared, in which he uses the venation of the wings as taxonomic characters, and proposes to make the following divisions of the Lepidoptera:

A. Suborder JUGATÆ.
  B. *The Macrojugata* .... Family HEPIALIDÆ.
    Microjugatæ .... Family MICROPTERYGIDÆ.
A A. Suborder FRENATÆ.
  B. *The microfrenatæ*.
    C. *The Tineids* .... Superfamily TINEINA.
    C C. *The Tortricida* .... Superfamily TORTRICINA.
    C C C. *The Pyralids* .... Superfamily PYRALIDINA.
  B B. *The Macrofrenatæ*.

Without entering into further details, we only add the succession of the families of this division given by the author in ascending order, beginning with the most generalized:

Megalopygidæ.	Cymatophoridæ.	Saturniina.
Zygaenidæ in part.	Noctuidæ.	Drepanidæ.
Psychidæ.	Liparidæ.	Lasiocampidæ.
Cossidæ.	Agaristidæ.	Hesperidæ.
Limacodidæ.	Arctiidæ.	Papilionidæ.
Dioptidæ.	Sesiidæ.	Pieridæ.
Notodontidæ.	Thyrididæ.	Lycaenidæ.
Brephidæ.	Zygaenina.	Nymphalidæ.
Geometridæ.		

The objection we should make to this arrangement of the Lepidoptera into two suborders, Jugatæ and Frenatæ, is that the characters used are too slight, and do not agree with the more fundamental pupal characters or with important imaginal features. The jugum is of slight if any functional value, and in Micropteryx, as in Trichoptera, occurs both in the hind and front wings,[2] a point apparently overlooked by Comstock. The Hepialidæ, as we shall hope to show, are much less generalized forms than the Eriocephalidæ, or even the Micropterygidæ; the pupæ of both these groups have free limbs and abdominal segments, belonging to what Speyer calls a group of *Pupa libera*. The Hepialidæ also neither possess maxillary palpi nor vestigial mandibles; they are borers in the larval state, and the pupa has not free limbs, but is a *pupa incompleta*. They are scarcely ancestral, though very primitive, forms, but have already become modified, having no traces of mandibles and no maxillæ, and in our native species the labial palpi have already begun to degenerate. We therefore scarcely see good reasons for placing the family at the very foot of the order below Micropteryx, but should regard the family as a side branch of the Palæolepidoptera, which, very soon after the appearance of the order, became somewhat specialized.

Comstock's Frenatæ comprises a heterogeneous collection of families, some of which have no frenulum at all; and when present they offer secondary sexual characters. The absence or presence of a frenulum is hardly, then, a sufficiently fundamental character to be used in establishing a great primary division. Besides this there is a rather close alliance between the Hepialidæ and Cossidæ, the latter having a rudimentary frenulum. Chapman remarks that while Cossus and Hepialus are quite distinct in pupal characters, there appear to exist in Australia many forms uniting them with Zenzera into one family. The venation is also quite similar, and while the two families of Cossidæ and Hepialidæ are in some most important respects quite far apart, one being, so to speak, tineid and the other tortricid in structure, yet it would, we think, be a forced and unsound taxonomy to assign them to different suborders.

[1] Evolution and Taxonomy. An essay on the application of the theory of natural selection in the classification of animals and plants, illustrated by a study of the wings of insects and by a contribution to the classification of the Lepidoptera. Ithaca, N. Y., 1893.

[2] In his drawing of the wings of Micropteryx Comstock has not represented the jugum-like flap on the hind wing, which is present in *Micropteryx purpurella*, though not apparently in *Eriocephala calthella*. Since it occurs on the hind as well as fore wings, I doubt that it is of much use in keeping the wings spread.

Suborder I.—Lepidoptera laciniata or Protolepidoptera.

The taxonomic importance of Walter's most interesting discovery, that *Eriocephala calthella* has maxillæ constructed on the type of those of biting or mandibulate insects, i. e., with an inner (galea) and outer lobe (lacinia) besides the palpi (fig. 2), was apparently overlooked by him as well as others, though its bearings on the phylogeny of the Lepidoptera, insisted on by Walter, are, it seems to us, of the highest interest. The presence of two maxillary lobes, homologous with the galea and lacinia of the Mecoptera (Panorpidæ) and Neuroptera (Corydalus, Myrmeleon, as well as the lower orders, Dermaptera, Orthoptera, Coleoptera, etc.) in what in other important respects also is the "lowest" or most primitive genus of Lepidoptera, the lacinia being a rudimental, scarcely functional, haustellum or tongue, and not merely a vestigial structure, is of great significance from a phylogenetic point of view, besides affording a basis for a division of the Lepidoptera into two grand divisions or suborders, for which we would propose the names *Lepidoptera laciniata* and *Lepidoptera haustellata*.

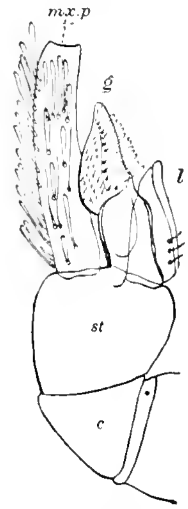


Fig. 2.—Maxilla of *Eriocephala calthella*; *l*, lacinia; *g*, galea; *mx.p*, maxillary palpus; *st*, stipes; *c*, cardo.—After Walter.

Walter thus writes of the first pair of maxillæ:

> The other mouth parts also of the lower Micropteryginæ have a most primitive characteristic. In the first pair of maxillæ of *Micropteryx calthella*, *aruncella*, *anderschella*, and *aureatella*, cardo and stipes are present as two clearly separate pieces. The former in *M. calthella* and *aruncella*, in comparison with the latter, is larger than in *anderschella* and *aureatella*. In the last two species the cardo is still tolerably broad, but reduced. The stipes is considerably longer than the cardo in the last two species, while it is of the same thickness. From the stipes arises the large six-jointed palpus maxillaris, making two or three bends and concealing the entire front of the head and all the mouth parts. At its base, and this is unique among all the Lepidoptera, two entirely separate maxillary lobes arise from the stipes. The external represents the most primitive rudiment[1] (anlage) of a lepidopterous tongue. (Fig. 2.)

It is evident from Walter's figures and description that this structure is not a case of reduction by disuse, but that it represents the primitive condition of this lobe, the galea of the maxilla, and this is confirmed by the presence of the lacinia, a lobe of the maxilla not known to exist in any other adult lepidopterous insect, it being the two galeæ which become elongated, united, and highly specialized to form the so-called tongue, haustellum, or glossa of all Lepidoptera above the Eriocephalidæ, which we may therefore regard as the types of the *Lepidoptera laciniata*.[2]

Another most important feature correlated with this, and not known to exist in *Lepidoptera haustellata*, is the presence of two lobes of the second maxillæ, besides the three-jointed labial palpi, and which correspond to the *mala exterior* and *mala interior* of the second maxillæ of Dermaptera, Orthoptera, Platyptera, Perlidæ, Termitidæ, and Odonata, and also, as Walter states, to the ligula and paraglossæ of Hymenoptera. In this respect the laciniate Lepidoptera are more generalized insects than the Trichoptera or Mecoptera.

Walter thus describes the two lobes or outer and inner mala of the second maxillæ:

> Within and at the base of the labial palpi is a pair of chitinous leaves provided with stiff bristles, being the external second lobes of the underlip, formed by the consolidation of the second pair of maxillæ and which reach when extended to about the second third of the length of the second palpal joint. Its inner edge is directly connected with the inner lobe (mala interna). The latter are coalesced into a short wide tube which, by the greater size of the hinder wall, opens externally on the point, also appearing as if at the same time cut off obliquely from within outward.

[1] In accordance with an English author, I think, but whose name escapes me, I use the term rudiment in the sense of the German word Anlage, and vestige for an organ which has or is undergoing reduction, degeneration, or atrophy. I am aware that the word Anlage has no English equivalent, but can scarcely accept the word "fundament" as better than rudiment. We may, then, speak of germs or rudiments, and of rudimentary when referring to the incipient organs of the young or adult, regarding vestigial organs as those on the point of atrophy from disuse. The term blast for Anlage I should accept for embryonic structures in their incipient or germinal condition.

[2] In his paper on the larva of Eriocephala, etc. (Trans. Ent. Soc. London, 1891, p. 335), Dr. Chapman separates the old genus Micropteryx into two families: *Eriocephalidæ* and *Micropterygidæ*. His group Eriocephalidæ I have regarded as comprising the type of the suborder *Lepidoptera laciniata* or *Protolepidoptera*.

The outer exterior edge of the tube forms a strongly chitinous semicircle which, becoming thinner, finally passes into the delicate membranous hinder wall. Also anteriorly a delicate membrane appears to cover the chitinous portion.

We have here in opposition to the weak naked underlip represented by a triangular chitinous plate in other Lepidoptera a true ligula formed by the coalescence of the inner lobes of the second maxillæ into a tube, as in many Hymenoptera, and with free external lobes which correspond to the paraglossæ of Hymenoptera.

Walter has also detected a paired[3] structure which he regards as the hypopharynx. As he states:

A portion of the inner surface of the tube-like ligula is covered by a furrow-like band which, close to the inner side, is coalesced with it, and in position, shape, as well as its appendages or teeth on the edge, may be regarded as nothing else than the hypopharynx.

While he refers to Burgess's discovery of a hypopharynx in *Danais archippus*, he remarks that this organ in the lower Micropteryginæ (Eriocephalidæ) exhibits a great similarity to the relations observable in the lower insects, adding:

The furrow is here within coalesced with the inner side of the labium, and though I see in the entire structure of the head the inner edge of the ligula tube extended under the epipharynx as far as the mandible, I must also accept the fact that here also the hypopharynx extends to the mouth-opening as in all other sucking insects with a well-developed underlip, viz, the Diptera and Hymenoptera.

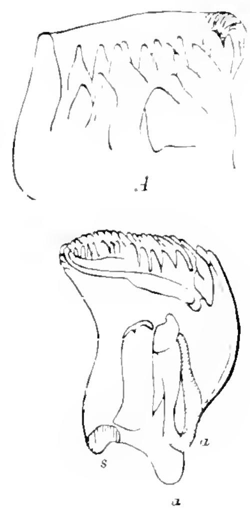


FIG. 3.—Mandible of *Eriocephala calthella*; *a*, *a*, inner and outer articulation; *s*, cavity of the joint (acetabulum); *A*, end seen from side of the cutting edge.—After Walter.

Another feature of importance diagnostic of this suborder is the mandibles (fig. 3), which, in form, size, and the presence of teeth, are closely related to those of the lower mandibulate orders, being, as Walter states, in the form of true gnawing jaws, like those of the biting insects. They possess powerful chitinous teeth on the opposed cutting edge, twelve to fifteen on each mandible, and also the typical articulating hook-like processes by which they are joined to the gena, and fit in corresponding cavities in the latter. In Micropteryx and other of the more generalized moths the mandibles in a very reduced form have survived as functionless vestiges of the condition in Eriocephala.

Turning now to the head and trunk, we find other primitive characters correlated with those just mentioned.

The head is of moderate size, as well as the body, with small compound eyes, and with two ocelli. The occipital region is well developed, as is the epicranium; the clypeus and labrum are of moderate size.

The generalized nature of the thorax is especially noteworthy. The prothorax is seen to be very much reduced, the two tergites being separate and minute, not readily seen from above. The rest of the thorax is very long, exhibiting but little concentration.

The mesothorax is but slightly larger than the metathorax. The mesoscutum is very short: the scutellum rather triangular than scutellate.

The metathorax is but little shorter and smaller than the mesothorax and remarkable for the widely separated halves of the scutum, a neuropterous character (compare Ascalaphus and Corydalus), in which it differs from Micropteryx. The shape of the scutellum is that of a low flattened triangle.

As regards the abdomen, attention should be called to the disparity in size and shape between the sexes; also to the male genital armature, which is very large and completely exserted, and reminds us of that of Corydalus, in which, however, the lateral claspers are much reduced; and also of that of certain Trichoptera (Sericostoma, Tinodes, Stenophylax, Hydropsyche, etc.). The venation of both pairs of wings is much as in Micropteryx.

The larval characters of this suborder it would be difficult to give, for in the remarkable larva of *Eriocephala calthella*, as described and figured in Dr. Chapman's elaborate account, we appear to have a highly modified form, entirely unlike the simple apodous larva of Micropteryx and perhaps quite unlike the primitive stem-forms of lepidopterous larvæ. Chapman well represents its form, as we can testify from mounted specimens in a slide kindly given us by him. The body is broad and flattened, the segments very short in proportion to their width, the prothoracic segment, however, very long in proportion to the others, but the surface rough and corrugated, not with a hard smooth dorsal plate, as in many Tineidæ, Tortricidæ, Cossidæ, etc., since it is not a boring insect. The eight pairs of abdominal prop-like tubercles, which we should hardly regard as homologues of the abdominal legs, are, like those of the Panorpidæ, simple tubercles armed with a spine. The tenth or last abdominal segment is armed with a pair of dorsal spines, each arising from a tubercle. The singular flattened and fluted setæ represented by Chapman are unique in lepidopterous larvæ. He also describes a trefoil-shaped sucker on the under side of the ninth and tenth abdominal segments, "very unusual," though as it appears to be paired it does not seem to me, as Chapman thinks, to indicate "a further point of relationship to Limacodids."

Dr. Chapman states that "the head is retractile so far that it may occupy the interior of the second thoracic segment," and he says that "the antennæ are remarkably long for a lepidopterous larva." He remarks that "there are two strong mandibles, with four brown teeth," and adds:

> Two pairs of palpi are also visible—two and three-jointed—apparently those usual in lepidopterous larvæ, but I have not defined their relations. There is also a central point (spinneret).

I add rough sketches of the mouth parts, as far as I could draw them with the camera from specimens mounted in balsam by Dr. Chapman. The labrum (fig. 4, D *lbr.*) is less divided than

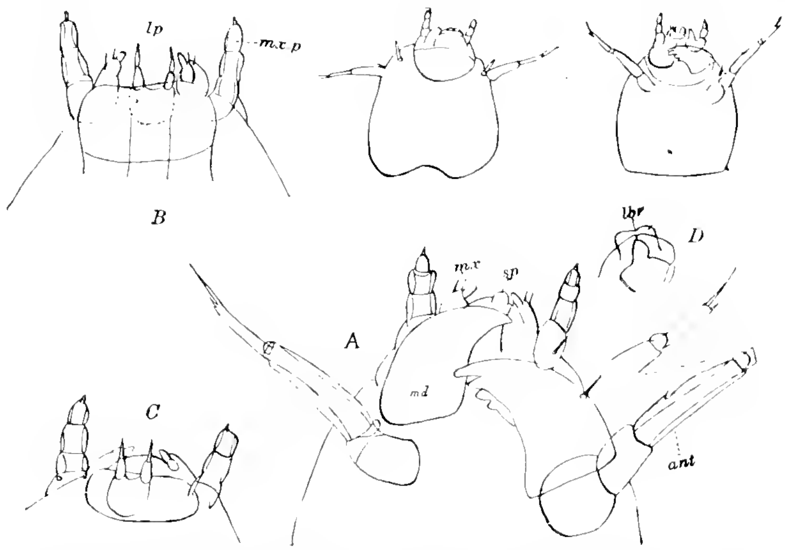


Fig. 4.—Head of larva of *Eriocephala calthella*. *A*, anterior region enlarged; *md*, mandible; *mx*, maxilla, *ant* antennæ *sp* spinneret?; *B*, 1st maxillæ and 2d maxillæ *lp*; *C*, the same, *D* labrum (*lbr*).

usual in lepidopterous larvæ, but is not, except in this respect, much unlike that of Tineids *eg.* Gracilaria (see Dimmock's fig. 2, p. 100, Psyche, iii). The four-jointed antennæ (fig. 4, *ant.*), ending in two unequal setæ, are of very unusual size and length, and so are the maxillary palpi (fig. 4, *mx. p.*), which are much larger than in any caterpillar known to me, and are greatly in disproportion to the maxillary lobes; the maxilla itself differs notably from that of other caterpillars; what appears to be the lacinia is palpiform and two-jointed. The labium and its palpi are much as in Gracilaria, but the palpi appear to be three-jointed, with a terminal bristle (it is possible that there are but two joints). Unlike the larva of Micropteryx, that of Eriocephala does not appear to possess a well-marked spinneret, while it is easy to see it in the former genus. In Eriocephala I can only detect a lobe, which appears to be simply the rudiment (Anlage) of a spinneret (unless the latter is in my specimens bent under the head); but this organ needs further examination on fresh specimens. It would be interesting if it should be found that the spinneret is in a generalized condition, as compared with that of Micropteryx.

The pupa.—Unfortunately we are as yet ignorant of the pupa form. Dr. Chapman has only found the headpiece of the pupa, but refers it to the "Incompletæ," and thinks it probable that the pupa has the "third and following abdominal segments free."

The egg.—The egg, according to Chapman, is "large and spherical," in confinement deposited in little groups, to the number of 25 in all.

Diagnostic characters of the Lepidoptera laciniata.—I add the characters of this suborder. Imago: Maxilla, with a well-developed lacinia and galea, arising, as in mandibulate insects, from a definite stipes and cardo; the galeæ not elongated, nor united and differentiated into a haustellum, each being separate from its fellow. The maxillary palpi enormous, six-jointed; mandibles large, scarcely vestigial, with a broad toothed cutting edge, and with three apparently functional hinge processes at the base, as usual in mandibulate insects. Hypopharynx well developed, somewhat as in Diptera and Hymenoptera. The second maxillæ divided into a mala exterior, recalling those of mandibulate insects; palpi three-jointed. Thorax with prothorax very much reduced; metathorax very large, with the two halves of the scutum widely separate. Venation highly generalized; both fore and hind wings with the internal lobe or "jugum," as in Trichoptera; veins as in Micropteryx and showing no notable distinction compared with those of that genus; scales generalized; fine, scattered setæ present on costal edge and on the veins; abdomen elongated, with the male genital armature neuropteroid, exserted; the dorsal, lateral, and sternal appendages very large.

Egg spherical. Larva in form highly modified, compared with that of Micropteryx, with large four-jointed antennæ and very large three-jointed maxillary palpi; no spinneret ?. No abdominal legs, their place supplied by a pair of tubercles ending in a curved spine on segments 1–8; a sternal sucker at the end of the body. Pupa libera ?.

Suborder II.—LEPIDOPTERA HAUSTELLATA.[1]

This group may be defined thus: Maxillæ with no lacinia, the galeæ being highly specialized and united with each other to form a true tubular haustellum or glossa, coiled up between the labial palpi. The maxillary palpi large, and five or six-jointed in the more generalized forms, usually vestigial or entirely wanting in the more modern specialized families. Mandibles absent as a rule, only minute vestiges occurring in the same generalized forms. Wings both jugate and frenulate, mostly the latter; tending to become broad and with highly specialized scales, often ornamented with spots as well as bars, the colors and ornamentation often highly specialized; the thorax highly concentrated, the metathorax becoming more and more reduced and fused with the mesothorax; the abdomen in the generalized forms elongated and with a large exserted abdominal male genital armature.

Pupa incomplete, the abdominal segments 3 to 6 or 7 free; in the more generalized primitive forms the end of each maxillary palpus forming a visible subocular piece or "eye collar" or a flap-like piece on the outside of the maxillæ; the labial palpi often visible; clypeus and labrum distinct; paraclypeal pieces distinct; no cremaster, or only a rudimentary one, in the generalized primitive forms.

Larvæ with usually a prothoracic dorsal chitinous plate; the armature consisting in the primitive forms of minute one-haired tubercles, the four dorsal ones arranged in a trapezoid on abdominal segments 1–8, becoming specialized in various ways in the later families into fleshy tubercles or spines of various shapes; five pairs of abdominal legs, with hooklets or crochets forming a complete circle in the more generalized forms (in Hepialidæ several complete circles), the hooklets in the later, more specialized groups usually forming a semicircle situated on the inner side of the planta.

This suborder may be subdivided into two series of superfamilies and families, the *Paleolepidoptera* and the *Neolepidoptera*.

[1] If the term *Lepidoptera haustellata* should be thought inapplicable from the use of the word *Haustellata* for haustellate insects by former authors, the term *Lepidoptera glossata* could be used instead.

I. PALEOLEPIDOPTERA (*Pupæ liberæ*).

The characters of the group are those of Micropteryx, as this is the only genus yet known. Its larva has a well developed spinneret: though it has no abdominal legs, the other features are so truly lepidopterous that the absence of legs may be the result of reduction by disuse rather than a primitive feature.

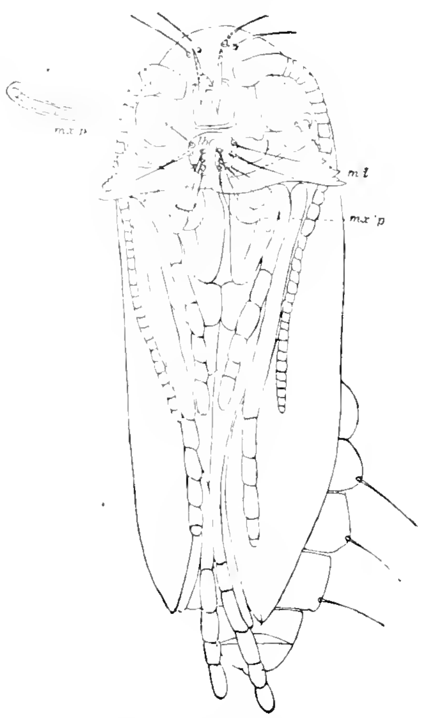


Fig. 5.—Pupa of *Micropteryx purpurella*, front view: *md.* mandibles; *m.x. p.* maxillary palpus; *mx. p.* labial palpus; *lb.* labrum, with its long setæ.

The pupa (fig. 5) has entirely free antennæ, mouth-parts, and limbs, and bears considerable resemblance to that of a caddis fly. It is a *pupa libera*.

The mandibles (fig. 5 *md.*) are enormous and, as described by Chapman, are adapted for cutting through the dense cocoon. The maxillæ are separate and curled up on each side and partly concealed by the second maxillary (labial) palpi (fig. 5 *m.x. p.*), not extending straight down, as in the *Pupæ incompletæ* and *obtectæ*; the maxillary palpi are situated just in front of the mandibles and extend outward and forward, reaching to the antennæ. The labrum is deeply cleft and strongly setose, as is the epicranium; the clypeus is square, with a singular white delicate membrane projecting from it, the use of which is unknown. The hind legs extend beyond the end of the abdomen, which is simple, not terminating in a cremaster; the sides of the segments bear a single large seta.

The trunk characters of the imago are much as in Eriocephala. The head is larger and squarer; the eyes very small; there are two ocelli present; the clypeus and labrum are short and small.

The prothorax is very much reduced, much as in Eriocephala; the metathoracic scuta show an advance over those of Eriocephala in being united on the median line instead of separated; the metascutellum is very large, longer and more scutellate than that of Eriocephala.

The shape and venation of the wings (fig. 6) are nearly identical with those of Eriocephala, being long, narrow, and pointed, both pairs nearly alike in size, and except that on the hinder pair there is a "jugum" or angular anal fold; the scales are of generalized shape all over the wings.

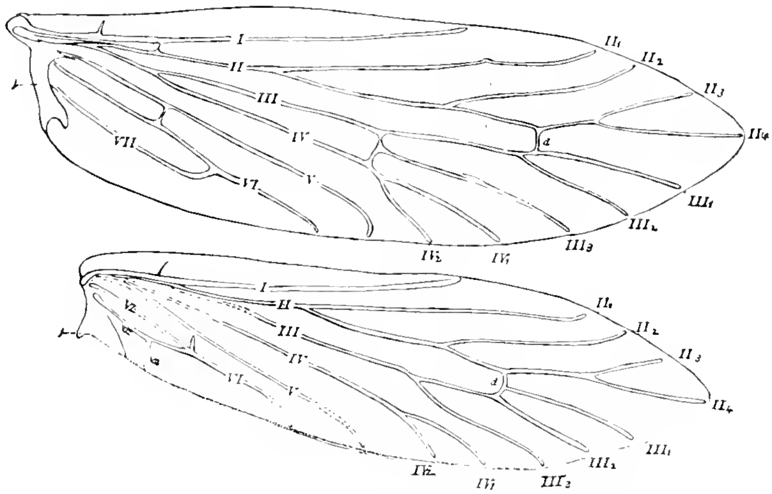


Fig. 6.—Venation of fore and hind wings of *Micropteryx purpurella*; *j*, jugum, on each wing; *d*, discal vein. I costa; II, subcosta; III, media; IV, cubitus, etc.

II. NEOLEPIDOPTERA.

This series may be divided into two sections, corresponding in the main to the *Pupæ incompletæ* of Chapman (the Eriocephalidæ and Micropterygidæ included by Chapman being removed) and his *Pupæ obtectæ*, for the first of which we would suggest the name *Tineoids*, and for the second, comprising the large broad-winged forms, Macrolepidoptera or Platylepidoptera.

1. Tineoids or *Stenopterygia.*

These are Tineoid forms with many vestiges of archaic features, usually with narrow wings, of dull hues or with metallic bars, or with highly specialized scales, and spots, and the venation generalized in the earlier forms. The maxillæ are sometimes aborted (wholly so in Hepialidæ); palpi either well developed, more or less reduced, or wanting; mandibles rarely occurring as minute vestiges; the thorax neuropteroid; in the more primitive forms, becoming shorter, and the segments fused together in the later or more specialized groups.

The pupæ are incomplete; the more primitive forms with the eye collar; labial palpi visible; paraclypeal pieces distinct; abdomen often in the most primitive forms with no cremaster.

Larvæ with one-haired tubercles, the four dorsal ones arranged in a trapezoid on abdominal segments 1–8; usually a prothoracic dorsal plate; the abdominal legs sometimes wanting in certain mining forms and Cochliopodidæ; larvæ often case-bearers or borers; crochets on the abdominal

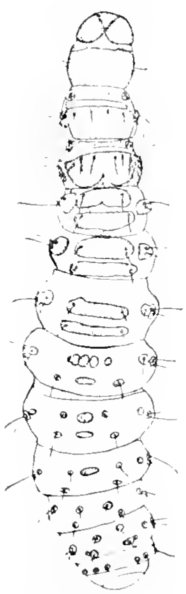


FIG. 7.—Larva of *Adela viridella*; enlarged.

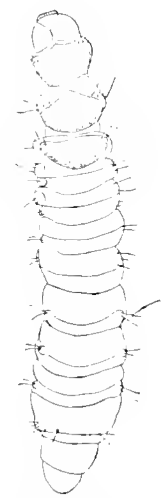


FIG. 8.—Larva of *Nematois violellus*, enlarged

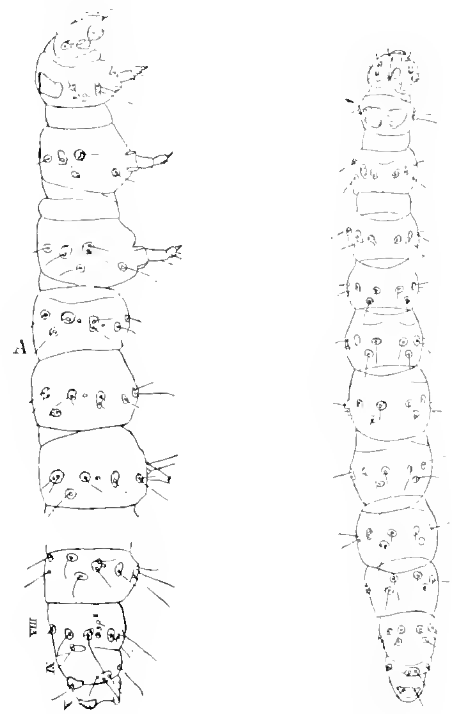


FIG. 9.—Larva of *Simaethis oxyacantha*, *A* side view.

legs in the primitive types arranged in two or more complete circles; in the lowest forms a well-marked spinneret.

From the generalized types many offshoots or lines of descent arose whose position is difficult to assign until we know more about the pupæ, as well as the venation, so that the following grouping is entirely provisional; the more generalized forms are evidently archaic and very primitive, and the members of the groups may be briefly called for convenience Tineoids, from their general resemblance to the Tineina.

Remarks on the Tineina.—It must now be very obvious that we need to reexamine and revise the Tineina, and especially their pupæ and imagines, particularly those of the more generalized forms, such as the Tineidæ (Tinea and Blabophanes) and the Talæporidæ, comprising all those ancestral forms with broad wings and generalized venation, which may have given rise to the neolepidopterous families.

Then careful studies should be made on the Adelidæ, Choreutidæ, and Nepticulidæ, and other families and genera in which the mandibles have persisted (though in a vestigial condition).

and also those with functional or vestigial maxillary palpi, such as Tineidæ, Gracilariidæ, Elachistidæ, etc.

It is evident that the classification of the Tineina will have to be entirely recast. Instead of placing the Tineidæ, with their broad wings and generalized venation, at the head of the Tineina, as done in our catalogues and general works, they should go to the base of the series, not far from the Micropterygidæ. On looking over the venation of the Tineidæ represented on Spuler's Pl. XXVI, it is evident that the very narrow-winged genera such as Coleophora, Ornix, Lithocolletis, Nepticula, Gelechia, Cemiostoma, and Œcophora, are highly modified recent forms when compared with Tinea and Blabophanes, as well as the Adelidæ (Adela, fig. 7), Nematois (fig. 8), and Choreutidæ (Simæthis, fig. 9, larva, and Choreutis), and justify Chapman in associating them with the Pyraloids in his group of *Pupæ obtectæ*.

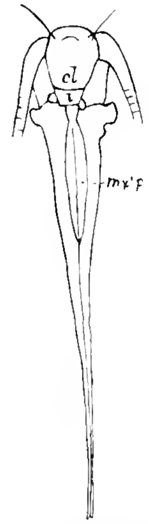


FIG. 10.—Head of pupa of Gracilaria; *cl*, clypeus; *l*, labrum.

The pupa of Gracilaria (fig. 10) and of Bucculatrix (fig. 11) shows the eye-collar, the paraclypeal tubercles, as well as the labial palpi. On the other hand, the pupa of the pyraloid genus Cryptolechia (figs. 22, 23, *C. quercicella*, *C. schlaginiella*) shows no traces of the maxillary palpi (eye-collar).

Family Prodoxidæ.—Having already discussed the chief characteristics of the Palæolepidoptera, represented by the family Micropterygidæ, we may next call attention to the most primitive of the Neolepidoptera. These we believe to be the very remarkable genera Tegeticula (Pronuba) and Prodoxus, representing the family Prodoxidæ. The structure of the imagines and their larval and pupal forms have been described at length and figured by Dr. C. V. Riley,[1] who has described the egg as being very long, cylindrical, soft, and flexible; the boring larvæ as being either without abdominal legs, but with thoracic ones (Tegeticula), or entirely apodous (Pronuba). Dr. Riley gives a careful and detailed account of the male and female pupa of Tegeticula (Pronuba), but does not mention the "eye-collar" or case of the end of the maxillary palpi (figs. 12, 13, *mx. p.*), which is very large, especially in Tegeticula, much more so than in the rest of the Tineina or in any of the other Neolepidoptera. It is thus in a degree intermediate between that of the Neo- and Paleolepidoptera. The maxillæ (*mx.*) are well developed, but there are no traces, so far as I can see, of the "maxillary tentacles" so greatly developed, according to Riley, in the imago; but the specimens kindly lent me by Dr. Riley for examination are the cast shells, and further examination and search for them should be made on living or alcoholic specimens. The labial palpi (*mx. p.*) and the paraclypeal pieces, as well as the eye-suture separating the "glazed eye" from the rest of the eye, are well developed. Abdominal segments 2–9 are free and armed with the enormous dorsal spines well described and figured by Riley. Figs. 14 and 15 represent the cast pupa skin of *Prodoxus decipiens* Riley.

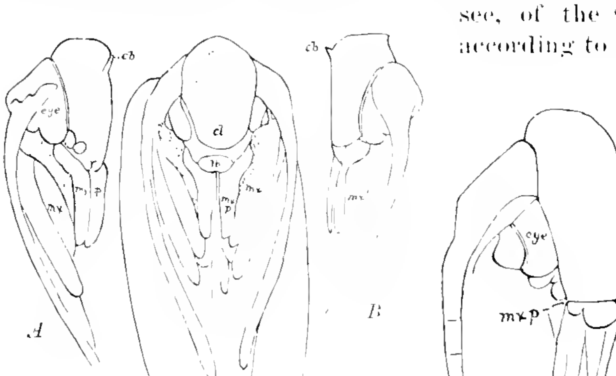


FIG. 11.—Pupa of *Bucculatrix quinquenotella*. *A*, oblique; *B*, side view of head; *cb*, cocoon-burster; *C*, side view of head of *C. canadensella*.

The venation is almost exactly as in Tineidæ, but the structure of the maxillæ, as described and figured by Riley, presents an extraordinary feature, in which this family, and especially the present genus, differs from all the other insects. I refer to the remarkable "maxillary tentacles." Riley thus describes them:

The male possesses no very marked characters, but the female is most anomalous; first, in possessing a pair of prehensile, spinous, maxillary tentacles (fig. 1*b*), found, so far as we now know, in no other genus of Lepidoptera.

[1] Proc. Amer. Assoc. Adv. Sc., xxix, 1880.

With her maxillary tentacle, so wonderfully modified for the purpose, she collects the pollen in large pellets and holds it under the neck and against the front trochanters. In this manner she sometimes carries a mass thrice the size of her head (fig. *a*, 7*b*, *mt.*).

In Riley's figure of *Tegeticula* (Pronuba) *maculata* this organ is represented as arising from the same joint (palpifer) as the maxillary palpi: it is jointed and bears stout bristles, and would naturally be regarded as the maxilla itself, but Riley, in his diagnosis of the family Prodoxidæ, says: "Maxillary palpi long, elbowed, five jointed, the basal joint either protuberant (Prodoxus) or modified into a prehensile tentacle" (Tegeticula). It is evident that this structure needs further examination to establish its real nature or homology.

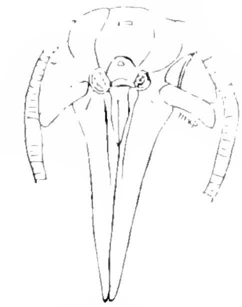


FIG. 12.—Head of pupa of *Tegeticula yuccasella.*

FIG. 13.—Cast pupal skin of *Tegeticula yuccasella*; *mx. p.*, maxillary palpus.

Indeed, I am disposed to regard the so-called "maxillary tentacle" as the maxilla itself, and perhaps the "maxilla" of Riley is the lacinia or inner lobe of the maxilla, but have had no material for examination to settle this point. If this should prove to be the case it would carry the family down among the *Lepidoptera laciniata.*

Another striking feature of the imagines of this family is the long ovipositor, which is very "extensile, the terminal joint horny, in one piece, and adapted to piercing and sawing." (Riley.)

The family evidently is a more primitive one than the Hepialidæ, although the larva in one genus is entirely apodous and thus much modified.

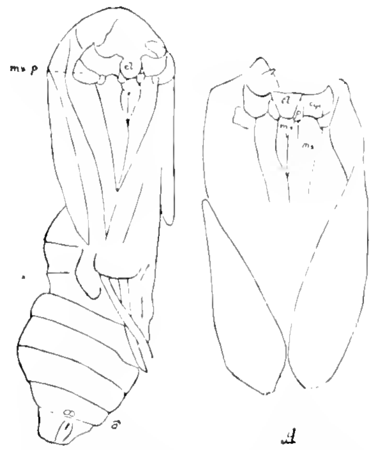


FIG. 14.—Cast pupal skin of *Prodoxus decipiens*; *A*, another specimen; *p.* paraclypeal piece; *mx. p.* maxillary palpus; *mx* maxilla; *mx* labial palpus.

Family Tineidæ.—This group comprises generalized forms of Tineina. The larvæ are sack-bearers, but have five pairs of abdominal legs; the wings are rather broad and the venation is generalized, that of *Tinea biselliella* showing no reduction in the number of veins. The maxillary palpi are five and six-jointed. The pupa (fig. 16, *Tinea tapetzella*) has well-developed maxillary palpi (*mx. p.*); the maxillæ are short, indeed not so long as the labial palpi (*mx. p.*); the abdominal segments 4–7 are free; there is no true cremaster, though a pair of terminal plates. As regards Blabophanes (fig. 17), Spuler[1] (p. 627) remarks that the differences in venation between this and Tinea are so much greater than usual within the limits of a single family that a more isolated position should perhaps be assigned to this genus.

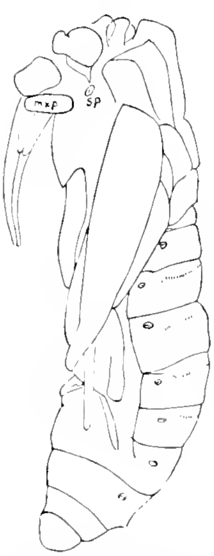


FIG. 15.—Pupa of *Prodoxus decipiens*, side view; *sp.* prothoracic spiracle.

The succeeding families of genuine Tineina may provisionally be arranged in the following ascending order, beginning with *A*, the more generalized, and ending with *B*, the most modified forms.

A.

Adelidæ.—Maxillary palpi five-jointed in Nemophora, in Adela no maxillary palpi in moth. Larva of Adela with numerous dorsal piliferous plates, those of Simæthis being similar; those of Nematois (fig. 8) being confined to the thoracic segment.

Gracilariidæ.—Maxillary palpi present. Pupa with maxillary palpi well developed (fig. 10).

Nepticulidæ.

[1] Zur Phylogenie und Ontogenie des Flügelgeaders der Schmetterlinge. Zeits. wissens. Zoologie, 1892.

B.

Lithocolletidæ.—No maxillary palpi in moth. Pupa of Tischeria (figs. 19, 20) with no traces of maxillary palpi, but the labial palpi well developed; no cremaster.

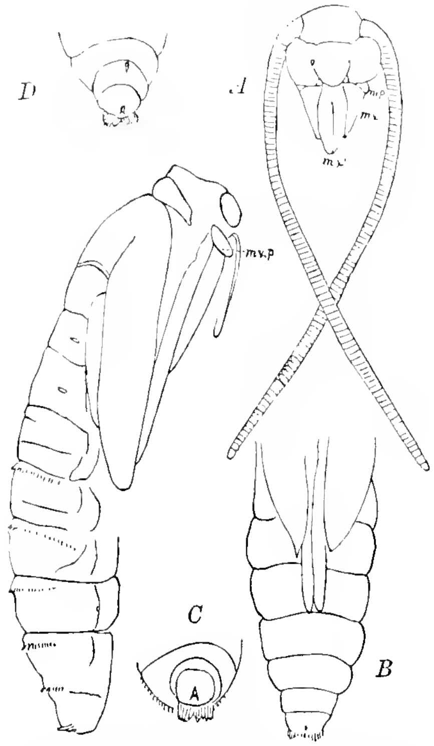


FIG. 16.—Cast skin of pupa of *Tinea tapetzella*: *A*, head; *B*, end of abdomen; *C*, last three segments of same enlarged; *D*, another view of *C*.

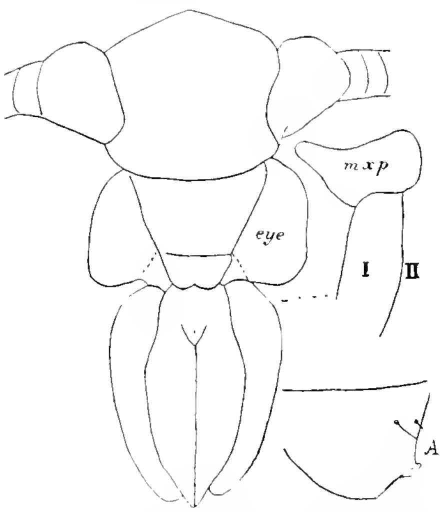


FIG. 17.—Pupa of *Blabophanes ferruginella*, head; *I*, fore, *II*, middle leg; *A*, hook on end of abdomen.

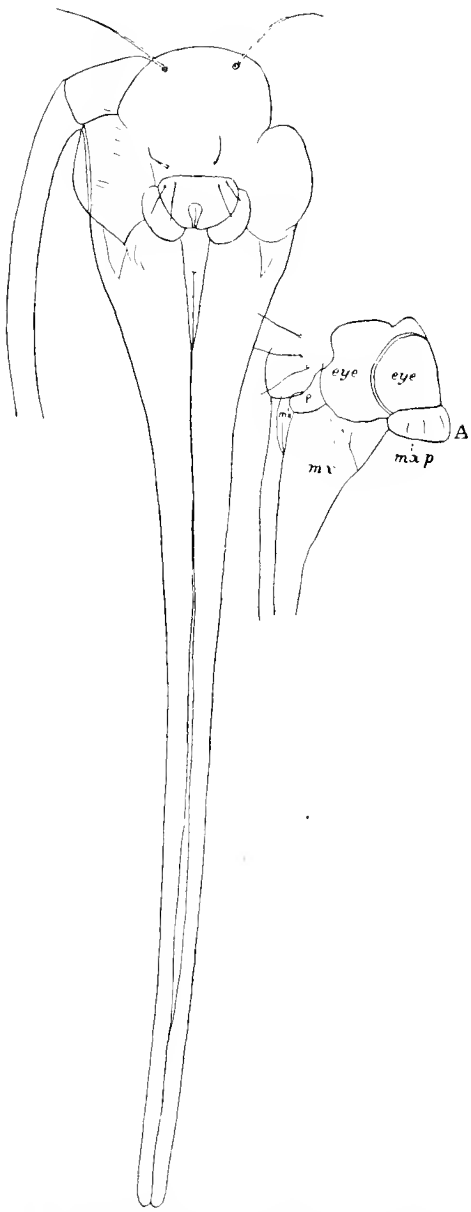


FIG. 18.—Head of pupa of *Adela caprella*: *A*, side view of part of head, showing maxillary palpi (*mx. p.*), etc.

Lyonetidæ.—In Bucculatrix (fig. 11, B.) maxillary palpi present in the pupa, but minute; labial palpi large.

Choreutidæ.—The pupa[1] (fig. 21) is like that of Tischeria in wanting maxillary palpi. As to the true position of the family from other characters I have no knowledge.

[1] For the pupa of this and other rare Tineids I am indebted to M. P. Chretien, of Paris.

Elachistidæ.—Maxillary palpi of imago minute. Wings narrow and the veins reduced in number of branches.

Lavernidæ.
Hyponomeutidæ.
Argyresthidæ.
Glyphipterygidæ.
Coleophoridæ.
Oecophoridæ.
Plutellidæ.

Gelechidæ.—In the pupa of *Cryptolechia* (figs. 22, 23) we have an example of the modern *Pupa obtecta*, there being no eyepiece (maxillary palpi) and no labial palpi visible, while a cremaster is well developed. Both in its larval, pupal, and imaginal characters the transition to the Pterophoridæ, Crambidæ, Phycidæ, and Pyralidæ is not great, and we can thus see that these families may have descended from the Tineina.

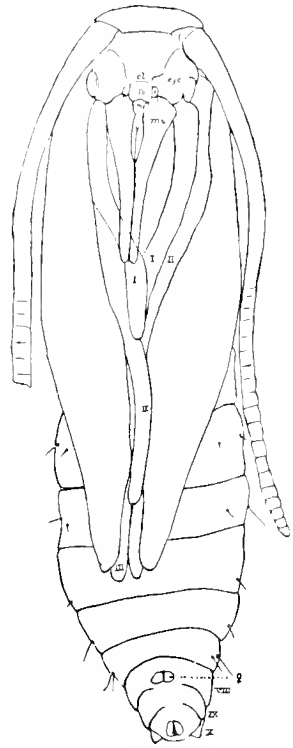


FIG. 19.—Pupa of *Tischeria ginestorella* ♀.

Family Talæporidæ.—This group, comprising the genera Solenobia and Talæporia, has evidently either directly descended from the case-bearing Tineidæ or the two families have had a common origin. They form a side branch by themselves and are the direct ancestors of the broad-winged, more recent Psychidæ. Their relations are shown in the genealogical tree at the end of this chapter.

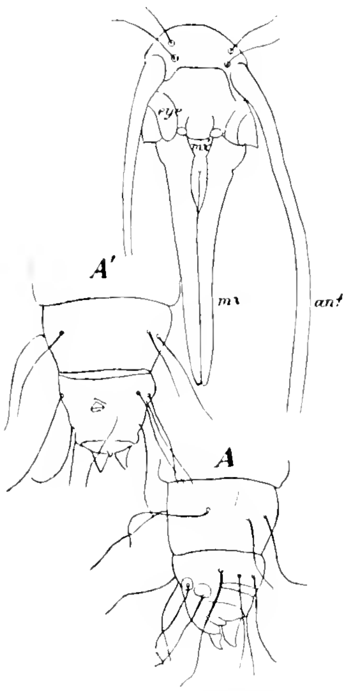


FIG. 20.—Pupa of *Tischeria marginea*. A′, end of body, showing spines; A, the same, side view.

The imagines have, according to Stainton, no maxillary palpi, and the tongue is wanting, while the females are wingless. The head is broad, and in fact in this group we have, so to speak, Tineid Bombyces. The venation (fig. 50) is generalized Tineid, and it is evident from a long abode in cases that the features which separate the family so widely from the Tineidæ are the result of disuse and resulting adaptation. The family had diverged considerably from the Tineid source along a path which unmistakably ends in the Psychidæ. Without specimens of the wingless female we are unable at present to compare them with those of the Psychidæ; and we still need examples of the larvæ (living and in alcohol) to compare with those of the Tineids on the one hand and those of the Psychidæ on the other.

The pupa of *Talæporia pseudobombycella*[1] (fig. 24) has a broad head, with distinct paraclypeal pieces and glazed-eye-sutures. The maxillary palpi (*mx. p.*) are large and well developed, extending under the eye from the antennæ to the labial palpi, which are large, but short and very broad. The maxillæ are present, but small. The abdomen bears no cremaster, but there are two terminal small spines which may be the homologues of the anal-leg hooks of the pupæ of Psychidæ. The scars of the four pairs of anterior abdominal legs are present, as in Psychidæ.

In *T. conspurcatella* (fig. 25) the maxillæ are much more rudimentary, and before exuviation concealed by the long labial palpi (*mx. p.*); the maxillary palpi (*mx. p.*) are large and triangular.

[1] I am greatly indebted to Dr. T. Algernon Chapman for kindly sending me the pupæ of the European *T. pseudobombycella*, and pupæ, with imago, of *T. conspurcatella*. For the loan of *Solenobia pineti* and *walshella*, pupæ and other specimens, I am indebted to the Museum of Comparative Zoology, Harvard University.

In the pupa of *Solenobia walshella* Clemens (fig. 26), the maxillæ (*mx.*) have undergone less reduction than in Talæporia, as they are well developed, but the European species *S. pineti*

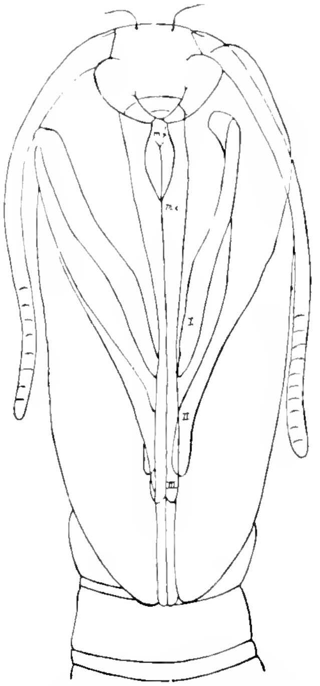


FIG. 21.—Pupa of *Choreutes bjerkandella*; outer eyepiece and maxillary palpi not drawn; *mx'*, labium.

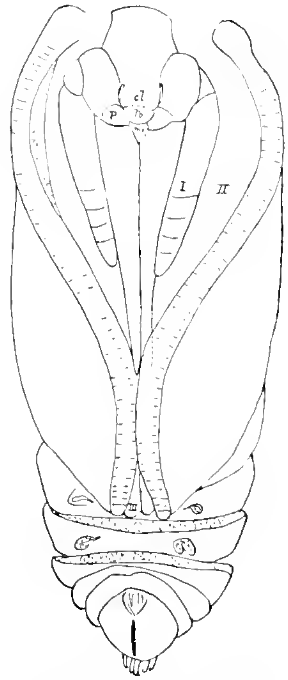


FIG. 22.—Cast shell of pupa of *Cryptolechia schlaginiella*, *p*, paraclypeal piece; *mx'*, labium.

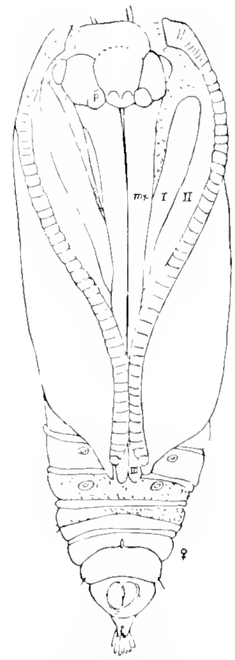
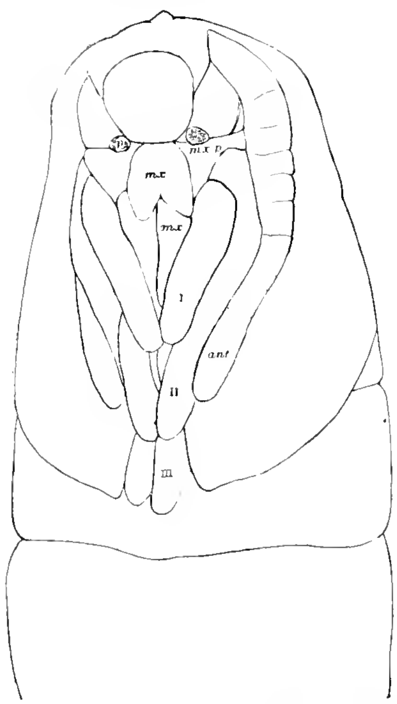
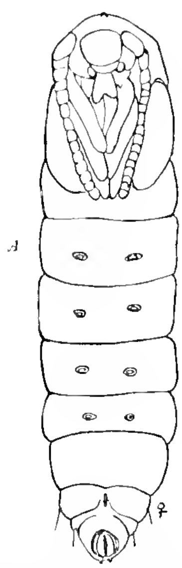


FIG. 23.—Pupa of *Cryptolechia quercella*, ♀; I—III, legs.

Zeller, has outstripped the American one in the process of degeneration and modification, and the maxillæ (fig. 27, *mx.*) are very much shorter and smaller, though the maxillary palpi are of the same shape and size. In this genus the abdomen has no cremaster and no terminal hooked spines, the pupa in exuviation being fastened to the sides of the cocoon by numerous hooked setæ (fig. 26, A).

Family Psychidæ.—The transition from the Talæporidæ to the Psychidæ is a most natural one, whether we compare the pupa or imago. In Fumea the wingless females have legs and antennæ, while in Psyche they are wanting and they never leave their case, or when the female of Fumea "escapes from the pupa, it emerges from the case and sits on the outside" (Stainton). On reading the views of Spuler we discovered, by comparing the pupæ of the two groups, their evident relationship. Indeed, Spuler appears to place Talæporia in the Psychidæ, though at present they are universally referred to the Tineina,





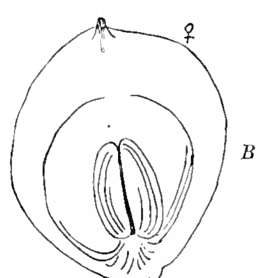


FIG. 24.—Pupa of *Talæporia pseudobombycella*; A, head enlarged; B, end of body.

remarking that its venation is typically Tineinan. He adds that in shape and mode of life the females of many species of Fumea, and those of Epichnopteryx and of the Talæporidæ, are much more nearly related to each other than those of other species of Fumea and Psyche the species of the latter genus falling into two groups, judging by their venation, and he states that *Psyche febretta* is "the nearest relation of the type from which on the one side the Zygænidæ and on the other the Arctiidæ and Liparidæ have descended. The Lithosiidæ are also perhaps to be added, and indeed belong to a branch which extends from the Talæporidæ to the Crambidæ and Phycidæ." From an examination of the pupa, and also the statements of Chapman and of Comstock, it is evident that the Psychidæ should be removed from the Bombyces and placed among the Tineoid moths.

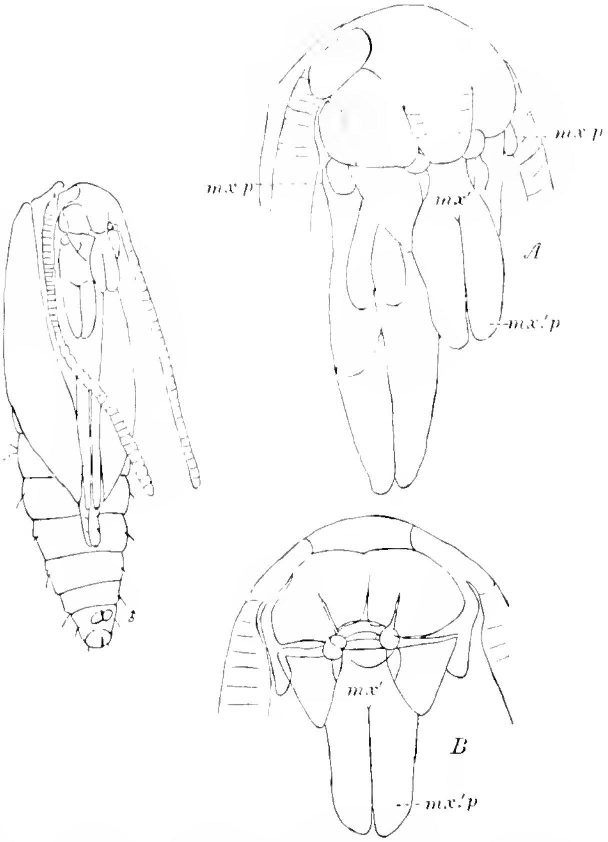


FIG. 25.—Pupa of *Talæporia conspurcatella*; *A*, head enlarged; *B*, the same, seen from within; *mx p.*, maxillary palpi.

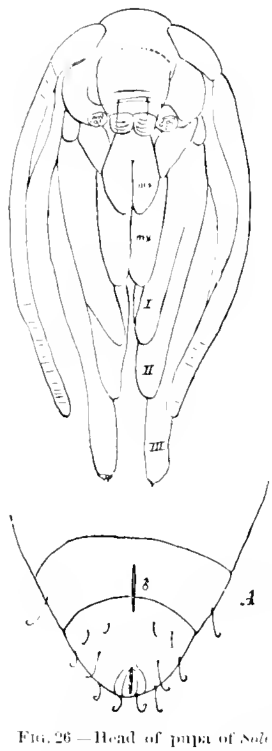


FIG. 26.—Head of pupa of *Solenobia walshella*; *A*, end of body.

It is evident that the line of development from the narrow tineid-winged Talæporidæ to the broad-winged Psychidæ was nearly direct. Perhaps the slight changes in venation and much greater breadth of the wings and the pectinated antennæ are the result of adaptation to the stationary mode of life of the females, the males acquiring greater power of extended flight and a more acute sense of smell in order to discover the presence of the females.

In comparing the pupæ of different genera of Psychidæ with those of the Talæporidæ, the resemblance is most striking and naturally suggests the direct evolution of the Psychids from the latter group. The head is broad and has the same general shape as in the Talæporidæ, including the form of the eyes, of the clypeus and of the labrum, which, however, in the Psychidæ is more distinct from the clypeus, though in *Solenobia walshella* it is nearly as separate.

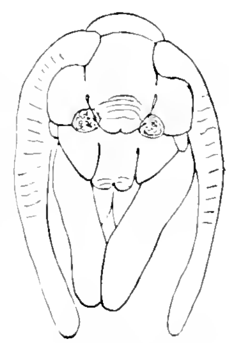


FIG. 27.—Head of pupa of *Solenobia pineti*.

The shape of the cases of the maxillary palpi of *Psyche graminella*, (*Œceticus abbotii*, fig. 28), and *Metrua elongata* is as in *Solenobia walshella* and *S. pineti*. The maxillæ (*mx.*), fairly well developed in the Psychidæ, are much as in *Solenobia walshella*. The labial palpi (*mx'. p.*), though varying much in the different genera of Psychidæ, are essentially as in the *Talæporidæ*. Compare those of Psyche, Œceticus, and Entometa with those of *Talæporia pseudobombycella*. Those of Platœceticus are longer than in the other Psychidæ, but still more rudimentary than in Solenobia. In regard to the shape of the maxillary palpi, which unite, forming a continuous bar or piece in front of the labrum, Thyridopteryx (fig. 29, *mx. p.*) differs from other Psychidæ and approximates to certain Hepialidæ (fig. 33).

Fig. 29 represents the pupa of *Thyridopteryx ephemeræformis*, and its close resemblance to that of *Oncopera intricata* (fig. 33) will be seen in the presence of the large piece between the base of the maxillary palpi. In *Œceticus abbotii* (fig. 28) the maxillary palpi are separated by the second maxillary (labial) palpi. The former (*mx. p.*) is subdivided into an inner and an outer small lobe. In the Psychidæ the paraclypeal pieces, or tubercles, as we might call them, are always present. They are convex and very rugose. The labial or second maxillary piece in the Australian *Eumetopa ignobilis* is of the same shape and sculpturing as in *Psyche graminella*, but the large, round, rugose pieces on each side, or first maxillary palpi, are single, not divided into two parts, unless the irregularly trapezoidal pieces between the maxillary palpi and the eyepiece be the homologue of the outer portion.

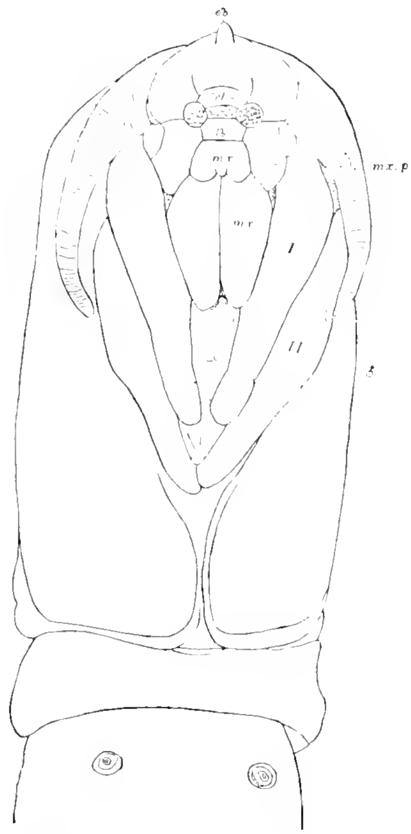


FIG. 28.—Pupa of *Œceticus abbotii*: *cb*, cocoon-opener.

In the Australian *Metura elongata* (fig. 30) the short reduced labial palpi are much as in *Psyche graminella*, but are more deeply divided. The two divisions I am inclined to consider as the second maxillary (labial) palpi. In this genus the first maxillary palpi are also as in *Psyche graminella*.

It will then be seen that in the pupa of this family the first and second maxillary palpi vary very much in form, as they probably do in the imagines, being more or less atrophied in the latter, where they need to be carefully examined. On the other hand, the maxillæ themselves (for in their pupal condition in haustellate Lepidoptera they have retained the separated condition of those of the laciniate Lepidoptera), though short, are quite persistent in form.

The pupa of *Platœceticus gloverii* differs from that of *Œceticus abbotii* in the undivided first maxillary palpus (eyepiece) and the elongated second maxillæ, as well as the narrower clypeal region, and the lack of a cocoon or case-opener.

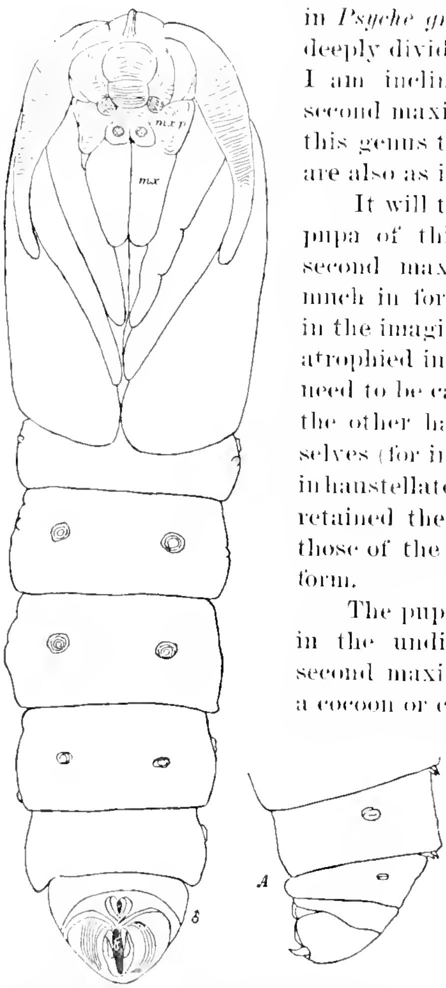


FIG. 29.—Pupa of *Thyridopteryx ephemeræformis*, ♂: *A*, side view of end of body, showing one of the two terminal hooks; vestiges of 3 pairs of abdominal legs.

By an examination of the figures it will be seen that the outer division of the eyepiece varies much in size. This is due to the varying width of the male antennæ, which, when wide, as in Pinara (Entometa), Metrua, Thyridopteryx, and Pysche overlap and nearly conceal it, while it is entirely hidden in Platœceticus. On the other hand, in male pupæ of Hepialus and Oncopera, where the antennæ are small, narrow, and not pectinated, these pieces are large. The end of the body has no cremaster, but, what is unique, a hook arising from each vestigial anal leg.

Finally, it will be readily seen that from an examination of the pupæ the views of Speyer, of Chapman, and of Comstock, as to the position of the Psychidæ is fully confirmed, while I should go a little further and place them still nearer the Hepialidæ. They are, however, still more modified than this last-named group, since the females are wingless and limbless. It is very plain that they are an offshoot from the Tineoids, and especially from the Talæporidæ, which have no tongue and whose females are wingless and sack-bearers.

Remarks on the Family Hepialidæ.—This group is assigned by Comstock, from the venation alone, to a position at the bottom of the lepidopterous scale, even below the Micropterygidæ. By Chapman it is more correctly placed above the latter group. He even places it above the Nepticulidæ, Adelidæ, and Tischeria. The family evidently branched off from tineid like forms.

Since receiving and studying Chapman's paper it has become very plain to me that Hepialus and its allies are simply colossal Tineoids, and that Speyer was right in 1870 in suggesting that the Hepialidæ stand very near to the tineids.[1]

These views, arrived at independently by these authors, are confirmed by the trunk characters and also by the larval characters, as pointed out by Dyar,[2] and which I have been able to confirm by an examination of the freshly hatched larva of *Hepialus mustelinus* and fully grown larvæ of the Australian *Oncopera intricata* Walk., as well as those of *Hepialus humuli* and *H. hectus* of Europe.

In 1863[3] I pointed out the similarity in the head and thorax of *Hepialus* (*Sthenopis*) *argenteo-maculatus* to those of the neuropterous Polystoechotes, and referred to the elongated thorax of Hepialus, especially "the unnatural length of the metathorax, accompanying which is the enlarged pair of wings, a character essentially neuropterous." Reference was also made to the metascutum, which is divided into two halves, being separated widely by the very large triangular scutellum. I also drew attention to the transverse venule or spur of the costal vein and to the great irregularity in the arrangement of the branches of the cubital nervure, also to the elongated abdomen, and finally I remarked, "the Hepiali are the lowest subfamily of the Bombyces." But in those days I did not fully perceive the taxonomic value of these generalized characters, which have so well been proved by Chapman from imaginal and pupal characters to be such as to place the Hepialidæ at or near the base of the Tineoid series. Chapman, unaware of the existence of mine and of Speyer's paper, says:

The metathoracic structure of Hepialus came as a very unexpected confirmation of the idea that of the Tortricoid group it was the nearest to the lower Adelids, and despite its specialization was near the line by which Tortrix was derived from some Adelid form (p. 113).

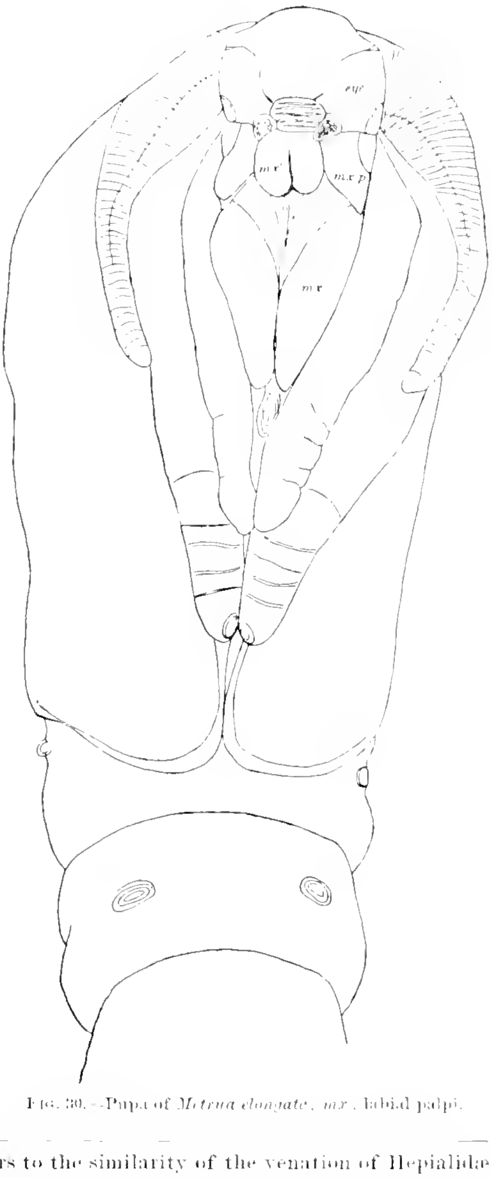


Fig. 30.—Pupa of *Metrua elongata*; *mx*, labial palpi.

[1] In his suggestive paper (Ent. Zeit. Stettin, 1870), Speyer refers to the similarity of the venation of Hepialidæ and Cossidæ, and remarks that they resemble the Trichoptera no less than the Micropterygidæ, though the Hepialidæ exhibit other close analogies to the Trichoptera. He adds that the middle cell of the wing in the Phryganeidæ is not fundamentally different from that of the Hepialidæ, Cossidæ, and Micropteryx, also the hind wings of Psychidæ. On page 221 he associates the Zygaenidæ with the Cossidæ, Cochliopodidæ, Heterogynidæ, Psychidæ, and Hepialidæ, and remarks that all these families are isolated among the Macros; the Cochliopodidæ and Zygaenidæ alike in the pupa state by the delicate integument and the partially loose sheath, these groups standing nearest to the Tineidæ with complete maxillary palpi, forming the oldest branch of the lepidopterous stem, and having been developed earlier than the Macros.

[2] A classification of lepidopterous larvæ. Annals N. Y. Acad. Sci., viii, 1894, p. 196.

[3] On "Synthetic types in insects." Boston Jour. of Nat. Hist., 1863, pp. 590-603.

I will now refer to some characters of the Hepialidæ which further show that they are colossal Tineoids, and should be placed very near the base of the order, though still proving, in their boring larval habits and in the reduced maxillary and labial palpi, the entire absence of a haustellum and of mandibles, that the family (at least Hepialus and Sthenopis) has undergone a considerable degree of modification, compared with the Micropterygidæ.

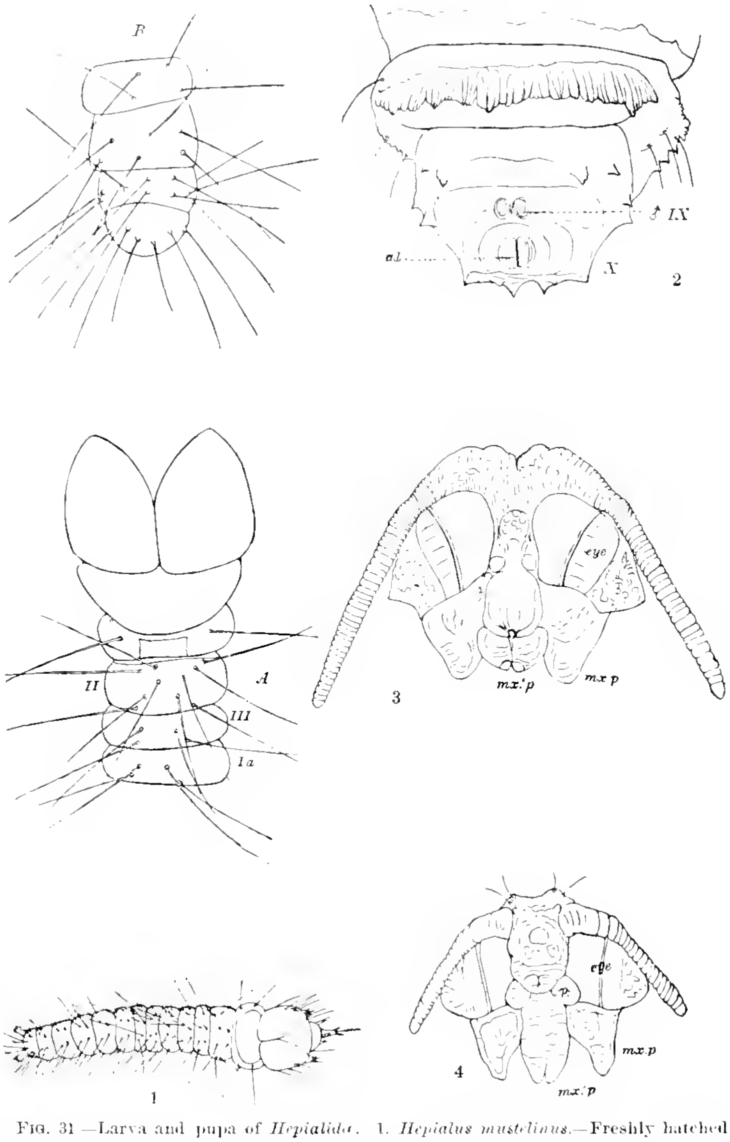


FIG. 31.—Larva and pupa of *Hepialidæ*. 1. *Hepialus mustelinus.*—Freshly hatched larva: *A*, thoracic segments; *B*, terminal abdominal segments. 2. *Hepialus humuli.*—End of body of pupa; *a.l.*, anal legs; *IX*, male genital organs. 3. *Œnetus virescens.*—Head of pupa; *mxp*, maxillary palpi; *mx'. p*, labial palpi. 4. *H. humuli.*—Head of pupa.

(Cut loaned by the New York Entomological Society.)

Beginning with the larva, that of the Australian *Oncopera intricata*, when compared with the larva of the colossal Tineoid moth, *Maroga unipunctaria*, of South Australia, is the same in structure, though less specialized in the colors of the tubercles and in the sculpturing of the head, but it has the same shape of the body, the same arrangement of the one-haired tubercles, though the setæ are smaller and shorter, and the same complete circles of crochets on all the abdominal legs.

Fig. 31_1 represents the freshly hatched larva of *Hepialus mustelinus*, 1.3 mm. in length. The head is no wider than the prothoracic segment, whose dorsal plate is well developed. The mouth-parts are quite large, especially the spinneret, while the hairs, which are acute at the end, are in this stage as long as the body is broad. Fig. 31_1, *A* shows the arrangement of the one-haired tubercles on the thoracic and first abdominal segment, and fig. 31_1, *B* those on the four terminal segments. The abdominal legs appear to have at this stage only ten crochets, or at least very few.

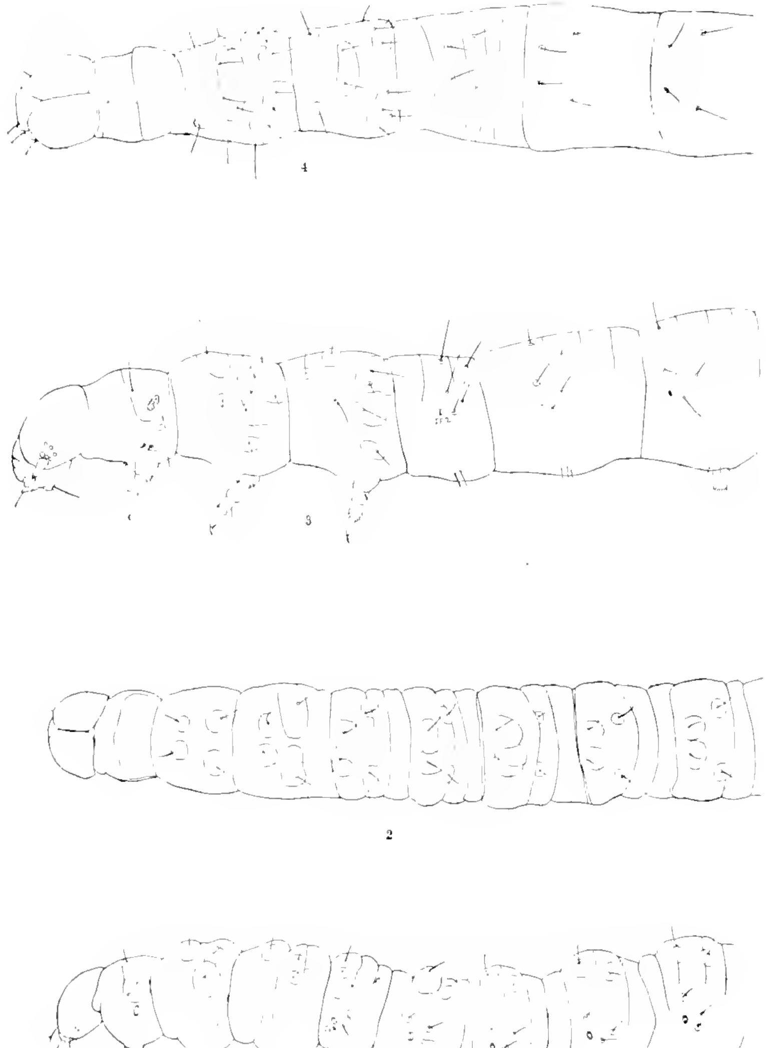


FIG. 32.—1, 2, Full-fed larva of *Hepialus humuli*; 3, 4 *H. hectus*.
(Cut loaned by the New York Entomological Society.)

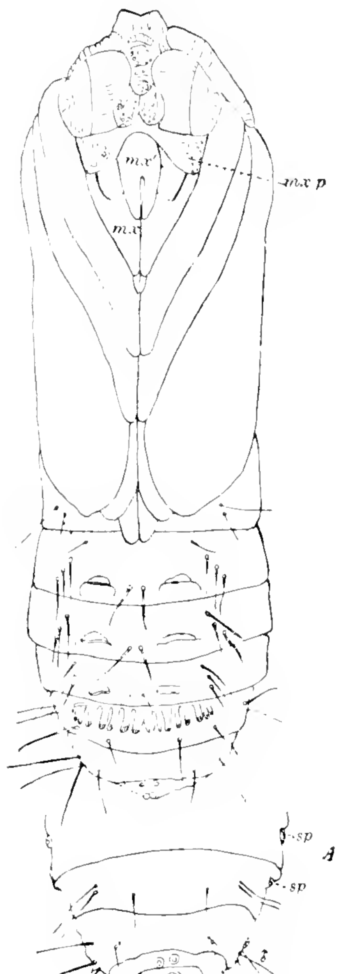


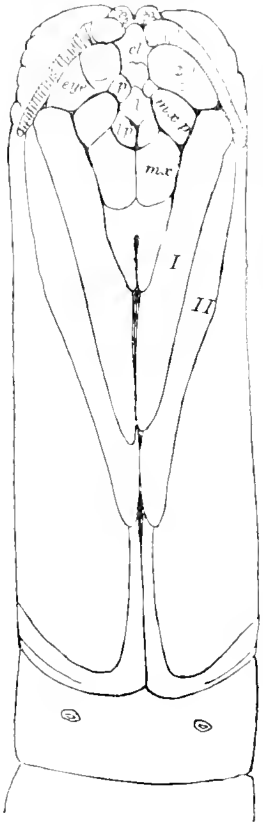
FIG. 33.—Pupa of *Oncopera intricata*; *A* end of body enlarged; *sp*, spiracle.

Fig. $32_{1,2}$ represents the larva of the European *Hepialus humuli*[1] and the arrangement of the one-haired tubercles; the prothoracic plate is thin and slight. In *H. hectus* (fig. $32_{3,4}$), which is more specialized, the prothoracic plate is more developed, and the piliferous tubercles (except one) are much larger, forming plates. Yet this larva will be seen to be much less specialized than that of

[1] For blown specimens of this and *Hepialus hectus*, and numerous other rare specimens of other larvæ and pupæ, I am greatly indebted to the kindness of Dr. O. Staudinger, who presented them to me from the immense collection of Lepidoptera and other insects in his establishment at Blasewitz-Dresden, Germany.

the sack-bearing *Adela viridella* (fig. 7), which has similar enlarged dorsal and lateral plates, not only on the thoracic but also on the abdominal segment (fig. 31_2).

The pupa of Hepialus is said by Chapman to differ from that of Tortrix, "in having the third abdominal segment free, but in a peculiar and modified manner," etc. He does not refer to the mouth-parts. I also add a figure of the front of the head of the pupa of *Hepialus humuli*, which, with that of *Œnotus virescens*, from New Zealand. I owe to the kindness of Dr. T. Algernon Chapman. The structure of the head is very peculiar. On the vertex are prominent callosities, giving strength to the head in breaking out of the cell. The eye is large, divided by a distinct line, the outer part of the eye more or less corrugated. Directly under the eye are the large triangular maxillary palpi (fig. 31_4 *m.x. p.*). The maxillæ themselves are short, but not shown in the figure. The clypeal region is narrow, with tubercles and rugosities; the labrum is scarcely differentiated from the front edge of the clypeus, but is slightly bilobate on the base. On each side are what I call the paraclypeal pieces or sclerites (*p.*), of the homology of which I am not sure, unless they are identical with the tubercles seen in most Lepidoptera on each side of the labrum, and formerly regarded as the mandibles. It is present, though small and reduced, in Hepialus. The labial palpi (*m.x.' p.*) are large and wide, and divided at the end.



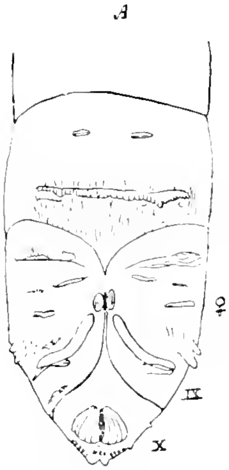


Fig. 34.—Pupa of *Phassus triangularis*. A, end of body.

Fig. 31_3 represents the head of *Œnotus virescens* Doubleday. The paraclypeal pieces are not differentiated; while the labrum appears to be slightly distinct from the clypeus, and excavated in the middle of the front edge, the labial palpi (*m.x.' p.*) are very short; the maxillary palpi are as in *Hepialus*.

The underside of the end of the body of this pupa, including abdominal segments 8 to 10, is represented by fig. 31_2; on the eighth segment is the well-developed toothed ridge, while each side of the segment is irregularly dentate. On the ninth segment (IX) are the rudiments of the male genital opening of the moth, a longitudinal scar situated between the usual two tubercles, while the vestiges of the anal legs of the larva (*a. l.*) are represented by the longitudinal flattened tubercles inclosing the scar or vestige of the anus.

I have examined the pupa of the Australian *Oncopera intricata* (fig. 33) (in the specimen figured the right antennæ was nearly obsolete) and of the Mexican *Phassus triangularis* H. Edw., all of which present some remarkable generalized features. In *Oncopera* the labial palpi (*m.x.'*) are visible; the entire piece is very wide at the base, and is divided at the middle into the two palpal cases. Between it and the deeply lobed labrum is a piece, unless the two lobes are the paraclypeal pieces, of the nature of which I am uncertain. Is it the homologue of the eye collar; and if so, are the two lateral portions the maxillary palpi? The maxillæ themselves (*m.x*) are well developed, but at their base are divided by an impressed line, representing a portion which I am unable to name. The three pairs of feet are easily identified. The outer division of the eye is large, and the cocoon-breaker, consisting of two solid thick ridges on the vertex, adapted for breaking out of its cell in the tree it inhabits, are well marked. Abdominal segments 3–7 are free in the ♂, and on 3 to 6 is a row of spines at each end; on segments 7 and 8 there are four transverse rows of stout spines, and on 9 two rows of small spines. There is no cremaster. On the underside of segment 8 is a row of about fifteen stout spines, and vestiges of three pairs of abdominal legs are distinct. The pupa is provided on the abdomen with a few long setæ.

The pupa of Phassus (fig. 34) is remarkable. The larva bores into a very hard tree, according to the late Mr. H. Edwards, who kindly gave me a specimen of the pupa. The head is remarkably adapted for its life in a cell, being broad, obliquely truncated, the small antennae being protected by the flaring sides of the head, which is very solid, with numerous rugosities and small tubercles. The region about the mouth is remarkable. The clypeus and labrum are very narrow, the eye transversely elongated, with an impressed line in the middle. The eye-collar (*mx. p.*) is distinctly separated from the maxillae (*mx.*).

The two pieces (*lp.*) at the base of the maxillae may possibly prove to be the labial palpi; if so, is the piece marked *l.* the labium? The two paraclypeal pieces or tubercles (*p.*) appear to be the homologues of those in the Psychidae.

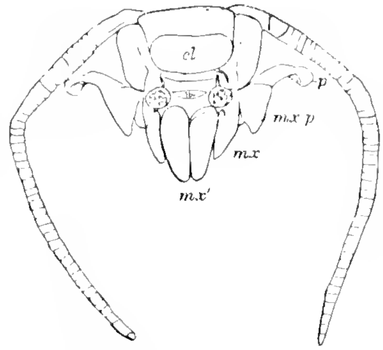


Fig. 35.—Head of *Parasa chloris*

The pupae of this family are very extraordinary, but it will be seen that they are *Pupae incompletae*, not *Pupae liberae*, and prove that the family should stand much above the Micropterygidae rather than below them, so far as regards pupal characters.

The shape of the head of *Hepialus mustelinus* and the reduced labium, with its two-jointed palpi and the still more atrophied maxillary palpi, are interesting. In *H. tacomae* the palpi of both pairs are larger, showing that the process of reduction in Hepialus is a rather late one.

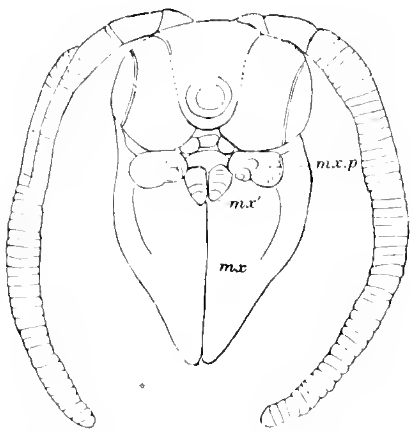


Fig. 36.—Head of pupa of Megalopyge (Lagoa), from Florida.

The very primitive, generalized shape of the thorax of the Hepialidae is noteworthy. In *Hepialus mustelinus* the collar or prothorax is very much reduced, while in *H. tacomae* it is very long and generalized, as in Sthenopis and the Australian *Abantiades argenteus*. The mesoscutum is considerably shorter than in *H. tacomae*. In the latter species the metascutum is entirely divided by the large scutellum, while in *H. mustelinus* it is only partly divided, the apex of the scutellum passing a little beyond the middle of the scutum.

It is thus quite evident that Sthenopis is an earlier form than *H. tacomae*, and that the latter is more generalized, having undergone less modification than *H. mustelinus*.

The genus Hepialus occurs in Australia, and that continent appears to be the original home of the family. In *Abantiades argenteus* the antennae are tripectinate, and the labial palpi are very large; in *Hectomanes fusca* the antennae are bipectinated, but the labial palpi are much reduced, being scarcely visible, while *Oncopera intricata* is remarkably modified: though the antennae are simple, the eyes are very large, nearly meeting on the front, while the three-jointed labial palpi are remarkably long and slender, extending upward, and the hind legs have a remarkable broad, flattened, curved pencil of hairs.

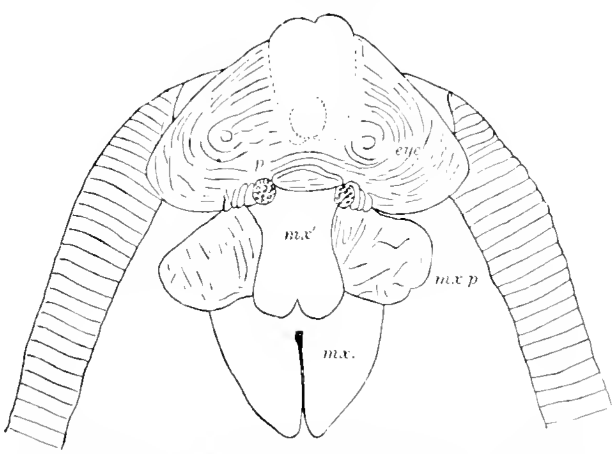


Fig. 37.—Head of pupa of Lagoa, from Jalapa, Mexico; *mx'.* labial palpi; *p.* paraclypeal piece; *mx.*, maxillae *mx. p.* maxillary palpi.

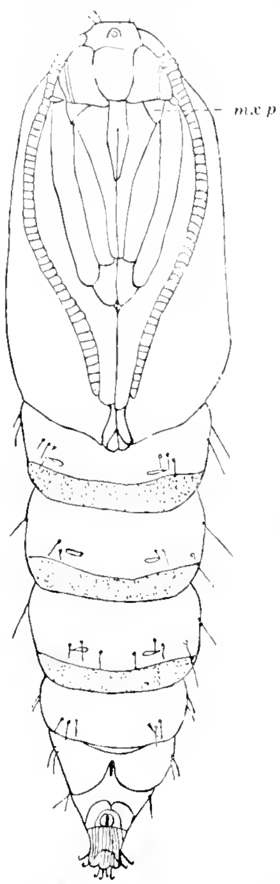
It thus appears that on the Australian continent this interesting family, which may be a survival of Jurassic times and coeval with the marsupials, has branched out along several lines of specialization, the most degenerate form being Hepialus, which has survived also in Europe and in North America, especially on the Pacific Coast. On the whole, however, as we have seen, it is not so generalized a group as the Micropterygidae, a group common to Europe and North America.

Its relations to the Cossidæ, including the Zeuzerinæ, remain still to be elaborated; they are rather close, yet the Tortricoid affinities are very apparent, and need further examination. The pupa of *Zeuzera pyrina* (fig. 40) is of the same character as in Prionoxystus, but the maxillary palpi are larger, the lateral palpi more reduced, while the cell-breaker is very long, being much more developed.

Fig. 39 shows the front of the head and maxillæ of the Cossid, *Prionoxystus robiniæ*, which is more Tortricid than Hepialid; *p.*, paraclypeal pieces; *mx. p.*, maxillary palpi; *l.*, labial palpi; *mx.*, maxillæ. Fig. 40 represents the head and end of the body of *Zeuzera pyrina*.

Remarks on the Cochliopodidæ.—Chapman removes this group from the Bombyces after a study of their larval and pupal characters. We should, after studying the pupæ of five or six genera, agree with his suggestion that this and the family Megalopygidæ (Lagoidæ) should be removed from the Bombyces and placed near the Tineoids, from which they have undoubtedly descended. That the line of descent, however, was directly, as Chapman suggests, from the Eriocephalidæ seems to us a matter of doubt. The larvæ of the Cochliopodids present some notable differences from that of Eriocephala, whose so-called "eight pairs of abdominal legs" appear to be merely spine-bearing tubercles. Although the head of Eriocephala is partially retractile, this adaptation may have no phylogenetic significance.

Fig. 35 represents the front of the head of *Parasa chloris*, showing the maxillary palpi, and a lateral process (*p*) connected with it, which I have not seen in any other pupæ, and may be internal. I have also observed it in the cast pupal skin of *Tortricidea testacea*. The maxillæ are either shorter or no longer than the large labial palpi. The paraclypeal tubercles are well developed in this group. If we compare the head of the pupa of Parasa and of other genera, especially Limacodes and Heterogenea, with that of Tinea, there will be observed a close resemblance, especially in the maxillæ, maxillary palpi, and labial palpi, indicating the more or less direct descent of the family from some tineid form, perhaps an extinct ally of Nepticula, since Chapman speaks of "a resemblance that is almost identity in the pupa" of Nepticula as compared with that of Limacodes.



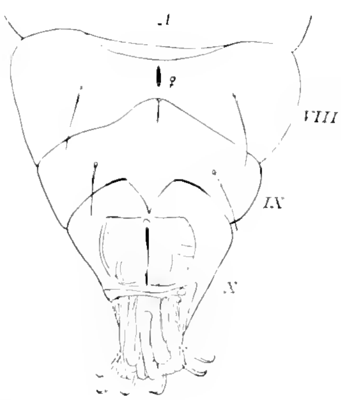


FIG. 38.—Pupa of *Tortrix rileyana* ♂; A, ♀, end of body, with cremaster.

Remarks on the Megalopygidæ.—The genus Megalopyge (Lagoa) is remarkable for the shape of the pupa, which is somewhat as in Cochliopodidæ, confirming the view that the two families are allied, though still presenting some notable differences in larval characters. Fig. 36 represents the pupal features as seen in the front of the head of a Megalopyge from Florida (probably *M. crispata* or *opercularis*). The maxillæ seem to be aborted; on each side of the second maxillary (labial) palpi, under the eye, are the first maxillary palpi, whose structure needs further examination.

Very different is the head of an allied Mexican species, *Lagoa superba* (fig. 37), in which the second maxillæ (labium) are well marked, though the palpi are only represented by two short lobes. Here the maxillæ are present, and the maxillary palpi are represented by a large lateral irregular round piece.

The next series of families begins with the *Tortricidæ*, from which may have descended the Cossidæ. As will be seen by comparing fig. 38 of the pupa of *Tortrix rileyana* with that of the Cossidæ (fig. 39, head and mouth parts of the pupa of *Prionoxystus robiniæ*), Dr. Chapman's opinion that Cossus has "no character at any stage to distinguish it from Tortrices" is well sustained. The pupal characters of *Zeuzera pyrina* (fig. 40) also show that it belongs to the same family as Cossus and its allies. In the Cossidæ there are no separate pupal maxillary palpi, the lateral flap (*mx. p.*) not being separate. The labium and its palpi are long and narrow, as in Tortrix. The paraclypeal pieces are distinct.

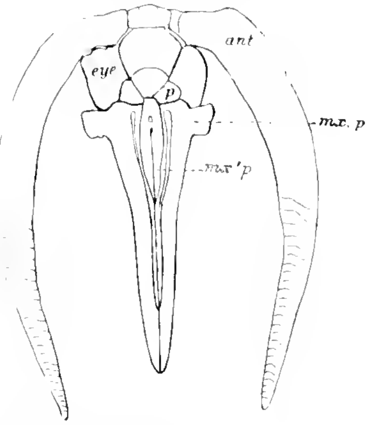


FIG. 39.—Front of head of pupa of *Prionoxystus robiniae*. *mx. p*, labial palpi.

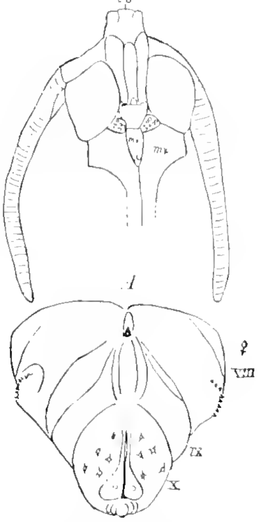


FIG. 40.—Pupa of *Zeuzera pyrina*. *cb*, cocoon burster. *A*, end of body of ♀.

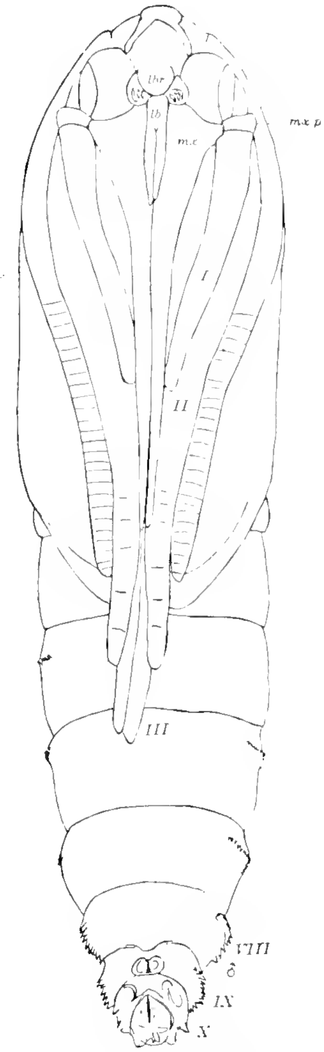


FIG. 41.—Pupa of *Trochilium fraxini*, ♂. *lb*, labium and palpi; *mx. p.*, maxillary palpi; *lbr*, labrum.

The point of departure of Tortricidæ from the Tineina has still to be worked out; it must have been some generalized genus in the pupa of which the eye-collar (maxillary palpi) and labial palpi were well developed.

Here might be placed the two families Thyrididæ and Sesiidæ. After a reconsideration of the transformations of these groups we agree with Dr. Chapman that as regards the latter "it is Tineoid in spite of some Tortricid characters." We should, however, not absolutely place these families in the Tineina, but should rather regard them as immediate descendants from some Tineoid genus with a well-developed eye-collar (fig. 41, *Trochilium fraxini*, *mx. p.*) and with a well-developed labrum. The generalized nature of the pupa of Trochilium is also shown in the large distinct paraclypeal pieces. The two families have evidently directly descended from some Tineoids, but they may have become much modified and specialized, especially in the venation, and form a side branch of the Tineoid series, with absolutely no relation to the Sphingidæ, near which they are usually placed. We have been unable to obtain the pupa of Thyris for examination.

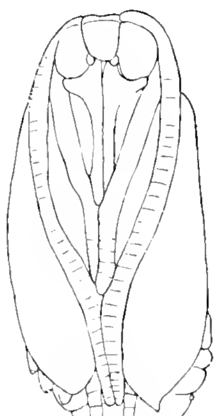


FIG. 42.—Pupa of *Harrisina americana*, ♀.

Family Zygænidæ.—Another group supposed by Spuler (venation) and also Chapman (pupa) to be closely related to the Tineoids is the Zygænidæ, from which I should separate the Syntomidæ. The pupa of Zygæna is said by Dr. Chapman to possess "ill developed eye collars (maxillary palpi)," and the dehiscence is typically incomplete. I have been unable in the specimens kindly given me by Dr. Chapman to detect the vestiges of the "eye-collar," but the cast pupa skins examined are not well preserved, and these pieces may be more easily detected in living and alcoholic specimens. Comstock places the Zygænidæ high up, remote from the Tineina, but at present I am disposed to regard the Syntomidæ as a distinct group, with a different origin, and more nearly related to the Arctiidæ. I fully agree with Chapman that Zygæna is near the Tineina; and I also agree with Comstock that Tripocris and Pyromorpha have "a remarkably generalized condition of wing structure."

I should regard Ino (Triprocris) as a more generalized genus than Zygæna. Judging from the venation, Harrisina has undergone a little more modification than Ino; Pyromorpha also seems rather more primitive than Zygæna. I see no reason for regarding Pyromorpha as the type of a distinct family.

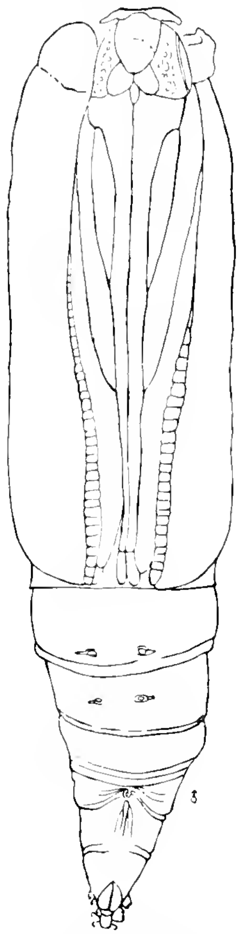


FIG. 43.—Pupa of *Œta aurea*, drawn from a cast skin.

I have only the pupa of *Harrisina americana* (fig. 12) and of two species of Zygæna to examine, but with this scanty material, that of Harrisina seems to be the more generalized form, that of Zygæna the more specialized. As Zygæna does not occur in America, but is an Eurasian and African genus, it is possible that in its generalized Zygænid fauna America, as in other groups of animals, has lagged behind Europe, Zygæna, with its numerous species, being a more advanced or specialized type brought into existence by more favorable conditions.

Origin of the Lithosiidæ.—It seems to me that the group of forms usually referred to the Lithosiidæ, but which are nearest to the Tineina, is that represented by Enæmia (Eustixis, Mieza), Œta, and Tantura (Penthetria), as the imagines of these genera, whether we consider the shape of the head and body, antennæ, and legs, or the venation and shape of the wings, are the nearest to the Tineidæ and appear to form a family of Tineoid moths. Indeed, Enæmia is now referred to the Tineina of the family Hyponomeutidæ, and possibly the Lithosiidæ originated from that family or from a group standing between it and the Prodoxidæ.

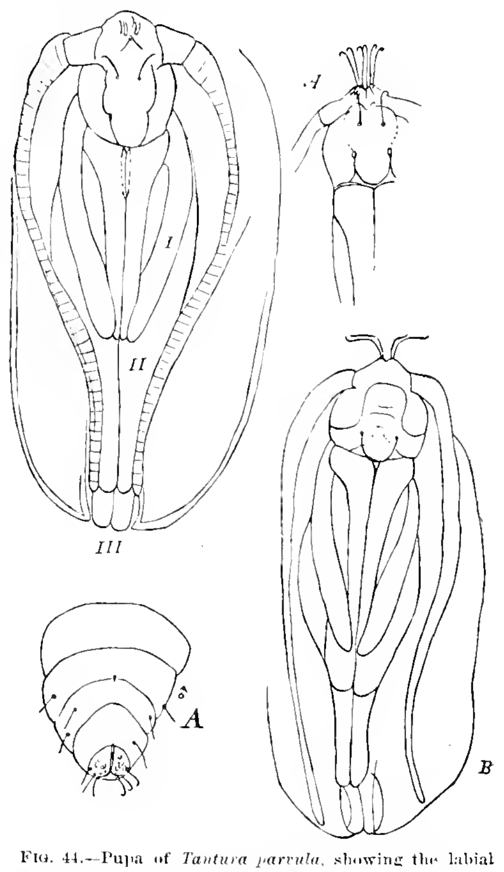


FIG. 44.—Pupa of *Tantura parvula*, showing the labial palpi on the inside. *A*, view of head and hooked setæ; *A* ♂, end of body of ♂; *B*, another pupa.

The pupæ have the long, narrow head and eyes of Tineina. The eye-collar is wanting, but vestiges of the labial palpi are present, and also vestiges of the paraclypeal pieces. Judging by the venation, Enæmia is the more generalized and Tantura the more modified genus. The pupa of *Œta aurea* (fig. 43) in the head characters is rather more generalized than that of Tantura, the labial palpi being a little larger and the base of the maxillæ more flaring, as if forming rudimentary eye-collars or palpi; but the abdomen and its end is much more specialized than in Tantura, as it is long, slender, conical, and ends in a well-developed cremaster, provided with curved setæ, adapting it for retaining its hold in its slight cocoon. In general appearance and structure it is like a Geometrid pupa, resembling one also in its markings, having longitudinal stripes. In Tantura (fig. 44) the shape of the abdomen is more generalized, there being no cremaster, but hooked setæ enabling it to retain its hold within its beautiful loose basket-like cocoon.

It is probable that these genera descended from some broad-winged Tineina, and possibly from the Prodoxidæ; Hyponomeuta, and especially Argyresthia, appear to be later, more specialized forms.

This group (Enaemia, Œta, and Tantura) almost directly intergrade, judging by the venation, with the Lithosiidæ; Byssophaga, Cisthene, and Crocota connecting them with Lithosia, though the larvæ of the latter are much more specialized and Arctiiform. Hence the line of descent from the generalized Tineina to the group represented by Enaemia, Œta, and Tantura to the Lithosiidæ and from these to the Arctiidæ is more or less direct. It is interesting to note the gradual widening of the wings, especially the fore wings, as we pass from Lithosia to Arctia; also to notice the gradual change in the larval and pupæ characters, those of the Arctiian pupæ being slightly less primitive than in the more generalized Lithosiidæ.

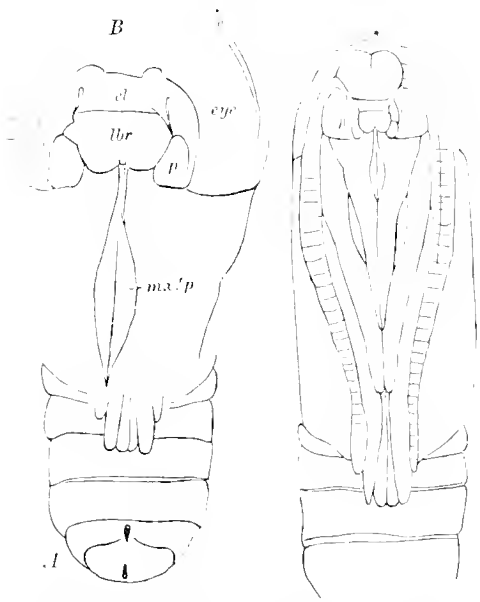


FIG. 45.—Pupa of *Nola ovilla*: A end of body of ♀. B, head; p, paraclypeal piece; ma. p, labial or second maxillary palpi.

It is also interesting to note that in ascending from the Tineoid precursors of the Lithosiidæ to the members of the latter family we pass from incomplete to obtected pupæ, showing that the division into *pupæ incompletæ* and *pupæ obtectæ* may be at times artificial, these divisions placing arbitrary metes and bounds to series passing from the more generalized to the more specialized forms, and perhaps representing unbroken lines of descent.

Family Nolidæ.—The structure of the pupa of Nola (fig. 45, *N. ovilla*), besides its larval and adult characters, convinces me that the genus is the type of a distinct family, and forms a line of descent somewhat parallel with and near to the Lithosiidæ. The pupa has the labial palpi well developed and the paraclypeal pieces large. The end of the abdomen is rounded and uncovered, in adaptation to its inclosure in a dense cocoon.

Family Syntomidæ.—The position of the Syntomidæ is difficult to determine. The pupa is obtected, though it has in Scepsis retained the labial palpi. Judging by the larval and pupal characters, the family stands much nearer the Arctiidæ than the Zygaenidæ, but yet is more generalized than the former. In the venation the group stands near the Arctiidæ, i. e., the venation of the generalized Ctenucha approximates that of *Epicallia virginalis*, while in Didasys and Syntomis the venation is more aberrant and modified; so also are the long-tufted larvæ of Syntomis and Cosmosoma, compared with that of Ctenucha, in which the tufts are shorter, less developed, and less specialized.

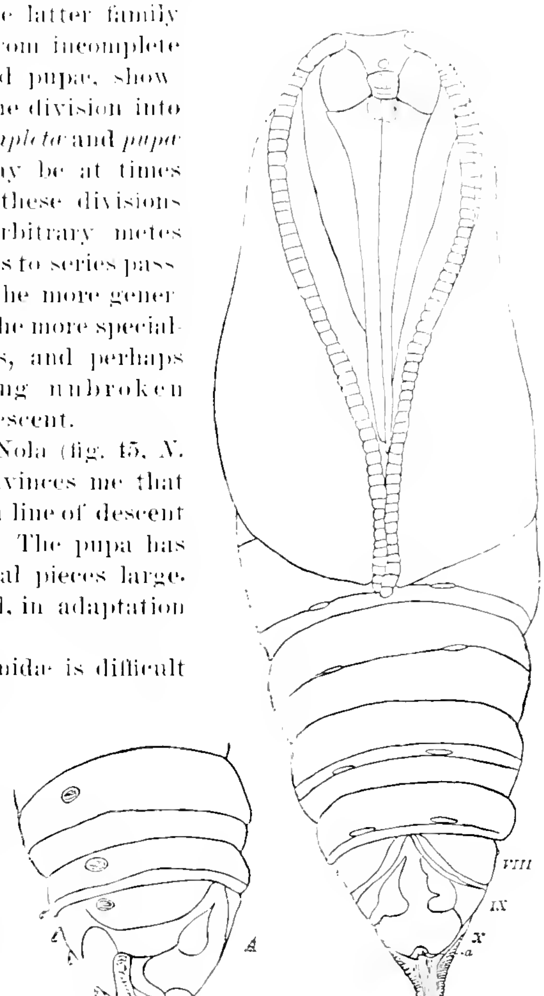


FIG. 46.—Pupa of *Phryganidia californica*. a, anus. A, end of body side view, with cremaster.

A clew to the origin of the geometrid moths.—In examining the pupa of *Phryganidia californica*, and finding the more essential features to be as much like those of the geometrid moths as any other group, I came upon results entirely unexpected to myself and which give a clue to the origin of this great group of moths. It has become evident that Phryganidia can neither be placed among the Zygaenidæ or Syntomidæ, though possessing some pterogostic features like those of the latter group.

Another fact considered was that the larva of *Melanchroia* (*M. cephise* and *M. geometroides*), formerly associated with the Lithosiidæ, has been shown by Dewitz to be geometrids. Another is the absence of a pair of legs in the Nolidæ, which I find must, by their pupal and other characters, be regarded as a distinct family from the Lithosiidæ. Still another fact is the conclusion I have arrived at that the Lithosiidæ have almost directly descended from the Tineidæ or from an extinct group closely allied to them, and that from the Lithosiidæ have arisen not only the Dioptidæ, perhaps including Phryganidia, the Cyllopodidæ, and Hypsidæ, but also the Syntomidæ and Nyctemeridæ, as well as the Arctiidæ.

On reexamining the larva, pupa, and imago of Phryganidia (we have no knowledge of the transformations of the genuine Dioptidæ as at present limited), it has seemed to me that the genus has little of fundamental value to separate it from the geometrid moths.

First, as to the larva of Phryganidia, while in the shape of the head and the slender cylindrical body it differs little from the larva of Melanchroia and that of geometrids in general, if the two anterior pairs of abdominal legs were atrophied there would be no essential difference. That this is probable is seen in the larva of Nola, which has but four pairs of abdominal legs, one pair being atrophied.

The end of the body (eighth abdominal segment) is humped, but the larvæ of the East Indian Eusemia and Hypsa are also humped at the end of the body. Phryganidia only differs in being slenderer and without hairs, and seems more closely allied to the larvæ of the Hypsidæ than to that of any of the allied groups. It does not spin a cocoon.

The pupa is obtected, and in its essential features more like those of geometrids than those of Lithosiidæ or any Zygænid or Syntomid genera. It is naked and suspended by a remarkably long cremaster; the end of the abdomen is otherwise peculiar. The head presents no vestigial characters, there being no traces of maxillary palpi, of paraclypeal pieces, or apparently of labial palpi (fig. 46). With a complete knowledge of all its stages, it is still difficult to assign it a definite position. When we know more about the Dioptidæ, where it probably belongs, the problem may approach a solution, but that its affinities are closely with the Geometridæ is shown by comparing the pupa with that of Cleora. In the general shape of the head, of the eyes, of the front, and especially of the abdomen, the resemblance is close; the peculiar shape and markings of the last three abdominal segments are nearly identical in both genera, though the cremaster of Cleora is much shorter.

In this connection reference should be made to the striking resemblance between the pupæ of *Œta aurea* and *Cleora pulchraria*. To my great astonishment I find the pupa of Cleora has the same vestigial head-characters as Œta; the general shape of the pupa is the same; the mode of dehiscence the same, the shape of the vertex and its mode of separating when the moth issues from the pupa case; also the same shape of the eyes, of the peculiar clypeus and labrum, while the more pronounced vestigial characters are the labial palpi, forming a triangular area, and the large semidetached paraclypeal pieces. Cleora shows that it is a more modern form in having no traces of a vestigial eye-collar (maxillary palpi) such as occur (though very slightly developed) in Œta. The shape of the end of the body, with the cremaster, is much the same, the shorter cremaster of Cleora being an adaptation to its life in a slight openwork cocoon. In the peculiar markings of the eighth and ninth abdominal segments Cleora is more like Phryganidia.

Judging by the pupal characters, then, the Geometridæ have directly descended from the Lithosiidæ, the latter, as I have satisfied myself, having directly originated from the generalized Tineina.

The imago of Phryganidia appears not to differ much from those of the Dioptidæ, to which it has been referred by Butler. I am unable to see any important differences between the Dioptidæ and Cyllopodidæ, though my material is scanty. In the slender body, shape of the head, and proportions of the clypeus, shape of antennæ and palpi, both of these families do not essentially differ from Melanchroia, which is now known to be a geometrid, nor from the geometrids themselves.

In its venation Phryganidia is nearly identical with that of a Josia from Jalapa, Mexico, in my collection; the peculiarity is the origin of veins II_2 and III_3 from a common stem, in which Phryganidia apparently differs from some if not all other Dioptidæ. But the venation of the

Dioptidæ (including Phryganidia) and of the Cyllopodidæ is nearly identical with that of Melanchroia, and the latter is a true geometrid in its venation, and in the shape of its larva, being a looper. Of its pupa we know nothing. The venation of the geometrids is very persistent. Hence I conclude that the day-flying, usually bright-colored Dioptidæ and Cyllopodidæ, as well as the Hypsidæ, are direct offshoots from the Lithosian stem, and that their general resemblance to such Lithosians as Crocota and Eubule, as well as Ameria, is based on real affinity. The day-flying habits of some geometrids is also well known. The larva of Euphanessa is a geometrid, but its moth has been usually associated with the Lithosiidæ, though its venation is geometrid. Riley describes the larva of *Œta aurea* as having "extremely small" anterior abdominal legs, the anal ones being much longer. Probably when we learn more of the transformations of the families we have mentioned it will be found that the presence or absence of certain abdominal legs will be found to be a secondary adaptational character. It is noticeable that the dull-colored Phryganidia, with only incipient clouds instead of bars and spots, is a primitive form as regards markings.

After an examination of the pupal and imaginal characters of Geometrids, Dioptids, Hypsids and Syntomids, it seems to me that all these groups represent more or less parallel lines of development which originated from the generalized Lithosiidæ, the latter, with the Zygænidæ, having sprung from generalized Tineina. The Nolidæ represent a side branch, which evolved from a Lithosian perhaps like Clemensia. The Arctiidæ have also apparently directly descended from the Lithosiidæ. The Syntomidæ and Nyctemeridæ, which seem closely allied by larval characters, have also directly descended from the Lithosiidæ.

Finally, it appears that the Geometridæ are a rather more primitive type, and have no relationship to the Noctuidæ, the latter having more or less directly descended from the Agaristidæ, the latter from the Hypsidæ or an allied group. The fact that the young larvæ of many Noctuidæ have only two pairs of legs seems to have no phylogenetic significance.

In this preliminary abstract space has prevented my giving details and figures to prove the truth of the assertions and conclusions here presented.

Hints on the origin of the Noctuidæ.—The Noctuidæ may have descended from the Agaristidæ, since the pupæ of several genera I have examined are of the same type as those of Alypia and Eudryas, having a similar lanceolate labium (second maxillary palpi). It is possible that the Agaristidæ are the direct offshoots of the Hypsidæ or came from an extinct group closely allied to them. Of this I can, from the want of specimens, only judge from the figures in Horsfield and Moore's Catalogue of Lepidopterous Insects, etc., Part II. The caterpillars of Hypsa, Eusemia, particularly *E. basalis*, are not only much like ordinary Noctuidæ, but are also closely similar to those of Eudryas and Alypia, that of *E. basalis* being humped on the eighth abdominal segment, and with the dark bars and spots of the larvæ of these Agaristids. Hence, quite contrary to our former prepossessions, it appears probable that the Noctuidæ may be the descendants of the Agaristidæ, instead of being connected by the Deltoids with the Pyralids. That the Noctuidæ, as well as the Geometridæ, are a modern group is shown not only by the pupal and other characters, but by the fact that they comprise so many closely allied genera and species, the pupæ as well as imagines possessing no vestigial characters.

The following tabular view will express in a tentative way my present views as to the phylogeny of the Lepidoptera, or, in other words, the relationship of the suborders and of the principal families, and will thus serve temporarily as a genealogical tree of the order.

It will be seen by this scheme that the genera of the Protolepidoptera, Palaeolepidoptera, and those Neolepidoptera with incomplete pupæ (including all the families up to Lithosiidæ) have narrow wings, the internal border of the wings, or "folded portion" of Spuler, being slightly developed. The flight of these genera is a fluttering one and, in general, of short duration.

In the later Lithosiidæ we see a rapid enlargement of the folded portion or a widening of the wings, and with this widening of the wings, with an increase in wing-power and the ability to take longer and higher flights, we seem to have had a great increase in the number of genera and families, until in the butterflies, with their very broad wings, we have not only a fluttering and direct long flight, but also the power of soaring high in the air. On the other hand, the

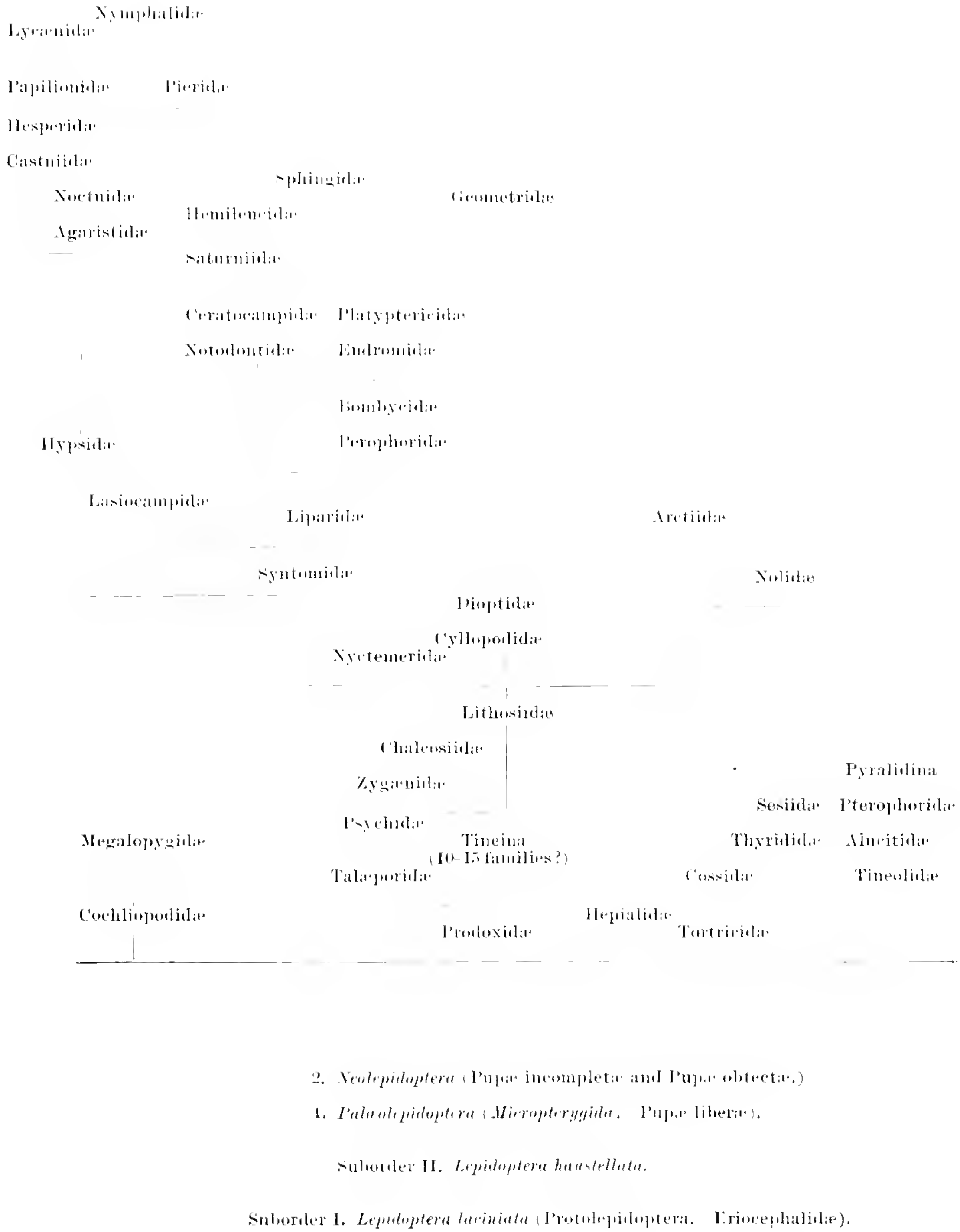
Sphinges, with their peculiar swift, powerful flight, met with success in life much beyond that of the Ceratocampidæ, from which they probably originated.

We have, from time to time, for thirty years past, insisted on the generalized and primitive features of the Bombycine moths or those families generally included under this head, and now it seems very clear that they have retained many more vestigial characters, and are thus more generalized and ancient groups than the Noctuidæ, Geometridæ, and Sphingidæ.

Space has prevented our speaking of the vestigial characters of the imagines of the Bombycine moths, such as the vestigial maxillary palpi of the Saturniidæ.

It is hoped that hereafter more attention will be paid to a study of the pupal structures of Lepidoptera, particularly of the Tineoid moths. And it need scarcely be urged that it is most desirable that the authors of future catalogues of Lepidoptera will begin with the most generalized forms, the tineids, and end with the butterflies, as being in better accord with the results of recent studies and with the principles of evolution. In that way there will gradually be infused among collectors and beginners more scientific conceptions of the origin of the Lepidoptera, and thus the collection and examination of these insects will have an educational value which at present seems in some quarters entirely lacking.

GENEALOGICAL TREE OF THE LEPIDOPTERA.



IX.—A RATIONAL NOMENCLATURE OF THE VEINS OF INSECTS, ESPECIALLY THOSE OF LEPIDOPTERA.

Hitherto there has been an unfortunate lack of uniformity in the nomenclature of the veins of the wings, different names having been applied to the veins of different orders of insects.

In his paper on the phylogeny and ontogeny of the veins of the wings of Lepidoptera, Spuler has, however, given us a simple scheme and a numbering of the veins which will, we think, apply in general to the wings of insects of all orders.

Redtenbacher had previously pointed out that "the geologically older Orthoptera and Neuroptera have a much richer and more complicated venation than the Coleoptera, Lepidoptera, Hymenoptera, and Diptera; thus among the Rhynchota the oldest forms, the Cicadidæ and Fulgoridæ, have a much greater number of veins than the Hemiptera. There is no doubt but that the oldest insects were provided with an excess of veins; that, on the other hand, in the course of development this superfluity has disappeared by a process of reduction, and in this way a simpler system of venation has resulted. It is also to be observed that the size of the wings has had a considerable influence on the number of the veins, since small forms almost without exception have fewer veins than insects with large wings." Redtenbacher also believes "that the normal type of a differentiated wing may be found in those insects whose fore and hind wings are most similar in size and shape," and states that the venation is not useful as an ordinal character, but is of more service in separating suborders and families.

We agree with Spuler in rejecting Redtenbacher's system, which is partly based on Adolph's untenable theory of convex and concave veins, but more especially for the reason that Redtenbacher assumes that the primitive form of venation is that of the Ephemeridæ. He remarks: "There is scarcely another group of insects whose wings show the primitive type, the fan-shaped form, as the May flies." It may be objected to this that the Ephemeridæ, though in most respects generalized and primitive insects, yet are, as regards the wings, highly modified or specialized. That this is the case is also suggested by the reduction or atrophy of the mouth parts. On the other hand, the retention of sexual organs paired throughout, the ducts remaining separate, with open, paired outlets, shows that the May flies are, in this respect, more primitive than any other winged insects. But as regards the thorax and the wings, we observe that in them a high degree of modification has taken place. Thus the two pairs of wings are very unlike in size and shape, and this feature is a secondary one. Hence the large number of main longitudinal veins in the wings of Ephemera is a case of irrelative repetition of parts mostly situated in the fan-like field, due to a process of specialization, a process which is manifested in quite another way in the wings of the Dermaptera, also a primitive type.

Redtenbacher regards the eleven longitudinal veins (I–XI) of Ephemerids as the normal number, and considers that the Trichoptera, Lepidoptera, etc., have lost certain of the veins by a process of reduction. This view has been adopted by Comstock in his suggestive paper, "Evolution and taxonomy," but it seems to us to be untenable, the anal field ("faltentheil" of Spuler) not being of primary importance. On the other hand, Redtenbacher's use of Roman numerals for the main veins, and of a combination of Roman and Arabic numerals for their branches, is very convenient.

Spuler divides the wings of each pair into an outspread portion (*Spreitentheil*) and a folded part (*Faltentheil*). The veins of the former area he numbers in the same manner as Redtenbacher, beginning on the costal edge of the wing, while those of the folded area (the submedian and internal or first and second anal veins of other authors) he does not name, but simply numbers with the Greek letters α β. He considers that Hagen was right in believing the Phryganidæ, Tipulariæ, and some Microlepidoptera to be forms with a schematic, i. e., primitive venation (Stettin. Ent. Zeit., p. 316, 1870).

Spuler shares the opinion of Fritz Müller (Termitidæ), Brauer and Redtenbacher (Libellulidæ), and Haase (Papilionidæ), that the costa is only a hypodermal structure, a thickening of the edge, which does not have a trachea as its origin (Anlage), and which therefore has nothing to do with the veins.

Spuler also shows that the venation of the Orthoptera, especially their most generalized form Blatta, is fundamentally nearly identical with that of the Lepidoptera, veins I–V being readily homologized with those of the latter group; so also with the most generalized Hemiptera (Fulgora, fig. 47). We may also draw attention to the remarkable resemblance in the venation of the generalized Psocid genus Amphientomum, which at first sight, from the shape and size of the wings, reminds one of a Micropteryx or Eriocephala, while it also has a few scales like those of these moths.

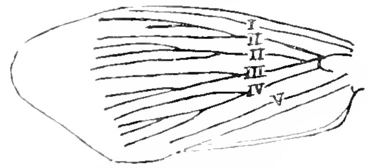


FIG. 47.—Venation of fore wing of Fulgora.—After Spuler.

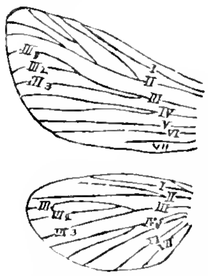


FIG. 48.—Venation of semipupa of *Cerura vinula*.—After Spuler.

But that the system of venation of Spuler is morphologically the correct one is fully and satisfactorily proved by the ontogenetic development of the veins. Fritz Müller (Kosmos, i, p. 390) was the first to examine the incipient venation of two semipupal moths (*Castnia ardalus*). He observed that in the immature pupa the cross veins were wanting, and that different longitudinal veins, which afterwards more or less completely disappeared, were present, and hence he regarded the pupal venation as the primitive one. This view Spuler has adopted and extended, and it plainly enough, supported by the researches of Brauer and Redtenbacher on the venation of the nymph of Odonata, solves the problem of the venation of insects in general and especially for Neuroptera, Trichoptera, Mecoptera (Panorpidæ), Lepidoptera, and Diptera.

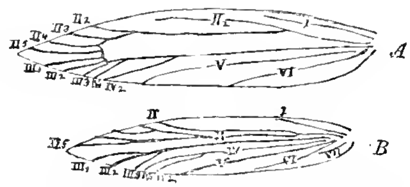


FIG. 49. Venation of *Gracilaria syringella*, *A* moth, *B* of semipupa.—After Spuler.

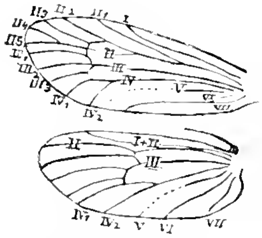


FIG. 50.—Venation of *Talæporia pseudobombycella*.—After Spuler.

Spuler's method was to strip off the loose skin of a caterpillar just beginning to pupate, and examine the incipient venation of the wings of the young pupa on the living insect. He placed the living pupa in water and then, since the process of thickening and resulting concealment of the veins of the wing is retarded, the tracheal branches become slightly enlarged, filled with air, and thus are more easily seen. Hence small pupæ from which the larval skin has just been cast, and are transparent, are the fittest objects for examination.

The primitive and generalized condition of the semipupal wing is shown in Spuler's figure of *Cerura vinula* (fig. 48), to which we have added the numbering of all the veins. He shows that the fundamental pupal venation of Lepidoptera will also apply to Orthoptera (Blatta), Hemiptera, Trichoptera, etc. He proves that the cross veins are of quite secondary and subordinate importance. The results of Spuler's investigations, extended through different groups from Tineina to Rhopalocera, and illustrated by many figures, are both interesting and convincing. The comparison of the venation of the fore wing of the adult of *Gracilaria syringella* (fig. 49, *A*), compared with that of its semipupa (fig. 49, *B*), shows that the generalized venation of the latter is similar to that of Micropteryx, veins IV_1 IV_2 not being connected by a cross vein with III and its branches: and veins II and III with their branches, being separate. The veins and their numbering are indicated by Spuler's figure of *Talæporia pseudobombycella* and one we have drawn of *Hepialus mustelinus* (fig. 51).

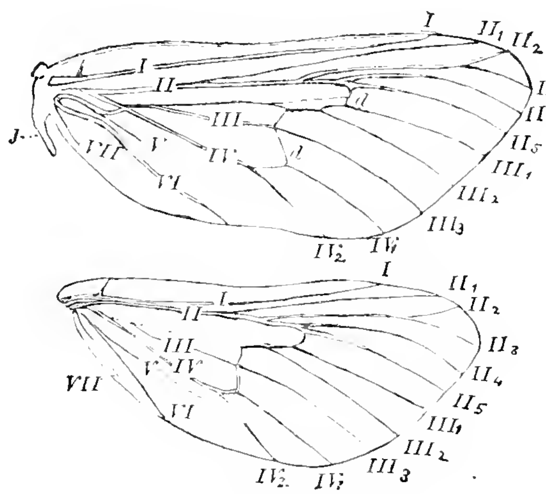


FIG. 51.—Venation of *Hepialus mustelinus*; *d*. anterior, *d*. posterior discal vein, *j*. jugum.

It may be remarked that Spuler agrees with Brauer and Redtenbacher, as well as Haase, that Adolph's system of convex and concave veins is entirely erroneous.

We adopt, then, Spuler's system of venation, and earnestly trust that it may be generally accepted as simple, intelligible, and applicable to all orders of insects, based as it is on ontogenetic, as well as anatomical, grounds.

The following system applies to the Lepidoptera as well as all other orders. Fig. 52 represents the venation of a Notodontian (*Heterocampa obliqua*). We merely deviate, from motives of convenience and for the sake of uniformity, from Spuler's numeration of the two anal veins, by numbering them VI and VII, instead of designating them by the Greek letters α β.

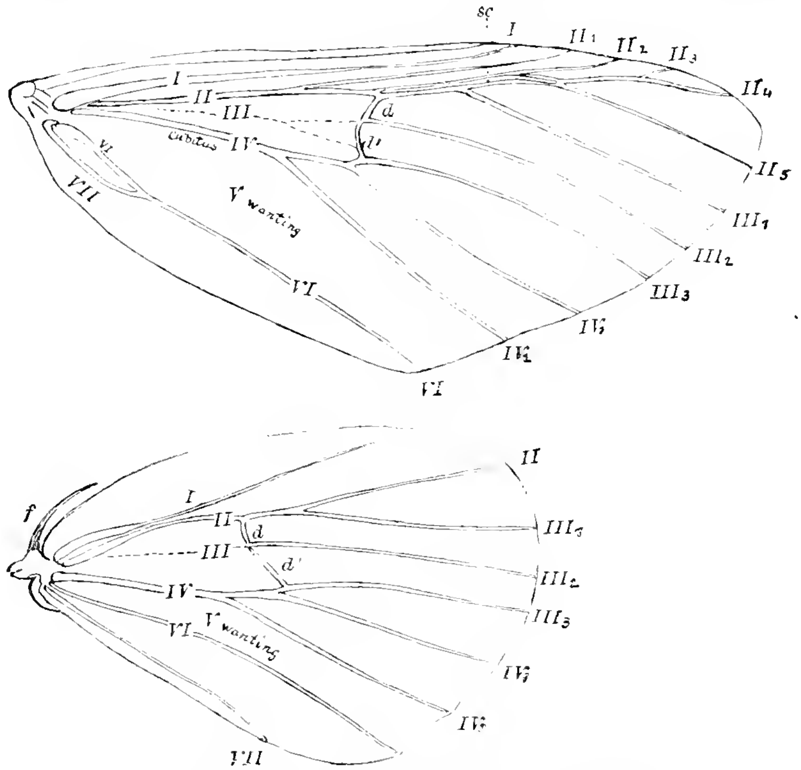


FIG. 52.—Venation of *Heterocampa obliqua*, the names of the veins as designated below; *d*, anterior, *d'* posterior discal vein; *f* frenulum; *sc* subcostal cell.

The following table will show the numbers and names of the five veins of the outspread portion of the wing and two (rarely three) of the fan like or inner portion. Instead of denoting the veins by the noun and adjective as, for example, the median vein, we may, with Comstock, call it in descriptions or diagnoses, *media*, or refer to it as Vein III.

I. Costa.
II. Subcosta (radius).
III. Media.
IV. Cubitus (median vein of some authors).
V. First anal (submedian).
VI. Second anal (internal).
VII. Third anal.

PARTIAL BIBLIOGRAPHY.

Müller, Fritz. Beiträge zur Kenntniss der Termiten. Jenaisch. Zeitschr. f. Naturw., 1875.

Brauer, F. Ansichten über die paläozoischen Insekten und deren Deutung. Annal K. K. naturh. Hofmus Wien, i. pp. 86–126. 2 Pl. 1886.

Redtenbacher, Joseph. Vergleichende Studien über das Flügelgeäder der Insecten. (Annalen des K. K. Naturh. Hofmus., Bd. i, pp. 153–231.) 12 Pls. Wien, 1886. Abstr. by J. H. Comstock in Amer. Nat., xxi, pp. 932–934. 1887.

Brauer, F., u. Redtenbacher, J. Ein Beitrag zur Entwicklung des Flügelgeäders der Insekten. Zool. Anz., 1888, pp. 443–447.

Haase, Erich. Zur Entwicklung der Flügelrippen der Schmetterlinge. Zool. Anz., xiv, 1891, pp. 116–117.

Spuler, A. Zur Phylogenie und Ontogenie des Flügelgeäders der Schmetterlinge. Zeits. wissens. Zoologie, liii, pp. 597–646. 2 Pl. 1892.

Comstock, J. H. Evolution and Taxonomy, etc. Ithaca, N. Y. 1893.

X.—SYSTEMATIC REVISION OF THE NOTODONTIDÆ, WITH SPECIAL REFERENCE TO THEIR TRANSFORMATIONS.

Family NOTODONTIDÆ Stephens.

Bombycites Div. *Legitimæ* (in part) Latreille, Gen. Crust. et Insect. iv, p. 217, 1809.
Dimorpha (in part), *Ptilodontes, Andria*, et *Melalopha* Hübn., Verz., pp. 145, 147, 162, 1816.
Notodontidæ Steph., Ill. Brit. Ins. Haust. ii, p. 10, 1828.
Notodonta (in part) Newman, Sphinx vespiformis, p. 42, 1832.
(in part) Duncan, in Brewster's Edin. Encycl., ix, p. 131, 1833.
Notodontites (in part) Newm., Entomologist, May, ii, p. 383, 1834.
Notodontides (in part) Boisd. Ind. Méth. Lép. Eur., p. 84, 1840.
Dicranuridæ Notodontidæ, et *Pygæridæ*, Duponch., Cat. Méth. Lép. Eur., pp. 86, 89, 95, 1846.
Dicranuridi Steph., Cat. Brit. Lep. Br. Mus., p. 38, 1850.
Ptilodontes Pack., Proc. Ent. Soc. Phil., iii, p. 351, 1864.
Grote, New Check List N. Amer. Moths, p. 18, 1882.
Notodontidæ Smith, List Lep. Bor. Amer., p. 29, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 559, 1892.
Dyar, Can. Ent., xxv, p. 121, May, 1893.
Neumœgen and Dyar, Trans. Amer. Ent. Soc. xxi, June, 1894, pp. 179–208.
Journ. N. Y. Ent. Soc., Sept., 1894, pp. 112–117.

Family characters.—Head squarish in front (when denuded), but in nature densely scaled, often crested between the antennæ. Clypeus large, subscutellate in shape, suddenly narrowing toward the labral region, which is slightly bent down; above, the clypeus is broad, the margin or base being straight transversely, not hollowed out on each side for the reception of the antennæ, the hole for the insertion of the latter being very shallow; the surface of the clypeus either somewhat convex or with a slight median elevation, terminating in the labral region. The epicranium and occiput both very short, occupying a very short (in a longitudinal sense) region behind the antennæ and eyes.

Base of epicranium ridged. Antennæ usually either wholly pectinated or pectinate on the basal two-thirds; the joints scaled above, the branches generally six times as long as the joints; in the ♀ the antennæ are simple, rarely with short pectinations. Maxillæ well developed; the maxillary palpi forming small papillæ at the base of the maxillæ. Labium indistinct, subtriangular, small; the labial palpi well developed, either porrect and reaching the front, or ascending and passing beyond the front (longest in *Symmerista*).

Thorax with a definite collar; the edge of the patagia distinct, often edged with dark scales, and often a dorsal tuft. When denuded the prothorax is seen to be small, much reduced in size; the mesonotum shorter than broad; the mesoscutellum transversely subovate or lozenge-shaped; the metathorax above very narrow, linear (in a transverse sense); metathoracic flanks narrow, half as wide as those of the mesothorax.

Wings: Fore wings narrow, noctuiform, about half as long as wide; costa either straight or slightly convex; apex either pointed or much rounded; outer margin very oblique; inner margin full near the base, with often a median tuft, the subcostal vein passing very near the costa toward the apex; a subcostal cell often present; the discondal or discal veins situated in the middle of the wing. The last subcostal vein (III_5) forms the independent vein. There are three branches of the cubital vein, and these features will enable one in difficult cases to determine whether the moth is a Notodontian or a Noctuid.

Hind wings reaching two-thirds of the way to the end of the abdomen, attached to the fore wings by a frenulum confined by a "frenulum hook" or loop, situated on the vein; costa straight; apex much rounded (compared with the Noctuidæ); outer edge long, rounded, the costal vein passing very near the subcostal, turning from it to the costa near the origin of the discal venules; three branches of the cubital vein; two subcostal venules (II, III_1).

Legs rather short; femora and tibiæ usually densely pilose; fore tibiæ sometimes (*Lophopteryx*) armed with a spur; hind tibiæ with two pairs of stout spurs.

Abdomen cylindrical, sometimes (*Heterocampa pulverea*) with a row of dorsal tufts, besides the one often present at the base on the first abdominal segment.

The Notodontidæ are associated with the Ceratocampidæ, Saturniidæ, and Hemileucidæ, both as regards their larval and adult characters. In the moths the head characters are somewhat like those of the Saturnians, the clypeus being large and longer than wide, while there are but three branches of the cubital vein in either pair of wings.

Larval characters.—The body is noctuiform, and either smooth and unarmed, or with simple subdorsal lines, or gaily banded and spotted, and armed either with double or simple tubercles, situated either on the eighth abdominal segment alone or on other abdominal segments. These tubercles may be double at the end and nutant, or the single one on the eighth abdominal segment may bear a horn and the larva become sphinx-like. Often the body is hairy and banded, but not usually (except in *Datana*) both hairy and banded. The eggs low, hemispherical, usually reticulated.

The pupa obtected, with no vestigial characters; either unarmed or with a well-developed cremaster. It is either subterranean or more usually protected by a thin, rarely dense, silken cocoon.

There are seven well-marked groups of the family which may be regarded as of the rank of subfamilies. The most generalized of these groups appear to be the Pygærinæ, the Gluphisinæ seeming to be a side branch, which has undergone reduction and modification in each stage.

SYNOPSIS OF THE SUBFAMILIES OF NOTODONTIDÆ.

Head small, antennæ short; palpi feeble; wings short. Larva noctuiform; body plain green, banded with yellow, sometimes with pink dorsal patches .... *Gluphisinæ*

Head broad in front; fore wings broad and falcate; antennæ heavily pectinated to the tips; abdomen three-tufted at tip. Larva with the body hidden by long wool like hair with short sparse hairs, like Gastropacha .. *Apatelodinæ*

Antennæ ciliated; body and wings reddish ocherous, fore wings crossed by from four to five straight parallel lines. Larva brightly banded and very hairy; no warts except in stage I .... *Pygærinæ*

Antennæ densely pectinated; wings short and hard. Larva banded, either with small warts or with two large dorsal tubercles .... *Ichthyurinæ*

Antennæ usually but slightly pectinated; rarely plumose; fore wings more or less rounded at apex; internal edge with a tuft. Larva either smooth or with two to eight abdominal humps .... *Notodontinæ*

Head tufted on the vertex; ♂ antennæ filiform on the distal fourth; vestiture of end of abdomen often forked. Larva either smooth or with high nutant dorsal humps; end of body elevated; anal legs more or less slender and rarely (Macrurocampa) forming stemapoda .... *Heterocampinæ*

Head large, front broad, triangular; antennæ pectinated to the tips in both sexes. Larvæ with the anal legs converted into stemapoda or long filaments; the thoracic legs in the Eurasian *Stauropus* very long .... *Cerurinæ*

Subfamily I.—GLUPHISINÆ.

Moth.—Head small, not prominent, broad in front; eyes hairy; antennæ shorter than usual, with long pectinations extending to the tips. Palpi small, feeble, slender, not reaching the front. Thorax either smooth or well crested.

Fore wings shorter and broader than usual; apex of hind wings moderately produced. No subcostal cell; the first subcostal venule of the hind wings varying much in length, usually very short. Legs densely scaled, the scales spreading out on each side. Abdomen short, tapering in ♂ rapidly to the end.

The species are ash-gray, varying in being whiter or darker in hue. But a single genus yet known.

Egg.—Low, flattened, hemispherical, of smaller size than in the other subfamilies; surface of shell smooth.

Larva.—Body noctuiform, tapering toward each end, smooth, entirely unarmed; green, with two subdorsal yellow lines, and either plain green or with dorsal pink-red spots. Freshly hatched larva with a large round head wider than the body, which is long and slender, tapering toward the end, entirely unarmed, with the sutures deep, segments not wrinkled.

Cocoon.—Very thin and slight, spun between the leaves.

Pupa.—Of unusual shape, being flattened, oval cylindrical; end of abdomen round and blunt; cremaster obsolete, with no spines. Darker in color than usual.

Although this is mentioned as the first subfamily of the group, it is, contrary to my former opinion, probably a side branch, rather than a primitive group. The smooth larva may be a case of reduction. The absence of a cremaster, and the simplicity of form in the pupa, and the small, feeble palpi and small head of the imago may be due to reduction of these parts.

Gluphisia Boisduval.

Pl. XXXVIII, figs. 1-4 (venation).

Bombyx auctorum.
Drymonia (in part) Huebner, Verz. Schmett., p. 141, 1816.
Notodonta (in part) Ochs., Schmett. Eur., iii, p. 79, 1810.
Notodonta (in part) Godart, Hist. Nat. Lep. France, iv, 20, 4, 1822.
Peridea (in part) Stephens, Cat. Brit. Ins., 1829.
Ill. Brit. Ins., Haust., ii, 32, 1829.
Gluphisia Boisd., Ind. Méth., 88, 1840.
Westwood, British Moths, 1841.
Duponchel, Cat. Méth. Lép. Eur., p. 91, 1844.
Glyphidia Herrich-Sch., Syst. Bearb. Schmett. Eur., ii, p. 124, 1845.
Gluphisia Staudinger, Cat. Lep. Eur., p. 74, 1871.
Grote, Check List, p. 18, 1882.
Smith, List Lep. Bor. America, p. 30, 1891.
Melia Neumoegen, Can. Ent., xxiv, p. 225, 1892.
Eumelia Neumoegen, Can. Ent., xxv, p. 25, 1892.
Gluphisia and *Eumelia*, Neum. and Dyar, Revis. Notod., Trans. Amer. Ent. Soc., xxi, pp. 193, 194, June, 1894.

Head rather small, not prominent; front broad in ♂, narrower in ♀, rather full, with loose, uneven, long scales; no tufts at the base of the antennæ; eyes with long, rather dense, hairs in ♂ and ♀. Antennæ shorter than usual, curved inward, with long pectinations extending to the tip; in ♀ the pectinations short, increasing in length to the middle; the upper side, including the pectinations, densely scaled. Palpi small, feeble, slender, cylindrical, with rather long hairs, not very distinct from those of the front; the end of the palpi themselves depressed, not reaching the front.

Thorax smooth, the scales of the prothorax not forming a "collar," but continuous with those behind or with a well marked median crest.

Wings: Primaries rather short and broad, a little more than one-half as broad as long; costa straight, a little convex toward the somewhat pointed apex; outer margin oblique, a little shorter than the internal. Hind wings reaching, when spread out, to near the end of the abdomen; costa straight; apex produced and slightly pointed; outer margin bent a little in the middle and so as to be parallel with the costa of the fore wings.

Venation: Fore wings, first subcostal venule not uniting with the main vein at the origin of the fifth venule to form a subcostal cell; the third subcostal venule very short, arising very near the apex, at or near the outer third of the fourth venule.

Hind wings with the first subcostal venule varying much in length, usually very short.

Legs: Femora and tibiæ clothed with long dense hairs, spreading out on each side.

Abdomen short, tapering in ♂ rapidly to the end; in ♀ thick, heavy, and obtuse at the end.

In coloration the species somewhat recall those of Cerura, being whitish gray, and often having a straight broad median band on the fore wings, of which the outer side is somewhat wavy, and bent just before the fourth median venule. The hind wings are nearly white. The style of markings is substantially the same in the two sections of the genus, and is more persistent than even the structural characters.

The genus is readily identified by the short, small, feeble palpi, the hairy eyes, the well pectinated antennæ, and the short, broad fore wings.

Structurally Gluphisia is in many respects the simplest genus of the group, its larva being noctuiform and without any projections. The larvæ are often, perhaps usually, even, without any red spots. *G. septentrionis* (*trilineata* Pack.) is the typical, and appears to be the more generalized, species.

Egg.—Low, flattened, hemispherical, much smaller than in any other known genus of the family; surface of the shell smooth; green.

Larva.—Body noctuiform, tapering toward each end; smooth, entirely unarmed. Head rounded, smooth, with a black stripe on each side. Body with a subdorsal yellow line on each side of back, otherwise pale green, or with several dorsal pink patches.

Freshly hatched larva with a large round head, wider than the elongated body, which tapers toward the end; segments smooth, sutures deeply impressed; glandular hairs short, minute, ending in three prongs; no lines or spots.

Cocoon.—Slight and thin, spun between leaves.

Pupa.—Flattened, oval, rounded obtusely at each end; cremaster obsolete, with no traces of spines. Color darker than usual.

Geographical distribution.—The species range throughout the Appalachian Subprovince into the Hudsonian fauna, and westward occur in the Campestrian Subprovince. None have yet been found south of the thirty-second parallel of latitude, either on the Atlantic or Pacific slopes of the continent. The genus also extends over Europe, being represented by a single species (*G. crenata*) which inhabits England and Europe, extending eastward into central Russia and doubtfully into Spain. One species (*C. liturata* Walk.) inhabits Silhet and India (Madras).

It is divided into two sections, as follows:

SYNOPSIS OF THE SPECIES.

I. Thorax with no tuft: in hind wings the two branches of the subcostal vein short, dark ash-gray, with a dull luteous median band on fore wings. . . . . *G. septentrionis*

Paler gray, median band on fore wings clearer and paler clay-yellow. . . . . *G. wrightii*

II. Thorax usually with a tuft: head rather small; palpi feeble; the two branches of the subcostal vein of hind wings long.

Mouse color; no discal spots; antennæ almost plumose. . . . . *G. lintneri*

A dorsal thoracic tuft, and a bright, distinct basal and discal spot . . . . *G. severa.*

SECTION I.

The differences between this section and the second are brought out in the description of the latter.

Gluphisia septentrionis Walker.

(Pl. I, figs. 1, 2, 3, 4; VII, fig. 1; VIII, fig. 6.)

Gluphisia? septentrionis Walker, Cat. Lep. Het. Br. Mus., v, p. 1038, 1855.
Gluphisia trilineata Pack., Proc. Ent. Soc. Phil., iii, p. 355, 1864.
Grote, Check List Lep. N. A., Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Dasychira clandestina Walk., Can. Nat. and Geol., vi, p. 36, 1861.
Gluphisia clandestina Grote, Can. Ent., ix, p. 27, Jan., 1877.
Not *Gluphisia trilineata* Pack., 5th Rep. U. S. Ent. Com., 270, 1890.[1]
Gluphisia septentrionalis Dyar, Can. Ent., xxv, p. 303, Dec., 1893.
Kirby, Syn. Cat. Lep. Het., p. 593, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 193, June, 1894.
Race *quinquelinea*, Dyar, Ent. News, iii, p. 158, 1892.

Larva.

(Pl. VIII, figs. 1–5.)

Edwards and Eliot, Papilio, iii, p. 129, 1883. (Brief description.)
Dyar, Psyche, vi, 146, Sept., 1891. (Describes egg and last stage, also cocoon and pupa.)
Edwards, Bibl. Cat. Transf. N. Amer. Lep., p. 68, 1889.
Beutenmüller, Bull. Amer. Mus. Nat. Hist., iv, p. 67, 1892. (Last stage described.)

Moth (6 ♂, 2 ♀).—Head, thorax, and abdomen ash-gray, varying in being darker or paler. Fore wings usually lighter than the thorax, with a short basal dark line composed of two scallops, one on the subcostal vein, the other situated in the median interspace, inclosing and bordered with whitish gray, beyond which is a broad dark diffuse band crossing the wing; the third or

[1] The larva referred to as living on the elm is *Seirodonta bilineata*. See also pp. 452, 665.

extradiscal line not always distinct, forming an oblique wedge shaped costal mark, which is bent outward on the subcostal vein and irregularly scalloped between all the venules, the space inclosed by these two lines forming a broad obscurely luteous or clay yellow band which is about two or three times as wide on the costal as on the inner edge of the wings. This broad band is, especially in the ♀, clouded with blackish scales toward the middle and hind edge, or in some ♂ ♂ grayish near the costal edge. A submarginal twice-bent line obtusely bent in the second median interspace, and again toward the apex of the wings. Fringe concolorous with the wings and spotted with dark on the ends of the venules.

Hind wings slightly paler than the fore wings, usually nearly as dark as the fore wings, becoming darker toward and at the outer edge, sometimes with a dark cloud on the inner angle. The wings beneath uniformly light ashen, with a distinct black costal spot on the outer third of the fore wings, and on the hind wings just beyond the middle of the costal edge a dark blotch, from which in some specimens a broad diffuse line passes in toward the middle of the wing.

Length of body, ♂, 9 to 12 mm.; ♀, 11 mm.; expanse of wings, ♂, 27–30 mm.; ♀, 33 mm.

The species will be recognized by the uniform cinereous tinge, by the three transverse lines on the fore wings, by the broad clay-yellowish band, limited within by the slight inwardly curved inner or second line and externally by the scalloped extradiscal line, and by the plain outer half of the wing, interrupted near the margin by the rather obscure twice waved darker line, and by the plain hind wings.

My original type, formerly in the museum of the Peabody Academy of Science, Salem, is now in my own collection.

Having obtained a colored drawing of Walker's type in the British Museum (Pl. VII, fig. 1), there seems no reasonable doubt but that his name has priority.

Egg.—Hemispherical in shape, though unusually low, shell smooth, shining greenish when fresh or the embryo is within, as the shell is unusually thin and transparent. Under a Tolles triplet the shell is seen to be very minutely pitted; under a half inch objective the shell is seen to be ornamented with closely crowded, convex swellings or blebs, with a distinct swollen or thickened hexagonal edge and a moderately sized central boss or low papilla. The egg is unusually small compared with those of other Notodontians, especially those of *Pheosia dimidiata*, being only half as large. Diameter, 9 mm. They are laid singly on the underside of the leaf of the aspen, and from their greenish color and small size are difficult to detect. The larva emerges from the egg through a bean shaped hole on one side of the egg, as in Pheosia.

Larva, Stage I.—Length when first hatched, before feeding, 2.5 to 3 mm.; length when described, soon after hatching, 4 mm. Head round, smooth, large, or twice wider than the body; pale whitish green, nearly of the color of the body, which is whitish green, with no stripes, spots, or markings of any kind; the body long and slender, rather flattened, with the sutures deeply impressed, the segments being unusually convex, but entirely smooth, not wrinkled. The glandular hairs (Pl. VIII, fig. 5) are very short, minute, moderately thick, and slightly swollen at the end, which is divided into three rather slender processes or forks. Body tapering to the end, which is not uplifted; in fact, the attitude of the young larva is singular, the body being curved laterally so that the head nearly touches the tail. The larva feeds on the underside of the leaf.

The eggs and young larva were found July 2, on Birch Island, Casco Bay, Maine; some freshly hatched larvæ also occurred July 6.

They had already spun on the underside of the leaf a roundish, white mat of silk, on which the caterpillar rested preparatory to exuviation.

When 7 mm. in length just before molting (July 4) the head is still much wider than the body, and now there are two faint dark dots on the head (on the vertex) and two subdorsal straw-yellow lines extending from the front edge of the prothoracic segment to the suranal plate. The sutures are also yellow. The body tapers from the prothoracic segment to the end.

One molted July 5, and is described as follows:

Larva, Stage II.—Length at first, 7 mm; differs from Stage I in the two conspicuous black dividing short bands on the head, ending above the eyes. The two yellow subdorsal lines and the transverse linear bars formed by the yellow sutures are as at the end of Stage I. The body is still rather flattened. The glandular hairs are retained in this stage, and are very short and of the same shape as in Stage I.

Larva, Stage III.—Length, 10 mm. The head is still large, much wider than the body, and green, with a purple stripe on each side. The yellow lines are more distinct than before, and the body has a purplish tinge. (Described from Bridgham's figure (Pl. VIII, fig. —) observed July 8.

Larva, Stage IV.—Length, 20 mm. In one observed July 20, and nearly full-grown, the head is still without the lateral black stripe, and the two subdorsal yellow stripes are very distinct, but there are no pink spots anywhere on the body. The small spiracles are pale orange.

In another drawn by Mr. Bridgham (Pl. VIII, fig. 4), and also 20 mm. in length, the head is not banded, but the body is prettily spotted with pinkish red, in the following manner: Two round dorsal spots on the first thoracic segment; a broad pink-red transverse band on the second and third thoracic segments, each broken into two by a transverse median whitish line; on abdominal segments 3–9 is a pair of dorsal red, rounded spots, growing larger and more distinct toward the end of the body, there being four spots on the ninth segment. The subdorsal yellow lines are well marked.

Larva, last (fifth) stage.—Length, 30 mm. One found on the aspen August 6, was pale green, near the color of the underside of the leaf. Head[1] smooth, polished, darker green than the body, with two black stripes on each side, not meeting above on the vertex. Body green, tapering at each end, smooth, nearly hairless, with no piliferous warts, the scattered hairs being minute; two fine subdorsal yellow lines, and Dyar has observed a faint whitish substigmatal line on second and third thoracic segments. Thoracic segments 1–3 each with dorsal pink-red blotches or spots, two on the prothoracic segment, while those behind are not so divided. Abdominal segments 3 to 9 each with a conspicuous pink-red dorsal square spot, the space between the spots more or less yellow; none on the suranal plate, which is smooth and rounded, while the two subdorsal yellow lines do not meet on it; no spots or dots on the side of the body below the subdorsal lines. Thoracic and abdominal legs of the same color as the body.

Dyar remarks that it is often associated with *Raphia frater*, which it much resembles in general structure, though it is more slender. (Psyche, vi, 146, September 18.)

Cocoon.—A very slight web of silk spun between two leaves, simply enough silk spun around the edge of the inclosure to hold the leaves together, the silk mostly confined to the edge of the cocoon, which measures about 22 by 20 mm. The pupa lies very loosely in its cocoon.

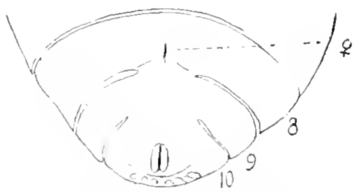


FIG. 53.—End of pupa of *Gluphisia septentrionis*. ♀, vestige of genital outlet of female.

Pupa.—Length, 15–16 mm. Of very unusual shape, being flattened oval cylindrical; posterior end of the body (fig. 53) much rounded and blunt, smooth, with no distinct traces of a cremaster, much less than in other pupæ inclosed in cocoons; surface of the body rather smooth, less pitted, and the minute pits or punctuations more distinct and numerous on the dorsal than on the ventral surface. In color dark brown, much darker than usual in Notodontians or other moths.

Habits.—The eggs are laid the last of June and during the first week in July in Maine, and probably two weeks earlier in southern New England. There are apparently five stages, and the duration of Stage I is about three days, as is that of Stage II, and that of Stage III about five days.

One larva July 26 spun a very slight cocoon between two leaves, and pupated July 28. On this caterpillar there were no red spots.

The moth appeared in the breeding box at Providence May 30, having been brought from Maine in the pupa state; another one appeared June 1, also from Maine, in the larva state.

Mr. Howard L. Clark has reared this moth from caterpillars found on the Balm of Gilead at Warwick, R. I. The moth appeared July 22, having been in the chrysalis state about ten days.

Riley states (MS. notes) that the moths occur in May, June, and July. Mr. G. H. Hudson gives the following dates of capture of the moths at Plattsburg, N. Y.: May 22, 1; May 29, 1; June 3, 1; June 5, 1; June 7 to 21, 22; July 10, 1; July 16, 1; July 17, 1; July 20, 1, July 27 to August 13, 30.

[1] Dyar's measurements of the width of the head for the last four stages are as follows: Calculated, 0.48, 0.74, 1.14, 1.75, 2.7 mm. Ratio, 0.65. Found, 0.7, 1.2, 1.7, 2.7 mm. (Psyche, vi, 147.)

Dyar states that there are two broods each year, and I suspect this is the case, though I have not observed this for myself. Mr. G. H. Hudson also thinks there are two broods, and writes me that this is the first bombycid to fly.

Food plants.—Usually occurring on the aspen or *Populus tremuloides*. I have also found it on the yellow birch, one from this tree beginning to pupate August 11. Mr. H. S. Clark has bred it from the Balm of Gilead, and S. L. Elliot found it on the willow and sweet gum.

Geographical distribution.—This is a species of wide range, and so far as yet known is more common in northern New England, especially in cool, elevated mountain stations, than in the Middle States. Mrs. Fernald has collected it at Orono, Me. I have found the larvæ commonly at Brunswick, Me., and Mrs. Slosson has collected the moths commonly from year to year at Franconia, N. H., a very cool, elevated valley about 1,200 to 1,300 feet above the sea. The locality of Walker's type is "St. Martin's Falls, Albany River, Hudson's Bay, Dr. Barnston." It has occurred at Cambridge, Mass. (Harris Coll. Bost. Soc. Nat. Hist.); Detroit, Mich.; Lawrence, Mass. (Mr. Treat, Mus. Comp. Zool.); Eastern New York (H. Edwards, Elliot, Dyar); New York and Middle States (Grote, and Coll. Amer. Ent. Soc. Philadelphia); Plattsburg, N. Y. (Hudson); Carbondale, Ill.; Wisconsin, Ohio, Maine, Middle States, New York (G. H. French); Racine, Wis.; Chicago, Ill. (Westcott); Fort Collins, Colo., June 21 (C. F. Baker); Pennsylvania (Strecker); Manhattan, Kans., June 20, just like New England examples, but a little larger than any except a bred one from Maine (Popenoe); New York and Nebraska (U. S. Nat. Mus.), race *quinquelinea* (Pl. I, p. 1), Pacific Coast, northwest (Dyar). Of its distribution southward we as yet know nothing, and so far as is known the species is restricted to the Appalachian subprovince (or the humid province of the cold temperate subregion of the North American region, of Allen).

Gluphisia wrightii H. Edwards.

(Pl. I, figs. 5, 6, 7, 8, 9, 10–15.)

Gluphisia wrightii H. Edwards, Ent. Amer., ii, p. 11, April, 1886.
Gluphisia ridenda H. Edwards, Ent. Amer., ii, p. 11, April, 1886.
Pack., Psyche, vi, p. 499, Aug., 1893.
Gluphisia rupta H. Edw., Ent. Amer., ii, p. 12, April, 1886.
Pack., Psyche, vi, p. 499, Aug., 1893.
Gluphisia albofascia H. Edw., Ent. Amer., ii, p. 12, April, 1886.
Pack., Psyche, p. 499, Aug., 1893.
Dyar, Trans. Amer. Ent. Soc., xxi, p. 196, 1894.
Gluphisia formosa H. Edw., Ent. Amer., ii, p. 12, April, 1886.
Kirby, Syn. Cat. Lep. Het., p. 593, 1892.
Pack., Psyche, vi, p. 500, Aug., 1893.
Neum. and Dyar, Revis. Notod., Trans. Amer. Ent. Soc., xxi, pp. 193, 194, June, 1894.

The following description of the single female example forming the type of Edwards's *wrightii* is copied from his paper in Entomologica Americana (ii, p. 11):

Gluphisia wrightii (n. sp.).—Head, thorax, and abdomen very dark gray, thickly speckled with black scales, but lighter on the underside; the primaries are also very heavily covered with black scales. A little above the basal half of wing runs a waved line of pale gray, and from internal angle another waved line more oblique. The space between them is closely scaled with black, but toward the inner margin is an almost square buff patch, across which runs a black line. Space behind the middle band blackish, shading into pale gray at the submarginal dentate line. Margin and fringe pale gray, spotted with black. Secondaries sordid white, with a dusky submarginal shade, connecting with the blackish anal spot. Beneath smoky white, with faint indications of a double median band. Expanse of wings, 42 mm., 1 ♀, San Bernardino, Cal.

I have been led to reconsider my view as to the affinities of *G. wrightii*, and agree for the present with Mr. Dyar that it is very near *G. rupta*; we need more examples and a better knowledge of the venation than we now possess to settle the question of its exact relationship.

As these forms have already been described by Mr. Edwards, I copy his descriptions, adding my own views as to their synonymy:

Head, thorax, and abdomen dark gray, plentifully sprinkled with black, especially on the upper side. Feet and legs also gray mottled with black. Antennæ with the shaft white, pectinations blackish. Primaries with a buff patch at the base, in which are a few black scales. Behind this a gray band, edged before and behind with black, and sprinkled with black scales. Then a rather wide buff or fawn-color shade, through which runs a waved rather indistinct blackish band. Behind this fawn-color band is another of white or silver-gray, edged with a conspicuous dentate black line, with some black scales toward the apex. The space behind the dentate line is pale gray. Fringe whitish, flecked with black. Secondaries yellowish gray, shading into dark smoky toward the margins. Underside sordid white, dark on the apex of the primaries, with faint traces of the median band.

Expanse of wings, 30 mm.; length of body, 12 mm.; 3 ♂, 1 ♀.

Denver, Colo., Hy. Edwards, 1 ♂, Montana, Coll. Neumoegen.

California (French); *G. ridenda*, Colorado, Montana (French); *G. rupta*, Colorado (French); *G. albofascia*, Utah (French).

G. ridenda (figs. 5, 6, Pl. VIII, fig. 7) Edw. is very closely allied, representing *G. trilineata* in Colorado. The Edwards collection contains 3 ♂. I have a ♀ from Colorado which I compared with Mr. Edwards's type specimen before his death. Its venation is the same as in *G. trilineata;* its body and wings are paler gray, the broad median band on the fore wings is clearer, and pale tawny yellowish. It is not improbable that *C. ridenda* will ultimately prove to be merely a climatic variety of the Eastern *trilineata.*

G. rupta Edw. (Pl. I, fig. 9) 1 ♀, Colorado. I regard as a variety which should be united with *G. ridenda.* The single (type) specimen is a ♀, without antennæ or abdomen.

It is of the same size and with the same shape of wings as in *G. ridenda.* Head and prothorax paler than in *G. ridenda.* Fore wings pale gray, as pale as in *ridenda* and whiter than in *trilineata;* base of wings pale, with a black longitudinal streak, a little oblique on the costa, and behind is a diffuse black irregular band; the inner line is black, and as in *ridenda.* The inner black line forming the inner border of the luteous or tawny yellowish median band is very distinct, oblique, not bent outward, as in *ridenda.* The band is much narrower than in *ridenda,* the outer and inner black lines nearly meeting on the inner edge of the wing. The outer line is not so much bent on the costa. No middle line present. The space beyond the narrow pale line just beyond the outer line is dusky, much as in *trilineata,* where it is pale in *ridenda.* Submarginal scalloped line not so near the edge of the wing as in *ridenda.* Fringe checkered as in *ridenda* and *trilineata.* The hind wings are as in *ridenda,* with no transverse line. Beneath as in *G. ridenda,* but with a broad dusky cloud on the outer fourth of the fore wings, not reaching the edge.

G. albofascia Edwards (Pl. I, figs. 7, 8).—The 2 ♂ type specimens are from Utah, and seem to be only a pale form of *G. ridenda,* probably due to its living in a drier, less rainy, more sunny region. It is to be noted that the Western varieties named have no longer fore wings than in the Eastern *trilineata.* It seems to be identical with *G. formosa,* but scarcely separable from *G. ridenda,* being, with little doubt, a climatic variety of the latter species. The 2 ♂ marked *albofascia* resemble *G. formosa,* only the nearly clear spaces of the latter in *albofascia* form dark, broad, very distinct bands. There are two dark dusky patches on the hind wings. The examples of *G. albofascia* are more typical of the species (if it be regarded as distinct from *ridenda*) than those placed under *G. formosa.*

The fore wings somewhat luteous-gray at base; on the inner third is a broad black band widening on the costa and still wider on the internal edge, where it reaches a little beyond the middle of the wing. A clear luteous-gray median space, beyond which on the outer third of the wing is a broad black band, between which and the submarginal scalloped line is a gray band. Hind wings with a diffuse broad band on the outer fourth, forming a dark patch on the internal angle, and another in the independent interspace. On the underside of the wings the dark bands show through, as do the two dusky spots on the hind wings.—Utah and Colorado (June, U. S. Nat. Mus.).

G. formosa Edwards (Pl. I, figs. 10–12).—Four ♂, all from Utah. As already stated, I regard this as a synonym of *G. albofascia,* both species being with little doubt climatic varieties of *G. ridenda.*

The antennæ are well pectinated, rather more so than in *G. ridenda.* The wings are much paler gray than in *ridenda,* the hind wings being almost white, but the thorax and abdomen are as in *ridenda.* Fore wings with black scales at the base, but with no definite lines such as are to be seen in *trilineata* and *ridenda,* but just beyond the base the wing is more or less luteous, as in *ridenda.* Middle of the wing with a broad, pale, flesh colored or luteous band, bordered on the inside by a very distinct black line, like that of *ridenda,* becoming wider on the costa. In the middle of the band is a dark line nearly parallel with the inner one, dilating on the veins and all the lines forming distinct dark costal spots. The outer third of the wing gray, with dark scales and with an irregular blackish wavy line, much as in *ridenda* and *rupta*. Hind wings whitish, with no lines, and with three dark dots on the fringe of the internal angle. The outer third of the wing faintly dusted more or less with fine dark scales. Wings pale whitish beneath: two blackish costal spots beyond the middle, and costa of both wings speckled with dark scales. A faint diffuse band passes across the hind wings just beyond the middle, and the margin of both wings is speckled with dark scales. Body beneath pale, and the legs (tarsi) ringed with dark scales.

After preparing the preceding descriptions I find that Mr. Edwards adds to his description of *G. formosa* the following remark:

> It is possible that *G. ridenda* and *G. rupta* are forms of one species, and that *G. albofascia* and *G. formosa* are forms of another, but I prefer to consider them as distinct until future investigation shall determine their true position.

Mr. Dyar tells me that he has a specimen of *G. formosa* from El Paso, Tex. Professor French reports it from Utah. *G.* var. *ridenda* occurred at Fort Collins, Colo., May 23, June 11, and at Denver July 25 (C. P. Gillette).

SECTION II (*Eumelia* Neum.).

This section corresponds to the genus (*sic*) *Melia* or *Eumelia* of Messrs. Neumoegen and Dyar. At first, with only a single specimen of var. *slossoniæ* to judge by, I thought it was the type of a distinct genus, as the head, antennæ, palpi, and venation seemed so different, but after careful and repeated examinations of specimens, labeled *arimacula*, *lintneri*, *wrightii*, and *severa*, and observing the general identity of form of body, wings, and especially of markings, as well as the larval characters, Dr. Dyar stating that the larva of the Californian *severa* does not differ generally from that of *E. trilineata*, I think with our present knowledge it would be quite unnecessary to recognize Eumelia as a distinct genus.

The structural differences between *G. trilineata* and *G. severa*, var. *slossoniæ*, and which at first led me to think them generically distinct, are the following:

A ♀. The head is remarkably small, much more so than in *G. trilineata*, and is loosely scaled in front. The antennæ are pectinated, the branches a little longer than in ♀ *trilineata*. The palpi are short, small, depressed, with loose scales; and they are not quite so large and long as in *trilineata*. The thorax differs from that of *Gluphisia trilineata* in having a median dorsal tuft. The legs are hairy, and much as in *trilineata*, the tarsi being ringed with gray and darker scales. The fore wings are narrow, but with the costa unusually convex, much more so than in *trilineata;* the apex is somewhat rounded, but much as in *trilineata:* the outer edge is very faintly excavated below the apex. The hind wings are of the same shape as in *trilineata*. There are six branches of the subcostal vein; branch 1 is longer than in *trilineata* and ends half way between the end of costal vein and end of branch 2 of the subcostal; the costal area is wider toward apex than in *trilineata*. The fifth and sixth branches are nearly as in *trilineata*. The lower discal vein is not so much bent as in the last-named species. The three cubital veins are nearly as in *trilineata*, but the second median space is wider than in that genus. The submedian vein (V) is represented by a simple fold. In the hind wings the two branches of the subcostal are much longer than in *trilineata*, the space between them long and narrow, in *trilineata* short and broad triangular. The discal veins are, taken together, slightly curved, where in *trilineata* they make a decided angle at the origin of the independent vein; and there is a common origin of the lower discal and of the two median veinlets. The second median interspace is much wider than in the species of the other section of the genus. Vein VI is represented by a simple fold.

Gluphisia lintneri (Grote.)

(Pl. I, fig. 18.)

Dasychira lintneri Grote, Can. Ent., ix, p. 85, 1877.
Gluphisia lintneri Dyar, Can. Ent. xxiii, p. 159, 1891.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Cat. Lep. Het., i, p. 593, 1892.
Pack., Psyche, vi, p. 500, Aug., 1893.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 194, 1894; Journ. N. Y. Ent. Soc., ii, p. 115, Sept., 1894.

Originally described as a Dasychira, this is a true Gluphisia, but, with *G. severa* and *avimacula*, belonging to a distinct section of the genus. The antennæ are provided with long, close pectinations; the body is stout and hairy, and there is not a well-marked dorsal tuft present; the costa of the fore wings is much more convex than in *G. septentrionis*, and the apex somewhat produced as in *G. severa*. Body stout and hairy; antennæ almost plumose, having long, dense branches, white, the branches dusky.

Body and wings ash or mouse gray. Head nearly as large in proportion as in *G. septentrionis*; palpi feeble, small, not distinct from the hairs of the front. Fore wings with the costa much more convex than in *G. septentrionis*, and the apex somewhat produced, of the same color as the body; a basal black line bent outward at a right angle on the costal vein, and again sending out a distinct long loop on the cubical vein; the middle or intradiscal black line firm, straight, not curved inward as in *septentrionis*, slightly bent outward on the cubical vein; extradiscal line slightly scalloped, bent inward on the costal edge. A very faint, linear, dark, discal spot. A tawny or clay-yellow (luteous) patch at base of wing in the median space and passing a little beyond the basal line. The space between the inner and the outer (extradiscal) line is filled in with clay-yellow, forming a broad median luteous band which is nearly as wide on the inner edge as on the costal edge. There is also a series of submarginal lunate faint luteous patches or blotches, with some black scales intermingled. The costal edge is entirely free from luteous scales. Hind wings dark, like the fore wings, with a distinct dark line on the outer third, which is most distinct on the inner edge of the wing, succeeded by a light shade. Beneath the wings are dusky and both crossed by a common dark diffuse line. No discal spot, as in *wrightii* and var. *avimacula*.

Expanse of wings, ♂ 40 mm.; length of body, ♂ 15 mm.

Geographical distribution.—Plattsburg, N. Y., April 23, flying to light April 12, 20, 23, 30, May 11 (G. H. Hudson) (U. S. Nat. Mus., No. 6217); Franconia, N. H. (Mrs. Slosson); New York ?, April (U. S. Nat. Mus.); New York (French).

Gluphisia severa Edwards.

(Pl. I, figs. 14–16.)

Gluphisia severa H. Edwards, Ent. Amer., ii, p. 167, Dec., 1886.
Gluphisia avimacula Hudson, Ent. News, ii, No. 8, p. 155, Oct., 1891.
Kirby, Syn. Cat. Lep. Het., p. 593, 1892.
Dyar, Trans. Amer. Ent. Soc., xxi, p. 194, 1894.
Gluphisia severa var. *slossoniæ*, Packard.
Melia danbyi Neum. Can. Ent., xxiv, p. 225, 1892.
Eumelia danbyi Neum. Can. Ent., xxv, p. 25, 1892.
Eumelia severa Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 194, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 115, Sept., 1894.

Larva.

Dyar, Psyche, vi, p. 503, Aug., 1893.

Of the two female specimens placed under *G. severa* in the Edwards collection, one (not the type, which is a ♀ from Soda Springs, Cal., April 15, with eggs), probably added after his description was published, I regarded provisionally as a specimen of *G. wrightii*. Its locality is Sierra Nevada, Cal. (and Mr. Beutenmüller suggests that it may have been taken at Mount Shasta). The specimen is perfectly preserved, and in its structural characters is closely allied to *G. severa*. The thorax has a median tuft, as in *G. severa*. From the type of *wrightii* it differs in the more distinct and darker markings, being less rubbed.

A decidedly luteous subtriangular spot extends from the base of the wing to the inner distinct line crossing the wing, which line is situated half way between the base of the wing and the inner side of the median band, this line having been rubbed off in the type of *wrightii*. The space between this line and the median band is whitish gray. The broad blackish median band incloses a sinuous linear luteous discal spot, and there is a luteous patch near the internal edge of the wing. The inner edge of the median band is less distinctly sinuous than in the type of *wrightii*, and so is the white outer bordering line, which, however, is more zigzag. The edge of the wing is stone-gray, as in the type of *wrightii*, and incloses the usual scalloped dark line, as in the type of *wrightii*. Hind wings as in the type; a diffuse dark band crosses the wing beyond the middle, and a second outer one is parallel to it, but does not reach the middle, and the two bands inclose a white linear spot, as in the type.

The species occurs in northern as well as southern California, and is quite variable.

G. severa Edwards.—The single type is a ♀ from Soda Springs, Cal.

The type is much larger than the Sierra Nevada specimen, and well preserved. Antennæ with short pectinations. Body and head dark gray. Wings unusually dark; fore wings dark gray on the basal third, with a very small luteous spot on the cubital and internal veins. Median band broad and dark, almost black, and not bordered by the narrow scalloped outer line, the wing being suffused with black to the outer edge. A narrow faint luteous linear discal spot. Halfway between the scalloped pale gray line and the outer edge of the wing is a submarginal series of tawny or luteous patches. Hind wings just as in the Sierra Nevada example, and venation as in *wrightii*. Wings underneath dark and much diffused, the line on the fore wing less sinuous than in the *wrightii* type. Hind wings with two parallel broad dark bands, just as in the Sierra Nevada specimen of *G. wrightii*. The shape of the head and the wings is the same in the Californian *severa* and the eastern form. In both forms the hind wings are nearly the same.

Var. *arimacula*.—The following is a description of a type specimen presented by Mr. Hudson to the United States National Museum: Body and fore wings ash gray, basal line black, with a large irregular loop just below the median vein filled in with luteous scales. Middle line black, sinuous; extradiscal line diffuse, oblique, and sinuous; no luteous median band, this space being ash-gray, with obscure luteous scales near and on inner edge; an indistinct submarginal series of blackish scallops; a very distinct, irregular, reniform black discal spot, filled in with distinct luteous scales, so that there are two distinct conspicuous clay-yellow spots in this species; hind wings with no distinct line and no common line beneath. Expanse of wings, 37 mm.; length of body 16 mm.

Plattsburg, N. Y., May 10, 15, 21, 22 (G. H. Hudson). Professor French has *danbyi* from Victoria and *severa* from Shasta County, Cal.

G. *severa* var. *slossoniæ*.—Body and wings pale ash-gray; the prothoracic segment colored as the head, but the rest of the thorax is dark brown, the median thoracic tuft also dark brown. Fore wings black-brown on basal one-fifth, this portion sending out five sharp tooth-like projections along the subcostal, internal, and second anal veins. A broad distinct median oblique band, with irrégular lobulate edges, and widening on the costa; it incloses a very distinct discal triangular white spot, the apex pointing outward. A submarginal broken row of dark spots arranged much as in *Gluphisia trilineata*.

Hind wings with no markings, but at the inner angle is a faint short curved dark band, edged externally with white, but not reaching beyond the middle of the internal space. Fringe concolorous with the wing, but checkered with small black spots.

Wings beneath much as in *Gluphisia trilineata*; the black band is faint, its outer edge indicated on the costa by a dark spot. Expanse of wings, 38 mm.; length of body, 15 mm.

I am indebted to Mrs. Annie Trumbull Slosson for the privilege of examining and describing a single remarkable specimen in a perfect state of preservation taken at Franconia, N. H. Mrs. Slosson, unlike many entomologists, has kindly allowed me to partially denude the under side of the wings of her unique specimen, so that the venation could be carefully drawn with the aid of the camera. She has determined the species to be new. The species was not to be found in the collections of Mr. Graef or Mr. Neumogen, and Mr. Beutenmüller had not seen it in the Henry Edwards collections, now fortunately in the possession of the American Museum of Natural History at Central Park, New York. I had described the form as *Ceruridia slossoniæ*, regarding it as the type of a new genus, allied to, but distinct from, Gluphisia, owing to the notable differences in the venation, as well as the presence of a dorsal tuft and other characters given below. After sending my description for publication Mr. Dyar wrote me that he had seen the specimen with my name on it in Mrs. Slosson's collection and that it seemed to him to be a dark ♀ of *Gluphisia avimacula* Hudson, adding that Mr. Neumogen's "*Melia danbyi*" is referable to the same genus, but his name "Melia" is preoccupied. Since then I have reexamined Edwards's type of *G. severa*, and have received from Mr. Dyar a specimen of *G. lintneri*. Mr. Dyar also wrote me as his opinion that the species of Ceruridia or Melia (Eumelia) are not generically different from Gluphisia, as he has collected *G. severa* in the Yosemite Valley, Cal.

As the result of my studies, especially of the venation, I am inclined to divide the genus Gluphisia into two sections and to believe that in the forms mentioned below we have a number of climatic or temperature varieties of a species allied to *G. lintneri* (originally referred to Dasychira by Grote), and which is common to both the Atlantic and Pacific coasts.

Of all these forms the variety *slossoniæ* is the most remarkable, from its very dark markings, and deserves to receive a distinct name. That these forms may be the result of climatic causes, acting on the insect in its pupal state, seems pretty well established from the remarkable results obtained not only by Weismann and W. H. Edwards, but also the more detailed experiments made by Mr. F. Merrifield and published with elaborate plates in the Transactions of the Entomological Society of London for 1891 (p. 155) and 1892 (p. 33) (xxxvi).

In comparing *G. slossoniæ* with Hudson's description of *avimacula*, it seems most probable that it is a melanotic form, due to the colder and damper situation of Franconia, N. H., which is about 1,490 feet above the sea. In *slossoniæ* the thorax is lighter, the pale ocherous basal and discal spots of *avimacula* are whitish gray in *slossoniæ*, and the basal and middle lines of the median band are swamped by the broad black-brown band of *slossoniæ*: the hind wings of *slossoniæ* agree with Hudson's description of *avimacula*.

The following account of its transformations is copied from Dyar (Psyche, vi, p. 503, Aug., 1893):

Egg (?).—Hemispherical, the base flat; smooth, slightly shiny whitish green, the micropyle round, small, black. Under a half-inch objective it is seen to be covered with irregular flattened reticulations, not raised above the surface of the egg, much as in Cerura, but more irregular, ranging in shape from quadrilateral to hexagonal. Diameter, 1.1 mm. Found on a poplar leaf, deposited singly. I am not sure that this egg belongs to this species, as it failed to hatch, but it was found with the larvæ and probably belongs here.

First larval stage.—Not observed.

Second stage.—Head slightly bilobed, not shiny, pale green; mouth whitish; ocelli black; width, 0.9 mm. Body smooth, slender, without humps or tubercles, uniform pale green, not shiny, with a faint yellow subdorsal line. No other markings.

Third stage.—Only the cast head-case was observed, the width of which was 1.45 mm.

Fourth stage.—Width of head, 2.3 mm. Much as in the first part of the last stage. There is a moderately distinct, pale yellow, subdorsal line without other markings, or else traces of lateral and stigmatal yellowish lines, the former broken, the latter continuous, but faint. Spiracles small, faintly ocherous. As the stage advances, the stigmatal line becomes the most distinct, the others becoming faint.

Fifth stage.—Head very slightly bilobed, somewhat flattened in front, uniform pale, sublustrous green, mouth parts paler, jaws black; width, 3.5 mm. Feet normal, all used in walking, concolorous with the body, the claspers whitish. Body long and slender, noctuiform in appearance, without humps or tubercles; piliferous dots absent, the hairs being reduced to mere rudiments. Color uniformly nonlustrous pale green, semitransparent, showing plainly the pulsations of the dorsal vessels. An obscure, pale yellow, stigmatal line. Spiracles dull ocher. The larva rests on a slight web on the back of the leaf, the head held out flat.

As the stage advances the markings become much more pronounced. The head is mottled with white, especially on each side of the clypeus; clypeus white centrally; a yellow line appears on the side of the head from the base of the antennæ behind the ocelli, in line with the stigmatal band when the insect is in its normal position of rest. Stigmatal line distinct, pale yellow, bordered above, very narrowly, with crimson on the thoracic segments, and reaching nearly to the end of the anal plate. Dorsal region whitish green, becoming almost white; subventral region clear green, with yellow dots; spiracles orange, feet faintly tipped with vinous. There are faint traces of a yellowish subdorsal line and one on each side of the dorsal vessel, but they become white and are seen as somewhat more distinct parts of the general whitish dorsal shading. Still later the rudimentary piliferous dots become surrounded with yellow. There are seven on each side above the stigmatal line, seven in the subventral space (where they appear more distinctly on account of the absence of white shading), and others on the venter of the legless segments.

Length of larva, 11 mm. at maturity.

Cocoon.—Spun among leaves. It is composed of gummy silk, slight, but tough.

Pupa.—Nearly cylindrical, rounded, no cremaster; abdomen punctured, cases coarsely creased; color uniform dark brown, nearly black. Length, 17 mm.; width, 6 mm.

Food plants.—Poplar (*Populus tremuloides* and *P. balsamifera*). Larvæ from Yosemite, Cal. (Dyar.

Dr. Dyar tells me that he has found at Keene Valley, New York, the larva of *G. armacenia* or *slossoniæ*, which is exactly like that of *G. severa*, described above.

Subfamily II.—Apatelodinæ.[1]

Head more prominent than in the previous family; antennæ well pectinated to the tips; palpi large, stout, ascending, reaching well beyond the front. Fore wings triangular, falcate, and with the outer edge bent in front of the middle on the sixth subcostal venule. Hind wings with the apex much rounded. Hind legs very thick, the femora oval.

Larva cylindrical, almost entirely concealed by the long wool-like hair, through which arise long pencils of hairs; in *angelica*, hairs short. Freshly hatched larva clothed with long white hairs.

The reference by Mr. Druce (Biologia Centr. Amer., p. 208) of this genus to the Lasiocampidæ seems to us to be quite erroneous, as the venation is truly Notodontian and very unlike that of any of the Lasiocampidæ known to us, in all of which there are four branches of the cubital vein of both wings, and no bristle (frenulum) on the hind wings. The larva does, however, have a superficial resemblance to that of some Lasiocampæ. Let the reader compare the venation of Apatelodes with that of Ichthyura and Nadata. The end of the abdomen is also tufted much as in Ichthyura. Apatelodes also spins no cocoon. Acronyctodus of Edwards is closely allied; the single species known is from Vera Cruz, Mexico.

Apatelodes Packard.

(Pl. XXXVIII, figs. 5, 5a–5c, venation.)

Phalæna, Abbot and Smith, Nat. Hist. Lep., Georgia, p. 151, 1797.
Pygæra (in part) Hübn., Verz. Schmett., p. 162, 1816.
Parathyris Hübn., Verz. Schmett., p. 158, 1816.
Apatelodes Packard, Syn. Bombycidæ U. S., Pt. II, Proc. Ent. Soc. Phil., p. 253, Nov., 1864.
Grote, Check List N. A. Moths, p. 18, 1882.
Druce, Biologia Centr. Amer., Pl. LVI, p. 208, March, 1887.
Smith, List Lep. Bor. Amer., p. 29, 1891.

Head moderately prominent, the front rather broad, more so than usual, subtriangular, the hairs clothing it rather uneven and loose. Antennæ in ♂ evenly branched to the end, but the pectinations shorter than usual, about as long as the thorax. Palpi large, thick, stout, slightly ascending, reaching well beyond the front, tips broad; third joint minute, nearly concealed, not distinct from second joint. Eyes naked.

Thorax simple, not tufted. Fore wings triangular; nearly one-half as broad as long; in the ♀ much broader; costa straight, much curved at the apex; outer margin hollowed just below the apex, rendering it unusually falcate. Below the apex the outer edge of the wing is oblique, not indented, but making an obtuse angle with the straight inner edge. Costal vein extending nearer the apex than usual. First, second, and third subcostal venules suddenly deflexed upon the costa very near each other. Apical interspace broadly triangular. The fourth and fifth subcostal venules of the same length; no subcostal cell. Discal area short and broad; the discal venules situated within the middle of the wing; the posterior discal venule oblique, though curvilinear.

Hind wings large, full, and rounded on the outer margin, of an irregular pentagonal form reaching nearly to the tips of the abdomen. Both discal venules very oblique, especially the hinder one. Tibiæ with broad flat concavo-convex tufts. Femora densely pilose, giving the joint an oval form; hind tibiæ with dense scales, making it unusually broad, with four large spurs. Abdomen of ♂ slender, with a tuft on each side of the tip.

Coloration, no discal spot; with gray-brown transverse lines and blotches.

The genus is easily recognized by the broad, very falcate fore wings, their peculiar venation, and by the unusually broad hind tibiæ and the large tufts at the end of the male abdomen.

[1] This name was proposed by me in MS., but Neumoegen and Dyar afterwards published it in 1894; the fact that it was proposed by two different authors shows that it is well founded.

The genus may be also distinguished by the short antennal pectinations; by the large palpi; by the simple, untufted thorax; by the falcate fore wings, the outer edge not scalloped, and by the broad concavo convex tibial tufts.

The generic name was suggested by the resemblance of the hairy larva to *Apatela americana*. Our species can not be referred to the same genus as *Parathyris cedo-nulli* of Cramer, at least until we have examples of that South American form for comparison.

Egg.—Very much flattened, resembling a very shallow inverted plate, with sloping sides, the surface appearing as if ringed, each ring inclosing a circle of 5 to 7 spines.

Larva.—Body cylindrical, nearly smooth, almost completely covered by long, fine, dense hairs, through which are seen on each side the lateral row of black spots; most of the hairs dark on the distal half, pale at base, and from the black dorsal spots arise from two to four spindle-shaped black hairs forming median dorsal pencils on the abdominal segments. A long, slender median pencil arises from the second and third thoracic segment, and a single median pencil is directed backward, arising from the eighth abdominal segment. Freshly hatched larva, smooth-bodied, thickly covered with long white hairs, arising from small tubercles.

Pupa.—?

Geographical distribution.—The species range from New England and Canada southward to Florida and Georgia, and appear to exist in Surinam and Brazil. The genus is well represented in Central America; three species, according to Druce, occurring in Mexico, one, *A. adrastria* Druce, near *A. torrefacta*, recorded from Cordova, Mexico, Yucatan, Costa Rica, and Panama; *A. ardeola* Druce occurs in Panama and also on the Amazons, while another inhabits Guatemala.

SYNOPSIS OF THE SPECIES.

Wings not dentate, fore wings with four brown lines and a double brown spot near base...... *A. torrefacta*
Wings dentate; fore wings with a square transparent spot near apex; no distinct lines......... *A. angelica*
"Fore wings grayish drab, tinged with reddish, the lines and marks all obsolete" (Edwards).. *A. indistincta*

Apatelodes torrefacta (Abbot and Smith).

(Pl. VII, fig. 10.)

Phalæna torrefacta Abbot and Smith, Nat. Hist. Lep. Ins. Georgia, p. 151, Pl. LXXVI, 1797.
Pygæra torrefacta Hübn., Verz. Schmett., p. 162, 1816.
Parathyris torrefacta Walk., Cat. Lep. Ins. Br. Mus., v, p. 1088, 1885.
Apatelodes torrefacta Pack., Proc. Ent. Soc. Phil., iii, p. 353, 1864.
Astasia torrefacta? Harris, Ent. Corr., p. 307, 1869.
Apatelodes torrefacta Grote, Check List N. A. Moths, p. 18, 1882.
var. *floridana* H. Edwards, Ent. Amer., ii, p. 13, April, 1886.
Smith, List Lep. Bor. Amer., p. 29, 1891.
Kirby, Syn. Cat. Lep. Het. I, p. 851, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 183, 1894; Journ. N. Y. Ent. Soc., ii, p. 113, Sept., 1894.

Larva.

(Pl. IX, figs. 1–8.)

Abbot. Abbot and Smith's Nat. Hist. Rarer Insects of Georgia, Pl. LXXVI, 1797.
Harris. Ent. Corresp., p. 307, 1869. (Full-fed larva and habits described.)
Soule. Psyche, v, p. 19, Jan., 1889. (Eggs and five stages described, with notes on habits.)
Packard. Proc. Bost. Soc. Nat. Hist., xxiv, pp. 519–522, 1890. (Stages I–VI described.) Fifth Rep. U. S. Ent. Comm. Forest Ins., p. 647, 1890.
Beutenmüller. Bull. Amer. Mus. Nat. Hist., N. Y., v, p. 87, 1893. (Egg and larval stages described.)

Moth (5 ♂, 2 ♀).—Soft velvety ashen. Palpi and hind margin of the thorax reddish brown. Fore wings with a large reddish brown spot on the base of the internal margin; no discal spots; beyond is a line of the same color which crosses the wings and is curved inward on the costa. An outer, nearly straight, slightly flexuous, very faint line. Just beyond the middle of the wing is a similar but more distinct line. A wavy submarginal line, curved outward just before reaching the costa. A minute subapical white spot margined externally with reddish brown. Hind wings tinged with reddish. A light median obsolete line terminates on the internal margin in a white spot, which above and below is reddish brown. Fore wings a little paler beneath; the subapical spot present, the apical region being reddish brown. Within is a regularly curved light line. In the middle of the wing is an obsolete reddish line.

Hind wings discolored with red along the median vein, there bending into the middle of the internal margin; this is faintly continued upon the costa. A submarginal white line. Fringe on the internal angle, reddish brown. The lateral tufts on the end of the abdomen reddish brown. The female only differs in the much broader wings.

Expanse of wings, ♂ 45 mm., ♀ 50 mm.; length of the body, ♂ 20 mm., ♀ 21 mm.

Var. *floridana* Edwards, much redder, lines fainter, the discal whitish spots more clearly defined. Beneath, wings foxy red. (Coll. Amer. Mus. Nat. Hist., New York, and Coll. Neumoegen.)

The following notes are based on the sketches and notes made for me by Mr. J. Bridgham, who kindly preserved for me in alcohol specimens of the two later stages, from which, with the aid of his excellent drawing, the following description of those two stages were drawn up. It appears that there are six larval stages.

Egg.—The eggs were laid on the wild cherry June 22, and hatched July 9; another lot received from Miss Morton, hatched July 5–6. They are much flattened, resembling a very shallow inverted plate, with sloping sides. The surface appears as if covered with overlapping rings, each inclosing a circle of five, six, and sometimes seven spines. Diameter, 1 mm.

Miss Caroline G. Soule describes the eggs as at first green, and five days later sordid yellowish white, circular, flat on both top and bottom, translucent, and looking like tiny gelatine lozenges, 1.5 mm. in diameter.

Larva, Stage I.—Length, 4–5 mm. Head and body pale greenish white or whitish flesh, with no black or dark marks; head moderately large; body covered thickly with long white hairs, mostly curled, which arise in irregular and scattering tufts from four dorsal and three lateral tubercles; the hairs arising from the thoracic are rather longer than those from the abdominal segments.

Larva, Stage II.—Length, 6 mm., July 16. Much as in the first stage, the hairs a little denser, and the head and body still whitish, with no dark spots.

Miss Soule says that after the first molt the larva becomes "even whiter and fluffier than before, with a dorsal line of black dashes, and a dark pencil on the tenth segment. A few had gray hairs over the head."

Larva, Stage III.—Length, 11 mm., July 25. Color of the head and body the same, but the woolly white hairs on the thoracic segments appear to be thick and matted. Now appears along the back of each abdominal segment a conspicuous black dash, and from the eighth abdominal segment arises a long, slender, tapering black pencil, which projects backward.

Miss Soule says: "As before, with the addition of a gray pencil on the second and third segment."

Larva, Stage IV.—Length, 20 mm., August 3. The head is yellowish white, but the body slightly pale gray. From the second and third thoracic and eighth abdominal segments arises a black pencil, each about the same length as the other, viz, about twice as long as the thickness of the body; the anterior pencil points forward, the two others backward. The interrupted black dorsal stripe is as before.

Miss Soule states that in this stage "a lateral and subventral line of black arrowheads appeared. One larva became bright yellow, with the pencils tan colored, with black tips, and one was of a soft gray, with black pencils."

Larva, Stage V.—Length, 27 mm., August 7. (This and the last stage described from alcoholic specimens as well as from Mr. Bridgham's colored drawing.) Head normal, rounded, the sides and top somewhat swollen, the median suture somewhat depressed; of a peculiar white-flesh color. Prothoracic segment without a pencil or a lateral black patch; second thoracic segment with two contiguous rounded tubercles from which arise two long pencils whose hairs blend together to form a common median deep ocherous pencil inclined forward, becoming black at the distal third. Third thoracic segment with a similar pencil inclined backward. A similar median pencil on the eighth abdominal segment. There is now a dorsal row of six long median black stripes on abdominal segments 2 to 7. Between these spots arise a pair of dorsal pencils composed of curious long spindle-shaped flexible black hairs, pale at the base, which taper from near the end to a sharp point. The pencils consist of three to four hairs arising from a pair of small warts, one close to but on each side of the median line and situated just behind each dark dorsal dash. On the sides of the second thoracic and the ninth abdominal segment is a black patch, more or less oblong and jagged on the upper edge. The sutures between the segments are not black. The underside of the body is blackish. At the base of the abdominal legs is a black ring, and another near the planta, and a longitudinal black stripe down the outside of the leg.

Miss Soule adds that "the yellow one came out with the body black, the hair maltese-gray, lighter over the head; pencils darker gray with black tips. The gray one was like it."

Larva, Stage VI.—Length, 35 mm., August 11. The hairs concealing the body are now uniformly white (Harris, referring to the living larva, says, "of a beautiful white color"), having entirely changed their color. The dorsal black lines are now more connected; the three long pencils are pale at base and black toward the tip. The lateral black spots send two points upward, and the sutures are now black. The head is stained with black on the vertex and along the sutures and around the mouth-parts. The thoracic and abdominal legs are black, but the plantæ of the abdominal feet are pale. Most of the hairs are dark on the distal half but pale at the basal half, and from the black lateral spots arise from two to four spindle-shaped black hairs; also several others which stand out from the mass of dull gray hairs, arising from minute tubercles along the sides of the body. The legs are hirsute, and the body is black beneath.

Miss Soule's full-fed larva was 51 mm. in length, "densely covered with long silky hair, varying in color from pure white to deep gray; pencils almost black with black tips. Head gray. Body hardly to be seen, but black wherever visible."

Summary of the larval changes.

1. No glandular hairs, and in Stage I the body is already covered with long woolly soft hairs.

2. In the third stage appears the dorsal black stripe, and a single black pencil on the eighth uromere.

3. The two other black thoracic pencils appear in Stage IV.

4. The hairs become yellow and the pencils bicolored, while the lateral black spots appear in Stage V.

5. The last stage (VI) is signalized by an entire change in color from ocher-yellow to white or gray.

Length of egg stage, sixteen to seventeen days; of first larval stage, seven days; Stage II, nine days; Stage III, eight to nine days; Stage IV, four days; Stage VI, nine days (Harris); prepupal stage, three days (Harris's pupal stage).

Cocoon.—Harris states that it does not spin a cocoon, but probably enters the earth. Miss Soule also states that no signs of spinning were found.

According to Abbot, in Georgia the caterpillar "went into the ground June 20, came out the 14th of July. Another went in the 17th of October and came out on the 25th of April."

Habits.—Dr. Lintner has described quite fully the larva of the other species (*A. angelica* Grote) which feeds on the ash and syringa, transforming to the pupa state September 14. His larva seems to differ in the "numerous fine black linings, among which may be traced two forming a vascular stripe and two similar lateral stripes on each side." Lintner also speaks of "four dorsal white lines, posteriorly black," on the prothoracic segment, and also of "short stiff red hairs on the sides of the second and third thoracic segments, and indeed it is evident that the larvæ of the two species differ considerably in markings." Our larva, on the other hand, appears to be identical with that described by Harris (Correspondence, p. 307) under the name of *Astasia torrefacta?* Sm. and Abb., the two last stages of which he describes. He found it on the burdock, and says that it "eats leaves of willow well," and further on states that he found one "on a leaf of *Prunus virginiana*."

Miss Soule states that a female found at Nonquitt, Mass., laid a mass of eggs July 13, the larvæ hatching on the 26th. The first molt occurred August 2, the second August 5, the third August 10, the fourth August 15, the fifth August 26. The freshly hatched caterpillar rested on both sides of the sassafras (*Sassafras officinale*) and ash (*Fraxinus*) leaves, and moved very fast. "When touched they curled up like the arctians. They drank greedily and ate their cast skin."

"The larva fed on sassafras grew faster and larger than those fed on ash, and molted and pupated earlier."

This conspicuous hairy caterpillar, which evidently feeds exposed on the leaves, seems to be somewhat omnivorous in its tastes, and sometimes feeds on herbaceous plants, as the burdock. Hence, it apparently belongs to the same category of hairy peniciled white and black spotted and tufted caterpillars, as those of Halesidota, those of the Liparidæ, and certain species of Noctuidæ, as *Platycerura furcilla*, etc. It is noteworthy as being in this respect exceptional among Notodontians.

Mr. Beutenmüller has bred this species; the eggs were laid June 24, the larva entered the ground August 2, pupated August 4, and the moth emerged August 27–29.

Pupa.—?

Food plants.—Wild cherry, *Prunus virginiana*; found on burdock; eats willow well (Harris Corr., 307); sassafras and ash (Soule); willow, alder, blackberry, bayberry, azalea, sassafras, viburnum, and hazel (Beutenmüller). Feeds on the ironwood, gall berry, sassafras, etc. (Abbot); *Phaseolus helvolus* (Abbot's MS. drawings in library of Bost. Soc. Nat. Hist.).

Geographical distribution.—Cambridge and vicinity of Boston (Mus. Comp. Zool., Sanborn, Mus. Bost. Soc. Nat. Hist.); Amherst, Mass. (Mrs. Fernald); New York (Grote); Georgia (Abbot); Florida (H. Edwards); Massachusetts, Wisconsin, Ohio, Texas, var. *floridana*, Florida (French); Chicago, Ill. (Westcott); New Jersey, Pennsylvania, July and August (Palm); Kanawha Valley, W. Va. (W. H. Edwards, Mus. Comp. Zool.). Larva, Bushburg, Mo., September 17; moth, Indiana, Ohio, Missouri, Alabama (U. S. Nat. Mus.).

Apatelodes angelica Grote.

(Pl. XLIX, fig. 1.)

Parathyris angelica Grote, Proc. Ent. Soc. Phil., iii, p. 322, Sept., 1864.
Apatelodes hyalinopuncta Pack., Proc. Ent. Soc. Phil., iii, p. 254, Nov., 1864.
Apatelodes angelica Grote, Proc. Ent. Soc. Phil., iv, p. 207, Feb., 1855. Pl. 4, fig. 1, 9, p. 181.
Kirby, Syn. Cat. Lep. Het., p. 852, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, 1894; Journ. N. Y. Ent. Soc., ii, p. 113, Sept. 1894.

Larva.

(Pl. XLIX, fig. 1.)

Lintner, Ent. Contr., iii, p. 130, 1874. (Detailed description).

Moth (3 ♂, 1 ♀).—The female differs from *A. torrefacta* in having both wings well toothed on the outer edge, the apex of the fore wings much more acute, the outer margin more oblique, and in having much smaller palpi. In coloration it is quite distinct, since it does not possess the prominent lines and spots of *A. torrefacta*. Both species have the subapical square transparent spot, but in *A. torrefacta* it is small and inconspicuous, while a second adjoining one is wanting.

Body and wings very uniformly pale cinereous. Head, legs, and thorax concolorous. On the inner third of the fore wings is a straight, rather broad, darker band, which increases in width toward the costa. Beyond the median broad pale gray band the wing is darker. The costal edge is fuscous, the median crest of the thorax is tipped with brown, and beyond the middle of the patagia is a narrow transverse line. Hind wings fuscous gray, with an indistinct submarginal line slightly waved and edged with gray. Upper part of abdomen reddish. Fringe darker. Beneath, the fore wings are crossed by two bands, the inner fuscous, the outer dark gray. The margin of the wings dark gray, especially the fringe. The thin broad tuft on the hind tibiæ is edged with brown. On each side of the base of the abdomen is a broad oblong spot, edged broadly with white before and behind.

Expanse of wings, ♂ 43 mm., ♀ 50 mm.; length of body, ♂ 20 mm., ♀ 22 mm.

The species derives the name I gave it from a peculiar square transparent spot edged with brown, situated just below the apex of the fore wings, nearly opposite the middle point of the wing. The lower subcostal venule separates it from a much smaller adjoining one in the extradiscal space.

Larva (full fed).—Head subrotund, dark brown, and two lines on the front lighter brown. Body with the thoracic segments tapering; terminal segments tapering and flattened posteriorly; ventral region flattened, the anal legs projecting behind. Color of the body, gray; numerous fine black linings, among which may be traced two forming a vascular stripe and two similar lateral stripes on each side. On segment 1, anteriorly, are four dorsal white lines; posteriorly, black; segment 2 is black anteriorly, behind which are irregular black linings; segment 3, as the preceding one; on segments 5 to 10 the dorsal black linings assume a V shape, the apex resting on the suture and inclosing centrally two yellow-green subelliptical spots, with a similar spot exterior to each within the superior lateral stripe.

From the first segment long whitish brown hairs project over the head, nearly concealing it; from the middle of the second and third segments whitish hairs project forward, of which those on the latter segment are shorter and arranged somewhat in tufts, beneath which, when extended, some short, stiff, red hairs are seen; laterally below the stigmata are two rows of fascicles of white hairs of unequal length, mingled with a few longer brown ones, extending rectangularly with the body until to its middle, whence the remainder are directed backward; from the terminal segment white and brown hairs, of greater length than elsewhere on the body, project horizontally, brush-like, backward; short whitish hairs are scattered sparsely over the body. (The larva escaped before its description could be completed, and the remainder is from memory.) On the vascular line on each segment is a tuft of black hairs about 0.06 inch long, the ends of which converge to a point. The prolegs project laterally, almost hidden by the hairs. Ventrally is a broad fuscous stripe. (Lintner.)

Habits.—Lintner found eight or ten larvæ near Albany, early in September, feeding on the ash, and Mr. Meske collected them from the lilac (*Syringa vulgaris*). When not eating, they usually occurred resting on and closely appressed to a twig. The first transformation to a pupa was on September 11. The larva has a marked gastropachan aspect. (Lintner.)

Food plants.—Ash and Syringa.

Geographical distribution.—Medford, Mass. (W. H. Dall, Mus. Comp. Zool. Cambridge); eastern New York (Lintner, Meske); Plattsburg, N. Y. (Hudson); Middle Atlantic States (Grote, Coll. Amer. Ent. Soc. Phil.); Ontario, Canada; New York, New Jersey (Palm); North Carolina, Ohio, Irvington, Ill. (French); Enterprise, Fla. (Thaxter).

Var. indistincta H. Edwards.

Apatelodes indistincta Edw. Ent. Amer., ii, p. 13, April, 1886.
Smith, List Lep. Bor. Amer., p. 29, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 852, 1892.
Var. *indistincta*, Neum. and Dyar, Trans. Amer. Ent. Soc., p. 181, 1894.

Primaries of a grayish drab, tinted with reddish, the lines and marks all obsolete; the surface dotted with black irrorations. There is near the apex a semitransparent square spot, with a smaller one beneath it. The fringe is reddish chestnut. The secondaries are reddish testaceous, without marks. Underside wholly reddish fawn-color, with a few black and brown specks, but wholly without the dark shading so conspicuous in *A. torrefacta*. Thorax color of primaries. Abdomen reddish testaceous, with brown dots. Expanse of wings, 35 mm.; length of body, 18 mm., 1 ♂. Indian River, Florida, Coll. B. Neumoegen. (Ent. Amer., ii, p. 13); Florida (French).

Subfamily III.—PYGÆRINÆ.

Head rather large, the front rather broad; the antennæ ciliated, not pectinated in the male. The body and wings are usually, and in all the species of Datana, reddish ocherous, the fore wings being crossed by from four to five straight parallel lines. Egg oval cylindrical, smooth; top depressed.

Larva brightly banded and very hairy; no tubercles, the body being smooth. They spin no cocoon, but pupate deep in the earth.[1]

[1] Harris says of *D. ministra*: "When ready to transform, all the individuals of the same brood quit the tree at once, descending by night, and burrow into the ground to the depth of 3 or 4 inches, and, within twenty-four hours afterwards, cast their caterpillar skins, and become chrysalids without making cocoons. They remain in the ground in this state all winter, and are changed to moths and come out between the middle and end of July." (Treatise, p. 130.)

Pupa rather stout, head prominent, notched at the end; the surface rugose and very coarsely punctured, the pits being more or less confluent, especially on the thorax. Cremaster wide at base, bearing a pair of double sharp spines.

I am at present inclined to think that this group may be the most generalized one of the family, owing to the smooth and hairy larvæ, resembling those of the Nyctemeridæ, Liparidæ, etc.

Datana Walker.

(Pl. XXXIX, and Pl. XL fig. 5. Venation.)

Phalæna Drury, Ill. Nat. Hist., ii, 1773.
Abbot and Smith, Lep. Ins. Georgia, 1797.
Pygæra? Harris, Cat. Ins. Mass., p. 73, 1835.
Petasia? Westwood, Drury's Ill. Exot. Ent., ii, p. 27, 1837.
Datana Walker, Cat. Lep. Het. Br. Mus., v, p. 1060, 1855.
Eumetopona Fitch, 2d Rep. Nox. Ins. N. Y., p. 235, 1856.
Datana Grote, New Check List N. Amer. Moths., p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 612, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 197, June, 1894; Journ. N. Y. Ent. Soc., ii, pp. 112, 116, Sept., 1894.

Moth.—Head not prominent, rather sunken; front vertically oblong, narrower in ♀; the scales clothing it short, closely, and evenly cut. Antennæ not pectinated in ♂, the joints only slightly produced beneath, and ciliated. Between the antennæ at base is a minute vertical pointed tuft. Maxillæ about as long as the head, sometimes separate, but usually united and rolled up. Palpi short and stout, ascending, second and third joints bent upward even with the front; the scales on the second joint long, bushy, even with or passing beyond the end of the minute third joint.

Thorax rather large, pilose, convex, not tufted. Fore wings one-half as long as broad, triangular; costa straight, becoming curved at the apex, which is pointed and slightly falcate; outer edge slightly scalloped and in ♂ very slightly excavated just below the apex. Hind wings with the costal edge convex and bent down toward the apex, which is somewhat produced; outer edge slightly bent on the second median venule. Venation: A narrow subrhomboidal subcostal cell, otherwise much as in Nadata, but with the costal region wider toward the apex.

Legs with the femora and tibiæ densely hairy; the second pair of spurs on the hind tibiæ longer than the first; tarsi rather thick. Abdomen long, somewhat flattened in ♂, with a slight tuft at the end; claspers large, long, and well developed.

Coloration usually very uniform, the species closely resembling each other, as do the larvæ, but differing somewhat in the venation of the fore wings; body and wings ocherous, thorax with a darker brownish patch, which is contracted and square behind; fore wings usually ocherous, reddish brown, with a regular curved basal whitish brown line, and three parallel more or less straight outer lines, with one or two discal dots; hind wings and body pale ocherous.

The species are readily recognized by the simple ciliated antennæ, short palpi, and the peculiar mode of coloration.

As regards the protective mimicry exhibited in these moths when at rest, Grote remarks that Datana in repose "looks like a broken twig, the shaded thorax, with its raised tufts at the sides, like the top of the twig at the break." (Can. Ent., xx., p. 184, Sept., 1888.)

Larva.—Body cylindrical, brightly banded, of uniform thickness, and with no tubercles or humps; usually with long, rather dense, pale hairs. Freshly hatched larva, head large; body with long clavate glandular hairs of unequal length; with faint subdorsal and lateral stripes.

Pupa.—Head prominent, projecting well beyond the body, and with two parallel dorsal ridges; the surface of the body quite rough, being corrugated and granulated.

Geographical distribution.—The species are confined to the Appalachian and Austroriparian subprovinces, except one (or two) species on the Pacific Coast. One species, *Datana integerrima*, is said by Mr. Druce (Biol. Centr. Amer., p. 215) to occur at Jalapa, Mexico, this being in the tropical or subtropical belt.

The following synopsis and descriptions of the moths of this genus have been kindly prepared for me by Mr. Dyar:

SYNOPSIS OF THE SPECIES OF DATANA.

Outer margin of primaries distinctly excavated between the veins.
  Color entirely smoky or blackish brown .... *angusii*
  Color yellowish brown or paler
    Discal spots faint or absent; size medium.
      Color yellow-brown .... *ministra*
      Color testaceous .... *californica*
    Discal spots distinct; size large .... *drexelii*
Outer margin indistinctly excavate, nearly entire in the ♂.
  Color tawny brown or purplish.
    Tawny brown, discal spots distinct; size large .... *major*
    More or less purplish, discal spots indistinct, of medium size.
      Thoracic patch reddish brown.
        Fore wings dark brown with a purplish flush .... *floridana*
        Fore wings dull whitish lilac, more or less covered with cinnamon-brown scales .... *palmii*
      Thoracic patch ocherous .... *modesta*
  Color yellowish buff.
    Thoracic patch tawny brown .... *perspicua*
    Thoracic patch as pale as the thorax .... *robusta*
Outer margin of primaries entire.
  Primaries dark reddish brown; lines and fringe concolorous .... *integerrima*
  Primaries luteous tawny, the lines and fringe not concolorous .... *contracta*

SYNOPSIS OF THE LARVÆ.

Secondary hairs shorter than primary ones; larvæ moderately hairy.
  Primary hairs (from the warts) and secondary (from the skin) concolorous, pale.
    Stripes very narrow, pale yellow .... *angusii*
    Stripes moderately broad, greenish yellow .... { *ministra* / *californica?* }
    Stripes lemon-yellow, confluent posteriorly .... *drexelii*
  Primary hairs pale, secondary discolorous, dark.
    Secondary hairs black; head red.
      Stripes broken into quadrate spots .... *major*
      Stripes continuous.
        Head dark red .... *floridana*
        Head paler red .... *palmii*
    Secondary hairs brown; head black or red .... *perspicua*
Secondary hairs long, concolorous with primary ones, pale; larvæ very hairy.
  Lines narrow or obsolete .... *integerrima*
  Lines broad, creamy white .... *contracta*

Datana ministra Walker.

(Pl. II; fig. 3, ♂; fig. 4, ♀.)

Phalæna ministra Drury, Illustr. Exot. Ent., ii, p. 25, pl. 11, fig. 3, 1773.
Abbot and Smith, N. H. Lep. Ins. Georgia, p. 161, Tab. lxxxi, 1797.
Pygæra? ministra Harr., Cat. Ins. Mass., p. 73, 1835; Rept. Ins. Mass., p. 312, 1841; ibid., third edit., Pl. VI, figs. 6, 212, 1862.
Pelasia ministra Westw. Edit. Drury, Illustr., 11, p. 27, pl. 11, 1837.
Datana ministra Walk., Cat. Lep. Br. Mus., v, p. 1061, 1855.
Eumetopona ministra Fitch, 2d Rept. Nox. Ins. N. York, p. 235, pl. 4, fig. 3, 1856; 3d Rept., p. 19, 1857.
Datana ministra Morris, Synopsis, Lep. N. Amer., p. 247, 1862.
Grote, New Check List N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 613, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 197, 1894.

Larva.

(Pl. X, figs. 1, 1*a*, 1*b*, 1*c*, 1*d*, 1*e*.)

Abbot and Smith, Lep. Ins. Georgia, p. 161, Pl. LXXXI, 1797.
Harris, Ins. Inj. Veg., 1st edit., p. 312, 1841; Ins. Inj. Veg., 2d edit., p. 332, 1852.
Fitch, 2d Rept. Nox. Ins. N. York, p. 237, 1856; 3d Rept. Ins. N. York, p. 337, 1857.

Harris, Ins. Inj. Veg., Flint's edit., p. 429, 1862.
Grote and *Robinson* (quote Angus in lit.), Proc. Ent. Soc. Philad., vi, p. 11, 1866.
B. D. Walsh, Practical Entom., ii, p. 7, 1866.
Harris, Entom. Corresp., p. 308, pl. 2, fig. 1, 1869.
Le Baron, 4th Illinois Rept., p. 186, 1873. Life history (figs.).
French, Trans. Dept. Agr. Ill., xv, p. 189, 1877.
J. Marten, Trans. Dept. Agr. Ill., xviii, Append., p. 119, 1880.
D. Coquillett, Trans. Dept. Agr. Ill., xviii, Append., p. 167, 1880.
W. Saunders, Ins. Inj. Fruits, p. 61, 1883.
W. Beutenmüller, Can. Ent., xx, p. 16, 1888. (Egg and all the larval stages.)
Lugger, Bull. 10, Agr. Stat. Univ. Minnesota, p. 78, March, 1890. Pl. I, fig. 5, larva; Pl. II, fig. 5, moth.

Moth.—Fore wings and base of thorax above cinnamon (Ridg.,[1] III, 20); costal shade russet (Ridg., III, 16), not well marked. Thoracic patch ochraceous (Ridg., V, 7) in front, shading posteriorly into chestnut (Ridg., IV, 9). Lines and discal dots as in *D. angusii*, but the discal dots are frequently obsolete, and the outer one, when well marked, is seldom linear. The sparse irroration, lines, discal dots, and fringe all concolorous, mars brown (Ridg., III, 13). Outer margin of fore wings distinctly scalloped, and hind wings also perceptibly so. Hind wings pale straw-yellow, cream buff (Ridg., V, 11), immaculate or slightly shaded with brown; abdomen a little darker. Underside a little darker than hind wings above, shading into brown on fore wings, especially toward the outer margin. Fringe dark, as above.

Expanse of wings, 42–53 mm.

Paler in color than *D. angusii*; darker than *D. californica*; distinguished from *D. drexelii* and *D. major* by its smaller size and less distinct discal dots; from *D. drexelii* further by the absence of a strongly contrasting costal shade; from *D. major* by the usually paler secondaries; but in this last instance specimens may occur very difficult to distinguish (Dyar).

The following description of preparatory stages of *Datana ministra* is by Mr. Beutenmüller (Can. Ent., xx, p. 16):

Egg.—Pure white, ovoid, with flattened base, the apex with black dot showing impregnation. Laid in masses, from 25 to 50 on underside of leaf.

Young larva.—Head black, shining, second segment orange-brown in front, cervical shield black. Body-color chestnut-brown, with the stripes a little darker, anal clasps and thoracic feet jet black. Length, 3 mm.

After first molt.—The head jet black, as is also the whole of the second segment and anal segment. Body-color now much darker, as are also the stripes, these being almost obscured, except along the lateral region. Thoracic feet black. Length, 12 mm.

After second molt.—Head black, rather small; second segment yellow except the cervical shield, black. The thoracic feet, abdominal and anal legs, and termination of anal segment jet black, while the stripes are very clear yellow on the chestnut-brown ground. Scattered over the body are also a few short sordid white hairs. Length, 20 mm.

Until after this molt the larvæ feed upon the underside of leaf (parenchyma), and do not attack the edges until after the third molt begins.

After third molt.—Head jet black, second segment orange, cervical shield black. Body color reddish brown with rather broad yellow stripes; anal clasps, tip of legs, and thoracic feet jet black; underside striped equally with reddish brown and bright yellow. Length, 30 mm.

After fourth molt.—Head jet black, neck yellow, cervical shield jet black, shining. Body chestnut-brown, the stripes bright yellow and equidistant; the feet and anal clasps jet black, abdominal legs yellow-banded, with jet black outside. The hairs over the body are now quite long. Length, 33 mm.

Stage next to last.—Length, 26 mm. Head black, as wide as the body. First thoracic segment black. The body is yellow, not greenish yellow, as in the adult, and the stripes are reddish brown, the color of brown roofing slate. Just before molting the first thoracic segment becomes gamboge-yellow on the plate and straw-yellow around the edges. A broad dorsal reddish-brown line, fully twice as wide as the others. There are four lateral stripes, all of the same width, the yellow spaces between them only a little more than one-half as wide as the brown bands. The third brown band includes the black spiracles. Thoracic feet black; suranal plate and anal legs black; middle abdominal legs dark, four of the legs pale livid reddish; plantæ pale. The hairs are minute, short, not apparent without a lens.

The head and thoracic segments often held bent over backward, so that the thoracic feet stick up, while the tail is so bent up as to nearly meet the head.

Last stage.—Length, 30 mm. Head black. Body with white, conspicuous hairs, many of them one-third longer than the body is thick. The body is now distinctly greenish yellow, and the prothoracic plate gamboge-yellow,

[1] See Ridgway's Nomenclature of Colors.

The stripes are black, not reddish dark brown, as before. The third or spiracular band is a little wider than before, and continued on to the prothoracic segment under the gamboge-yellow plate. Base of the legs and space around and between them honey-yellow, not dull reddish yellow, as in the previous stage. Middle abdominal legs reddish yellow, with a large black chitinous plate above the planta.

Among 77 specimens, forming a cluster on an apple tree at Salem, Mass., all molted August 18 into the last stage. There was no variation among these, except very slight differences in the width of the green stripes.

The larva spins no cocoon, but enters the ground to pupate.

Pupa.—Of the usual shape. End of abdomen obtuse, cremaster with a short bifid spine, each fork ending in two spinules, with an external shorter mesial one at base.

Habits.—From Mr. D. S. Harris, of Cuba, Ill., we learn that in 1882 the caterpillars of this species were "so abundant on the black walnut that many persons have cut down their walnut trees when they were near their houses." The larva is to be found from the latter part of July to the last of September. It is single brooded. It occurred at Providence, R. I., on the birch, September 10–12.

The characteristic attitude of this, as other species, when disturbed, is to raise the head and tail, each about as much as the other, the entire caterpillar forming three sides of an oblong square. When feeding, the last fourth of the body is slightly elevated. The larvæ remain clustered together throughout life, until they disperse to pupate.

Mr. Lugger states that the eggs are deposited, several hundred together, in a patch upon the underside of terminal leaves. Each egg is white and spherical. In Minnesota the caterpillars "frequently occur in vast numbers, entirely defoliating our largest oaks." The moth in Minnesota issues late in June or early in July.

Mr. Lugger found one caterpillar covered with 249 eggs of a Tachina fly.

Eggs, June (Riley); larvæ, August, September, October, and November (Riley); moth, May, July, and August (Riley).

Food plants.—Apple, pear, cherry, quince, linden, walnut, hickory, oak of various species, chestnut, beech, hazel, hornbeam, birch, locust, etc. (Beutenmüller). In Kansas, *Betula nigra* (Popenoe) and *Quercus palustris* (Popenoe); hickory, birch, oak, sumac, and walnut (Riley).

Geographical distribution.—Orono, Me. (Mrs. Fernald); Brunswick, Me. (Packard); Salem, Mass., Boston (Harris, Packard); Amherst, Mass. (Mrs. Fernald); New York (Angus, Beutenmüller, Dyar); New Jersey (Palm); Chicago (Bolter, Westcott); Pennsylvania (Strecker); Manhattan, Kans., June 13 (No. 5) (Popenoe); Canada, New Hampshire, Maine, New York, New Jersey, Pennsylvania (Palm); Missouri, District of Columbia, and Virginia (U. S. Nat. Mus.); New York, New Jersey, Ohio, Wisconsin, Champaign, Ill., California (French).

Datana californica Riley (inedited).

The only notes we have on this unpublished species are the following:

Datana Californica.

Dyar, Trans. Amer. Ent. Soc., xxi, p. 198. 1894.

Larvæ, October 13, also adult; Santa Clara County, Cal.

NOTE.—These larvæ have been known to fruit growers at Santa Clara for several years back as doing injuries by stripping whole rows of apple and plum trees. They do not attack pear trees. A few larvæ were still present on October 13, 1887, and about the defoliated trees many pupæ were found in the loose, dry soil, but most numerously among bunches of grass, where they frequently occurred several together. (Riley.) Professor French also reports it from California.

Dr. Dyar informs me that Dr. H. H. Behr has found the larvæ on the oak near San Francisco, but failed to obtain the moth. "According to recollection, it is just like *ministra*, but paler throughout; about the color of *Nadata behrensii* (pinkish buff)". (Ridgway, v. 14.)

Datana californica ?.

(Pl. XI, fig. 1, 1*a*–1*c*.)

I have received nine or ten larvæ from Olympia, Wash., from Mr. Trevor Kincaid, who sent them early in October, and one of which lived on until the second week in November, the others pupating in the earth. They were feeding on *Quercus garryana*. I have also received (August 1) several of the same species or variety from Judge P. C. Truman, of Volga, S. Dak., which differs from the same form only in slight respects (i. e., the yellow spot below the suranal plate), and which also lives on the oak. I will first describe the Oregon specimens from life.

Larva.—Length, 35 mm. Head black, rough, punctured, coarsely so below the vertex: the punctures more or less confluent on the sides and in front, with fine lines and ridges. Shape of the body as in *D. ministra:* prothoracic shield entirely ocher yellow (not lemon or sulphur yellow), the yellow extending down each side of the plate and, as in *D. ministra*, crossed longitudinally by a black line, below which is an ocherous yellow line. Body on each side with five narrow, somewhat wavy, lemon or greenish yellow lines; the fourth or lateral line wavy or scalloped and interrupted at the sutures; the fifth line broken and represented by short portions between the thoracic and the abdominal legs. All the lines are narrower than in *D. ministra*. Thoracic legs entirely black ocherous around the base, but not so much so as in *D. ministra*. Middle abdominal legs ocherous, with an external dusky brown, not black, not very large patch just above the planta. Two ocherous patches behind the thoracic, and behind the fourth pair of abdominal legs in the place where the abdominal legs would be if present; these patches as in *D. ministra*, but smaller. Of the four unbroken lines the three subdorsal ones are continuous; the uppermost or dorsal one is slightly narrower than the third one from the top or middle of the back. The ventral median line is broad and continuous, also lemon-yellow, like those above. End of the body black, the yellow lines scarcely reaching the tenth segment, and not coalescing under or below the suranal plate, as they do in *D. ministra*. In this respect the larva is more as in *D. angusii*, though in the South Dakota specimens two of the lines do coalesce and form a small yellowish patch. The body is hairy, much as in *D. ministra* in color, being pale gray or testaceous, i. e., pale tawny and not white, as in *D. angusii*. The hairs are long and abundant, those of the thoracic and three last abdominal segments longer than the others; the short dorsal ones form tufts, nearly meeting over the middle of the back, and the lateral pairs are grouped in tufts directed downward.

FIG. 54.—Pupa of Datana from Olympia, Wash. Dorsal view of head.

I at first referred the larva to *D. angusii* on account of the narrow lemon-yellow lines, but it differs from that species in having one more lateral line, the ventro-lateral one (though in a blown specimen of *D. angusii* given me by the late Mr. Elliot, this line is represented by a faint yellow mark on each segment); it also differs in the prothoracic plate being always ocher-yellow; also the thoracic segments between the legs are not "purplish black," but ocherous yellow.

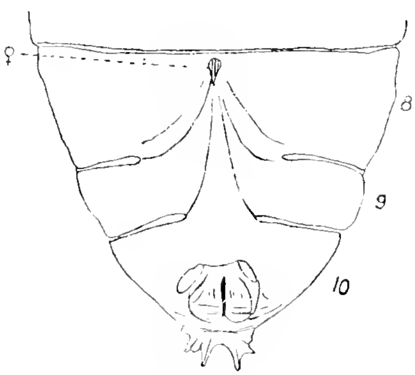


FIG. 55.—Pupa of Datana from Olympia, Wash.

It differs from *D. ministra*, to which it is nearest allied (and in this respect I agree with Dr. Dyar, to whom I sent specimens) in the narrow lemon rather than sulphur yellow lines, in these lines not being confluent on each side below the suranal plate (though in the South Dakota specimens slightly so), and in the ventro-lateral or fifth line not being so distinct. The body beneath with ocherous patches, but smaller, less extensive than in *D. ministra*, the latter, however, differing in this respect in different sets of specimens.

This may prove to be a climatic variety of *D. ministra:* I should certainly think so if its food plant in South Dakota and in Oregon were the apple, as we should hardly expect to find any species of the genus on the Pacific Coast, though *D. californica* may be authoctonous. The South Dakota specimens are in one respect, i. e., the small yellow bands on the sides of the tenth segment, intermediate between *D. ministra* and the Oregon examples.

The following is a description from life of the South Dakota specimens:

Larva.—Length, 17 mm. Head large, black; prothoracic shield ocherous yellow. Body black, with five narrow lemon or greenish yellow stripes on each side, all of nearly uniform width; the longest (fifth) are broken and not readily seen; end of the lines confluent on the tenth abdominal segment, forming a small ocherous spot below the suranal plate. A median ventral greenish yellow line. Thoracic legs black, greenish at the base; abdominal legs black on the outside, but greenish yellow at base within and on the plantæ. The body is dusted quite densely with long and abundant pale whitish gray hairs, those of the thoracic and eighth and ninth abdominal segments much longer than the others; the short dorsal hairs on the second and third thoracic and fourth to eighth abdominal segments forming tufts meeting over the middle of the back, while the lateral hairs are grouped in tufts which are directed downward.

Pupa.—The following description is that of the pupa of the Olympia, Wash., larva, ♀: Head a little less prominent than in pupa of *D. angusii*, not distinctly notched, and the ridges much less distinct. Body elongated, not very plump, suddenly pointed at the end, and bearing a large, broad cremaster ending in four spines, the two inner ones the longer, and with a small lateral spine at base. Surface of the body and abdomen coarsely punctured. Length, 20 mm.

Datana angusii Grote and Robinson.

(Pl. II, fig. 1, ♂; fig. 2, ♀.)

Datana angusii Grote and Rob., Proc. Ent. Soc. Phil., vi, p. 9, 1866, pl. 2, fig. 1.
Grote, New Check List N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het. Br. Mus., i, p. 613, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 197, 1894; Journ. N. Y. Ent., Soc. ii, p. 116 Sept., 1894.

Larva.

(Pl. X, fig. 2.)

Grote and Robinson, Proc. Ent. Soc. Phil., vi, p. 10, 1866. (Last larval stage.)
Beutenmüller, Can. Ent., xx, p. 135, 1888. (Last larval stage.)

Moth.—Exterior margin of fore wings excavated between the veins in both sexes. General color above and below smoky brown (mars brown, Ridgway's Nomenclature of Colors, Pl. III, fig. 13), but paler, shading into burnt umber (Ridg., III, 8) along costal edge of fore wings. The dark quadrate patch which covers the head and the anterior part of the thorax is burnt umber, shading darker posteriorly. Fore wings sparsely irrorate, with brown-black scales, crossed by five transverse lines which, with the apical streak, discal dots, and fringe, are concolorous. The lines have the same arrangement as in all the species of the genus and are not quite constant in their course. The first one crosses the wing at the basal third and is greatly arcuate; second at about the middle, passing outside of the rounded obscure inner discal dot and either inside or through the outer elongate, sublinear discal dot situated on discal cross vein; third line intermediate between second and fifth; fourth contiguous to fifth, which is at the outer third of wing; the fourth line is narrower than the other, and often obscure. All these lines, except first and fifth, are obscure on the costal edge. Apical streak short from just below apex or outer margin, and runs inward and downward, ending at about vein 4. Anterior to the streak, and between the median vein and costa, the wing is of a brighter tint, constructing the costal shade seen in all the species. Hind wings and abdomen evenly concolorous, mars brown, the abdomen darker at tip. Below uniformly paler than hind wings above; the body parts a shade darker. Primaries shading darker toward the apices; the fringe brown black, as above.

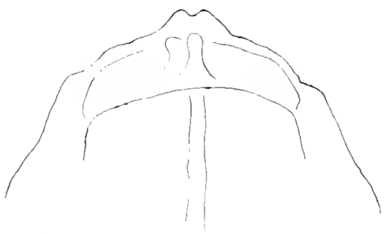


Fig. 56.—Pupa of *Datana angusii*. Head dorsal view.

Expanse of wings, 46–53 mm.

This species is marked exactly like *D. ministra* and *D. californica*, but differs in the dark smoky-brown color throughout. From *D. integerrima*, with which it is often confounded, it differs in the scalloped outer margin of the fore wings, the dark hind wings, nearly concolorous with the primaries, and in the comparative scarcity of irroration on the primaries and the absence of pale shades bordering the transverse lines (Dyar).

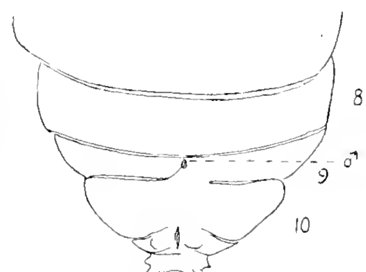


Fig. 57.—Pupa of *Datana angusii*. End of body.

Egg.—Laid in irregular patches of about 75 on the underside of a leaf; oval cylindrical, larger at the lower end by which they are attached, bulging out a little above the base, and contracting toward the top, which is somewhat crater-like; the micropyle dark, distinct, and situated at the bottom of a saucer-like depression; outside and below the rim of this crater is usually (not always) an irregular crenulated edge or rim, which is partly eaten away by the larva in escaping from the egg. The shell is smooth, polished, not pitted when examined by a strong lens, milk white, and resembling cheap white earthenware pottery. Under a ½ inch A eyepiece the shell is seen to be ornamented with fine polygonal areas, but those of the lower part of the egg are not distinctly six-sided, being less regular and distinct than in the egg of *D. palmii.* Diameter about two-thirds mm., being considerably less than the height.

Larva.—The specimens here described were received under the above name from Mr. James Angus, September 4. I failed to note their length, but they were nearly, if not quite, full-grown.

Head black, including the mouth-parts. The prothoracic shield is distinct, transversely oblong, black. Body black, with four narrow, pale whitish yellow stripes on each side. The two dorsal stripes are wide apart, leaving a broad dorsal median black stripe; the space between the first and second line is a little wider than between the second and third; the fourth line is slightly wider than the others, scalloped, and interrupted by the sutures between the segments. Beneath the lateral ridge along the base of the legs is an irregular livid purplish stripe beginning on the third thoracic segment. There are no hairs along the back, and those along the side are unusually short and are pale grayish in color. The body beneath is black, with a median livid pinkish line along the abdominal segments, widening between the abdominal legs, and ending on the seventh segment, the end of the body, including the anal legs, being black.

The following account of its transformations is copied from Beutenmüller:

> *Egg.*—Similar to that of *D. ministra;* can not be distinguished from it. Laid in masses on the underside of leaf.
>
> *Young larva after first and second molts.*—Can not be distinguished from those of *D. ministra.*
>
> *After third molt.*—Little change except in size. The stripes are now confluent about the anal segments. Length, 30 mm.
>
> *After fourth molt.*—Head jet-black, cervical shield now chestnut brown instead of black; otherwise as in *D. ministra.* Length, 40 mm.
>
> *Mature larva.*—Head jet-black, shining, slightly punctured; cervical shield and neck wholly golden-yellow. Body black, with four equidistant stripes of citron-yellow on each side and three on the underside. Abdominal legs and bases of thoracic feet orange. The stripes all become conjoined at the posterior extremity. The anal plate jet-black, very shiny and nearly smooth, and not roughly punctured, as in *D. ministra.* The hairs over the body are sordid white. Length, 55 mm. Single brooded.

Mr. Beutenmüller writes me that "the young larva of *D. angusii* is different in coloration from all the other known species. The first and third thoracic segments are wine colored, as are also the dorsal region of the fourth, fifth, and seventh abdominal segments, and the body is greenish brown, provided with the usual number of yellow longitudinal stripes."

Habits.—At Salem, Mass., I found (August 26) 14 full-grown larvæ and 10 others in the fourth stage; early in the morning of August 28 these had molted and begun to feed. Larva in July and August; moths April to July, District of Columbia and Maryland (Riley).

Pupa.—Body rather stout, surface very coarsely punctured, the pits more or less confluent, especially on the thorax; head prominent, deeply notched at the end, and with two prominent parallel ridges in front, with a deep valley between. The four terminal spines of the cremaster equal in length and shape. On each side of the common base is a conical projection. Length, 15 mm (Figs. 56, 57).

Food plants.—Hickory (*Carya*) and walnut (*Juglans*) Beutenmüller; linden (Packard). In Manhattan, Kans., Betula (Popenoe), black walnut and hickory (Riley).

Geographical distribution.—Brookline, Mass. (Shurtleff Mus. Bost. Soc. Nat. Hist.); Jamaica Plain, Mass. (Jack, Mus. Comp. Zool.); Beverly, Mass. (Burgess, Bost. Soc. Nat. Hist.); Plattsburg, N. Y. (Hudson); Chicago, Ill. (Bolter); Illinois, Pennsylvania (Strecker); Auburn, Me. (Mrs. Fernald); Salem, Mass. (Packard); West Farms, N. Y. (Angus); Missouri and District of Columbia (U. S. Nat. Mus.); New York, New Jersey, Pennsylvania, Arkansas (Palm); Ames, Iowa (H. Osborn); Canada, Rhode Island, New York, Wisconsin, West Virginia, Indiana, Carbondale, Ill. (French).

Datana drexelii Edwards.

(Pl. II, fig. 5, ♂; fig. 6, ♀.)

Datana drexelii H. Edw., Papilio, iv, p. 25, Feb., 1884.
Smith, List Lep. Bor. Amer., p. 30, 1892.
Kirby, Syn. Cat. Lep. Het., i, p. 613, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 198, 1894; Journ. N. Y. Ent. Soc., ii, p. 116, Sept., 1894.

Larva.

(Plate XI, figs. 2, 2*b*, 2*c*, 3.)

Edwards, Papilio, iv, p. 25, 1884.
Beutenmüller, Can. Ent., xx, p. 57, 1886.
Dyar, Psyche, v, p. 418, 1890.

Moth.—Exterior margin of the primaries less distinctly scalloped in the ♂ than in the ♀, but fore wings distinctly so in both, with the markings as in *D. ministra*, but larger, and the costal shade is bright, distinct, contrasting. Its tint is ochraceous (Ridg., V, 7). Thoracic patch tawny ochraceous (R., V, 4) in front, shading darker, as in *D. ministra*. Discal dot large and distinct, darker than the line ("Prouts brown," R., III, 11), the inner round, outer elliptical. Hind wings darker than is usual in *ministra*, shaded, somewhat powdered with russet (R., III, 16), a faint paler extramesial band sometimes perceptible. Underside essentially like *D. ministra*. Occasionally a dark shade, concolorous with the lines, fills up a part or most of the space between the first and fifth line below the costal shade. Expanse of wings, 48–55 mm (Dyar).

Egg.—Subspherical, shell thick opake, porcelain white; micropyle smaller than in *D. major*, see p. 116.

Larva, Stage I.—"Head rounded, black, shiny; width, 0.5 mm. When nearly hatched the larva is scarcely distinguishable from *D. major*. The anal feet are rather long and elevated. Body sordid yellow, cervical shield, anal plate, and feet blackish. A number of short hairs from the head and from about six rows of small blackish tubercles, which are larger in proportion than in the subsequent stages. As the stage advances the body becomes reddish, with four lateral stripes on each side and three ventral, about as wide as the intervening spaces, dull yellow and confluent posteriorly. During this stage the larvæ eat the parenchyma in the same manner as *D. major*. I have estimated that a single larva eats about 90 sq. mm. of witch-hazel leaf."

Stage II.—"Head black and shiny, with a few hairs; width, 1.1 mm. Body brown, stripes dull yellow, narrower than the intervening spaces, extending from the cervical shield and the anterior edge of the prothoracic segment to the anal plate, and becoming a little confluent there. Cervical shield, anal plate, thoracic and anal feet, and the abdominal feet outwardly black. Hairs short and pale. During this stage the larvæ eat the whole leaf."

Stage III.—"Head higher than wide, depressed at the sutures of the clypeus; smooth, shiny black; width, 1.8 mm. Body brown, the stripes yellow, confluent posteriorly and along the anterior edges of the prothoracic segment. Otherwise as in the previous stage."

Stage IV.—"Head shaped as before, smooth, centrally depressed at the top of the clypeus and more slightly along the central suture; clypeus and labrum wrinkled; all shining black; width, 3.2 mm. Cervical shield black or partly brown; in some examples nearly all light brown; anal plate, thoracic feet, and the abdominal feet outwardly black. Body black or partly brown, the anterior half of the prothoracic segment yellow, the stripes strongly confluent on the last segment. The bases of the legs and corresponding spots on the legless segments, as in the mature larva, of a darker yellow than the lines. Each segment is shaded centrally with this yellow, but it does not cause the lines to appear confluent, on account of its darker shade. Hairs sordid white, besides other short, fine, brownish hairs seen with a lens."

Stage V.—"Head as high as wide, flattened in front, depressed at the upper part of the sutures of the clypeus, punctured. Clypeus and labrum somewhat wrinkled. Color shiny black, the antennæ and palpi white ringed, their bases greenish. Width, 5.4 mm. Body black, cervical shield honey yellow; anal plate, thoracic and anal feet, and the abdominal feet outwardly black. Anterior half of the prothoracic segment yellow; stripes narrower than the spaces, citron-yellow, running into the yellow part of the prothoracic segment, and confluent posteriorly on the tenth abdominal, which is all yellow except the anal plate and a dorsal band. The three upper lateral lines are connected also on the eighth and ninth abdominal segments by a broad, dark yellow shade. The bases of the legs and corresponding spots on the apodous segments (on the first, second, and seventh, eighth, and ninth abdominal segments) also dark yellow, forming expansions of the subventral line and reaching the lowest lateral line, except on the thoracic segments and the ninth abdominal. On the apodous segments in the center of each yellow patch is a small, black spot, representing the absent legs, but this is not present in all examples. Hair rather abundant, sordid white, the long and short hairs concolorous, arising from minute blackish tubercles which, in the black parts of the body, are each surrounded by a minute yellow ring."

"*Pupa.*—Exactly like that of *D. major:* the two cremasters each bear three spines in a transverse row, the posterior one the longest. Length, 28 mm.; width, 10 mm.

"Single brooded, the winter being passed in the pupa state beneath the ground. The duration of the larval stages was as follows: First stage, five days; second stage, six days; third stage, six days; fourth stage, seven days; fifth stage, seven days.

"*Food plants.—Hamamelis virginica, Vaccinium stamineum.*

"Larvæ from Ulster County, N. Y."

(Dyar, Psyche, Vol. v., 1888–1890, pp. 418–420.)

Food plant.—High bush huckleberry (*Vaccinium corymbosum*), Hamamelis (Elliot and Edwards); *Tilia*, Popenoe.

Geographical distribution.—New York (Beutenmüller, Dyar): New York and New Jersey (U. S. Nat. Mus.): Plattsburg, N. Y. (Hudson): New York (French).

The belated larvæ of what I regard as *D. drexelii* (Pl. XI, fig. 2) occurred on the sassafras at Providence, R. I., October 3, and are described as follows:

Length, 26 mm., head black, body pale yellow ocher, prothoracic segment yellow; cervical plate transversely oblong, shining brown-black. Dorsal and subdorsal region of the body of a peculiar pale reddish vandyke brown, inclosing eight lines which are lemon-yellow, thus slightly differing in hue from the body beneath and on the sides. The dorsal and first or upper subdorsal lines somewhat wider than the two lines beneath, and the lowest or fourth (infraspiracular) line is waved and twice as wide as those above. Spiracles minute, black, situated in the pale reddish brown band above the fourth or lateral yellowish line. The ninth abdominal segment pale yellow ocher, the lines ending in this area, though not blending with each other before reaching the ninth segment. A ventral lemon yellow median line, with a broad, pale reddish brown band on each side. Thoracic legs black; the four pairs of middle abdominal legs externally tipped with black; anal legs slender, black. Suranal plate small, transversely oval, its surface shining black, with irregularly scattered punctures and piliferous depressions rather than warts, from which about twenty black and a few gray hairs arise. The hairs on the body are few and scattered, and no longer than the body is thick; they are uneven in length and pale in color.

Datana major Grote and Robinson.

(Pl. II, fig. 7, ♂; 8, ♀.)

Datana major Grote and Rob., Proc. Ent. Soc. Phil., vi, p. 12, May, 1866, pl. 2, fig. 30.
Grote, New Check List, N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 613, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 198, 1894.

Larva.

(Pl. XII, figs. 1–6.)

Andrews, Psyche, ii, p. 272, 1878.
Dyar, Can. Ent., xxi, p. 34, 1889.

Moth.—Exterior margin of primaries less distinctly scalloped than in any of the preceding, less in the ♂ than in the ♀. Of the size of *D. drexelii*, but almost identical with *D. ministra* in coloration. The tint is a little darker, and the secondaries are dark, darker than in *D. drexelii*, and almost concolorous with primaries. The discal dots are large and distinct, exactly as in *D. drexelii.* Otherwise the moth is the same as its allies.

Expanse of wings, 47–60 mm.

From *D. drexelii* it differs in the absence of the bright costal shade, the more uniform coloration; from *D. ministra*, as already pointed out under that species. With the other species it could scarcely be confounded. (Dyar.)

Egg.—Of nearly the same size and shape as in that of *D. drexelii*, but considerably smaller than that of *D. palmii*. Differs from that of *D. drexelii* in the upper end with the micropyle being somewhat depressed. It is round, barrel shaped, the shell porcelain white. The micropyle is somewhat larger than that of *D. drexelii*. Described from living specimens received from Miss C. G. Soule.

Larva.—I have not seen the larva alive. The excellent figures kindly loaned me by Miss Morton well represent this species, which is readily recognized by its checkered appearance.

The following description of the eggs and larval stages has been kindly sent me by Dr. Dyar:

Egg.—Laid in patches of 90, 95, 102, on underside of leaf of the food plant, *Andromeda ligustrina*. Cylindrico-pyriform, being of less diameter just below the summit, flattened at base and vertex. Uniform white, with a rather large central black spot at vertex. Diameter, 1.1 mm.; height, 0.7 mm.

Larva, first stage.—Head round, shining black; width, 0.5 mm.; cervical shield, anal plate, thoracic and anal feet, and leg-plates black. Body wine-red, a broad subdorsal and lateral yellow band, each containing a narrow red line. No lines on venter. Hairs, several from a wart, the warts minute, dark brown; no secondary hairs.

Second stage.—Head shining black or with a slight brownish tint, rounded, rather higher than wide; width, 1.1 mm. Body dark wine red, the bands as before, greenish yellow; venter with a narrow central pale yellow line. Later the bands become almost white. Besides the hairs from the warts, short, fine, secondary hairs are present on the skin.

Third stage.—Head higher than wide, narrowing toward apex, the sutures depressed. Color red-brown, the ocelli and mouth black; width, 1.6 m. Cervical shield black or partly orange; feet and anal plate shining black. Body blackish brown, the stripes at first as before, but later they appear as four very broad, lateral, clear white (or bright yellow) bands, with slight traces of the ventral lines. In a few the pedal line is tolerably distinct, but narrow. Bases of the legs and corresponding spots on legless segments dark wine-red. Hairs not abundant, pale, the secondary ones very short.

Fourth stage.—Head as before; width, 3.4 mm. Body black, the side stripes much broader than the intervening spaces, continuous, clear white (or yellow). The ventral stripes (two pedal and medio-ventral) are represented by a few linear dots or are absent. Cervical shield light brown; anal plate black or partly brown. Thoracic, anal feet, and leg plates black, the bases of the feet red, as before. The stripes are not confluent at either extremity.

Fifth stage.—Head rounded, as high as wide, shagreened, shining; color, orange-brown or light mahogany-red; width, 5.3 mm. Cervical shield, anal plate, bases of legs, and corresponding spots on legless segments mahogany-red. Anal and thoracic feet blackish. Body black, the ventral lines as before, but the lateral are broken by the black ground color into a series of subquadrate spots, as follows: The two upper lines are broken in all the segmental incisures and broadly through the center of the segment; the third (lateral) is broken in the same manner, but less broadly in the center of the segment, while the fourth (substigmatal) is not broken in the incisure nor center of the segment, but once before the spiracle and again toward the posterior edge of the segment. The spottings are partially obsolete at the extremities. Primary hairs arising from the wart-areas long, white; secondary ones very short, black. There are two forms of this larva in which the spots are pure white or bright yellow, respectively.

Larvæ from Dutchess and Ulster counties, N. Y. (Dyar.)

Pupa.—♂ and ♀. Head rather prominent, roughly corrugated, with the three frontal ridges moderately well marked; the head is broader and the ridges less marked than in *D. perspicua*. Thorax and body coarsely punctured, but not so much so as in *D. perspicua*. The body is less dull, more shining than in *D. perspicua*: in the latter species the metanotum varies in being either punctured or not. Cremaster almost exactly as in *D. perspicua*, but the underside is nearly smooth, not so coarsely corrugated, and without the six longitudinal ridges of *D. perspicua*: the four spines are nearly as in *D. perspicua*. The ♀ has one sexual scar, which is long and linear; in the ♂ the region on each side of the genital fossa or scar is regularly swollen, the surface convex. The transverse fossa at the base of the tenth abdominal segment with five or six teeth, the teeth less ridge like and regular than *D. perspicua*.

Remarks.—Vestiges of the abdominal legs appear in these pupae. On the fifth and sixth segments is a pair of irregular tubercles, none exactly alike, the left one on the fifth abdominal segment being conical. The rudiments of the anal legs are quite distinct. In pupa of *D. perspicua* there are faint vestiges of legs on the sixth segment. Vestiges of abdominal larval legs, due to their being imperfectly absorbed during the process of pupation, were also observed in the pupa of a Datana from Olympia, Wash., indicated on fourth and fifth abdominal segments by a deep crescentiform depression, perhaps representing the outer and inner edge of the planta. Similar vestiges were observed in the pupa of *D. angusii*. For specimens I am indebted to Miss Ida M. Elliot. The markings of the larva whose lines are divided into spots, indicates that it may be the latest form of the genus.

Habits.—Eggs of second brood deposited July 25; larvae of second brood in July, August, and September, New York and Maryland. (Riley.) "They always keep in close clusters and feed together." (Le Conte.)

Food plant.—*Andromeda ligustrina*, and in Georgia on *Andromeda mariana*.

Geographical distribution.—New Bedford, Mass. (Miss Elliot); Massachusetts (Mrs. Fernald); Narragansett Pier, R. I., and Newburg, N. Y. (Miss Morton), (U. S. Nat. Mus.); Maryland (Stratton Coll. Ent. Soc. Phil., U. S. Nat. Mus.); Arkansas (Palm); New York, Tiffin, Ohio; Maryland. Savannah, Ga. (Le Conte); Carbondale, Ill. (French).

Datana floridana Graef.

(Pl. II, fig. 11, ♂; 12, ♀.)

Datana floridana Graef, Bull. Brooklyn Ent. Soc., ii, p. 37, Sept., 1879.
Grote, New Check List N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 613, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 198, 1894; Journ. N. Y. Ent. Soc., ii, p. 116, 1894.

Larva.

(Pl. XIV, fig. 1.)

Koebele, Bull. Brooklyn Ent. Soc., iv, p. 21, 1881.
Dyar, Psyche, vi, p. 573, 1893.

Moth.—As in *D. palmii*, but browner, the pale scales less prominent, the lines less contrasting, obscure. The discal dots are, however, more distinct than in *D. palmii*. Secondaries more heavily tinged with brown. The Florida specimens show very little of the whitish or pale lilac tint, while specimens from Long Island are almost as pale as *D. palmii* from the Catskills.

Save *D. palmii*, the species has no very close allies. In general appearance it comes nearest to *D. integerrima*, but differs obviously in its purplish tint and entire lack of pale shades bordering the lines. (Dyar.) (For Dyar's description of the larva see Appendix A.)

Larva.—"The larva is black, with eleven parallel yellowish lines running the full length of the body. There is one immediately between the legs under the body, one on the line of, and interrupted by, the legs, the rest above and equidistant from each other, leaving the back with a somewhat broader black space. The head, the summit of the body-segment, the anal covering, and the summits of all the legs are deep mahogany-red in color. The feet are all black; those on the last segment are partially aborted.

Habits.—"It has the habit, which seems to be common to the genus, of raising and throwing back the head and tail over the body when disturbed." (Koebele.) Larvae in October, moths in March, Florida (U. S. Nat. Mus.).

Food plant.—*Andromeda mariana L.* (Riley).

Geographical distribution.—Florida (Graef, French).

Datana palmii Beutenmüller.

(Pl. II, fig. 9, ♂; 10, ♀.)

Datana palmii Beut., Psyche, vi, p. 299, Jan., 1890.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 613, 1872.
var. Trans. Amer. Ent. Soc., xxi, p. 198, 1894; Journ. N. Y. Ent. Soc., iv, p. 116, 1894.

Larva.

(Pl. XIV, figs. 2, 2*a*, 3, 3*a*.

Dyar, Ent. Amer, vi, p. 181, 1890.

Moth.—Thoracic patch burnt umber (R., III, 8), shading into tawny olive on head and collar (R., III, 17). Thorax and primaries of a pale whitish lilac color, between R., II, 13, and R., III, 21, but paler than either, and shading into a brownish tone along the costa; wings rather thickly irrorated with mars brown (R., III, 13) scales, with line and fringe of the same color. Lines 1, 2, and 5, are distinct, the others faint. Discal dot obsolete, represented by faint shades. Secondaries glossy pinkish buff (R., V, 11) more or less tinged with brown. Abdomen darker, especially toward the base. Below even paler than the secondaries above, shading into a brownish tint on primaries, the fringe on these wings being as dark as above. Exterior margin of primaries only slightly scalloped.

Expanse of wings, 40–50 mm.

This form is probably not specifically distinct from *D. floridana*. The color of the pale scales is brighter and they are more numerous, which gives the wing a lighter appearance and brings out the lines more prominently. In the larvæ, that of *D. palmii* has the head and other red parts lighter than in *D. floridana*, being nearly a cherry-stone color in the former and "mahogany-red" in the latter. The stripe may be a little narrower in *D. palmii*, though this is doubtful. (Dyar.)

Egg.—Laid in a patch of 75–80 on underside of the leaf. The egg differs from that of *D. drexelii* in being smaller, thin-shelled, somewhat like fine porcelain. Its diameter is nearly as great as its height. The tip is not depressed, being full, convex, forming a regular cap, which is clearly separated by a slight constriction from the rest of the egg; most of this cap is eaten away by the larva in hatching. Micropyle large, distinct, and dark, from the shell at this place being thin and transparent. Under half-inch objective, A eyepiece, the surface of the shell, including the cap, is seen to be ornamented with fine polygonal areas.

Larva, first stage.—Head black and shining; width, 0.5 mm. Body brown, with four lateral and three ventral dull yellowish stripes wider than the intervening spaces. Cervical shield, anal plate, and feet black. The hairs arise from minute blackish warts. During this stage the larvæ eat only the parenchyma of the leaf, and sit with the extremities of their bodies elevated like the other species of the genus.

Second stage.—Head higher than wide, flat in front, black (in a few examples, brownish), smooth, and shining; width, 0.9 mm.; furnished with a few pale hairs. Body reddish brown, the stripes yellowish. Cervical shield, anal plate, and feet shining black. During this and subsequent stages the larvæ eat the whole leaf, remaining together upon one twig until it is defoliated.

Third stage.—Head black to blackish red in different examples; eyes and mouth black; width, 1.6 mm. Body dark reddish brown, the stripes dull yellow, arranged as in the next stage, the subventral ones interrupted at the bases of the legs and correspondingly on the legless segments. Cervical shield, anal plate, thoracic and anal feet, and the abdominal feet outwardly black. A few short pale hairs.

Fourth stage.—Head higher than wide, rounded, quite flat in front; depressed a little at the sutures at the top of the triangular plate and furnished with a few hairs; color black or blackish red to light mahogany-red, or even orange tinted in different examples of the same brood; the eyes and jaws black, labium and antennæ yellowish; the latter black ringed. Body black, becoming brownish; four lateral stripes, a subventral and ventral one pale yellow, the lateral ones becoming almost white in some examples. All nearly as wide as the intervening spaces. They run nearly to the anterior edge of joint 2, except the first and second lateral, which stop at the cervical shield and end before reaching the anal plate, except the third lateral and the ventral. The subventral line is interrupted by the light reddish bases of the legs and by reddish spots on the legless segments, except on joint 13. Cervical shield, anal plates, thoracic feet, and the abdominal outwardly shining black; the anal plates punctured and narrowly bordered with ocher-yellow. In some examples with red heads this border is broader, and the cervical shield is partly ocherous orange. Hair whitish, thin, and short, growing from minute black tubercles.

Fifth stage.—Head as high as wide, rounded, a little flattened at the extreme front; depressed at the sutures at the top of the triangular plate, and very minutely punctured: a few blackish hairs; color light reddish orange or with a brownish tinge not unlike the color of a cherry stone; labium and antennæ paler, the latter with two black rings; jaws black; eyes blackish. Body black, the stripes pale yellow, the lateral ones in some examples becoming white and in a few canary-yellow; narrower than the intervening spaces, continuous from cervical shield and the anterior edge of joint 2, except the subventral; somewhat interrupted and irregular on joints 12 and 13, and barely reaching the anal plate, except the third lateral. Cervical shield, anal plate, and abdominal feet, except an outward blackish band on the latter, concolorous with the head. Bases of all the legs (except the anal) and corresponding spots on the legless segments darker red. Thoracic and anal feet black. Hair thin, about 5 mm. long, with some short, more numerous, fine black hairs, seen with a lens. At maturity the head is more of a brownish red. Length, about 50 mm. Pupation occurs in a subterraneous cell, and the winter is passed in this state.

Pupa.—Similar in shape and color to those of the other species of *Datana* and not to be distinguished from them. The two cremasters are short, each with three spines, of which the middle one is usually shortest.

Food plant.—*Vaccinium stamineum.* Larvæ from Ulster County, N. Y.

(Dyar in Entomologica Americana, Vol. VI, 1890, pp. 181–183.)

Geographical distribution.—Appalachian subprovince: Delaware Water Gap, Pa., June (Palm ex Beutenmüller, French); Arkansas (Palm).

Datana modesta Beutenmüller.

(Pl. II, fig. 13, ♀.)

Datana modesta Beut., Psyche, vi, p. 297, Jan., 1890.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 613, 1892.
Dyar, Trans. Amer. Ent. Soc., xxi, p. 198, 1894; Journ. N. Y. Ent. Soc., ii, p. 116, 1894.

Moth.—Exterior margin of wings rather distinctly scalloped, almost as much so as in *D. major.* Thoracic patch ochraceous (R., V, 7), scarcely darker posteriorly, paler than the thorax. Thorax and primaries "hazel" (R., IV, 12), but darker than the plate, with scarcely any costal shade. Lines obsolete, the first and fifth just discernible, a shade darker than the wing. Fringe concolorous. Discal dot large, distinct, blackish. At base and terminally, below the obsolete apical streak, a yellowish shade prevails, concolorous with the discal dots. Secondaries, abdomen, and underside almost exactly as in *D. floridana*, but the fore wings are in the present species brighter in tint, and the secondaries lack the peculiar gloss of *floridana* and *palmii.*

Expanse of wings: ♀, 51 mm. (no ♂).

A distinct species, which, in the absence of all knowledge of the larva, finds, we think, its nearest allies in *floridana* and *major.* The type is in the collection of Mr. Charles Palm.

Geographical distribution.—Florida (Graef); Kissimmee, Fla., May (Palm); Florida (Palm, French).

Datana perspicua Grote and Robinson.

(Pl. II., fig. 14, ♂; 15, ♀.)

Datana perspicua Grote and Robinson, Proc. Ent. Soc. Phil., iv, p. 189, 1865, pl. 3, fig. 1; Proc. Ent. Soc. Phil., vi, p. 14, May, 1866.
Grote, New Check List N. Amer. Moths, p. 18, 1882
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 613, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 199, 1894; Journ. N. Y. Ent. Soc., ii, p. 116, 1894.

Larva.

(Pl. XIV, figs. 4, 4*a*, 4*b*.)

Angus in *Grote and Rob.*, Proc. Ent. Soc. Phil., vi, p. 15, May, 1866.
Edwards, Ent. Amer., iii, p. 170, 1887.
Dyar, Can. Ent., xxiii, p. 82, April, 1891. (Egg and all the stages, pupa, etc.)
Packard, Journ. N. Y. Ent. Soc., i, p. 61, June, 1893. (Last three stages.)

Moth.—Exterior margin slightly scalloped. Thoracic patch ocher-yellow (R., V, 9), shading posteriorly into ochraceous (R., V, 7) and finally into tawny (R., V, 1). Thorax and fore wings buff-yellow (R., VI, 19), the latter with a few brown scales, which are absent on the costal portion. Lines, discal spots, and fringe hazel (R., IV, 12). First and fifth line distinct, and second and third very faint on their costal third, the fourth line obsolete. Discal dots large, the outer somewhat diffuse and spreading. Apical streak unusually long and distinct. The three branches of the median vein are outlined distinctly in brown, and there is a faint shading of this color along internal margin centrally. Hind wings very pale buff (R., V, 13), but much paler, without dark shades; underside as hind wings above, the outer edge of primaries darker, with the fringe dark brown, as above.

Expanse of wings, 47–53 mm.

A very distinct species with only one close ally, namely, *D. robusta* Strecker. It differs from all the other species in its bright yellow color. (Dyar.)

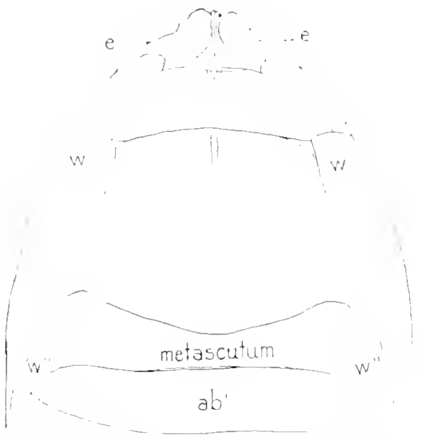


FIG. 58.—Head and thorax of pupa of *D. perspicua* seen from above. *e*, eye; *w*, first pair; *w''*, second pair of wings; *ab'*, first abdominal segment.

Egg.—"In general shape subpyriform; flattened at base and top, depressed centrally at vertex, the usual black spot small and indistinct, situated at the bottom of the puncti form depression; the whole surface punctured. Color, white; the lid like top of a somewhat brighter white. Width, 0.9 mm.; height, 0.8 mm. The egg is of the type of that of *D. major*, but resembles that of *D. ministra* in coloration, by possessing a discolorous lid like top. This is the part of the shell eaten by the young larva in hatching. Laid in masses of varying numbers on the underside of the leaves of the food plant." (Dyar.)

Larva, Stage I.—"Length near the end of the stage, about 5 mm. When first hatched the head is black, 0.5 mm. wide; the body is yellowish, with a reddish dorsal and subdorsal line, not reaching the extremities; cervical shield, feet, and anal plate black. As the stage advances, the body becomes reddish, with four lateral yellow stripes on each side and three ventral, as in its allies, which remain throughout the larval stages. They are nearly as wide as the intervening lateral spaces, a little confluent posteriorly, and are colored yellow. Black hairs arise from small black tubercles and from the elevated anal feet." (Dyar.)

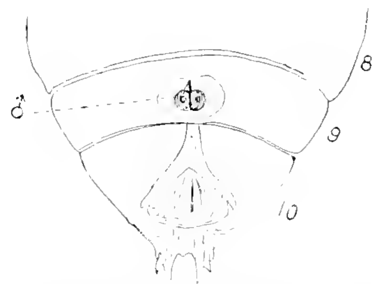


FIG. 60.—Pupa of *Datana perspicua*. End of abdomen, showing the vestiges of the male genital outlet, of the anal legs, and the cremaster.

Larva, Stage II.—"Head higher than wide, slightly punctured, black; width, 1.1 mm. Body parts colored as before. The hair is short, blackish, and arises from minute tubercles that are much smaller than in the previous stage." (Dyar.)

Larva, Stage III.—"Head shiny black, punctured, the clypeus smooth; width, 1.6–1.8 mm. Cervical shield, anal plate, and thoracic feet black. Body dark red, the stripes broader than the intervening spaces, bright yellow; abdominal feet red, the anal pair black. A few short hairs; spiracles small, black." (Dyar.)

FIG. 59.—Pupa of *Datana perspicua*, underside of head.

The specimens described below were received August 23, from Mr. James Angus, and so named by him.

Larva, Stage III or IV?—Length, 17 mm. The head is black, not quite so wide as the body. A shining black chitinous transversely oblong prothoracic shield. The body is moderately hairy, the hairs reddish; it is deep straw or lemon yellow, with eleven pitchy reddish lines; the median dorsal line is much broader than any of the others and broader than the spiracular line; of the two subdorsal lines, the upper is a little wider than the lower; the lowest or infraspiracular line is interrupted by the sutures; the two ventral lines of the same reddish color pass along at and including the base of the thoracic and abdominal legs. The suranal plate is small, shining black. The anal legs are conical, black, except the reddish planta, which is distinctly eversible, being seen at times to be retracted, though armed with hooks. The two paranal plates are dark at the end; the end of the body is constantly upheld. The thoracic and abdominal legs are black.

Immediately after molting one can see the fluids of the body under the neck; the head is cherry-red, while the suranal plate, anal and other abdominal, and also the thoracic legs are pale carneous.

Stage V?—Length at first, 20 mm., becoming the next day 23–25 mm. Body as before, but the stripes are blackish red, there being no other change of importance. The suranal plate is a little larger than before.

Last stage.—Length, 40 mm. Head large, black, as wide as the body. Prothoracic shield dark reddish black.

The stripes are of the same relative width as in Stage III, but have lost their red color, and are brown-black, while the yellow of the body has a greenish tinge. There is no red at all on the prothoracic segment or on the legs or on any part of the body. The suranal plate is large and black, the black median dorsal line wider on the segment in front. The hairs are now whitish and thicker than in the previous stages.

I notice that the hairs on the thoracic segments have at times an individual motion, and are jerked one way and another, as also the warts which give rise to them.

When irritated it discharges a drop of green fluid, its partly digested food.

One pupated September 20, and another a little later.

Pupa.—Body long, but not very thick. Head projecting in front, with three ridges, one median. Cremaster with four long equal acute spines, the points long and tapering, almost setiferous; surface rugose. A lateral small, stout spine on each side of the base. The vestiges of the ♂ sexual opening broad, with a round tubercle on each side. Surface of the body corrugated with confluent punctures on head and thorax; abdomen coarsely punctured. Length, 22 mm.

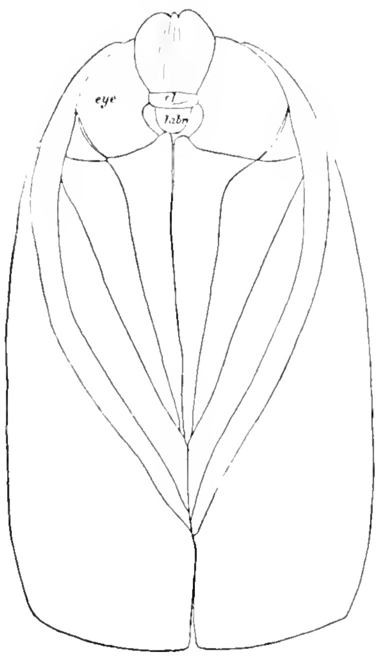


FIG. 61.—Pupa of *Datana perspicua*

Food plants.—Sumac (*Rhus glabra* and *R. typhina*) (Miss Morton, Mr. Dyar, Dr. C. V. Riley).

Habits.—Larvæ occurring in July and September; moths in June, July, and September (Riley).

Geographical distribution.—Chicago, Ill. (Westcott); Colorado Springs, Colo., June 25, at light (Gillette); West Farms, N. Y. (Angus); Newburg, N. Y. (Miss Morton); New Jersey and Pennsylvania (Palm); Chicago, Ill. (Bolter); Manhattan, Kans. (Popenoe); Colorado (Edwards Coll. Amer. Mus. Nat. Hist., N. Y.); Illinois (Strecker); Mr. Dyar has received this species from Miles City, central Montana; Missouri, District of Columbia, Kansas, Virginia, and New York (U. S. Nat. Mus.); New York, Pennsylvania, Wisconsin, Missouri, Carbondale, Ill. (French).

Datana robusta Strecker.

(Pl. II, fig. 16, ♂; 17, ♀.)

Datana robusta Streck., Lep. ind. and Exot., p. 131, 1872.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 613, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 199, 1894; Journ. N. Y. Ent. Soc., ii, p. 116, 1894.

Moth.—Closely allied to *D. perspicua* and marked in exactly the same way. The outer margin of primaries seems less distinctly scalloped. Thoracic patch ocher-yellow, shading into tawny posteriorly exactly as in *D. perspicua*, or entirely ocher yellow, with only a few tawny scales defining its posterior border. In this latter case it is paler than the thorax. Thorax and primaries clay color (R., V, 8, a little paler), heavily dusted with hazel scales (R., IV, 12), these predominating in the space between first and fifth lines below the median vein, all throughout giving a dark cast to the wing; lines, spots, and fringe, as in *D. perspicua*, or rather fainter. Rarely, only the outer lines are discernible. Median venules marked with brown rather more heavily than in *D.*

perspicua. Secondaries as in *D. perspicua*, but tinged with brown along outer marg'n or on the outer half.

Expanse of wings, 48–50 mm.

There are no good specific differences between this form and *D. perspicua*. Though quite different in general appearance, it is simply *D. perspicua* intensified. I would not suggest uniting the two, however, especially as the larva of *D. robusta* is unknown. (Dyar.)

Geographical distribution.—Dallas, Tex. (Strecker Coll.); San Antonio, Tex. (Bolter); Texas (French).

Datana integerrima Grote and Robinson.

(Pl. II, fig. 20, ♂; 21, ♀.)

Datana integerrima Grote and Rob., Proc. Ent. Soc. Phil., vi, p. 12, 1866, pl. 2, fig. 4.
Grote, New Check List N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het. Br. Mus., i, p. 613, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 199, 1894; Journ. N. Y. Ent. Soc., ii, p. 116, 1894.

Larva.

(Pl. XIII, figs. 1–6.)

Angus in *Grote and Rob.*, Proc. Ent. Soc. Phil., vi, p. 13, 1866. (Full-fed larva described.)
Beutenmüller, Can. Ent., xx, p. 134, 1888. (Stages IV and V, last described.)
Dyar, Psyche, p. 421, Dec., 1890. (Last stage described.)
Packard, Journ. N. York Ent. Soc., i, p. 59, June, 1893. (Last stage described.)

Moth.—Fore wings entire, as in *D. contracta*; body colored in the same manner except that the abdomen is less yellowish. Fore wings cream-buff (R., V, 11), so heavily irrorated with mars brown (R., III, 13) as to appear of the latter color; costal shade brighter, tawny, but not as dark as the thoracic patch. Lines distinct, concolorous with the fringe and irroration; the irrorations are absent for a short space bordering the lines, causing them to appear bordered distinctly by paler shades. These shades border all the lines on the outside except the first, which is bordered on the inner side only, but rather faintly. Discal dots obscure, blackish. Hind wings and underside as in *D. contracta*, but paler, lacking the yellowish tint of that species.

Expanse of wings, 45–50 mm.

Allied to *D. contracta*, but the ground color is less yellowish, the irrorations more numerous, and all the markings are concolorous with the fringe. (Dyar.)

Egg.—"Deposited on underside of leaf of walnut in a closely placed mass of 300 and upward. Rather small, elongate, hemispherical, approaching cylindrical; apex somewhat flattened, color dull white. Surface somewhat roughened, but without regular markings. Diameter, 0.7 mm." (Riley MS. notes.)

Larva.—The following notes are written out from an examination of greatly enlarged drawings, made by Mr. Bridgham at Providence. The figure of the fourth stage agrees with Mr. Beutenmüller's description of the fourth stage of *Datana integerrima*. The food plant is the walnut. As is well known, these larvæ feed in large conspicuous clusters, being social through larval life.

First stage.—Length, when 24 hours old, 5 mm., July 24. In this larva the head is very large, entirely black and hairy, being nearly twice as wide as the end of the body. The body is brick red, with a faint subdorsal and lateral yellowish stripe along the body, and a diffuse spiracular yellowish line. There is a distinct small, black prothoracic shield, transversely oblong, from which arise about twenty black hairs, slightly clavate, two or three of them as long as the segment is thick. A distinct black suranal plate is present; it is entire and rather large, though not so wide as the tenth abdominal segment. The piliferous warts are minute, and the dorsal and lateral glandular hairs arising from them are more or less club-shaped, some of them markedly so, and not quite so long as the body is thick. The thoracic legs are black; the middle abdominal legs are concolorous with the body; the plantæ dusky; the anal legs are about half as thick as the others and black at the end.

In another specimen of this stage, of the same length, which is just about exuviating (July 23), the body being very long and the head small in proportion to the body, the suranal plate is divided into two oval lanceolate black plates, the small ends pointing toward the head. Otherwise the body is marked as in the above-described specimen, except that there are black spots at the base of the middle abdominal legs. The hairs are not represented as so clavate as in the other specimen. It is possible that the latter is in the second stage, but if so, the suranal plate would not probably be so large and entire.

Third stage.—Length, 7 mm. (probably not of the normal length, owing to confinement), July 30. About ready to molt, as the prothoracic segment is somewhat swollen. The black prothoracic plate still persists, and the hairs arising from it are about twice as long as those elsewhere, but the black suranal plate has disappeared; the anal legs are still slight, and the body beyond the sixth abdominal segment is upraised. The reddish color has deepened, and the yellowish lines are more distinct, while the spiracular line, inclosing the distinct black spiracles, is pale lilac; the middle abdominal legs do not appear to be spotted.

Fourth stage.—Length, 10 mm., August 13 (evidently underfed and unnaturally small). The head is large, as wide as the body in front; the cervical shield still persists, as do the clavate hairs. The color has now changed to a dark reddish brown, above and beneath, with longitudinal gray stripes seen from above and four seen sideways; the additional stripe is the infraspiracular one, while the spiracular one has moved up, the spiracles being situated between them.

The following is a description of another larva of this stage received from Mr. Angus, August 25:

Length, 15 mm. Head shining black, as wide as the body.

The body of the usual cylindrical shape, rather slender, dark pitchy reddish brown all over. Prothoracic shield transversely oblong, not so square at the corners as in *D. perspicua.* There are four dull whitish rather obscure lines on each side, which are of nearly the same width and of exactly the same color; they are somewhat irregular on the edges, being somewhat broken and of the same distance apart. The lowest or infraspiracular line is a little wider and more distinct than the others, and extends along the lateral ridge. The body beneath is of the same color as above. The suranal plate is black, rounded; the anal legs are black at the tips. The middle abdominal legs are stained black above the plantæ, and the thoracic legs are black. The hairs are long and white; those on first thoracic segment, and eighth and ninth abdominal, longer than those elsewhere; those on the prothoracic segment stand up and curl over the head, and two or three of them are as long as the three thoracic segments put together. The spiracles are black.

Fifth stage.—Length, 28 mm., August 29. Very different from the fourth stage, the color being still darker, while only two grayish lines are seen from above, and two lines when the larva is seen from the side. The two dorsal and the supraspiracular lines have disappeared. The body is now clothed with numerous soft fine gray hairs, many of which are nearly as long as the body. The anal legs are still smaller than in the preceding stage.

Recapitulation.—1. In this species the larvæ of the first four stages apparently have clavate glandular hairs, an unusually late persistence.

2. The body is reddish in the three first stages, but becomes dark in the fourth, while in *D. ministra* the body is reddish in the fourth, being less precocious than in this species.

3. The loss of two of the longitudinal stripes in stage V is noteworthy, and the habits of the larva should be noted by the future observer to learn the probable cause of such a change; also why in *D. ministra*, and perhaps in other species, there is such a decided change in the general color and stripes in the last as compared with the penultimate stage.

4. The black suranal plate seems in Stage I to be entire, and to divide in two at the end of the stage, not being present in the third stage. It is to be hoped that those who may hereafter rear the species of *Datana* will preserve specimens of the earlier stages in alcohol for future study.

Habits.—Eggs, August; larvæ, August and September; adults, May and August; localities, Kansas, Missouri, Indiana, New York, Maine, and District of Columbia; food plants, walnut, hickory, larkspur, thorn. (Riley MS. notes.)

Food plants.—The larvæ prefer black walnut, but feed on hickory, butternut, etc. (Angus); walnut (Pilate); "Live together in large companies on walnut (*Juglans*), hickory (*Carya*), beech, (*Fagus*), and also on oak (*Quercus*), but very rarely" (Beutenmüller); willow, honey locust, thorn, and apple (Riley). In Kansas, *Juglans nigra* (Popenoe).

Geographical distribution.—Orono, Me. (Mrs. Fernald); Plattsburg, N. Y. (Hudson); West Farms, N. Y. (Angus); Kanawha Valley, West Virginia (W. H. Edwards, Mus. Comp. Zool.); Ohio (Pilate); Kittery, Me.; New York, Rhode Island, Wisconsin, Champaign, Ill. (French); Chicago, Ill. (Westcott); Manhattan, Kans., moth, May 25–June 2 (Popenoe); Arkansas (Palm).

Datana contracta Walker.

(Pl. II, fig. 18, ♂; 19, ♀.)

Datana contracta Walker, Cat. Lep. Het. Br. Mus., v, p. 1062, 1855.
Morris, Syn. Lep. N. Amer., p. 247, 1862.
Grote and Rob., Proc. Ent. Soc. Phil., vi, p. 14, 1866; pl. 2, fig. 8, fig. 6, var.
Pack., Proc. Ent. Soc. Phil., iii, p. 355, 1864.
Grote, New Check List N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 613, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 199, 1894; Journ. N. Y. Ent. Soc., ii, p. 116, 1894.

Larva.

(Pl. XIV, figs. 7, 7*a*, 7*b*.)

Angus in *Grote and Rob.*, Proc. Ent. Soc. Phil., vi, p. 14, 1866. (Full-fed larva described.)
Beutenmüller, Can. Ent., xx, p. 134, 1888. (Fourth and last stage described.)
Packard, Jour. N. York Ent. Soc., i, p. 60, June, 1893. (Full-fed larva described.)

Moth.—Exterior margin of fore wings entire. Thoracic patch ocher-yellow shading into tawny behind; thorax a little paler than the fore wings, which are buff (R., V, 13); the costal shade brighter, more ocherous; the wing rather thickly dusted with brown-black scales, concolorous with the pulverulent line and with moderately distinct discal dots. Bordering the lines the irrorations are absent for a short space, causing the lines to appear as if bordered with obscure pale shades. Frequently lines 1 and 2 are joined or approximated on the internal margin, though the character is variable. Fringe mars brown (R., III, 13), not concolorous with the lines. Hind wings paler than the fore wings, slightly glossy, powdered with brown scales most thickly toward the outer margin. Below pale, the terminal area of fore wings shaded with bright brown.

Expanse of wings, 40–45 mm. (Dyar.)

Larva before the last molt.—"Head and cervical shield jet-black, shining. Body black, with four equidistant sordid white stripes along each side, being as wide as the intervening spaces, except the dorsal space, which is the widest. Body beneath concolorous with the upper side, with three longitudinal stripes, and the intervening spaces much broader. On each of the fourth, fifth, tenth, and eleventh segments two reddish brown patches. Thoracic feet and claspers of the abdominal legs jet-black, with their bases reddish brown. The body is also sparsely covered with sordid white hairs. Length, about 30 mm." (Beutenmüller.)

The larvæ were sent me by Mr. James Angus, and were received September 1. It feeds on the walnut, and will eat the ash or rose.

Full-grown larva.—Length, 30 mm. Head large, as broad as the body, entirely black, including the mouth parts. First thoracic segment with a distinct gamboge-colored transversely oblong plate, with three indistinct blackish clouds on it. The body is jet-black, with four continuous whitish yellow very distinct stripes on each side, and a fifth broken one between the bases of the legs, both thoracic and abdominal. The three upper stripes are equidistant, the upper or subdorsal one being slightly wider than the others. The fourth stripe is on the lateral ridge, and is broader than the others, and wavy. The width of the dorsal black stripe is like that of *D. perspicua*. There is a median ventral whitish yellow stripe which ends before reaching the anal legs. The thoracic legs are black, but gamboge-yellow at the enlarged fleshy base. The middle abdominal legs are gamboge-yellow, each with a large external black patch above the planta. The two subdorsal whitish yellow lines end before reaching the suranal plate, leaving a black space; the plate is also black, and the anal legs are wholly black above and beneath and on the sides. The head and body are clothed with long white hairs, much longer and thicker than in *D. perspicua* and longer than the body is thick.

Mr. Angus writes me that there seem to be two varieties of *D. contracta*.

One of them is a light chestnut-brown with the usual yellow lines, and the other is more the color of *D. ministra*; indeed, so much so that I thought they might prove to be that species, but the lines are precisely the same as the other variety in width and color.

Habits.—Eggs, August 9; larvae, June, August, and September; adults, June, July, October, and November; localities, Missouri, District of Columbia, and New York. (Riley.)

Food plant.—Oak (Miss Morton and Mr. Angus); "Oak (*Quercus*), chestnut (*Castania*), hickory (*Carya*)" (Beutenmüller); oak and witch hazel (Riley).

Geographical distribution.—Massachusetts (Very, Mus. Comp. Zool.); New York, New Jersey, Pennsylvania, Wisconsin, Illinois (French); West Farms, N. Y. (Angus); New York (Palm); Newburg, N. Y. (Miss Morton and Mrs. Fernald); Buffalo, N. Y., and Chicago, Ill. (Bolter); Racine, Wis.; Chicago, Ill. (Westcott); New York, southwestern Arkansas (Palm).

Subfamily IV.—ICHTHYURINÆ.

Head larger than in the *Gluphisinæ*, but yet not so prominent as in the succeeding subfamilies; the front rather broad; clypeus (denuded) scutellate; eyes hairy; antennæ short, well pectinated to the tips; palpi large, long, ascending. Thorax usually with a dark median crest. Fore wings short and broad, apex slightly upturned; outer edge a little bent; no subcostal cell, the first three subcostal venules turned abruptly up on the costa; usually marked by four cross lines, two of them forming a large V. Hind wings with a rounded apex. Legs very densely scaled. Abdomen in ♂ long and slender, with a spreading dark tuft at the end.

Egg.—Hemispherical, with meridional ribs, on the surface ornamented with polygonal areas.

Cocoon.—Thin and irregular in shape; spun between leaves.

Larva.—Body rather long, slightly flattened, striped with yellow and dark, and somewhat hairy, usually with a pair of twin tubercles on first and eighth abdominal segments each. Freshly hatched larva with the hairs all tapering, at first without abdominal tubercles or hairs.

Pupa.—Unusually thick, full and blunt at the end; cremaster ending in a spine bearing two broad upcurved flattened hooks, each bearing four to five long setæ.

Ichthyura Hübner.

(Pl. XL, figs. 1-4, venation.)

Melalopha Hübner, Tentamen, p. 1 (no descr.), 1806 (1810?).
Pygæra Ochs., Schmett. Eut., ii, p. 224, 1810.
Ichthyura Hübn., Verz. Schmett., p. 162, 1816.
Melalophæ Hübn. (in part) Verz. Schmett., p. 162, 1816.
Clostera Stephens, Ill. Br. Ent. Haust., ii, p. 12, 1828.
Boisduval, Gen. et Ind. Méth., p. 89, 1840.
Duponchel, Cat. Méth. Lep. Eur., p. 95, 1844.
Herr.-Schaeff., Syst. Bearb. Schmett. Eur., 1845.
Ichthyura Walk., Cat. Lep. Het. Br. Mus., v, p. 1054, 1855.
Pack., Proc. Ent. Soc. Phil., iii, p. 351, 1864.
Grote, Check List N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 29, 1891.
Melalopha Kirby[1] Syn. Cat. Het., i, p. 608, 1892.
Neum. and Dyar, Can. Ent. xxxv, p. 121, May 1, 1894.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 190, June, 1894.

Moth.—Head not prominent, the front rather broader than usual, squarish; the clypeus (denuded) scutellate in shape, raised in the middle and on the edges in front. Eyes hairy; antennæ short, as long as the thorax, thickly scaled above; branches long, slowly shortening toward the end, sparsely ciliated. In the ♀ the branches short, but distinct. Maxillæ distinct.

[1] The use of this name by Kirby in place of Ichthyura seems scarcely justifiable, since in the Tentamen no description is given, and in the Verzeichniss the name Melalophæ is the name of a stirps, under which are the groups or coitus *Pygæra* and *Ichthyura*, the species under each being enumerated. Hübner also does not in the Verzeichniss spell the word *Melalopha*, the singular of Melalophæ; he simply uses it to designate a group or coitus or genus (in the modern sense). To resurrect and rehabilitate *Melalopha* under the name *Melalopha* seems scarcely defensible or advisable.

but separate. Palpi large, long, ascending, appressed to the front below; second joint long, continuous, pilose beneath; third joint small, pointed, not very distinct from the second.

Thorax with a conical well-marked median crest, which sends off a spur backward, and a slight ridge on each side. Wings: Primaries oblong, more than one-half as broad as long; costa convex to beyond the middle, thence ascending to the upturned apex, which is slightly pointed; outer margin a little bent, entire, nearly straight over halfway down, thence regularly rounded to the internal angle. Venation: No subcostal cell; the first three branches of the subcostal vein turned abruptly up to the costa, and ending farther from the apex than in Gluphisia, Nadata, or Datana.

Hind wings broad, apex rounded, outer edge rounded, longer than the internal margin.

Legs densely hairy; fore legs densely hairy to the ungues. Abdomen with a long spreading tuft on the upper side of the end, reaching beyond the genitals.

Coloration: The species usually whitish ocherous, with oblique, in part dislocated, transverse lines, two of these usually forming a distinct large V-shaped mark; a deep brown patch extending from the vertex of the head between the antennæ back to the top of the crest; the outer line on the costa very distinct silvery white, more or less oblique and sometimes S-shaped; beyond this mark is a subapical rust-red patch.

The genus is readily identified by the broad front, the hairy eyes, the well-pectinated antennæ of both sexes, the large palpi, and the unusually short and broad fore wings, which are not falcate at the apex; also by the well-marked dark brown median crest on the thorax, and by the laterally tufted tip of the abdomen.

Egg.—Hemispherical, moderately high, with irregular meridional swollen portions and the surface ornamented with polygonal areas inclosed by slightly thickened walls.

Larva.—Body rather long, slightly flattened, ornamented with bright, usually yellow, and dark stripes, and usually with two twin dark dorsal tubercles on the first and eighth abdominal segments, with numerous pale hairs. The tubercles (in *apicalis*) obsolete, the body being smooth but striped, as usual. In Stage I cylindrical, with fine hairs all tapering; with indications at the end of the stage of lines and abdominal tubercles.

Cocoon.—Thin, irregular in shape, spun between two leaves.

Pupa.—Body unusually thick, and full and blunt at the end, with a slender cylindrical cremaster, ending in two broad stout upcurved flattened hooks, each bearing four to five long setæ.

Geographical distribution.—The species are common to the Atlantic and Pacific coasts and the intervening region, covering the Appalachian, Austroriparian, and Campestrian subprovinces. Whether any extends into the Mexican (Sonoran) is doubtful. The genus is represented in Europe and America by several species in each hemisphere, and does not occur in either Asia or Africa, nor in the tropics.

SYNOPSIS OF THE SPECIES AND VARIETIES.

A. Lines anastomosing; basal line dislocated on cubital vein, not toothed; white costal mark oblique or more nearly straight.
  Basal line forming a sharp angle; usually mouse colored .... *I. apicalis*
    Larger and paler than Eastern *apicalis* .... var. *ornata*
    Pale, almost sordid white .... var. *astoriæ*
    Pale purplish; arms of V sinuous .... var. *bifiria*
  Largest and palest species; white costal mark oblique; apex of V forming a loop; no thoracic band. *I. inornata.*
  Smaller than *inclusa*; pale subocherous; second, third, and fourth lines much more sinuous than in *apicalis* or *inclusa*; subapical patch pale ocherous; costal mark oblique, sinuous; brown thoracic band obscure .... *I. strigosa*
    Costal mark more oblique and distinct than in *strigosa*; no thoracic band .... var. *luculenta*
  Usually large; a white, nearly straight, costal mark; subapical patch ocherous .... *I. inclusa*
    Small, dark mouse-color; subapical patch rust-red .... var. *inversa*
    Small, pale ocherous; subapical patch ocherous .... var. *palla*
    White costal mark oblique; subocherous, inner arm of V firmer, less sinuous .... var. *jocosa*
  Near *apicalis*, pale, lines subparallel, not anastomosing .... *I. brucei*
    Unusually dark, costal mark obscure .... var. *multnoma*
  Smaller, basal line bent and curved; subapical patch very obscure .... *var. alethe*
B. Lines not anastomosing; V very narrow; white costal mark S-like .... *I. albosigma*
  Paler subapical patch brown .... var. *specifica*

SYNOPSIS OF KNOWN LARVÆ.

A. No tubercles on first and eighth abdominal segments.
  A dorsal gray band containing three brown lines. . . . . *I. apicalis*
  Like *apicalis*, but with a broad orange stigmatal band, inclosing a black line; body purplish black. . . . . *I. brucei*, var. *multnoma*
  Three faint dorsal red lines; three dark lake-red lateral stripes, and two yellow lateral stripes. . *I. strigosa*
B. A dark tubercle on first and eighth abdominal segments.
  Body yellow, with three dorsal and three lateral black lines. . . . . *I. inclusa*
  Body yellow, three dark dorsal lines, and a broad lateral dark band, below which the warts are ocherous *I. albosigma*

Ichthyura apicalis Walker.

(Pl. III, figs. 1–8.)

Ichthyura apicalis Walk., Cat. Lep. Het. Br. Mus., v, p. 1058, 1855.
Clostera vau Fitch, Fifth Rep. Nox. Ins. N. Y., p. 65, 1859.
Ichthyura indentata Pack., Proc. Ent. Soc. Phil., iii, p. 352, 1864.
Ichthyura ornata Gr. and Rob., Trans. Amer. Ent. Soc., ii, p. 191, 1868.
Clostera incarcerata Boisd., Lep. Cal., p. 86, 1869.
Ichthyura indentata Grote, Check List N. Amer. Moths, p. 18, May, 1882.
Ichthyura astoria Edw., Ent. Amer., ii, p. 11, April, 1886.
Ichthyura bifiria Edw., Ent. Amer., ii, p. 167, Dec., 1886.
  Pack., Ent. News, iv, p. 79, March, 1893.
Ichthyura vau Smith, List Lep. Bor. Amer., p. 29, 1891.
  var. *ornata* Pack., Ent. News, iv, p. 77, March, 1893.
Melalopha vau Kirby, Syn. Cat. Lep. Het., i, p. 611, 1892.
Ichthyura incarcerata Pack., Ent. News, iv, p. 78, March, 1893.
  var. *astoria* Pack., Ent. News, iv, p. 79, March, 1893.
Melalopha vau Neum. and Dyar, Can. Ent., xxv, p. 123, May, 1893.
  var. *ornata* Neum. and Dyar, Can. Ent., xxv, p. 123, May 1893.
  var. *bifiria* Neum. and Dyar, Can. Ent., xxv, p. 123, May, 1893.
  var. *astoria* Neum. and Dyar, Can. Ent., xxv, p. 123, May, 1893.
Ichthyura apicalis Dyar, Can. Ent., xxv, p. 303, Dec., 1893.
Melalopha apicalis Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 192, 1894; Journ. N. Y. Ent. Soc., ii, p. 115, 1894.

Larva.

(Pl. XV, fig. 1; var. *astoria*, figs. 2, 2*a*, 2*b*, 2*c*, 2*d*, 3, 3*a*, 3*b*, 3*c*, 3*d*, 3*e*, 3*f*.)

French, Can. Ent., xvii, pp. 248–250, Dec., 1885. (Eggs, full life history; cocoon and pupa of *I. ornata*.)
Beutenmüller, Bull. Amer. Mus. Nat. Hist., iv, p. 67, 1892. (Two last stages described.)
Dyar, Ent. News, iii, p. 5, 1892. (Complete larval history of var. *bifiria*.)
Packard, Journ. N. York Ent. Soc., i, p. 26, March, 1893. (Third and last stage described.)
Dyar, Can. Ent., 1892. (All the stages.)

Moth.—Several ♂ and ♀. Ground color of body and wings unusually dark mouse-ash, much darker as a rule than in *I. inclusa*. Fore wings with the basal line straight in its general course, making a more distinct and complete angle on the cubital vein than in *I. inclusa* or var. *inversa*. Second line slightly bowed inward, meeting the short third line on the cubital vein. The V-shaped mark (composed of the third and fourth line) distinct; its outer arm ending on the costa as a distinct white oblique sinuous mark, much more obliquely bent outward than in *I. inclusa* and *inversa*. This costal mark is bordered externally by a deep rusty reddish brown patch, much as in *I. inclusa*, the patch often being more or less faded and obsolete. A submarginal, slightly sinuous series of dark spots. Hind wings mouse colored, with a dark diffuse transverse line beyond the middle, which is often wanting.

Beneath, the wings are concolorous with the hind wings above; the whitish costal mark distinct, and from it originates a darker diffuse line common to both wings, and on the hind wings very sinuous, being bent outward behind the subcostal vein and inward behind the cubital vein.

Expanse of wings: ♂, 27 mm; ♀, 29 mm; length of body: ♂, 13 mm; ♀, 12 mm.

This common and variable species is usually considerably smaller than *I. inclusa*, and I always recognize it by the very distinct and oblique white costal mark (as I will call this costal ending of the fourth line). This mark is bent inward in the middle, and thus forms a rounded loop (sometimes an angle), which is directed outward, behind the costal edge, and becomes indistinct between the fourth and fifth branches of the subcostal vein.

That this species (Fitch's *rau*) is Walker's *I. apicalis* is not to be doubted, since I now have an excellent colored drawing of Walker's type in the British Museum which leaves no doubt as to its specific relations, having the markings and hue of normal *rau* from Maine. His type was collected by Dr. Barnston.

This species is very variable, and what, with my present material, seem to constitute its varieties I will endeavor to point out, premising that my views are subject to future correction after we have much fuller collections of the moths and after we know more of their transformations. Meanwhile it is to be hoped that there will not be a further multiplication of nominal species in a genus already so burdened with synonyms.

Walker's *Ichthyura apicalis*[1] is the same as *I. rau*, as I judge from an excellent colored figure (Pl. VII, fig. 4) made for me by Mr. H. Knight from Walker's type, but it is impossible to determine from his brief description, as he does not say whether the *albida maculaque costali* is oblique or not. Mr. Dyar has also come to the same conclusion from a pen and ink sketch of the type received from Mr. Butler. In Barnston's MS. description, quoted by Walker, the larva is described as "brown, thick, with 16 feet, and with a band on part of the back;" "feeds on the poplar leaf." This description will apply better to *rau* than to any other species known to me, as I have reared *rau* from the poplar, and the larva is brown, short, though not with "a band on part of the back."

After examination of my type of *I. indentata* in the Harris collection, I find it agrees with Fitch's description of *rau*.

I regard *I. ornata* G. & R. as only a climatic variety of Fitch's *rau*, and a specimen of *I. ornata* G. & R., so labeled by Mr. Edwards, is also labeled "*incarcerata* Boisd.;" and on comparing Boisduval's description of *incarcerata* with specimens of *ornata* from California, Truckee Valley, Reno, Nev., and Colorado, I do not see any specific differences.

I. incarcerata (*I. ornata*), Pl. II, figs. 4–7: While these represent small individuals, many are larger, and it is a larger and generally paler form than *I. apicalis* (*rau*) of the Eastern States, and I think it is simply a climatic variety of the Eastern form. One ♂ and a ♀ in the Edwards collection are as dark as the typical Eastern *rau*, and the pale form may be a seasonal variety. Indeed, Mr. Beutenmüller informs me that in *I. apicalis* (*rau*), which he has reared, this pale form is the summer brood, the dark individuals belonging to the winter brood.

One ♀ from Truckee and a small ♂ from Sierra Nevada, California, are very pale (expanse of wings, 33 mm.). Also from Alameda County, Cal. (U. S. Nat. Mus.).

A large, well-preserved, fresh specimen from Lincoln, Nebr. (U. S. Nat. Mus.), collected May 21 by Prof. L. Bruner, is unusually pale, having a faded-out look, and is evidently a form (*astoriæ* Edw.) of var. *incarcerata* (*ornata*), being like one of that variety (a ♀) from Colorado, but differing in having no reddish brown shade on it. (See Pl. VII, fig. 3.) This form, subvar. *astoriæ*, has also been reared by Mr. Dyar from eggs sent him from Miles City, Mont., and whose larval stages I have described beyond, my pupæ not having disclosed any moths. Although the rainfall at Astoria, Oreg., is very heavy (80 inches annually) and the climate humid, yet the Astoria specimen in the Edwards collection is no darker than those from Montana and from Kansas. This is somewhat unexpected and remains to be explained, unless it be discovered that there is a dark winter brood.

The young larva was found feeding on the aspen at Brunswick, Me., and molted August 10–12, when it became 10 mm. in length.

Young larva in third stage.—Length, 10. mm. Head black. The body is on the sides and at the end livid dark brown. The warts and lumps on the first thoracic and first and eighth

[1] Walker (Cat. Lep. Het. British Museum, v, 1058) thus refers to a moth which he describes as *Ichthyura apicalis*:

Mas. Cinerea; caput nigro-fuscum; frons et palpi subtus albida; antennæ canæ ramis cinereis; thorax vitta dorsali nigro-fusca; alæ anticæ fusco-cinereæ, linea undulosa albida maculaque costali rufo-fusca; posticæ cinereæ; subtus albidæ fascia gracili discali undulosa fuscescente.

"Larva brown, thick, with 16 feet, and with a band on part of the back; feeds on the poplar leaf, which it draws together with silk. Cocoon slight and white. The moth appears in June."—Barnston MSS.

a, b.—St. Martin's Falls, Albany River, Hudson Bay. Presented by Dr. Barnston.

abdominal segments are of the same color, but the other piliferous dorsal warts are yellow. There are four parallel whitish gray dorsal lines, or rather three dark, livid-brown, fine dorsal lines on a grayish white field.

Last stage (Pl. XV, fig. 1).—Length, 25 mm. Head brown black, flattened, as wide as the body; with gray hairs. The prothoracic plate is widely divided into two transversely oval brown black plates. The body is marked with a broad, dorsal, ash-gray band, containing three vandyke brown more or less broken lines. The sides of the body darker and containing two darker, irregular, broken lines. On the first thoracic segment are no dorsal yellow warts, but two on each side, the upper one in front of the spiracle, button like, prominent. On the second and third thoracic segments are four yellow tubercles, forming a transverse series. On the second to eighth abdominal segments the yellow warts are arranged in a very low trapezoid, and the two anterior ones are minute. Those on the ninth segment form a curved line. The suranal plate is broad and rounded, speckled with black. There are no humps or specialized warts on the first and eighth abdominal segments, thus differing from the larva of *I. inclusa*. The thoracic legs are blackish; the abdominal and anal legs livid ash.

The larva differs decidedly from that of *I. inclusa*, though the moth is nearly allied.

The moth bred from this caterpillar is of the dark mouse-colored form, normal, usual in Maine and Franconia, N. H. One like it from Illinois is in my collection.

The following description is of a larva reared in Maine from eggs received from Mr. Wiley, of Miles City, Mont., and, as Dr. Dyar states, is "the pale Western form," and perhaps var. *astoriæ* (Edw.).

Life history of var. ornata subvar. astoriæ (Pl. XV, figs. 2, 3).—The eggs were kindly sent me by Mr. C. A. Wiley, of Miles City, Mont.; they were deposited on the willow May 24, 1893, and were received June 5, but the larva had hatched out and must have been feeding several days, as the body was filled out, the head not being quite so wide as the body. The larvæ feed on the underside of the leaf, and if transferred to the upper side walk back beneath.

Egg.—Diameter, 0.7 mm.; hemispherical or flattened conical, moderately high, very broad, broader than high; the surface not regular, having an irregular meridional swollen portion, the top being somewhat swollen. The surface is pitted as seen under a lens. Under a one half-inch objective it is divided into slightly convex polygonal areas, with definite thin raised edges.

The hole eaten by the larva for its exit is characteristic, being round, with the edge crenulated, each concavity representing the incision made by the jaws; in some cases the disk cut out is connected by a stalk with the side of the hole.

Larva, Stage I.—Length, 4 mm.; head black; body long and full, with the segments rather full and convex, especially on the sides, particularly on the sides of the third abdominal segment. *The first and eighth abdominal segments fuller, more convex than the others, and dorsally swollen, almost humped, and dull dark varnish or pitchy red, causing them to be very distinct in appearance from the other abdominal segments.* Along the sides of the body is a broad longitudinal band of the same pitchy red hue; it is most distinct and continuous on the abdominal segments, but divided into two broken lines on the upper edge, and it is a little broken on the three thoracic segments, where it is most emphasized on the swollen sides of each segment, and wanting in the sutures between the segments. The body is greenish yellow, and in the dorsal yellow portion of the back are three faint broken parallel equidistant dorsal lines. On the side of the body low down are three broken reddish brown lines, the lower one the broadest, and passing along the base of the abdominal legs. The hairs are of unequal length, whitish. Prothoracic plate short and wide, black, distinct. Suranal plate broad, short, triangular, black. Thoracic legs blackish; abdominal legs (including the anal ones) pale greenish, the color of the body, but with a dark chitinous callosity on the outside just above the planta.

The larva molted June 14–15.

Stage II.—Length, 8–11 mm. Head flattened, small, not so wide as the body. A short, broad, dark brown prothoracic shield, *not interrupted in the middle.* The first and eighth abdominal segments decidedly swollen above, almost humped; the color chocolate-brown, and concolorous with the broad lateral band, which incloses two faint, pale, broken lines, and is often broken into rings inclosing whitish spaces. Four straw-yellow dorsal bands, varying from whitish to straw-yellow, and inclosing three narrow, broken chocolate lines. Below the broad lateral chocolate band are two whitish yellow irregular lines, one just above and the other just beneath the spiracles. Underside of the body with the abdominal legs pale livid-gray. On the outside of the abdominal legs above the planta is a dark chocolate-brown patch. Suranal plate dark chocolate brown. The hairs are sparse and pale gray, uneven in length; the few longest ones arise from the thoracic segments and from the eighth to ninth abdominal segments. The piliferous warts are yellow on the yellow ground and brown on the brown portions of the skin. On the eighth abdominal segment are two yellow piliferous tubercles situated on the brown skin.

It molted June 22.

It seems to be like the Eastern *apicalis* (*rau*) in Stage III.

Stage III.—Length, 15 mm. Head chitinous brown, mottled with close-set dark spots. Prothoracic shield divided into two parts by a pale median space. In general as in Stage II, *but the four pale dorsal lines are whiter than before*, becoming straw-yellow around the bases of the yellow piliferous warts. The brown lines and lateral band and the brown swollen first and eighth abdominal segments are as before. Hairs long whitish. On the brown bands and segments the piliferous warts are pale, not prominent.

The larvæ have now sewed together two leaves and live between them much as does *I. inclusa*.

The larvæ molted into the last stage June 28 to July 12.

The larva when of this stage is more like *I. inclusa* when about 15 mm. long than the fully grown Eastern *apicalis* (*rau*), though in *I. inclusa* the eighth abdominal segment is not brown, according to Bridgham's figure, and is somewhat as is *albosigma* in its third stage.

Last stage.—Length, 30 mm. Body thick and full. Head not so wide as the body by a fifth; pale yellowish brown or chitin colored, with darker flecks; it is much flattened in front, the clypeus flat and sunken. Jaws and ocelli blackish, contrasting with the light-colored head. Body of a peculiar light yellowish sienna-brown, with a grayish tinge. Skin somewhat rough, with fine minute warts giving rise to fine close-set pale gray hairs of unequal length. On the prothoracic segment are two dusky dorsal flattened low warts elongated transversely, the corresponding ones on the succeeding segments being bright yellowish brown, each giving rise to one or two long thick pale hairs. A lateral yellowish brown wart in front of the prothoracic spiracles. On the second thoracic segment are three yellowish brown warts on each side, forming a transversely straight line of six warts crossing the segment. On the third thoracic segment is a transverse row of eight similar warts, the additional ones being one just above the base of each leg of the third pair; corresponding warts are present on the prothoracic segment. *No trace of a hump or of any other distinctive mark on the first or eighth abdominal segments, but in place of them are two small yellowish brown warts, situated just in front of the line of six warts common to all the abdominal segments*, though there are two similar but much smaller, nearly obsolete, warts which occur in the same position as on the other abdominal segments, those on the second abdominal segment being the most distinct. Three faint broken parallel dorsal lines and a faint lateral spiracular band, above and below which is a faint whitish line. The skin is covered with somewhat irregular confluent colorless spots of irregular shape. All the legs are of the same color as the body.

It pupated between the leaves July 12.

Var. *bifiria* Edwards.

Pl. III, fig. 8.

Var. *Ichthyura bifiria* H. Edwards, Ent. Americana, ii, 167, December, 1886.
Pack., Ent. News, iv, p. 79, March, 1893.

The single type differs from Mr. Edwards's type of *brucei* in the oblique silver-white costal streak being more sinuous, as is also the line across the wing which forms the continuation of the streak. On the other hand, the other (inner) arm of the V is straight, not sinuous, the inner two lines about the same. The submarginal spots and streaks are the same in both species.

I am inclined to agree with Mr. Dyar that this is a variety of *I. apicalis.* I am unable, however, to see any important difference between *I. apicalis*, var. *incarcerata*, and *alethe* Neum. and Dyar, though I leave it as a synonym of *brucei*, as Mr. Beutenmüller suggests, Dyar agreeing with his view.

The following account of the preparatory stages of *Ichthyura bifiria* Hy. Edw., by Dr. Harrison G. Dyar, is copied from the Entomological News, 1892, p. 5:

Egg.—Hemispherical or slightly conoidal, the base flat, but rounded at its edges; smooth under a lens, but under the microscope covered with numerous, crowded, shallow depressions, which form by their edges narrow, roundedly, hexagonal reticulations. The color is dark gray before the egg hatches. Diameter, 0.7 mm.

First stage.—Head shining black, labrum pale; width, 0.35 mm. Body slightly flattened, whitish; cervical shield black; a few pale hairs; joints 5 and 12 are slightly enlarged dorsally; the lateral region and joints 5, 7, and 12 dorsally are wine red. Thoracic feet large, pale; the abdominal normal, all used in walking. Length, 2.5 mm. The larva hatches by eating a round hole in the vertex of the egg, leaving the rest of the shell untouched. It lives, singly, in a shelter constructed by spinning two or more leaves together.

Second stage.—Head black and shining, the central suture deep; width, 0.65 mm. Body flattened, pale whitish yellow, with narrow triplicate dorsal, and very broad lateral bands of dull wine color, as are also the humps on joints 5 and 12. Cervical shield and anal plate black; venter dull greenish; legs black.

Third stage.—Head flat in front, slightly bilobed, brownish black, but paler centrally around the clypeus; a few dark hairs; width, 1.1 mm. Body pale yellow; joints 5 and 12, a triple dorsal line, broad lateral and confused triple subventral lines all dark brown. Cervical shield and anal plate blackish; scattered pale hairs arise from smooth, low, round tubercles, concolorous with the markings.

Fourth stage.—Head pale brown, shaded with black in front; jaws and ocelli black; a white shade on each side of the clypeus; width, 2.6 mm. Body as before, but the lateral band is faintly divided by a double yellowish line, and joint 13 is nearly all yellowish. The round, smooth, piliferous tubercles are distinctly yellow in the yellow markings. Cervical shield small, bisected, pale brown; anal plate not distinguishable. Hair whitish, both from body and head. As the stage advances the colors become quite pale, and the appearance is much changed; humps on joints 5 and 12 very slight, dark purple. Ground color whitish gray, becoming pale purple, a triplicate dark purple dorsal line, the central one most distinct, the others broader and diffuse. All these lines are more or less broken into mottlings. A similar stigmatal line with some purple mottlings subventrally; venter paler; spiracles black. The piliferous tubercles are normal in arrangement, much as the warts in *Halesidota;* row (4) small, posteriorly to the spiracles, row (7) apparently absent. The head is held out flat, as in *Gluphisia*.

Cocoon.—Composed of several leaves spun together and lined with threads.

Pupa.—Nearly cylindrical, flattened a little ventrally, gradually tapering posteriorly, but of nearly even width, no part enlarged; last abdominal segments rounded, cremaster long and slender, terminating in a knob that, under the microscope, is seen to consist of a row of radiating, strongly recurved hooks, which hold firmly to the silk of the cocoon. Color dark red-brown, the thorax and cases nearly black. Length, 11 mm.; width, 3.5 mm.

Food plant.—Willow (*Salix*).

Larvæ from Yosemite Valley, California. These larvæ had but four stages, and there are two broods in a year.

Ichthyura bifiria, as well as *I. brucei* Hy. Edw., must come very near *I. vau* Fitch, if they are not merely Western forms of it, but the larva of *I. vau* is still unknown, so that it is impossible to compare the early stages.

We now return to the normal *I. apicalis*.

Cocoon.—The cocoon which I have is more completely formed than that of *I. inclusa*, the surface next the leaves being a continuous firm web, more cocoon-like. It is tent-like and spun between two leaves, as in *I. inclusa*. It measures 22 by 15 mm.

Pupa.—Not so full, rounded, and blunt at the end as in that of *I. inclusa*. Abdominal segments with scattered coarse punctures, and the surface is dull, not so shining as in *I. inclusa*. Cremaster slenderer than in *I. inclusa*, the two dorsally curved hooks not so broad and thick as in *I. inclusa* and about half as large. Length, 16 mm.

Habits.—In general the same as those of *I. inclusa*, the moth laying its eggs in northern New England probably late in June and in July, the larvæ occurring throughout August. In Miles City, Mont., the eggs are stated by Mr. Wiley to have been laid on the willow as early as May 24. Whether it is double-brooded remains to be seen. It occurred in Kansas May 21. (Bruner).

Food plant.—The normal New England form of *apicalis* feeds on the aspen, while "the pale western form *astoriæ*" in Montana feeds on the willow.

Geographical distribution.—The species with its varieties range from New England, including the colder portions, as Franconia, N. H., to the Pacific Coast. It is to be looked for throughout the greater part of the "cold temperate subregion of Allen, or the boreal (Canadian) province of authors from lower Canada (Quebec Province) westward to Alaska." It also spreads in its varieties (*ornata*, *bifiria*, and *astoriæ*) through the Appalachian and Campestrian subprovinces, including Montana, Washington, and California. Var. *indentata*, New Jersey, Pennsylvania, Arkansas (Palm[1]); normal form. St. Martins Falls, Albany River, Hudson Bay (Dr. Barnston fide Walker); Brunswick, Me. (Packard); Franconia, N. H. (Slosson); Boston, Mass.; Poughkeepsie, N. Y. (Dyar); Dublin, N. H. (Leonard, Harris coll.); Plattsburg, N. Y. (Hudson); Illinois, Manhattan, Kans. (Popenoe); Colorado, a ♀ about halfway between the normal form and *incarcerata* (Pack. coll.); Yo Semite, Cal.; Portland, Oreg.; Seattle, Wash.; Victoria, British Columbia; Denver, Colo., May 2. The Western form *incarcerata* (*ornata*). Kansas (Bruner); Colorado (Pack. coll.). California (Morrison), in hue and size exactly like one from Truckee Valley (Mr. Glasham); a very small pale ♀ from Reno, Nev. (Pack. coll.); a rather large one from Olympia, Wash. (T. Kincaid); Seattle, Wash. (Dyar); *indentata*, Kittery, Me.; New Hampshire; *vau*, Maine, New York; *ornata*, California; *bifiria*, Soda Springs, Colo. (French); var. *ornata*, Fort Collins, Colo. (Baker).

Ichthyura inornata Neumoegen.

(Pl. III, figs. 9–11.)

Ichthyura inornata Neum., Papilio, ii, p. 131, Oct. 7, 1882.
Pack., Ent. News, iv, p. 78, March, 1893.
Neum. and Dyar, Can. Ent., xxv, p. 123, May, 1893.
Melalopha inornata Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 192, 1894; Journ. N. Y. Ent. Soc., ii, p. 115, 1894.

Apparently, although at first sight this is a distinct species, it may prove to intergrade with *apicalis* (*incarcerata*). Its characters are brought out in the following notes published in Entomological News, 1893. Until we know its larval history it may be better to regard it as a distinct species.

I am strongly inclined to regard this form as a climatic variety of *I. vau* var. *ornata*. One medium-sized *ornata* from southern California intergrades with *I. inornata*, though it is much smaller. It has the large diffuse discal spot and pale leaden intervenular patches of *inornata*.

Of *I. inornata* Neum., a male and female from Arizona are in the Edwards collection. It is the largest and palest of all our forms. It scarcely differs from *I. ornata* in the situation of the lines and their relative distribution; the oblique costal white line and its continuation across the wing are the same, and the obtuse almost rounded apex of the V does not quite reach the edge, just as it does not in *ornata*, but the loop made by the obtuse apex is more marked in *inornata*. The short middle line, ending on the hind edge of the wing, and the dislocated basal line are exactly as in *ornata*.

I. inornata, then, appears to be only a very large and unusually pale subocherous form of *apicalis*, following the same law of climatic variation, i. e., increase in size and a pale, faded appearance in Pacific Coast examples (south of Oregon), due probably to a hot, dry, desert region, with a light-colored surface soil. By adaptation to these conditions the moths are better protected from observation, and thus the life of the species is assured.

Geographical distribution.—So far as known confined to southeastern Arizona. Mr. Neumoegen does not state the exact locality in "southeastern Arizona" whence this form was brought, but it would seem to be a member of the Mexican (Sonoran) subprovince. Thus far no species of Ichthyura is cited from Mexico by Mr. Druce in the Biologia Centrali-Americana.

Ichthyura strigosa Grote.

(Pl. III, figs. 12–14).

Ichthyura strigosa Grote, Bull. U. S. Geol. Geogr. Survey Terr., vi, p. 582, Aug. 30, 1882; Check List N. Amer. Moths, p. 18, 1882.
Pack., Fifth Rep. U. S. Ent. Com. Forest Trees, p. 153, 1890.
Smith, List Lep. Bor. Amer., p. 29, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 610, 1892.
var. *luculenta* Edw. Ent. Amer., ii, 10, April, 1886.
Pack., Ent. News, p. 78, March, 1893.
Melalopha strigosa Neum. and Dyar, Trans. Amer. Ent. Soc., p. 191, 1894; Journ. N. Y. Ent. Soc., ii, p. 115, 1894.

[1] All the species found by Mr. Palm in Arkansas were collected in the southwestern counties of that State.

Larva.

Packard, Fifth Rep. U. S. Ent. Comm. Ins. inj. Forest Trees, p. 153, 1890.

Moth.—One male. Smaller and duller brown than *I. apicalis*, with a slight lilac tint on the head, thorax, and fore wings. Palpi whitish below, dark brown above, as in *I. apicalis;* front of head slightly broader and squarer; median thoracic brown band as in *I. apicalis.* Fore wings with the costal edge straighter and the apex less turned up than in *I. apicalis*, the apex being slightly more rounded than in that species or in *I. inclusa.* Basal line distinct, making a sharp angle on the cubital vein, and more incurved in the subcubital space than in *I. apicalis:* second line much more suddenly incurved than in *I. apicalis*, the same line being straight in *I. inclusa;* the short third line as in *I. apicalis*, but more sinuous. Fourth and outer line much as in *I. apicalis*, but the species differs from all the others known by the large conspicuous irregular whitish ocherous patch which fills in the costal curve of this line and extends halfway from the costal end of the line to the apex of the wing; no deep brick-red discoloration on each side of costal half of fourth line, so distinct in *I. apicalis*, but a long distal blackish stripe extends along the first cubital venule to the submarginal row of brown dots, which are not so distinct as in *I. apicalis* or *I. inclusa*, though the marginal row of dark brown lunules is as distinct as in *I. inclusa.* Fringe as in *I. inclusa*, but that on the hind wings much darker. Hind wings darker than in *I. apicalis.* Wings beneath much as in *I. apicalis*, but there is no reddish tint toward the apex. and the white oblique costal streak is much less distinct. There are traces of a common brown diffuse line. Abdomen a little shorter, the fan or tuft of scales perhaps shorter and expanding wider.

Expanse of wings, 25 mm.; length of body, 12 mm.

This species differs from *I. inclusa* and *apicalis* in the transverse lines on the fore wings being very much more sinuous, and it need not be confounded with any of our other species. The white costal mark is oblique and curved much as in *apicalis.*

Larva before the last molt.—Head broader than the body, flattened in front, dull black, with long white hairs. Body flattened, with yellow and reddish longitudinal stripes; three dorsal faint red stripes on a yellowish ground, and three deep lake-red lateral stripes, the lowermost the broadest and deepest in hue. Two bright yellow lateral stripes. Five pairs of flesh-colored abdominal legs, which are pale amber, colored like the underside of the body. Length, 9 mm.

Larva after the last molt.—Markings much as in the previous stage. Length, 17 to 18 mm.

Cocoon.—The rude cocoon is formed by tying a few leaves together, gathering them by a web at the edges, thus forming a roomy chamber, partly lined with silk, within which the chrysalis rests.

Pupa.—Smaller and not so full and rounded at the end as in *I. inclusa;* cremaster as in that species, ending in two stout, very short, recurved spines. Length, 12 mm.

Habits.—The caterpillar of this interesting species was found July 30, at Brunswick, Me., feeding on the aspen (*Populus tremuloides*). It molted August 10, and about the 20th began to spin a silken cocoon between two leaves. The moth (a male) appeared in the breeding cage at Providence, May 20. Like *I. inclusa*, it sits with the wings folded sharply over the back, with the fore legs held straight out in front and the tufted tail upcurved.

Food plant.—*Populus tremuloides.*

Geographical distribution.—This species is a member of the Appalachian fauna. Brunswick, Me. (Packard); Kittery Point, Me. (R. Thaxter); Maine (U. S. Nat. Mus.); Maine, Canada (French); var. *luculenta* Indiana (French).

Ichthyura inclusa Hübner.

(Pl. III, figs. 17-19.)

Phalæna anastomosa Abbot and Smith, Nat. Hist. Lep. Ins. Georgia, 1797.
Ichthyura inclusa Hübn., Zutr. Dritt. Hund., p. 36, figs. 561, 562, 1825.
Clostera americana Harris, Rep. Ins. Mass., p. 311, 1841, 3d edit., Pl. VI, fig. 12, and figs. 213-215.
Ichthyura inclusa Walk., Cat. Lep. Het. Br. Mus., iv, p. 1059, 1855.
Clostera americana Fitch, Fifth Rep. Nox. Ins. N. York, p. 65, 1859.
Ichthyura inclusa Morris, Synopsis Lep. N. Amer., p. 244, 1860.
Pack., Proc. Ent. Soc. Phil., iii, p. 351, 1864.

Ichthyura inversa Pack., Proc. Ent. Soc. Phil., p. 352, 1864.
Grote, Check List N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 29, 1891.
Melalopha inclusa Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 192, 1894; Jour. N. Y. Ent. Soc., ii, p. 115, 1894.
Pack., Ent. News, iv, p. 79, March, 1893.
Melalopha inclusa var. *inversa* Neum. and Dyar, Can. Ent., xxv, p. 127, May, 1893.
Ichthyura palla French, Can. Ent., xiv, p. 33, Feb., 1882.
Ichthyura inclusa Grote, Check List N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 29, 1881.
Melalopha inclusa Kirby, Syn. Cat. Lep. Het., i, p. 610, 1892.
Neum. and Dyar, Can. Ent., xxv, p. 123, 1893.
Ichthyura jocosa H. Edw., Ent. Amer., ii, p. 10, April, 1886.
Pack., Ent. News, iv, p. 79, March, 1893.
Melalopha jocosa Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 193, 1894; Jour. N. Y. Ent. Soc., ii, p. 115, 1894.

Larva.

(Pl. XVI, figs. 1, 1*a*, 2, 2*a*.)

Abbot and Smith, Lep. Ins. Georgia, p. 143, Tab. LXXII, 1797 (colored figure).
Harris, Ins. Inj. Vegetation, 1st edit., p. 311, 1841; 2d edit., p. 333, 1852; 3d edit., p. 431 (colored figure), 1862; Ent. Corr., p. 310 (Pl. III, fig. 3*b*), 1869.
Fitch, 5th Rep. Nox. Ins., N. York, p. 845, 1858.
H. Edwards, Papilio, iii, p. 21, 1883 (young larva).
French (*palla*), Can. Ent., xiv, p. 34, 1882 (full-fed larva); Can. Ent., xvii, p. 11, 1885 (life history).
Soule, Psyche, v, p. 262, Aug.–Dec., 1889 (life history).
Packard, Bulletin U. S. Ent. Comm. 7, Forest Ins., p. 122 (quotes Harris); Proc. Bost. Soc. Nat. Hist., xxiv, p. 517, 1890; Journ. N. York Ent. Soc., i, p. 22, 1893; 5th Rep. U. S. Ent. Comm. Forest Ins., p. 153, 1890 (life history); Jour. N. York Ent. Soc., i, p. 22, March, 1893 (eggs and life history).

Moth.—Numerous ♂ and ♀. Body and wings pale cinereous, with ocherous tints, and dusted with brown scales. Palpi brown on the side and above. A broad dark brown median band extending from between the antennæ back to the summit of the thoracic crest. Fore wings with a basal white line which is dislocated upon the cubital nervule, but not forming so distinct and regular an angle or point as in *I. apicalis* (*vau*). A short line beyond, meeting an oblique line which passes from the basal third of the costa to the outer third of the inner (hinder) margin of the wing, which, with the fourth line, forms a large V-shaped mark. Both lines are shaded within with brownish. The fourth line is slightly bent just below the costa on the last subcostal venule, but is not nearly so much so as in *I. apicalis*, and more distinct on the costa than in the middle of the wing; externally this costal white mark is shaded toward the costa with rusty ocherous.

A submarginal slightly undulating row of brown linear spots, which is dislocated inward on the second cubital interspace. Fringe with dark spots at the ends of the venules.

Hind wings with a darker waved line just beyond the middle; beneath they are lighter than the fore wings, with the submedian line present.

Expanse of wings, ♂, 30–35 mm.; ♀, 35 mm.; length of body, ♂, 18 mm.; ♀, 20 mm.

This species is the most common in the Appalachian subprovince, being the largest of all, and is distinguished by the white costal mark on the outer third of the wing being only slightly bent outward behind the costal edge, and not very oblique, as it is in *I. apicalis*.

It varies in hue, some individuals being dark, almost mouse-colored, and others with pale ocherous as a ground color. Whether there are seasonal varieties remains to be seen.

Var. *inversa* Pack. (Pl. II, figs. 20, 21). Smaller, darker, more mouse-colored than *I. inclusa*, since the areas corresponding to the light portions of *I. inclusa* are in the present form densely dusted with mouse-brown scales. The fore wings are also more bent on the outer edge than in normal *I. inclusa*. The dark reddish madder-brown thoracic band narrower than in *I. inclusa*. Fore wings with the basal line dislocated as in *I. inclusa*, but the lower portion is slightly waved, as on the outer lines. It differs from *I. inclusa* chiefly in the costal portion of the fourth line (outer arm of the V) being sinuous, and from *I. apicalis* in not being oblique; the costal mark is bent outward near the costal edge, and bent inward and outward again before leaving the rusty ocherous costal patch in which the mark is situated. The third and fourth lines situated as in

I. inclusa, but the first and second lines are situated nearer together than in *I. inclusa*. The subapical brownish-tinged region bordering the upper half of the fourth line is narrower and of a deeper reddish brown line than in *I. inclusa*. The submarginal series of linear spots is not so distinct as in *I. inclusa*, while the dark line crossing the hind wings is paler than in that species.

Beneath, the wings are a little darker; the line common to both wings is much more distinct than in *I. inclusa*, and the costa of the fore wings is margined with reddish.

Expanse of wings, ♂, 24 mm.; ♀, 32 mm.; length of body, ♂, 12 mm.; ♀, 13 mm.

This variety differs in its smaller size and in the costal portion of the fourth line being sinuous, bent outward near the costal edge, then bent inward and again bent outward.

Geographical distribution.—Thus far only known to myself from the Appalachian province; New York City (Elliot); Janeville, Md. (Mus. Comp. Zool.). Professor French sends me the following localities: Canada, Lincoln, Nebr., Colorado.

Var. *Ichthyura palla* French.—The caterpillar of this moth was found feeding on willows in southern Illinois through the most of September, resting in an inclosure formed of several leaves fastened together at the ends of the twigs, but no more than half a dozen occurred in a nest. Those put in breeding cages pupated before the middle of October. The moths appeared in the following April and May.

The moth is related to *I. inclusa* Hübn. and *I. ornata* G. & R.; more nearly to the latter in size and coloration, but differs from both in several particulars. Besides size and color, it differs from *I. inclusa* in the coloring of its larva. It differs from *I. ornata* in the color of the scales sprinkled over the fore wings, the color of the spots outside the fourth line, and the continuation of that line, as it is seen here partially obsolete opposite the disk, as well as in some other points. The apices are no more produced than in *I. inclusa*, nor is the costa more bent (French). We would add that, judging from two specimens received from Professor French, we are inclined to think that this is a variety of *I. inclusa* Hübner.

Larva.—Length, 1.25 inches when crawling; body nearly cylindrical; two black tubercles, close together, on the top of third and eleventh segments. On the back are four bright but narrow yellow lines alternating with narrow black ones. The stigmatal line is black; above this, on the subdorsal space, an irregular alternation of black and white. Below the stigmata a narrow yellow line; below this, on the substigmatal space, the body is flesh colored. Head shining black. A few gray hairs scattered over the body. (French.)

The moth.—Length of body, 0.56 inch; expanse of wings, 1.10 inches. General color of body and fore wings, pale gray, the latter rather sparsely sprinkled with dark brown scales. Palpi brown above, scarcely projecting beyond the head, third joint concealed by the hairs of the others. Front slightly brownish, a tuft of pale gray scales at the base of each antenna, the usual deep brown mark from the antennæ to the top of the thoracic crest. Fore wings with the usual transverse lines almost white. The basal line makes a bend outward on the median vein; from this it goes in a straight course to the submedian vein; from this to the posterior or inner margin it curves a little outward. A second line extends from the costa about one-fourth of the distance from the base obliquely to the posterior margin, near the posterior angle. A third line passes straight across the wing from the posterior margin to the second, a little below the median vein. The fourth begins as a white spot on the costa a little more than two-thirds of the distance from the base, and joins the second on the posterior margin, making the usual "V" as in the allied species. The fourth line is slightly S-shaped in its costal third. Outside the fourth line is a subterminal, somewhat zigzag row of black spots, some of which are often faint or obsolete. In the discal cell there is usually a faint oblique line that seems to be a continuation of the third line, though it does not reach the costa, and the end of the cell sometimes appears like a short line. There are three oblique shades of brownish olive, more or less distinct, that cross the wing parallel to the second line; the first, beginning on the costa inside the basal line, faintly borders that line to the submedian vein, and is seen below that vein on the third line; the second, outside the second line through its whole course, is darkest next the line; the third from both sides of the fourth line to the middle of the outer border faint, except along the line. Just outside the S-part of the fourth line are three grayish yellow spots with a few reddish brown scales. Hind wings pale smoky gray with a faint whitish line from the fourth of the fore wings to the anal angle. Beneath, the fore wings are about the color of the hind wings above, pale along the costa and terminally; the hind wings are paler, with a dark transverse line. (French, Can. Ent., XIV, 33.)

Ichthyura jocosa H. Edw. (Pl. III, fig. 22). One ♀ type: Indian River, Florida. This is, as I have satisfied myself by an examination of the type in the American Museum of Natural History, New York, only a small *inclusa*, differing from the normal form of the species in the inner arm of the V being firmer and less sinuous, being interrupted at the union with it of the short middle line which ends on the hind edge of the wing, while in *inclusa* the line is not usually interrupted, although two of the *inclusa* in Mr. Edwards's collection do have the line interrupted as in his type of *I. jocosa*. The latter is also more generally subocherous than usual, and without a line on the hind wing.

For the opportunity of examining five alcoholic examples of the first stage of this larva, I am indebted to Professor Riley; those of the last stage I have collected from the poplar. Mr. H. Edwards (Papilio, iii, 21) briefly describes the second stage, and adds that it "feeds in companies until after the second molt; the larvæ then separate and act independently of each other."

The eggs of the normal form of this species (i. e., *I. inclusa*) were received from Mr. W. N. Tallant, of Columbus, Ohio. They were laid July 20 and the larvæ hatched August 10 or 11. It feeds at first socially on the aspen, eating out patches on the under surface of the leaf.

Egg.—Diameter about 0.6 mm. Hemispherical, rather high; the shell is thin, white (the egg is reddish just before the larva hatches). The shell under a Tolles half inch objective is seen to be covered with minute polygonal cells which are tolerably distinct, with slightly thickened walls.

Larva, Stage I.—(Hatched August 10–11. Described two days after hatching, and also from alcoholic specimens of the same brood.) Length, 3 mm. The body is rather long, cylindrical, head rounded, but little wider than the body at first before the latter becomes filled out after eating a few days, as later it is no wider than the body; it is shining jet-black, and provided with scattered, long, stiff, tapering bristles. The prothoracic and suranal plates are shining brown-black. The former is moderately large, about three times as broad as long, irregularly trapezoidal, narrowing a little behind, and shows no signs of division into two halves; four hairs arise from the front and four from the hinder edge. The piliferous warts on the thoracic as well as abdominal segments are more or less conical, and none bear more than a single hair. The second thoracic segment bears two minute median dorsal tubercles, one on each side of the median line of the body, and smaller than those on the third segment, while the next one on each side of the body is larger than the homologous ones on the third thoracic segment. The tubercles on the second and third thoracic segments are arranged across the segment in a straight line, four of them being visible on each side above. On the abdominal segments the four dorsal tubercles are arranged in a more or less curved line, the curve becoming more marked toward the end of the body, until on abdominal segment 8 the curve is almost semicircular. On the first abdominal segment the two median tubercles are larger than any on the thoracic segment, and are larger than the subdorsal and lateral ones on the segment in question, and are decidedly larger than the homologous ones on the second to seventh abdominal segments. The four dorsal tubercles on segments 2 to 7 are all of the same size, but the two on the eighth segment are nearly as large as those on the first, and are about twice as large as those on the seventh abdominal segment; on the eighth segment, however, the subdorsal tubercles are nearly as large, but are narrower than the two in the middle. This segment is slightly humped, and bears a brown spot surrounding the bases of the two twin tubercles, and a similar spot occurs on the first abdominal segment. The four dorsal warts on segment 9 are arranged in a trapezoid, the two in front being one-half as large as the two behind. The upper subdorsal row of tubercles are partly connected by short lines or streaks, and between this and the next row of warts lower down is a broken fine brown line, which is, however, almost obsolete. A fine nearly obsolete (or is it incipient?) dorsal brown line. In more advanced specimens the body is plainly striped on each side with three interrupted dark reddish lines. The piliferous tubercles or warts are dark brown, and give rise all over the body to but a single hair. A pair of especially large long hairs arises from the second thoracic and ninth abdominal segments. The hairs are long and slender, and though under a low power they appear to be tapering, under a one fifth objective they are seen to be docked or blunt at the end and some at least slightly but distinctly bulbous at the tip; they are also seen to be hollow and truly glandular; the end appears to be flattened; as seen sideways, the hairs appear to taper. The hairs vary much in length, some being longer than the body is thick. An unusual, if not unique, feature, exceptional among bombycid larvæ in the first stage, is the microscopic hirsuties clothing the body. Under a one-fifth inch objective the microscopic hairs are very short, quite uniform in length, very dense, and taper to a point.

The suranal plate is distinct, blackish, nearly as long as broad, rounded triangular, and bears on the edge eight piliferous warts of nearly equal size, besides two arising from the surface, a little in front of the middle. The spiracles are round and remarkably small.

The thoracic legs are black, and at the end near the claw are two tenant hairs which are long and large, curved backward and somewhat knife shaped. The abdominal legs have a black chitinous scale on the outside above the planta. These are at first crotchets.

The general color of the body is deep straw-yellow, with a greenish tinge and a waxy appearance or gloss on the skin, while the obscurely marked stripes are reddish.

Stage II.—Length, 5-6 mm. (August 18-20). Now the generic and part of the specific characters are assumed, the species in this stage being easily distinguishable from the others of the genus. The larvæ feed socially on the underside of the leaves, in confinement hiding between the leaves in the breeding box.

The head is black, as wide as the body. The prothoracic shield is pitch-black, and now is divided by a pale median line. The body is bright yellowish green. There are three dorsal dark brown lines, the median less broken than the others. The three lateral lines are now distinct, the middle one being one half as wide as the others, the two others bearing the larger subdorsal and lateral tubercles, respectively. The situation and relative proportion in size of the tubercles (which are dark) are as described in Stage I; the two large twin dorsal pairs on abdominal segments 1 and 8 are larger, higher, and more distinct than before, and each bears about four or five stiff, dark bristles of unequal size and length. The suranal plate is blackish. The hairs are now slender, pale or dull whitish, tapering, and in general about as long as the body is thick. The legs as before, but the abdominal ones with a larger and rather more distinct squarish chitinous patch above the planta. (Described soon after molting).

Stage III.—(Described August 29, immediately after molting). Length, 12 mm. The head is now not so wide as the body, black. The prothoracic shield is distinctly divided. Body bright, glistening, yellowish green, with three narrow dorsal black lines, the median one less broken than the others. These are succeeded by a broad diffuse subdorsal, almost double black stripe, on which a black piliferous wart is situated, one for each segment. Below is a similar wart, including a broad line, and above and below this is a fine black brown, somewhat broken line; the lower one is the spiracular line, the dark spiracles being minute and interrupting the line, so that there are four instead of three lateral lines in this stage, the additional line being the lowest or spiracular one.

The two large twin tubercles on the first and eighth abdominal segments arise from a common fleshy lump, that on the eighth segment being slightly the smaller of the two pairs. Each bears six to seven black hairs. The hairs are in general sordid white, and are not so long as the body is thick. The suranal plate is large, black, and the anal legs are nearly all black on the sides.

Recapitulation.—(Corrected from that published in Proc. Bost. Soc., xxiv, 517.)

1. In Stage I the two median dorsal tubercles on the first and eighth abdominal segments are larger than the homologous ones on the second to seventh abdominal segments, and each pair is situated on a brown raised ground.

2. The prothoracic shield is undivided; in Stage II it begins to be divided, becoming separate in the last stages.

3. Toward the end of Stage I the three lateral lines are faintly indicated.

4. The hairs in Stage I are glandular and slightly bulbous.

5. The tubercles in Stage I all give rise to but a single hair.

6. The three dorsal dark reddish lines appear at the end of Stage II.

7. The spiracular line appears in Stage III.

Cocoon.—The caterpillar, living during the last stages in a rude cocoon or tent spun between two leaves, or within a folded leaf, transforms within it, the cocoon being a loose web with abundant brown silken strands.

Pupa.—Large and thick; wings not reaching to the hinder edge of the third abdominal segment; abdomen unusually full and rounded at the end; the two last segments smooth and polished, scarcely pitted; the terminal spine (cremaster) forming a slender rounded spine scarcely thicker at the end than at the base, and terminating in two broad, stout, suddenly upcurved flattened hooks, with a broad sharp edge sending off three or four long, slender setæ, which are entangled in the silk strands of the cocoon. Length, 17 to 18 mm. (Fig. 60).

Habits.—Dr. Harris, in his "Treatise," quite fully describes the habits of this tent-inhabiting caterpillar, remarking: "When young they sometimes fold up one side of a leaf for a nest, and eat the other half." He also fully describes the tent made by the social mature larvæ, which we have also observed on the poplar, "made of a single leaf folded or curled at the sides, and lined with a thin web of silk." He also states that "the caterpillars go out to feed upon the leaves near to their nests." It thus appears that from early larval life the caterpillars live in much the same way as the fully grown larvæ, dwelling in tents, and, unlike most Notodontians, continuing to live socially in "swarms of twenty or more," until they disperse, preparatory to pupation. While feeding exposed, they are probably not eaten by birds, as their colors and markings serve as "danger signals."

The following account is copied from Harris's Correspondence (p. 210). He observed them on the Balm of Gilead:

August and September, 1835: Gregarious caterpillars on the Balm of Gilead tree; folding up the leaf and lining it with silk as a common web, the petiole being also fastened to the trunk by silk.

Larva.—Color of the larva yellow; head, geminate tubercles on the fourth and eleventh segments, tip of last segment, and true feet, black; three narrow dorsal and three broader lateral vittæ, and spiracles, black. The larva is much like that of *Clostera anachoreta* (Ernst, 165, fig. 214) and *C. reclusa* (Ernst, 165, fig. 216) and closely resembles *C. anastomosis.* Thin cocoon formed in a box October 4, 1835. Another cocoon formed in October, 1837, disclosed the imago June 15, 1838.

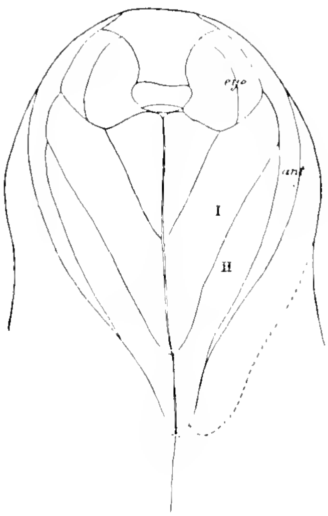


FIG. 62.—Head of pupa of *Ichthyura inclusa*.

August 10, 1838: Found the larvæ in great abundance on the Balm of Gilead tree. These caterpillars are gregarious, and form a common shelter consisting of a leaf folded longitudinally and lined with a thick web of silk, beneath which the insects are sheltered when not feeding. They eat the whole of the leaves except the veins, which remain untouched. The petioles of the small leaves used as habitations are fastened with silk. The larger leaves subsequently used for shelter are not thus secured. They do not eat the leaves which serve for habitations, but sometimes fold one-half of the leaf and eat the corresponding side. When fully grown the caterpillar measures 1½ inches or more in length. They do not vary in color or markings at different ages. Body slightly hairy, light yellow; the head, true feet, a double wart on the fourth, another on the eleventh anal valve, three slender dorsal stripes and three broader lateral ones on a dusky ground, and the spiracles, black. In the oldest caterpillars there is an orange-colored line at the sides of the body below the spiracles. The upper lateral black stripe is the breadest and becomes indistinct toward the second, which gives to the sides the appearance of a broad, dusky stripe marked with three black lines. The thinly scattered hairs on the body are whitish, and proceed indiscriminately from the surface, and not from regular tubercles.

The caterpillar of this moth occurred on the poplar (*P. grandidentata*), at Providence, September 11 to 15. They were living within a tent made by drawing two or three leaves together, several smaller branches of the tree having been defoliated by them. It pupated a few days after, the moth appearing in the breeding cage June 1 of the next year.

The eggs occur in April and May and July and August; the larvæ from May to July and August to September; adults, March, April, and May, and July and August (also all winter months in confinement in breeding cages. (Riley.)

Food plants.—Different species of poplar, especially *P. tremuloides.* *I. palla* was reared by Professor French on the willow, poplar, willow maple.) (Riley.)

Geographical distribution.—It ranges from Maine and Canada to Georgia (Abbot) and Florida (Packard), thus extending through the Appalachian and Austroriparian subprovinces. Maine (Packard); Massachusetts (Harris, Sanborn, Shurtleff); Amherst, Mass. (Mrs. Fernald); Rhode Island (Packard); New York (H. Edwards, Elliot, Dyar); Racine, Wis.; Chicago, Ill. (Westcott); southern Illinois (French); Georgia (Abbot); Jacksonville, Fla. (Packard); Indian River, Florida (H. Edwards); Texas (Riley); Denver, Colo., April 30, May 9 (Gillette). Its western and southwestern limits are not exactly known. Professor French sends me the following localities of specimens in his collection: *I. inclusa*, Maine, New York, Pennsylvania, Wisconsin, Ohio; var. *inversa*, Canada, Lincoln, Nebr.; Colorado; var. *palla*, normal, Carbondale, Ill.; Lincoln, Nebr.

Ichthyura brucei H. Edwards.

(Pl. III, figs 23–25.)

Ichthyura brucei, H. Edw., Ent. Amer., i, p. 17, April, 1885.
Dyar, Ent. News, iii, p. 6, Jan., 1892.
Kirby, Syn. Cat. Lep. Het., i, p. 611, 1892.
Pack., Ent. News, iv, p. 79, March, 1892.
Dyar, Ent. News, iv, p. 170, May, 1893; Can. Ent., xxiv, p. 180, May, 1892.
Ichthyura multnoma, Dyar, Can. Ent., xxiv, p. 179, July, 1892.
Melalopha brucei, Neum. and Dyar, Can. Ent., xxv, p. 123, May, 1893; Trans. Amer. Ent. Soc., xxi, p. 191, 1894; Journ. N. Y. Ent. Soc., ii, p. 115, 1894.
Melalopha althe Neum. and Dyar, Can. Ent., xxv, p. 122, May, 1893.

Larva.

Dyar, Psyche, vi, p. 403, Feb., 1893.

Moth.—I will first copy Mr. Edwards's description of this form, and then add some observations of my own:

Ground color of primaries sordid white, with the lines and marks rich brown. A basal and subbasal line, the former whitish, edged with brown, and dentate in the middle, the latter almost straight. Behind the middle is a broad brown shade through which from costa to internal angle runs a clear white line, which on costa is broadly produced into the distinct white mark usual in the genus. Between this and the margin a row of seven brown spots, in the middle of which is a brownish cloud resting on posterior margin, which with the fringe is brownish. Secondaries wholly mouse-color; thorax sordid white at the sides, the center broadly brown. Abdomen dull sordid white; antennæ and palpi brown, the shaft of the former whitish. Underside mouse-color, with darker bent median band common to both wings, and the white costal mark on primaries indicated by a pale dash.

I. brucei differs from *I. apicalis* (*rau*) in the V being about one half as wide, the base of the inner arm of the V ending just about the middle of the wing, hence the four lines are much more parallel to each other than in *I. apicalis* or *I. inclusa*. In *I. brucei* the oblique costal white mark is less sinuous and in var. *multnoma* less bent behind the costa than in *brucei*.

Geographical distribution.—Franconia, N. H. (Mrs. Slosson); Brunswick, Me. (Packard, Mus. Comp. Zool.); Kittery, Me. (R. Thaxter); Plattsburg, N. Y. (Hudson); Colorado (Bruce, fide Edwards, French).

Var. *multnoma* Dyar (Pl. III, fig. 26). I regard this as a dark variety of *I. brucei*. The markings of a male kindly loaned me by Mr. Dyar are identical in position with those of a specimen of *I. brucei* from Franconia, N. H.; it only differs in the much darker colors. The basal line is widely dislocated in the same way. In my *I. brucei* the fourth or outermost line is situated a little nearer the outer edge of the wing, and the incomplete V mark is a little narrower than in *multnoma*, but this is a common variation. In size, in the marginal dark spots, and the subapical reddish orange patch the two forms are identical.

First larval stage.—Head round, shining black, with a few hairs; width, 0.5 mm. Body somewhat flattened, with long pale and black hairs rising singly from large concolorous tubercles; color sordid grayish, tinged with dark vinous on joints 2, 5, 7, 8, 11, and 12 over the dorsum. Feet normal, the thoracic dark, the abdominal concolorous with the body. As the stage advances the whitish spaces on the back become nearly white and the piliferous tubercles come out black and distinct in three rows on each side. At the end of this, and of each following stage, the larva spins a house of thread and leaves in which it molts, and in which it remains during the succeeding stage, when not eating. The larvæ are solitary.

Second stage.—Head as before; width, 0.9 mm. Body flattened, with deep segmental incisures; piliferous tubercles large, concolorous at first, but later black; setæ short, black. Color blackish vinous, except the dorsum of joints 3, 4, 6, 9, 10, and 13, which is greenish white, containing tubercle I and a very narrow dark dorsal line. The anal plate (i. e., joint 14 or the tenth abdominal segment) is vinous. Lateral and subventral tubercles pale. Thoracic feet black.

Third stage.—Head rounded, median suture deep, shiny black, hairy; width, 1.8 mm. Warts rather large, each with a hair, and other somewhat shorter hairs arise from the body. Color vinous black with pale yellow dorsal patches on joints 3, 4, 6, 9, 10, and 13 anteriorly, inclosing warts i and ii. A dark dorsal line, each side of which are a few yellow mottlings on the dark segments; subventral warts largely yellow, the others concolorous with the markings, except row i, which is dark on the yellow segments. Setæ all blackish. Later, joints 5 and 12 are seen to be a little enlarged dorsally; a narrow, broken, waved line appears along warts i in the yellow markings; the yellow patch on joints 9 and 10 extends faintly on joint 11; there is a broken, irregular, yellow, superstigmatal line, distinct only on the yellow-marked segments, and some rather more continuous yellow mottlings along the substigmatal ridge.

Fourth stage.—Head rounded clypeus depressed, median suture deep; hair short, dense, white; color black, slightly shiny, brownish centrally in the depression around the median suture; width, 3 mm. Warts rather large, rows i and ii on joints 3, 4, 6, 9, 10, and 13 and all the subventral warts yellow, the others black. Joints 5 and 12 enlarged dorsally, velvety black. Color purplish black, a broad, yellow, dorsal band, except on joints 5 and 12, containing a broken, triple, dorsal line, fainter on joints 7, 8, and 11. The rest of the body is purplish black, the subventral region included. Hair dense, white, consisting of fine short hairs from the body, with single, slightly longer and larger ones from the warts. As the stage advances a marked change takes place. A broad pale grey dorsal band, containing very faint triple dark line, obsolescent and broken; warts i and ii orange, except on joints 2 and 5, row ii on joints 3, 4, 6, 9, 10, and 13 broadly orange; a broad, pale bluish, subdorsal band, heavily mottled with vinous black; joints 5 and 12 dorsally, and lateral spots on all segments (most distinct on joints 3–5), velvety black. A broad, broken, deep orange, stigmatal band, divided by an irregular black stigmatal line and consisting of orange spots spreading from the warts of rows iv and v and adjacent mottlings, barely confluent. Venter blackish; thoracic feet shiny black.

Cocoon.—Not different from the house made at the end of each stage, except that there are a few transverse threads to support the pupa.

Pupa.—Small but robust. Dorsal outline arched, ventral nearly straight, rounded at both ends; cremaster, a long spine of even thickness throughout, smooth, shining; abdomen very slightly punctured. Color red-brown, darker ventrally and dorsally, nearly black on the thorax and cases, with a green tinge on the latter. Length, 13 mm.; width, 4.5 mm. There are two broods each year.

Food plant.—Willow (Salix).

Habitat.—Oregon and Washington west of the Cascade range and, probably, also western British Columbia. Found by Prof. O. B. Johnson at Seattle, Wash. Larva from Portland, Oreg. (Dyar.)

Ichthyura albosigma (Fitch).

(Pl. III, figs. 27–30).

Clostera albosigma Fitch, 2d Rep. Nox. Ins. N. York, p. 271, pl. 2, fig. 4, 1855; 5th Rep. Nox. Ins. N. York, p. 64, 1859.

Ichthyura albosigma Morris, Synopsis Lep. N. Amer., p. 244, 1862.
Pack., Proc. Ent. Soc. Phil., iii, p. 352, 1864.
Grote, Check List N. Amer. Moths, p. 18, 1882.
Pack., 5th Rep. U. S. Ent. Com. Forest Ins., p. 154, 1890 (figure of moth in text).
Smith, List Lep. Bor. Amer., p. 29, 1891.

Melalopha albosigma (sic) Kirby, Syn. Cat. Lep. Het., i, p. 610, 1892.
var. *specifica*, Dyar, Can. Ent., xxiv, p. 180, July, 1892.
Neum. and Dyar, Can. Ent., xxv, p. 122, 1893; Trans. Amer. Ent. Soc., xxi, p. 191, 1894; Journ. N. Y. Ent. Soc., p. 114, 1894.

Larva.

(Pl. XVI, figs. 3, 3*a*, 3*b*, 4, 5.)

Fitch, 2d Rep. Nox. Ins., p. 271, 1855 (egg, full-fed larva, cocoon); 5th Rep. Nox. Ins. N. York, p. 64, 1859.
Packard, Jour. N. York Ent. Soc., i, p. 27, March, 1893 (three last stages described).

Moth.—Several ♂ and ♀. Wings less ocherous than in *I. inclusa*, quite clear, and bathed with a slight lilac tinge. The dark brown thoracic band is wider, more triangular in front than in *I. inclusa* and *apicalis*, extending on the low thoracic tuft as a broad cordate concolorous mark. Fore wings, with the basal and second lines distinct and parallel, crossing the entire wing, the basal line not being dislocated. The third line, reaching only as far as the subcostal vein, slightly bent, connected at its base with the fourth line and forming a narrow obscure V, very different in shape from that of the other species. The outer or fourth line, passing forward from the hinder edge of the wing, curves outward on the fourth subcostal venule, where it becomes a white V-shaped mark, the deep, large sinus being filled in with a large patch of reddish vandyke brown, the patch being bounded behind by the cubical vein. From this sinus the line obliquely retreats to the costa, after forming a very distinct subcostal loop. Beyond the loops and sinus the wing is brownish to the edge, including the apical region. Discal spot forming a faint line with a second inner parallel one. An obsolete dark submarginal diffuse line, paler within. Hind wings with no line, quite pale.

Beneath, light clay-yellow, with no common line; the outer line shows faintly, while the broad costal whitish mark is quite distinct through the wing; costa ferruginous. The abdominal tuft edged with dark brown, much as in the other species.

Expanse of wings, ♂, 30 mm.; length of body, ♂, 11 mm.

This not uncommon species differs from all the others in the distinct S-shaped portion of the fourth or outer line, situated between the costal edge and the cubital vein, the outer curves of the S being filled in with reddish brown. Also the basal line is not dislocated, both this and the second line crossing the entire wing and being parallel.

Var. *specifica* Dyar. Under this name Dr. Dyar briefly mentions a form of this species captured at Manitou, Colo., May 2, "which differs from the type by its much paler color." Colorado (French).

Egg.—"Of a hemispheric form and dark brown, with a wide glaucous gray ring on the outer margin." (Fitch, p. 275.)

Larva.—The following description is drawn up from Mr. Bridgham's colored drawings of the three last stages and an alcoholic specimen of the mature larva. It occurred on the poplar, July 9 to 13, those in the three last stages occurring at these dates. Other specimens were reared by Mr. Bridgham and the moths obtained from them. (For stage II see Appendix A.)

Larva in Stage III.—Length, 26 mm. Head as wide as the body, reddish. The body reddish on the sides, and green along the back, interrupted by a reddish patch on the first and one on the eighth abdominal segments, each of which incloses a median tubercle. The green back incloses three parallel dark green, indistinct, interrupted lines. There are two greenish tubercles on the side of the body, one above and the other below the spiracle.

Stage IV.—Length, 30 mm. The hair is still reddish, but the body has now lost its green shade on the back, which is pale, with three darker parallel dorsal lines. The two median tubercles are now as well developed as in the last stage. The side of the body is pale reddish, with dark lateral tubercles on the thoracic and first abdominal segments, those on the succeeding segments being yellowish, as on the abdominal legs, including the anal pair and suranal plate. The thoracic legs are pale.

Full-fed larva.—Length, 30 mm. Head hardly as wide as the body, black, with a y-shaped, pale brown line in front, formed of a median line extending down from the vertex to the apex of the clypeus, and then dividing so as to extend down on each side, ending before reaching the antennae. The head is flattened and densely covered with grayish hairs. The three thoracic segments bear each six lateral, rather large, yellowish warts, the lowest one the largest, each bearing about six or seven hairs of unequal length. There is a high median finger-shaped, fleshy mutant black tubercle on the first abdominal segment, bearing numerous short, unequal hairs; it is rather high, finger-shaped, and bent over backward. On the eighth segment is a shorter, smaller, paler one. It is evidently of double origin, its longest diameter being transverse to the body, and somewhat wedge-shaped; the end is somewhat swollen on each side, with a slight valley between the swellings, showing that it was originally formed of two separate tubercles, and this is also suggested by the fact that each swelling bears eight or ten short unequal hairs. The thoracic legs are black; the abdominal legs are dark, especially toward the planta.

Colors (described from Bridgham's figure): Body straw-yellow, with three dorsal, more or less interrupted grayish or pearly pale brown lines and a broad lateral stripe, below which the tubercles are yellow ocherous. The suranal plate is flattened, rounded in outline, and hairy, with the surface rather rough and hairy. In my single alcoholic specimen there is no sign of a prothoracic shield or plate.

Although the imago of *I. apicalis* is very near that of *I. inclusa* in markings, the larva is very different, there being no median dorsal tubercle on the first abdominal segment. In the lack of these tubercles *I. strigosa* resembles *I. apicalis*. On the other hand, the larva of *I. albosigma*, in respect to the presence of the two dorsal abdominal tubercles, approaches that of *I. inclusa*. These two species, then, as larvae, belong to the same genus, while the two other species (*apicalis* and *strigosa*), as respects the larvae, differ generically from *inclusa* and *albosigma*, though the moths are congeneric. It is evident that the larvae of *apicalis* and *strigosa* are more generalized, since they lack the rather highly specialized dorsal tubercles so prominent in the two other species of the genus. If we regarded the moths alone we might erroneously consider that *apicalis* and *inclusa* were both coeval, whereas *apicalis* must be a much older, more generalized form; hence, speculations on the phylogeny of Lepidoptera based on the imagines alone may often be uncertain.

The larva of *I. albosigma* is closely allied in shape and in the two dorsal abdominal dark tubercles to the European *I. reclusa*, except that the tubercles in the American species are much larger and more prominent.

Fitch states that the "white stripes along each side form divers-shaped rings and letter-like marks. The stripes upon the back are interrupted upon the two humped segments."

Cocoon.—"Formed of yellowish gray silk, loosely woven and attached to the underside of a leaf." (Fitch, p. 275.)

Food plant.—Species of Populus, the aspen, etc.; poplar and willow (Beutenmüller).

Geographical distribution.—This fine species extends throughout the Appalachian into the Campestrian subprovince as far as the Rocky Mountains, in this region, however, varying from the type in being "much paler." Orono, Me.; Amherst, Mass. (Mrs. Fernald, Riley, U. S. Nat. Mus.); Maine (Mus. Comp. Zool.); Massachusetts, July 15 (Sanborn); Providence, R. I. (J. Bridgham); New York (Fitch); Plattsburg, N. Y. (Hudson); Ohio, July (Riley); Seattle, Wash. (coll. of Professor Johnson, fide Dyar); Portland, Oreg. (Dyar); Canada, Maine, Newton, Mass.; New York, Wisconsin, Tiffin, Ohio (French); var. *specifica*, Manitou, Colo. (Dyar, French).

Habits.—Fitch, who has carefully observed the habits of this species, states that the caterpillar attains its full size about the middle of July.

Several of the caterpillars commonly live together upon a particular limb, which they strip of its leaves, eating all the leaf except its median and portions of the other coarse veins. They construct a kind of nest by drawing two or more leaves together with the silken threads which they spin from their mouths, forming a hollow, ball-like cavity within, in which they repose when not engaged in feeding. Three of these caterpillars which I transferred with their nests to a feeding cage on the 11th of July all spun their cocoon within the nest a day or two afterward. The moths all came out on the 25th of July, thus remaining in their pupa state but a little over a week. The moth crawls from its cocoon, and, with its fore feet clinging to a twig, hangs perpendicularly downward, swinging with the breezes until its wings become dry and stiff. It then discharges one or more drops of an opaque birch-red fluid and takes to flight. (Fitch.)

Subfamily V. Notodontinæ.

Moth.—Head moderately large, but not prominent; ♂ antennæ often feebly pectinated to the tips, often with short stout branches ciliated at the tips; in the ♀ either ciliated or simple (Symmerista). Palpi moderately long, reaching to the front of the head, or unusually long (Symmerista). Thorax either smooth or with a high tuft. Fore wings usually broad, with the costa often convex and the apex well rounded; internal edge with a tuft in the more typical genera; costal region usually rather wide or sometimes narrower (Pheosia). Subcostal cell either absent or present. Abdomen full, not forked at the end in the ♂.

Egg.—Low hemispherical; shell finely pitted with polygonal areas.

Larva.—The body either smooth, subnoctuiform, with no markings except a lateral line (Nadata and Lophodonta), or humped either on the eighth abdominal (Pheosia, Dasylophia, Symmerista) or on second and third or on several (4–5) of the abdominal segments (Notodonta), or on abdominal segments 1–8 (Nerice); the dorsal humps in Pheosia bearing a horn in the American species. All except Nadata and Lophodonta gaily banded, spotted, or otherwise conspicuously colored and marked, with bright longitudinal stripes.

Cocoon.—Either thin and slight or the larva enters the ground to pupate; in Pheosia a subterranean earthen cell lined with silk.

Pupa.—Body somewhat elongated; head not prominent; cremaster either obsolete, without spines (Lophodonta), or ending in a broad spinulated stout plate or ending in two stout spines (Symmerista), or armed with four spines (Nadata); or the spine is very long, slender, cylindrical, and ending in two hooks (Nerice), no subfamily pupal characters being present.

SYNOPSIS OF THE GENERA OF NOTODONTINÆ.

A very high thoracic tuft; palpi large; species yellow ocherous, with two twin silvery white discal spots; outer edge of wings scalloped .... *Nadata*

Fore wings with a tuft on the inner edge; palpi large; antennæ with slightly larger branches than in Notodonta. *Lophodonta*

Antennæ heavily pectinated; palpi larger than in Lophodonta .... *Drymonia*
Fore wings acute at apex, and with a large tuft; with no cross lines; outer edge of fore wings scalloped. *Lophopteryx*
Antennæ well pectinated; palpi small; fore wings long, much produced toward the rounded apex; dark brown intervenular streaks; no cross lines .... *Pheosia*
Antennæ subsimple; apex of fore wings well rounded; no subcostal cell; tuft rather small .... *Notodonta*
Antennæ more widely pectinated than in Notodonta; fore wings squarer, less rounded at apex .... *Ellida*
Antennæ pectinated to the tips; palpi large and long; a high thoracic tuft; apex of fore wings well rounded; inner edge with no tuft .... *Nerice*
Head with a high tuft; palpi long slender, fore wings acute, with black longitudinal slashes .... *Dasylophia*
Head with a high tuft; apex of forewings square; costal edge of fore wings white .... *Symmerista*

SYNOPSIS OF THE LARVÆ (THAT OF ELLIDA NOT KNOWN).

A. Body not humped, noctuiform.
Body cylindrical; not hairy; with two faint yellow subdorsal lines .... *Nadata*
As in Nadata, but more wrinkled; a faint double dorsal line and a lateral pink line extending along side of head .... *Lophodonta*
Body as in Lophodonta, green, a lateral yellow spiracular line besides the subdorsal one .... *Drymonia*
(Larva of American species not known) European larvæ with two separate large high dorsal papillæ on eighth abdominal segment .... *Lophopteryx*
B. Body sphinx-like, with a caudal horn or only a hump.
No lines or bands; skin smooth, porcelain-like .... *Pheosia*
C. Body with from three to five humps on abdominal region.
Head large, square; anal legs used in walking .... *Notodonta*
D. Abdominal segments 1 to 8 with a forked hump.
Divisions of the humps opened and closed like a bird's bill .... *Nerice*
E. A low dorsal knob on the eighth abdominal segment.
Anal legs with no hooks; end of body uplifted; body gaily striped .... *Dasylophia*
F. Eighth abdominal segment swollen on sides and above.
Head small, rounded; body conspicuously banded; suranal plate lunate; anal legs with hooks .... *Symmerista*

Nadata Walker.

(Pl. XLI, fig. 1, venation.)

Phalæna Abbot and Smith, Lep. Ins. Georgia, p. 163, 1797.
Cosmotricha (in part) Hübner, Samml. Exot. Schmett., iii, 1816.
Nadata Walk., Cat. Lep. Het. Br. Mus., v, p. 1062, 1855.
Pack., Proc. Ent. Soc. Phil., iii, p. 356, 1864.
Hastor Boisd., Lep. Cal., p. 87, 1869.
Nadata Grote, New Check List N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 611, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 185, 1894; Journ. N. Y. Ent. Soc., p. 113, Sept., 1894.

Moth.—Head moderately prominent; front triangular, broad above; below the base of each antenna is a large spreading tuft of long scales reaching halfway down the front and partially covering the eyes, which are naked, not hairy. Antennæ in ♂ with long slender pectinations, the branches extending to the tips; in the ♀ the pectinations hardly longer than the joints. Palpi large, long, stout, ascending porrect, the third joint rather short, thick, but distinct; second joint not hairy at the end. Maxillæ small, rather short.

Thorax with a remarkably high pointed tuft on the front part and sending a ridge down each side to the end of the tegulæ; beneath, very hairy. Fore wings distinctly pointed at the apex, which is somewhat more so than in Datana; costa convex on the outer half, especially in the ♀; outer edge regularly convex behind the apex, but little shorter than the internal edge, more oblique in ♀ than in ♂; in ♀ slightly scalloped. Discal veins situated within the middle of the wing, so that all the venules are longer than usual. A rather short subcostal cell; apical region of the costa very narrow, the first, second, third, and fourth subcostal venules ending very near each other and near the apex. Hind wings somewhat produced toward the apex; outer edge regularly convex, much longer than the internal edge; the lower discal vein oblique, much curved; both discal venules, as in Datana and Gluphisia, situated nearer the base of the wing than usual.

Legs hairy, the hind tibiae with long scales spreading outward; two pairs of spurs, the apical ones much larger than the first pair. Abdomen in ♂ rather broad, with rather prominent lateral tufts, adding to the breadth of the hind body.

The genus differs from its allies in the well pectinated antennae, the large palpi, the high sharp thoracic tuft, and the scalloped fore wings, the species being yellow ocherous, with two twin silvery white discal dots.

Egg.—Hemispherical.

Larva.—Body cylindrical; piliferous warts minute; no tubercles or humps present; the ornamentation consisting only of two yellowish subdorsal bands, with no spots. Freshly hatched larva in shape like the mature larva, only the head is larger in proportion and the body is provided with bulbous glandular hairs.

The larva does not spin a cocoon, probably entering the earth to pupate.

Pupa.—Stout, thick; cremaster ending in a conical stout spine, with four upcurved spinules.

Geographical distribution.—The single species known ranges from Maine and Canada to Oregon and southward on the Pacific Coast to California, and on the Atlantic Coast to the Gulf States, including Florida and Texas. The genus thus prevails over the Appalachian, Austroriparian, and Campestrian subprovinces, spreading throughout the whole of America north of Mexico and south of the Hudsonian faunal limits.

Nadata gibbosa Abbot and Smith.

(Pl. XVII, fig. 3.)

Phalæna gibbosa Abbot and Smith, Lep. Ins. Georgia, p. 163, Tab. LXXXII, 1797.
Cosmotriche gibbosa Hübn., Samml. Exot. Schmett., iii, Taf. XIX, fig. 1–4, Penn., 1816.
Nadata gibbosa Walk., Cat. Lep. Het. Br. Mus., v, p. 1062, 1855.
Pack., Proc. Ent. Soc. Phil., iii, p. 356, 1864.
Alastor gibbosa Boisd., Lep. Cal., p. 87, 1869.
Grote, Check List N. Amer. Moths, p. 18, 1882.
Nadata gibbosa Smith, List Lep. Bor. Amer., p. 30, 1891.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 186, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 113, Sept. 1894.
Nadata doubledayi Pack., Proc. Ent. Soc. Phil., iii, p. 365, 1864.
Grote, Check List N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 611, 1892.
Nadata doubledayi, var. *oregonensis*, Butler, Ann. and Mag. Nat. Hist., Oct. 1881, p. 317.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Nadata behrensii H. Edwards, Ent. Amer., i, p. 49, June, 1885.
Nadata gibbosa, var. *rubripennis* Neum. and Dyar, Journ. N. Y. Ent. Soc., i, p. 24, March, 1893; Trans. Amer. Ent. Soc., xxi, p. 186, 1894; Jour. N. Y. Ent. Soc., ii, p. 113, Sept. 1894.

Larva.

(Pl. XVII, figs. 1, 1*a*, 1*b*, 2, 2*a*.)

Abbot and Smith, Lep. Ins. Georgia, Pl. LXXXII, 1797 (colored fig.). Full-fed larva.
Harris, Ent. Corresp., p. 308, 1869.
Boisduval, Lep. Cal., p. 87, 1869.
Lintner, Ent. Contr., iii, p. 150, 1874, fig. 8 (uncolored fig.). Full-fed larva.
Packard, American Naturalist, viii, p. 691, 1874. (Quotes Lintner.)
Riley, 5th Rep. U. S. Ent. Comm. on Forest and Shade Tree Insects, pp. 153, 424, 1890, Pl. XI; ibid. (fig. 6, colored fig. from drawing by Lintner).
Soule, Psyche, vi, p. 197, Dec., 1891. (Description of egg, five larval stages, and pupa.)
Packard, Journ. N. York Ent. Soc., i, pp. 57, 58, June, 1893. (Five stages described.)

Moth.—Of a uniform light buff, with a rusty tinge; fore wings a little deeper in tone, with an extradiscal slightly curved ferruginous line, parallel with the margin. Two small silvery discal dots, varying in size; the discal space within these dots clearer than the rest of the wing. An inner straight rusty line, which is slightly bent below the cubital vein. The wings beneath much paler. The fringe between the points of the scallops is white. Hind wings above of the same pale hue as the underside of both pairs of wings.

Expanse of wings, ♂, 40–45 mm.; ♀, 46 mm.; length of body, ♂, 17 mm.; ♀, 21 mm.

Nadata behrensii H. Edwards (types examined, 2 ♂, 1 ♀), from Siskiyou County and Butte County, Cal. It does not seem to differ from *N. gibbosa*. The ♀ has a paler body and wings; the fore wings are more pointed, and, as in a number of Pacific Coast moths, it is on the whole larger than the Eastern form of *gibbosa*.

On examining my type of *N. doubledayi* in the collection of the American Entomological Society I find that it is not even a variety of *gibbosa*. It only differs in having the underside of the palpi and of the fore legs dusky, characters which are not of varietal importance.

The three examples labeled *N. doubledayi* in the United States National Museum are without discal dots, there being only a dusky shade in their place. A single ♀ from Washington, D. C., has only one discal dot, and there is another ♀ without any. One ♀ in the same collection from the St. Cruz Mountains, California, is as large as any specimen I have seen, and with two discal dots larger than in any of the other fourteen specimens examined; it is less deep ocherous than usual.

The eggs were received from Mr. H. Meeske, and hatched June 12. They were laid on the oak, and the larvæ were raised on the leaves of that tree. Compare also the description of the five stages by Miss Soule in Psyche, Vol. VI, p. 197.

Egg.—Described by Miss Soule (Psyche, vi, 197) as hemispherical and opaque yellow, with a white bloom all over them. I still need specimens for examination under high powers of the microscope. (See Appendix A for a fuller description of the egg.)

Larva, Stage I.—Length, 2.5 mm. The head is large, full, and rounded, pale green, with a yellowish tinge like the body, only clearer, more amber-like; it is wider than the body, which is pale yellowish green. The body is smooth, without distinct piliferous tubercles, though there are scattered long, fine glandular hairs, which are ocherous brown in color, arising from microscopic tubercles. These hairs under a ½ inch objective at first appear to be simple tapering hairs, but after close observation are seen to be clear and slightly flattened and bifid at the tip. The body tapers regularly from the prothoracic segment to the end.

Stage II (end of stage?).—Length, 12 mm., June 20. The head is rounded, smooth, as wide as the body where it is thickest; yellowish green. The body is cylindrical, tapering decidedly toward the end; the segments are distinctly wrinkled above. The body is pale green, with two broad diffuse yellowish longitudinal bands, one on each side from the prothoracic segment to the end of the body. The hairs are minute, and, with the tubercles they arise from, not easily seen.

Stage III.—Length, 13 mm., June 23. Of the same shape as before. The head is still much wider than the body; it is a little deeper green, but the color of the body differs from that of the previous stage in being whitish glaucous green, since the body is covered with a soft whitish exudation or bloom, so as to obscure the lateral faint yellow stripe.

Stage IV.—Length, 18 mm., June 29. The head is very large, wider than the body, and pea-green in color, while the body is more whitish, covered with a white bloom. The lateral pale, straw-yellow line is not very distinct. There is a faint, very narrow, vascular median dorsal line over the dorsal vessel. The skin is wrinkled above, and flecked above and on the sides with white. The suranal plate is well rounded and edged with straw-yellow. The prothoracic segment is much wider than those behind, and the body tapers rapidly toward the end. The spiracles are ringed with light sienna-brown, rendering them rather conspicuous. The thoracic and abdominal legs are pale green.

Stage V and last.—Body green, large; head very large, full, rounded, high toward the vertex, as wide as the body, deep pea-green; the labrum whitish green; mandibles bright yellow, tipped with black, making them very conspicuous. Body glaucous pea-green, thick, full, soft, tapering toward the end, and the surface with minute, raised, flattened, more or less confluent granulations. A lateral yellow line formed of yellow, raised, flattened areas. Spiracles deep red. Supraanal plate conical, flattened, apex much rounded, the edge colored bright yellow. Thoracic and abdominal feet pale pea-green; all concolorous. Length, 33 mm.; thickness, 6 mm.

CONGENITAL LARVAL CHARACTERS.

The freshly hatched larva is in shape like the adult, only the head is larger in proportion, and the body is provided with bulbous glandular hairs. There are no lines nor white dots.

ACQUIRED LARVAL CHARACTERS.

The two subdorsal yellowish longitudinal stripes probably appear at the end of the second stage. In Stage III the whitish bloom appears. In Stage IV the suranal plate is edged with yellow.

This is, next to *Gluphisia*, the simplest, least specialized Notodontian larva; more so than that of *Lophodonta*. The body is without tubercles or humps; the piliferous warts are minute and the simplest markings are colorational, i. e., two yellowish subdorsal bands, with no spots. In the Notodontians the subdorsal lines are the first to appear, before the lateral ones.

The following is a copy of an article entitled "The number of larval stages in the genus Nadata," by Mr. Harrison G. Dyar, Psyche, October, 1892, which we reproduce, as it gives a full account of the transformations of this species in California, and contains interesting notes on the habits:

In Psyche, recently, I expressed the opinion that species of *Nadata* had more than six larval stages, which was founded on certain measurements made from *Nadata gibbosa*. I have not since obtained this species in the early stages,[1] but have bred another from the egg, which is *N. oregonensis* Butl. In this species, the number of stages appears to be normally six; but two individuals carefully bred in confinement and two bred in the open air had but five stages, while another specimen, less carefully reared in confinement beside another bred in the open air on its growing food plant under a net exhibited six stages, but not the normal ones. All the larvæ appeared to omit the normal second stage, even those that had six stages. These latter inserted an extra stage between the fourth and fifth, not differing in markings from the fourth, as will be seen in what follows. The growth during the first stage was very great, out of all proportion to the subsequent growth, and, previous to molting, the new head, in process of formation behind the old one, caused an enormous projection of the body.

The calculated normal series for the widths of head stands as follows: I, 0.79 [II, 1.13]; III, 1.62; IV, 2.31; V, 3.3; VI, 4.7 mm.; ratio, 0.70 mm.

From the larvæ that had five stages I obtained the following measurements: First, 0.75; second, 1.55; third, 2.35; fourth, 3.3; fifth, 4.7 mm.

From those that had six stages—first example: First, —;[2] second, 1.4; third, 2.2; fourth, 2.7; fifth, 3.2; sixth, — mm.[3] Second example: First, —;[2] second, 1.5; third, 2.3; fourth, 2.8; fifth, 3.7; sixth, 4.8 mm.

It will be seen that in the first example an extra stage occurred between the normal Stages IV and V, and this is verified by the changes in markings; for in those that had five stages, the markings changed in the fourth stage, while in this the fourth stage was like the third and the change did not occur till the fifth stage.

In the second example the fifth stage was abnormally large, so much so that the last four stages in this case present a good series with the ratio 0.77, and, judging from these stages only, it would certainly be inferred that the species had eight larval stages,[4] with the following series of widths of head (calculated): 0.77, 1.0, 1.3, 1.7, 2.2, 2.8, 3.7, 4.8 mm; ratio, 0.77 mm. Compare with this the last four measurements of the second example.

The species of Nadata, then, present examples of variation in the number of larval stages, as well as an abnormal development.

It is probable that *Edema albicosta* acts in a similar though less pronounced manner.[5]

The following descriptions apply to the species of Nadata that is common in the Yosemite Valley, California.

[1] Miss Soule has recently written the life history of *N. gibbosa* (Psyche, v. 6, 197) and found five stages, as did also Dr. Riley (see 5th Rept. U. S. Ent. Com., 1890). Unfortunately, Miss Soule has given no measurements of the head, but she has given the length of the larva in all its stages, and the numbers she gives correspond well with a series derived with the ratio 0.60. This does not corroborate my observations (on *N. oregonensis*), as to do so a stage should appear lacking between Stages I and II, provided that the measurements were made at the first of each stage. Miss Soule's figures are $\frac{3}{16}$ (=19), $\frac{1}{4}$ (=.25), $\frac{1}{2}$ (=.50), $\frac{3}{4}$ (=.75), and $1\frac{1}{4}$ (=1.25) inches, while the calculated series would be .16, .27, .45, .75, 1.25 inches, thus showing no gap in the series anywhere. To suit my observations the newly hatched larva should have measured 0.10 inch instead of 0.16 inch. Miss Soule says "not quite $\frac{3}{16}$ inches," which is certainly nearer 0.16 than 0.10, as the latter would be not quite $\frac{1}{8}$ inch.

But I do not think the length of the larva is a reliable measurement to take, as it is subject to great change throughout the stage, and, even if taken as nearly as possible at the same time in each stage, is subject to inaccuracies through the expansion or contraction of the larval segments. Moreover, it takes no account of the growth during either the first or the last stage, according as the measurements are made at the end or beginning of each stage, and I should hesitate to assume that the growth was always strictly proportional. In fact, I believe that in Nadata it is not so, for double growth seems to take place in the first stage.

The measurement of the width of head is open to none of the above objections and possesses besides several advantages not shown by measurements of the length of the larva.

[2] Measurement not recorded.

[3] This larva died before molting the last time.

[4] From similar measurements made in the case of *N. gibbosa*, I inferred that that species had more than six stages (see Psyche, v. 6, p. 117), but this inference is not justified by the facts. It will be found, however, to have occasionally as many as six stages.

[5] The series of widths of head as observed by me for *Edema albicosta* were 0.40, 0.70, 1.30, 1.7, 2.3, 3.2, and I have twice attempted in the pages of Psyche to make them fit a series in regular geometrical progression, but without

Pupa.—Body stout and thick, not tapering much to the end. Surface of the abdominal segments moderately punctured, the two last segments quite smooth. The cremaster ends in a conical stout spine, broad at the base and sharp at the end, the point terminating in an unusual kind of armature which, seen from above or beneath, consists of four laterally radiating, slightly upturned, stout spinules, the lower ones considerably smaller than the distal ones. Length, 22–23 mm.

Habits.—The caterpillar is most commonly found on the oak. Dr. Harris found it on the oak, the moth occurring June 20. By the middle or last of September, in New England (Maine and Rhode Island), it begins to pupate, not spinning a cocoon, and probably entering the ground before assuming the chrysalis state. In Providence it occurred on the white oak, in Maine on the red oak. In Georgia, according to Smith and Abbot, it "feeds on the chestnut oak and other oaks. It went into the ground October 10 and came out March 13. Another went in June 1 and came out the 19th of the same month." It is therefore double-brooded in the Gulf States and single brooded in the North. The following notes on its habits have been given us by Professor Riley:

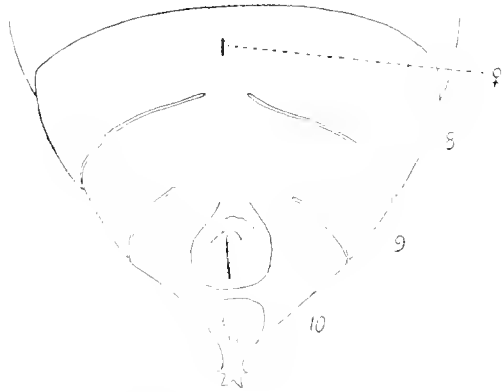


FIG. 63.—Pupa of *Nadata gibbosa*.

A pair of this moth were taken May 2, 1882, from the eggs of which larvæ hatched on the 9th. They went through their first molt May 15; second, May 22; third, May 26, and fourth, May 31. Pupated June 12 to 14. The moths issued from June 26 to July 10. Several larvæ of this moth were found by beating on oak June 26 and July 10, 1882. The larvæ are now very plentiful and of all sizes, on several oaks. (5th Rep. U. S. Ent. Comm.)

Food plants.—Oak (Quercus of different species), maple (Lintner), maple, white birch, sugar plum (Dyar). (The statement in my Forest Insects, p. 114, that Mr. Reed had found it on the maple, is an error.)

Geographical distribution.—Ranges from Maine and Canada northward to Oregon and California, occurring southward on the Atlantic and Gulf coasts to Florida, Georgia, and Texas.

Amherst, Mass. (Mrs. Fernald). I have a ♂ collected June 21 on the Vermejo River, northeastern New Mexico, by Lieut. W. L. Carpenter, of the Wheeler survey. Plattsburg, N. Y.

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marked success. A series calculated with the ratio 0.55 would give 0.41, 0.75, 1.27, 2.30, 4.3, and one with the ratio 0.73 or thereabout would interpolate a term between each one and give 0.41, 0.55, 0.75, 0.96, 1.27, 1.7, 2.3, 3.15, 4.3. Thus it might be considered either that the species normally had eight stages (ratio, 0.73) and omitted the second and fourth normal stages, or that it had normally five stages (ratio, 0.55), but interpolated a stage between the third and fourth normal stages, and reduced the measurement in the last stage to correspond with the ratio between those that immediately preceded it. The latter seems the more probable, but the fact is that the growth of the head at the first and second molts is double what it is at the third, fourth, and fifth. It is a curious case.

Nadata oregonensis Butler.

This was described as a variety of *N. doubledayi* Pack.; but Mr. Butler writes me under date of June 30, 1892: "The types * * * have pale creamy buff-colored palpi; quite uniform in tint * * * if there is a brown line above it must be on the second joint, but I do not think there is one * * * looking at the moth without a lens you would say the fringe was dark ferruginous on primaries * * and white tipped on interspaces." These are the characters used to separate *N. gibbosa* from *D. doubledayi* in Dr. Packard's description, and Mr. Butler's words show that his form is not a variety of *N. doubledayi*, but the same as Hy. Edwards's *N. behrensii*.

1881—Butler, Ann. and Mag. Nat. Hist., p. 317.

behrensii Hy. Edwards.

1885—Hy. Edw., Ent. Amer., i, 49.

Egg.—Rather more than hemispherical, the base flattened; smooth, not shiny, white with a yellowish tinge; diameter, 1.2 mm. Under a microscope the surface is seen to be covered with very slight, obscure, rounded depressions, but, is in fact, almost smooth.

Laid singly on the underside of the leaves of its food plants in early summer.

Normal Stage I (first larval stage).—Head slightly bilobed, rounded, shining pale greenish with a few hairs; mouth brownish, ocelli black; width, 0.75 mm. Body slender, no tubercles or humps; feet normal, smooth, shiny, pale yellowish green. Setæ minute, rather long but not evident, color blackish. As the stage advances great

(Hudson): New York, Wisconsin, Ohio, Missouri, Alabama, Colorado, and California (U. S. Nat. Mus.); Maine, Massachusetts, New York, Pennsylvania, Ohio, Wisconsin, Carbondale, Ill.; North Carolina, New Mexico (French); Dallas, Tex. (Boll, Mus. Comp. Zool.); Topeka and Manhattan, Kans. (Popenoe); Racine, Wis.; Chicago, Ill. (Westcott); Colorado Springs, Colo., June 25 (Gillette); Yo Semite, Cal.; Portland, Oreg.; Seattle, Wash.; Nanaimo, British Columbia (Dyar).

It thus appears to extend throughout the Appalachian, Austroriparian, and Campestrian subprovinces; whether it occurs in the Mexican (Sonoran) subprovince remains yet to be determined, as well as its extreme northern limits.

Lophodonta Packard.

(Pl. XLI, figs. 2-3, venation.)

Phalæna (in part) Abbot and Smith, Nat. Hist. Lep. Georgia, p. 165, Tab. LXXXIII, 1797.
Peridea Stephens, Ill. Brit. Ent. Haust., ii, p. 32, 1829.
Notodonta (in part) Walk., Cat. Lep. Br. Mus., v, p. 995, 1855.
Herr-Schaeff., Samml. aussereur. Schmett., p. 66, 1855.
Morris, Synopsis Lep. N. Amer., p. 239, 1862.

growth takes place; the color becomes green with a yellow subdorsal line much as in the mature larva. The body is transversely creased. Duration of this stage about four days.

Normal Stage II.—Not exhibited in any specimen seen by me, and probably does not occur.

Normal Stage III (second stage).—Head large, slightly bilobed, narrowing a little to vertex and flattened in front, pale green, hardly shiny, mouth white, ocelli and tips of jaws black; width, 1.4 to 1.55 mm. Body slender smooth, no perceptible hairs; legs normal, green, somewhat shiny; a broad yellowish green subdorsal line; spiracles black.

Normal Stage IV (third stage).—Head as before; width, 2 to 2.35 mm. Body slender, uniform green; a very distinct, rather broad, pale yellow, subdorsal band from joint 2 to the anal plate; spiracles black, faintly surrounded by yellowish. Scattered, very small, and short setæ.

Normal Stage IV (fourth stage in same larvæ).—Head large, flattened in front, very slightly bilobed, smooth, not shiny, pale green; ocelli black, labrum white, jaws black at tips, otherwise green; width, 2.7 to 2.8 mm. Body transversely creased, leaf-green, with yellow piliferous dots bearing very small setæ. A slightly darker dorsal line and broad yellow subdorsal line from joint 2 to the end of the anal plate. Spiracles black, with small white centers.

Normal Stage V (fourth or fifth stage).—Head shaped as before, pale green, not shiny; ocelli black on a white ground, labrum white at tip, jaws green tipped with black, antennæ yellowish; width, 3.2 to 3.7 mm. Body yellowish green with many yellow irregular elliptical granulations and a distinct broad yellow subdorsal line, continuous from joint 2 to joint 13 and bordering the anal plate, which is rounded. Joint 2 is narrowly edged with yellow in front. Spiracles dark brown, paler centrally. Feet green, without any yellow spots.

Normal Stage VI (fifth or sixth stage).—Head full, rounded, slightly shiny, and absolutely shagreened; partly retracted under joint 2; uniform leaf-green, ocelli black on a white ground, mouth-parts whitish, jaws straw-yellow, tipped with black; clypeus small, triangular; width, 4.6 to 4.8 mm. Body cylindrical, full, and rounded, tapering slightly to the last segment, which is smaller than the rest, leaf-green or whitish green, densely covered with white, irregular, flattened elliptical granulations, which on the venter become transverse streaks. In specimens in which the ground color is suffused with whitish, joint 2, joint 13 posteriorly, and the anal feet remain leaf-green. A broad, distinct, white subdorsal line, faint on the anterior part of joint 2. The anterior edge of joint 2 and the border of the anal plate are bright yellow. Feet green, the abdominal ones covered with white granulations, and a white line before claspers. Spiracles orange-red, faintly bordered with white. The edges of the white subdorsal band are not even, but more or less incised, on the anterior segments being narrowly broken into contiguous elliptical areas, or in some specimens broken throughout the whole length.

Cocoon.—The larvæ enter the ground to pupate and form a rough cocoon of a few strong silken threads.

Pupa.—Cylindrical, tapering, rather thick posteriorly to the thorax, the ends rounded, most so anteriorly; movable sutures of abdomen deep; cremaster long, rather thick, tapering, and ending in two short divergent points. Body shiny, densely punctured; cases creased and also shiny. Color black, with a shade of brown on the abdomen. Length, 22 mm.; width, 7 mm.

Food plant.—Black oak (*Quercus kelloggii* Newberry).

Nadata oregonensis is not well distinguished from *N. gibbosa* Sm. & Abb., especially in the larval state. It seems to be related to *gibbosa* much as *Papilio rutulus* is related to *P. turnus* among the butterflies. Its habitat is very probably coextensive with that of its food plant, which is said to be "on the coast ranges and on the western slope of the Sierra Nevada throughout California and as far north as the middle of Oregon; on mountain sides and summits only or in the elevated valleys, not on the plains or near the sea." Mr. Edwards recorded it from Siskiyou and Butte counties, and I found it in Mariposa County and at Portland, Oreg., but I am not aware that any record of its capture in the coast ranges has yet been made.

Lophodonta Pack., Proc. Ent. Soc. Phil., iii, p. 358, 1864.
Grote, Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 601, 1892.
Lophodonta and *Pheosia* in part, Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 196, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 115, Sept., 1894.

Head larger than in Notodonta, with the front pilose in ♂, the hairs passing a little beyond the front. The antennæ are more broadly pectinated than in Notodonta, but in the ♀ simple, though densely ciliated. The eyes are naked. The thorax is slightly crested in front, with a posterior low median tuft of pale blue and black metallic scales.

Fore wings more triangular than usual; the costa straight, apex produced, though rounded at the tip; internal edge nearly straight, tufted much as in Notodonta. Venation: Very similar to that of Notodonta (*N. basitriens*), there being no subcostal cell, only differing in the second and third subcostal venules, originating very near each other; venation of the hind wings the same as in Notodonta. Hind wings with the costa straight; the outer margin much shorter than in Notodonta.

Although the larva is so different from that of Notodonta, the adult is very similar, differing chiefly in the longer palpi and the longer branches of the antennæ.

Coloration much as in Notodonta, with transverse waved lines on the fore wings. Our species are congeneric with *Notodonta dromedaria* of Europe, *L. ferruginea* resembling it closely in markings and colors. I find that the European *Peridea trepida* Esp. *tremula* (S. V., Hübn.) has the same venation, with no subcostal cell, as our three species of Lophodonta, and when the European genera undergo the necessary revision the genus Lophodonta may have to be dropped for Stephen's Peridea.

Egg.—Hemispherical, rather high; shell finely pitted, with microscopic, dense, crowded granulations; no polygonal areas.

Larva.—Body much as in Nadata, but the head is smaller and it has no such suranal plate, this being small and rounded at the end, while the body is smooth, the skin not granulated. From Notodonta it differs in the body being noctuiform, not humped. A faint double median dorsal line and a lateral line; the whole body pea green. Spins no cocoon. When young the caterpillars, according to Dyar, rest on a perch.

Pupa.—Body full and plump, the end of the abdomen very much rounded and obtuse, with no distinct cremaster.

Geographical distribution.—So far as is yet known, this genus is confined to the Appalachian subprovince and to western Europe.

SYNOPSIS OF THE SPECIES.

Mouse-gray, with no reddish median band on the fore wings; extradiscal line not sinuous...... *L. angulosa*
Brick-reddish; a broad median brick-red band on fore wings; extradiscal line sinuous......... *L. ferruginea*
Ash-gray; base of fore wings within the extrabasilar scalloped line rusty brown.............. *L. basitriens*

Lophodonta angulosa (Abbot and Smith).

(Plate IV, fig. 3.)

Phalæna angulosa Abbot and Smith, Nat. Hist. Lep. Ins. Georgia, p. 165, Tab. LXXXIII, 1797.
Notodonta angulosa Walk., Cat. Lep. Het. Br. Mus., v, p. 999, 1855.
Morris, Synopsis Lep. N. Amer., p. 239, 1862.
Lophodonta angulosa Pack., Proc. Ent. Soc. Phil., iii, p. 358, 1864.
Grote, Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 601, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 196, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 115, Sept., 1894.

Larva.

(Pl. XVII, fig. 5.)

Dyar, Proc. Bost. Soc. Nat. Hist., xxvi, p. 162, 1894.

Moth.—Two ♀. Body and wings mouse or ash-gray, with no brick-reddish scales except on the lines. Thorax mouse-gray, behind the middle a rounded subtriangular area inclosing paler tawny scales, and bordered with steel-blue scales. Fore wings with a basal angulated line bent outward in the median space, and widely bordered with a pale reddish tawny patch, the line not continued to the inner (hinder) edge of the wing. The middle (intradiscal) line very distinctly bent outward on the costal edge, making a large rectangle on the cubital vein, ending, after making a small tooth, on the distinct reddish brown tuft on the hinder edge of the wing. Within the costal portion of this line is a small white patch, and a very large white patch on the outside extending from the apex of the angle in the median space to the costa.

Extradiscal line wavy, forming about eight fine teeth, reddish brown, edged externally with white, the line itself nearly straight, not wavy nor very oblique (much less sinuous than in *L. ferruginea*), and on each side of the costal end the wing is more or less marked with white. The space between these two lines does not differ in shade from the ground color of the wing (while in *L. ferruginea* the space forms a distinct broad reddish brown band). A very faint submarginal diffuse line composed of very obscure dark colored lunules. Fringe of the same hue as the wings, with linear white marks at the end of the venules.

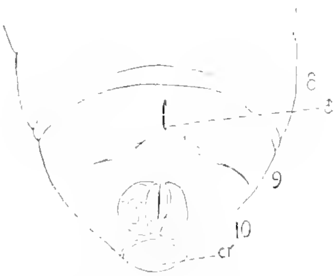

FIG. 64. Pupa of *Lophodonta angulosa*. *cr*, rudimentary cremaster.

Hind wings and abdomen pale soft flesh-whitish, the costal edge broadly margined with mouse color, interrupted by a transverse broad costal band, and another at the apex, not reaching inward beyond the second subcostal venule.

Beneath, both wings uniformly whitish, the costal edge slightly and irregularly clouded, but the lines not reproduced beneath.

Expanse of wings, ♀, 40–45 mm.; length of body, ♀, 17 mm.

Egg.—Hemispherical, rather high, not flattened; the empty shell chalky white, under a lens appearing to be very finely pitted; under ¼-inch objective seen to be ornamented with dense close set rounded granulations, with no space between them, and no polygonal areas; micropyle apical, distinct. Diameter, 0.7 mm. The orifice eaten by the larva is irregularly oval.

Larva.—Somewhat like *Nadata gibbosa*, but the head is smaller, and it has no supraanal plate, and the body is smooth, not granulated. Head nearly as wide as the prothoracic segment, but not so wide as the body; full and rounded, though a little flattened above; deep pea-green, but concolorous with the body. On the side a pink line edged above with white extending to base of the antennæ. Mandibles green at base, with an orange-red line along upper edge. Tips black. A short black line above at base of antennæ. Body noctuiform, tapering toward the anal legs, which are short and small, no larger than the other abdominal legs, supraanal plate small, rounded at the end, not large and conspicuous as in *Nadata gibbosa*. Segments not convex, but the sutures distinct. A faint double median, whitish, somewhat broken line, the two lines converging and forming a single one on the middle of the supraanal plate and tinged slightly with pink. A distinct lateral pink line begins on side of the head and extends to end of the body along the edge of supraanal plate. The line is somewhat finely brown, and is edged below with white. The whole body and legs pea-green, slightly darker below than along the back. Thoracic feet, greenish amber, spotted externally with black. Length, 0.40 mm.

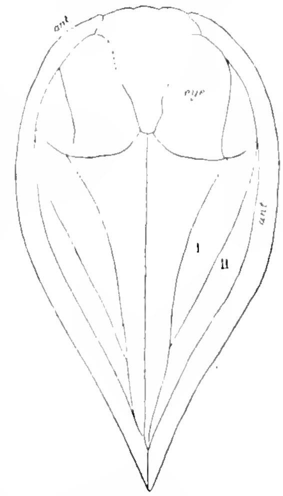

FIG. 65.—Head of pupa of *Lophodonta angulosa*.

The following description of the larval stages, pupa, etc., are copied from Mr. Dyar's paper in Proceedings of the Boston Society of Natural History, November, 1894:

"*First larval stage.*—The newly hatched larva is entirely shining yellow, 3 mm. long. Head cordate, as wide as high, pale brown, slightly shining; eyes black, mouth brown; width, 0.6 mm. Body slender, long, smooth, with minute black setæ arising from inconspicuous black dots. Anal feet extended nearly backward, slender, partly aborted. Color, leaf-green, shining, a yellow shade stigmatally. All the feet black, contrasting.

"*Second stage.*—Head only very slightly depressed on top; rounded, green, not shining; jaws reddish; a black stripe extends from the ocelli up the side of each lobe, running posteriorly, not attaining the vertex and diminishing in width upward; width, 1.1 mm. Body smooth, with minute dark setæ; green; a faint stigmatal yellow line; all the feet except the anal ones are black.

"*Third stage.*—Head flattened before, clypeus small, depressed; median suture deep, but the head not bilobed. Light green, not shining; a mottled brown band from jaw on each side, not attaining the vertex, but narrowing upward, black at its extremities; ocelli black, jaws green, tipped with brown; width, 1.8 mm. Body smooth, the setæ minute, green, with four narrow yellow bands on each side the lower substigmatal and bordered above narrowly with red-brown. Thoracic feet blackish; abdominal ones black tipped. The anal feet are not elevated, and are used in walking, but they are small, and joint 13 is tapering.

"*Fourth stage.*—Head shaped as before, always large for the body, held out nearly flat, recalling the position of the head in Gluphisia. The line on the side is red-brown, bordered on both sides with yellow, and is continuous with the stigmatal line of the body in the normal position. It does not attain the vertex of the head, terminating in a black point at each end. Jaws yellow, with two small reddish lines. Later the sides of the clypeus are defined by a pale yellow line and there are two little yellow streaks at the vertex of each lobe continuing the lines on the body. Width, 2.6 mm. Body green, including the feet, which are only faintly tinged with blackish, the thoracic ones most strongly so. Slender, tapering posteriorly, the last segment small, though the feet are used in walking and are not elevated in the normal position of rest. No cervical shield nor anal plate distinguishable. There is a broad, double, dorsal, and single, waved, subdorsal, whitish line; a lateral row of yellowish dots, obsoletely connected into a waved line, and a distinct, straight, narrow, stigmatal, yellow line, bordered above with red-brown. Spiracle on joint 2 large, black-ringed, the others reddish. The larva eats away the substance of the leaf from a midrib or vein which it leaves and rests upon with the head generally turned toward the base of the leaf.

"*Fifth stage.*—Head full, rounded, a little higher than wide, flattened in front, the sutures not deep; smooth, shining green, under the lens minutely granular; jaws yellow, with a broad central reddish band, and tipped with black; antennæ white, the last joint reddish; a red-brown at joint 3 posteriorly; the second widens rapidly, reaching below the band over the ocelli, running posteriorly to about the middle of the side of the head, in line with the stigmatal band of the body, bordered on both sides narrowly with yellow; ocelli black; labrum pale, a whitish line on each side of the clypeal sutures, and a faint double mark at the vertex, continuing the double dorsal line of the body. Width, 4.2 mm. Body cylindrical, smooth, tapering posteriorly; joint 13 small, the last feet no larger than the others. Setæ not distinguishable. Dorsum leaf-green, with a suffusion of white, a distinct white geminate dorsal line; a very faint, narrow, waved and broken subdorsal one; a lateral row of yellowish dots, obsolete at the extremities, three on each segment, the central one higher than the others; a distinct yellow stigmatal line bordered above narrowly and irregularly with red-brown. Spiracle on joint 2 large, white, black-ringed, the others whitish and brown ringed. Subventral space clear green, unspotted. Thoracic feet pale, testaceous, with a few black dots outwardly.

"The larva seems a close ally of Nadata, but differs in habit, for it rests on the edge of the leaf instead of the back, as Nadata does. In its normal position the clear green of the subventral space joins nicely with the green of the leaf, and the distinct stigmatal line seems to represent an edge or rib of the leaf.

"*Cocoon.*—Found beneath the surface of the earth; composed of silk mixed with grains of dirt; elliptical, thin, complete; size, 25 by 12 mm.

"*Pupa.*—Cylindrical, rounded at both ends, thickest through the fourth abdominal segment; anal end almost flat; no cremaster, but a low rounded prominence. Cases creased; abdomen sparsely punctured; color dark mahogany brown, shining. Length, 21 mm.; width, 7 mm.

"*Food plant.*—Oak (Quercus).

"Larvæ from Clinton County, N. Y." (Dyar).

Pupa.—Body full and plump, but not very thick at the end; of the usual form and color; the end of the abdomen very much rounded and obtuse, with no rudiment of a cremaster, only a rounded knob. The segments slightly, not deeply or coarsely, punctured. Length, 18 mm.

"The pupa of this species is quite similar to that of others of the genus, presenting little if any good distinguishing characters. The specimen in the collection is a shell only, and the anterior half is destroyed by the emergence of the perfect insect. The general shape is robust and the posterior extremity is obtusely truncate, and there is a slight obtuse undivided elevation at the extreme tip." (Riley MS.)

Cocoon.—"This is composed of scattering, coarse threads of reddish brown silk, in which particles of earth and sand are incorporated. Length, 25 mm.; width, 10 mm." (Riley MS.)

Habits.—It occurred on *Quercus alba* October 7, at Providence, when it began to pupate, the moth appearing the following June. The larva is less common than that of *Nadata gibbosa*. Abbot and Smith remark that in Georgia it "feeds on the overcup oak and other kinds of the same genus. Some went into the ground May 30 and came out the 15th of June. Others that went in the 16th of October remained till the 20th of April." From this it appears that in the Southern States this species is double brooded.

Dr. Harris found it at Milton, Mass., June 17, "inactive on trunk of an oak." Larva occurs in September and October; the moths in June, July, and August. (Riley).

Food plants.—Different species of oak.

Geographical distribution.—It ranges from Massachusetts (Harris) to Georgia (Abbot); Ithaca, N. Y. (Mrs. Fernald); Plattsburg, N. Y. (Hudson); Texas, Missouri, Georgia, and District of Columbia (U. S. Nat. Mus.); Maine, Massachusetts, Georgia (French); New Jersey, Arkansas (Palm); Illinois, Florida (Strecker).

Lophodonta ferruginea Packard.

(Pl. IV, figs. 1, 2.)

Lophodonta ferruginea Pack., Proc. Ent. Soc. Phil., iii, p. 357, 1864.
Grote, Check List N. Amer. Lep., p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 602, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 196, June, 1894, Journ. N. Y. Ent. Soc. ii, p. 115, Sept., 1894.

Larva.

(Pl. XVIII, figs. 1–4c.)

Thaxter, Can. Ent., xxiii, p. 34, Feb., 1891. (Food plant stated.)
Dyar, Proc. Bost. Soc. Nat. Hist., xxvi, p. 394, Nov., 1891.

Moth.—♂ and ♀. Ferruginous or brick-red, with blackish ashen scales. The head and prothorax are blackish ashen, while the red of the thorax, together with most of the fore wings is ferruginous; the latter are ferruginous at base, interrupted on the costa by two short white lines forming the end of a single line. Beyond is a dark band shaded within with ashen, and lined without by four rusty, whitish lunules, margined beyond by a ferruginous line. Toward the costa beyond this line and within the twin united rusty white discal spots are some transverse irregular whitish patches. The outer third of the wing is darker than the middle, while the veins are almost black. There is a submarginal waved lunate rusty white line, and while the fringe is dark, there are some white scales, and, what is generally not the case, the ends of the venules are white. The tuft on the inner margin of the wing is broad and dark.

Hind wings rusty white, with an obscure middle band which becomes brown toward the costa, which is margined without with whitish; beyond these is a broad dusky band, most distinct upon the costa, where it is twice waved, and limited externally with a short white line. The margin is black, while the fringe is dusky cinereous and concolorous with the abdomen.

Beneath, the body is much lighter in hue, and the wings are still paler, being dirty white and crossed by a common middle obscure dusky line, while the margin next to the fringe is dark brown and interrupted by venules.

Expanse of wings, ♂, 45 mm.; length of body, ♂, 18 mm.

This species is closely allied to the European *L. dromedarius*, not being congeneric with the European *N. ziczac*, which is a true Notodonta. *Lophodonta plumosa* Edwards is a species of Heterocampa.

Habits.—The moth was collected at Kittery, Me., July 18, by Mr. R. Thaxter, and at Manchester, Vt., August 3, by Mr. C. H. Roberts (as by labels in U. S. Nat. Mus., Washington). Pupa in August; moth, May, June, and August (Riley MS.).

"The species is doubled-brooded at Plattsburg, N. Y., single-brooded in the Adirondacks, though a single ♂ emerged the same season" (Dyar).

Food plants.—Betula (Thaxter, Can. Ent., xxiii, p. 34, Feb., 1891); *Betula papyrifera* (Dyar).

Geographical distribution.—Thus far only known to inhabit the Appalachian subprovince. The following localities are the only ones yet known to me: Orono, Me. (Mrs. Fernald); Kittery, Me. (Thaxter); Vermont, New York (U. S. Nat. Mus.); New Hampshire (C. A. Walker); Catskill, N. Y. (Mus. Comp. Zool.); Plattsburg, N. Y., Keens Valley, Essex Co., N. Y., (Dyar); Boston, Mass. (Sanborn); Manchester, Vt. (Roberts, U. S. Nat. Mus.); Maine, Canada, New York, North Carolina (French); Plattsburg, N. Y. (Hudson); Fort Collins, Colo., June 21, at light (C. H. Baker).

Egg.—Flattened hemispherical; shell under a hand lens appears almost smooth, but under a ⅙ inch A eyepiece seen to be ornamented with six-sided areas, with raised, beaded edges. Diameter, 0.7 mm.

Larva, Stage I.—Just hatched. Length, 3 mm. Head large, much wider than the body, black-brown, smooth, polished, with a few scattered long slender hairs. Body uniformly pale yellowish green, tapering to the end, the segments transversely wrinkled, hairs long and dark, slender and tapering. A faint darker dusty greenish prothoracic subcrescentiform plate. Body with no markings; no lines or spots.

Providence, June 19. Eggs kindly given me by Mr. W. Dearden. All the eggs hatched at nearly the same time and on the same day.

The larva eats a hole out of one side, of the usual irregular kidney shape.

Pupa, August; adults, May, July, and August; localities, New York, Vermont, and District of Columbia.

Pupa.—About 19 mm. long, robust, tip truncate, very slightly tapering; a very slight and blunt projection at tip scarcely noticeable; general surface shiny, somewhat rugose, and remotely punctate. No processes or teeth at sutures between meso and metathorax.

"*Egg*[1].—Laid singly, usually on the upper side, near the middle of the leaf of its food plant (*Betula papyrifera*). Rounded, somewhat flattened, about the shape of two-thirds of a sphere with flat base; diameter, 1 mm.; height, 0.6 mm. Slightly shining, fine turquoise-blue or more rarely of a greenish blue tint. Microscopic reticulations neatly defined, but rounded, scarcely angular, becoming small and indistinct at the micropylar region. On the sides the reticulating edges of the cells become broad, flat, almost like bands, reducing the inclosed depressions to shallow pits. Found during the early part of July at Keene Valley, Essex County, N. Y.

"*First larval stage.*—On hatching the larva leaves the shell largely intact and takes up a position at the extreme apex of the leaf, where it eats the upper epidermis and parenchyma. Head cordate, entirely shining black; width, 0.6 mm. Body rather bright greenish yellow, thoracic feet black, cervical shield transverse, dusky. Setæ fine, short, black, distinct, but without evident tubercles; not glandular; 1 and 2 nearly in line, 3 above spiracle, 4 substigmatal posteriorly, 5 subventral anteriorly, 6 absent as usual in the first stage. Feet all used; leg plates concolorous with the body. No anal plate. Length, about 3 mm.

"*Second stage.*—The larva eats away the substance from the midrib of the leaf at the apex, using the midrib as a perch on which it rests. Head slightly bilobed, greenish; a smoky black shade covers the side, including the ocelli, and a narrow smoky band reaches the apex in front of the lateral angle; mouth brown; a few setæ; width, about 1 mm. Body cylindrical, smooth, feet normal, all used. Thoracic feet and leg plates black, except the anal pair. Setæ short and fine, dark, from minute black tubercles, very inconspicuous; arrangement normal, six present. Body green, with very faintly indicated addorsal, subdorsal, lateral and superstigmatal waved whitish lines. Spiracles pale.

"*Third stage.*—Head rounded, flat before and held out flat; leaf-green; a smoky black band behind ocelli extends backward and upward to the side of the head, where it ends tapering; mouth reddish; width, 1.6 mm. Body as before, but the fine dark setæ have no tubercles. Color pale leaf-green; on joints 2–3 a yellowish line edged above with red extends up from below the spiracles

[1] The following notes on the transformations are copied from Dyar.

to the lateral line. Very obscure lines as before, waved, whitish. Thoracic feet black, except at joints; abdominal ones all green, the claspers smoky. Spiracles reddish centered. Later there is a broken obscure substigmatal line, composed of oblique, pulverulent, yellowish dashes; the stigmatal line forms undulations over the spiracles, and the addorsal line becomes broad, white, sometimes with a median red mark on joint 13.

"*Fourth stage.*—The larva rests on the petiole of a leaf and eats all but the midrib on which it rests. When the leaf is consumed the stem is bitten off. Head light green, not shining; behind the black ocelli a dark reddish band extends to middle of side posteriorly, ending in a blackish shade and continuous with an oblique line on the body, which extends over the spiracle on joint 2 and ends on joint 3 at the lateral line; palpi reddish; width, 2.5 mm. Body smooth, green, with a broad, geminate, white dorsal band (addorsal lines), filled in with dull red in some specimens; a narrow waved subdorsal line; a row of white dots in place of the lateral line and a few yellow dots for the stigmatal line. Spiracles light reddish. The oblique line on joints 2–3 is yellow below and smoky red above, and may be faintly repeated on joint 4. Setæ minute, dark. Feet green, the thoracic ones marked with black on the joints.

"*Fifth stage.*—Head rounded, broad, flattened before; light green; a white line on each side of clypeus and another from palpi converging slightly to vertex of each lobe; lateral band smoky purplish red, fading to yellowish on its lower side, continuous with the line on joints 2–3. Body soft, yellowish leaf-green, tapering posteriorly, full, plump, cylindrical. A broad, yellowish white geminate dorsal band, the space filled in with reddish on joint 13; faint traces of a broken subdorsal and two or three round yellow dots laterally and superstigmatally. Dorsum faintly white shaded; subventral region clear, soft green. Thoracic feet reddish, black at tip. Setæ extremely minute except on the legs. Claspers brownish. Length, about 30 mm.

"The species is double-brooded at Plattsburg, N. Y., single-brooded in the Adirondacks, though a single ♂ emerged the same season." (Dyar.)

Lophodonta basitriens (Walker).

(Pl. IV, fig. 5.)

Notodonta basitriens Walk., Cat. Lep. Het. Br. Mus., v, p. 1000, 1855.
Morris, Synopsis Lep. N. Amer., p. 239, 1862.
Grote, Proc. Ent. Soc. Phil., iii, p. 93, Pl. XI, fig. 1, June 1864; Check List N. Amer. Moths, p. 18, 1882.
Pack., Proc. Ent. Soc. Phil., iii, p. 365, Nov., 1864.
Smith, List Lep. Bor. Amer., p. 29, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 601, 1892.
Pheosia basitriens Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 196, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 115, Sept., 1894.

Moth.—Three ♂. Ground color, especially of the thorax and fore wings, ash-gray. Head and thorax ash-gray sprinkled with reddish brown scales; a distinct line extending across the thorax between the fore wings. Palpi with a dark brown line on the outside. Antennæ very slightly pectinated, as in *L. angulosa*

Fore wings more pointed at the apex than in *L. angulosa*, with an oblique dark line crossing the wing from the basal third of the costa to the outer fourth of the inner edge, and inclosing a dark rusty brown patch which fades out on the costa, and is deepest in hue next to the large but short and broad tuft, which is not acute as in *N. stragula*, but with the distal edge very broad, as in *L. angulosa*. Beyond the patch and tuft is a short sinuous or bent whitish line, the continuation of a faint sinuous line extending from the costa, but which becomes much more distinct behind the third cubital venule, ending on the inner edge of the wing, and continued on the costa of the hind wings, thence extending as a scalloped line across the hind wings, which are pale, though somewhat dusky on the outer margin. No brown marginal and apical brown spots like those of *N. stragula*, and the wing is not so clear, but dusted with brown scales. Underside pale subocherous, with a common diffuse scalloped line.

Expanse of wings, ♂, 46–49 mm.; length of body, ♂, 19–20 mm.

This species has the venation (no subcostal cell) of Lophodonta, and also agrees in the antennæ and shape of both pairs of wings. Dr. Dyar having called my attention to the absence of a cell, I have reviewed the generic characters.

In its color and markings it is more like *N. stragula* than a Lophodonta, and it is this superficial resemblance to Notodonta which doubtless has led to its reference to that genus. This species in general appearance, color, and markings is allied to and represents in our fauna the European *L. trepida* (*tremula*). Thus the genus Lophodonta is represented in the European fauna. Its larva, judging by Buckler's figure, is like our *L. angulosa* in shape, but marked with oblique yellow and red bars. It is to be seen whether the European genus Peridea, to which *trepida* is referred, is synonymous with the American Lophodonta.

Geographical distribution.—Not known out of the Appalachian subprovince. Augusta, Me. (C. G. Atkins); Maine (Mus. Comp. Zool.); Williamstown, Mass. (Grote); Amherst, Mass. (Mrs. Fernald); New York (French); New Jersey, Pennsylvania (Palm).

Drymonia Hübner.

(Pl. XLI, fig. 5, venation.)

Drymonia Hübn., Verz. Schmett., p. 144, 1816.
Chaonia Steph., Ill. Brit. Ent., Haust., ii, p. 40, 1829.
Notodonta Boisd., Gen. et Ind. Meth., p. 87, 1840.
Dup., Cat. Meth. Lep. Eur., p. 93, 1844.
Herr.-Schaeff., Syst. Bearbeit. Schmett. Eur., ii, 1845.
Staudinger, Cat. Lep. Eur., p. 73, 1871.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 181, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 113, Sept., 1894.

Moth.— ♂ and ♀. Antennæ heavily pectinated to tip, more so than in *Lophodonta*, *Lophopteryx*, or *Notodonta*, and only less so than in *Dasylophia* (simple in ♀ *trimacula*).

Palpi stout, slightly longer than in Lophodonta, and extending a little farther beyond the front. Eyes naked (both in the European *trimacula* and in *georgica*), as they are in Lophodonta.

Fore wings rather shorter and broader than in Lophodonta, less produced at the squarish apex; outer edge less oblique; a large broad tuft on the inner edge. A subcostal cell present in *D. georgica* (but absent in the European *trimacula*).

Hind wings a little shorter and rounder at the apex than in Notodonta or Lophopteryx.

Larva.—That of the European species noctuiform, with no tubercles, and much as in that of Lophodonta.

Our *D. georgica* is very nearly allied to the European *D. trimacula* in structure and in markings, only differing in a remarkable and unexpected way, considering the close similarity in other respects in the two species, there being in the latter no subcostal cell, the venation being much as in Lophodonta.

Hübner founded his genus on *D. crenosa*, *chaonia*, *querna*, and *dodonæa*, not mentioning *trimacula* (*dodonæa* being a synonym of it), which is closely allied with our species. Whether all these species are truly congeneric I can not state, since I have only *trimacula* to refer to, and since European authors do not seem to have critically examined the structural features of these species.

Drymonia georgica (Herrich-Schaeffer).

(Pl. IV, fig. 7.)

Phalæna angulosa Abbot and Smith, Lep. Ins. Georgia, 1797.
Notodonta georgica Herr.-Schaeff., Samml. aussereur. Schmett., p. 66, fig. 384, 1856.
Drynobia tortuosa Tepper, Bull. Brooklyn Ent. Soc., iv, p. 2, May, 1881, Pl. —, fig. 2
Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 601, 1892.
Notodonta georgica Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 185, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 113, Sept., 1894.
Notodonta tortuosa Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 185, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 113, Sept., 1894.

Larva.

Thaxter, Can. Ent., xxiii, p. 34, Feb., 1891.

Moth.—One ♂. Antennæ well pectinated to the tips; palpi passing beyond the front, longer than in *L. angulosa* or *ferruginea.* Body and fore wings ocherous gray, with black lines and patches. Collar edged with black; over the scutellum a transverse white stripe, behind which is a black patch.

Fore wings quite broad, shorter and broader than in any Lophodonta or Notodonta, and pointed at the apex. On base of wing, at origin of cubital vein, a short silvery white stripe, from which a black line passes along the whole cubital vein, this and its branches being black, and the base of the wing in front of the line dusky black. Wing covered by two white lines more or less edged with black, the linear black discal mark being nearest to the extradiscal line; inner (extrabasilar) line much curved and dentate, sending a tooth inward along the internal vein. Extradiscal line much curved outward opposite the discal mark and but slightly scalloped. Three subapical black intervenular black slashes, one in nearly each space behind, that in the second cubital space being large and distinct. The space between the two lines filled in behind the third cubital venule with black, relieved by fawn-brown on each side of the internal vein. Tuft on inner edge black. Fringe fawn color, with venular spots. Hind wings sordid white; no discal mark or extradiscal line. Beneath, sordid white; fore wings with faint discal mark and extradiscal line; hind wings with two nearly parallel oblique dusky costal stripes on outer half of the wing.

Expanse of wings, ♂ 40 mm.; length of body, ♂ 16 mm.

Larva.—"Length, 30 to 40 mm.; very robust; tapers slightly at either extremity; most noticeably posteriorly. Anal legs moderately long. Color green, more or less lined and dashed with yellowish white and very thickly and irregularly longitudinally dotted with dull wine-red dots, more numerous along lower lateral margin, coalescing into a more or less distinct line; trophi, thoracic feet, and tips of abdominal prolegs more or less marked with the same red color. Head with a broad central yellow area bordered with reddish brown, tapering toward posterior margin and continuous with very characteristic yellow stripe along the dorsum of the body, which is also bordered, though narrowly, with wine-red, and more or less dotted and suffused with same color, particularly on segments 1, 5, and 6. This stripe narrows rapidly on first segment, is uniform on second, widens very considerably to fifth, extending down on the side, narrows again to the posterior margin of the seventh, widens gradually from anterior margin of eighth, and narrows again slightly toward tip of anal plate. In the broadest portion, on segments 3–7 and 8 to tip, the central space is green, irregularly lined, and dotted with whitish.

"Three specimens from Atlanta, Ga.; two from St. Louis, Mo., and one from Fortress Monroe, Va." (Riley MS.)

Pupa.—"Similar to that of *L. ferruginea*, but somewhat more tapering, and projecting at the tip in two dorsally directed, very strong, short widely separated spurs. (Anterior half of pupal shell wanting.") (Riley MS.)

Habits.—Larva occurs in September; the moths in May, June, and July. (Riley MS.)

Food plant.—Quercus. (Thaxter and Riley.)

This is evidently Tepper's *Drynobia tortuosa* and Herrich-Schaeffer's species, as I have believed for several years past, and now feel sure after seeing specimens of it in Mr. Edwards's collection.

Geographical distribution.—Bangor, Me. (Neumoegen); New Jersey, (Palm); San Antonio, Tex. (Bolter); Dallas, Tex. (Boll, Mus. Comp. Zool.); Georgia (Abbot); Colorado (Coll. Tepper, French); Wisconsin, Missouri, Virginia, Florida, and Georgia (U. S. Nat. Mus.), Kittery Point, Me. (French); Plattsburg, N. Y. (Hudson); Fort Collins, Colo. (Baker).

Lophopteryx Stephens.

(Pl. XLII, fig. 2, venation, *2a*, *2b*, fore leg.)

Lophopteryx Stephens, Ill. Brit. Ent. Haust., ii, p. 26, 1829.
Odontosia, (in part) Hübner, Verz. Schmett., p. 145, 1816.
Lophopteryx Duponchel, Cat. Méth. Lép. Eur., p. 90, 1844.

Lophopteryx Staudinger, Cat. Lep. Eur., p. 73, 1871.
Grote, New Check List N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 605, 1892.
Notodonta (in part) and *Lophopteryx* Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, pp. 181, 196, June, 1894; Journ. N. Y. Ent. Soc., ii, pp. 113, 115, Sept., 1894.

Moth.—Head moderately prominent; front moderately wide, the scales long and dense, projecting irregularly and forming a slight median crest (most marked in *L. americana* and the European *L. camelina*); vertex slightly crested or very moderately so (in the European *cucullа* and *camelina*); palpi varying in not extending beyond (*elegans*) or surpassing the front (*camelina*, American example), loosely hairy, not very distinct from the front (much larger in *camelina* than in *elegans*); third joint not very distinct in *elegans*, but quite so in *camelina*. Eyes naked in *elegans*, but in the European *camelina* and the American example distinctly hairy. Antennæ in ♂ with short, stout, ciliated branches; in ♀ thick, with more or less rudimentary branches (in *elegans* they are slender, but distinct, acute, ciliated, but in the ♀ of the two above-named European species the branches are undeveloped).

Thorax either simple (*elegans*) or somewhat crested, or (as in the European species *camelina* and the Wisconsin example) with a high distinct crest, sloping backward and slightly inclined forward. Fore wings with the costa regularly but slightly curved (*elegans*), or straight (in the European species *camelina*, etc.); apex acute, square, outer edge a little bent and scalloped (less distinctly so in *cucullа*); inner edge with a distinct or quite large (*camelina*) tuft. Hind wings triangular, produced toward the apex; internal angle full and marked with a brown patch (*elegans*) or with two short parallel lines (in the European species *camelina* and *cucullа*). Venation: Fore wings with a short scale; no triangular subcostal cell; anterior discal venule very oblique, directed inward, the hinder ones curved, not oblique; the costal region very narrow in both wings.

Legs very hairy, rather long, hinder pair with a long stout tibial spur arising from the basal third.

Coloration: The species are wood or reddish gray, with longitudinal streaks, especially toward the costa, and either with (European species) or without transverse scalloped lines. Hind wings clear whitish, with (in *elegans*) a dark black patch at the internal angle.

The species differ from those of Notodonta in the larger tuft on the internal edge of the fore wings, in the more pointed fore wings which are square at the apex, and in the presence of a subcostal cell, as well as in the distinctly scalloped outer edge of the wing.

The genus is on the whole nearly allied to Pheosia, as seen in the venation, the shape of the wings, the anterior pair being pointed toward the apex, with the outer edge very oblique, and also in the markings, the fore wings in both having (in *elegans*) no cross lines, and being striped longitudinally with dark brown in the subcostal interspace, and (in *elegans*) with a conspicuous bent silvery white stripe extending from the base of the wing along the internal vein. In *camelina* there are two scalloped cross lines on the fore wings, converging from the costa to the tuft on the inner edge; there are also no silvery white markings.

While we unfortunately know nothing of the transformations of our American species, those of Europe have been figured and described. The larva of the European *L. camelina*, which I owe to the kindness of Dr. Heylaerts, of Breda, Holland, is characterized by two twin diverging high dorsal papillæ or tubercles on the eighth abdominal segment, a very interesting feature, since they probably represent what may have been the primitive double nature of the hump or horn of Pheosia and other larvæ with a "caudal horn." The larva is not humped on any other segment, and the body increases in thickness toward the eighth abdominal segment, as in Pheosia. I should regard, therefore, Lophopteryx as the more primitive genus, and standing below Pheosia and above Lophodonta, which has no hump at all.

Mr. Hellins says the larva of *L. camelina* spins a cocoon of fine silk, covered with fine earth, etc. The pupa ends in a small straight spike, tipped with four diverging tiny sharp points (Buckler's Larvæ of British Butterflies and Moths, ii, p. 163). The larva of *L. cucullа* has on abdominal segments 3 to 7 slightly raised dorsal humps, and on segment 8 "a more prominent and sharper hump, ending in twin points, which are set with six hairs. "The larva of *L. carmelita* is not humped, the skin is polished and much wrinkled, and the end of the pupa is rounded, with no cremaster, though the larva spins a tough cocoon of dirty gray silk, stuck over with fine earth" (Hellins). (Is it possible that *L. carmelita* belongs to a different genus (*Odontosia*) from *L. camelina?* *L. cucullа* and *camelina* are closely related in structure and coloration. I have not a specimen of *carmelita* to examine.)

Lophopteryx elegans Strecker.

(Pl. IV, fig. 8.)

Lophopteryx elegans Strecker, Proc. Acad. Nat. Sci. Phil., 1884, p. 255, Jan., 1885.
Notodonta notaria Edwards, Ent. Amer. i, p. 17, April, 1885.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Notodonta elegans Kirby, Syn. Cat. Lep. Het., i, p. 606, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 184, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 113, Sept., 1894.

Moth.—Two ♂, one ♀. Head and thorax mouse color, the head, and the breast directly under the former, darker than the thorax above; thorax behind the scutum edged with silvery white scales, while the tegulæ are edged with brown scales. Fore wings of a uniform pale vandyke brown, darker on the costal region than on the outer margin, the limits extending between the apex and the middle of the inner edge. Veins and their branches darker than the rest of the wing. There are no cross lines. Four reddish brown streaks on the outer fourth of the costa, one ending very near the apex; a large one in the fourth subcostal interspace, and a smaller, very narrow streak in the fifth subcostal interspace.

The distinctive mark is the conspicuous silvery white stripe shaded with brown in front, beginning at the base of the wing at the origin of the subcostal and cubital veins and extending along the internal vein to its basal third, not reaching a point opposite the tuft. The latter is small, subacute, and consists of pale ocherous and brown scales. Hind wings pale ocherous, dusky at the inner angle, which is full and prominent, and brown in tint. There is no line on the wing. At the base of the pale fringe in both wings is a distinct scalloped brown line. Underneath, the fore wings are pale mouse-gray; the hind wings mouse color on the costal region, while the rest of the wing is whitish ocherous with no spots or lines.

Expanse of wings, ♂, 50 mm.; ♀, 57 mm.; length of body, ♂, 20 mm.; ♀, 24 mm.

Mr. Edwards's Colorado specimens do not essentially differ from Maine examples.

This is an exceedingly richly colored moth, and easily recognized by its mouse-brown hue and the conspicuous but silvery white shade on the base of the fore wings. The Colorado examples are frosty ash rather than reddish brown, as Eastern specimens are.

Geographical distribution.—Oldtown, Me. (Fish, fide Strecker); Umbagog Lake, Maine, July 4 (Packard); Lonsdale, R. I. (W. Dearden); Manhattan, Kans., June 15 (Popenoe); Colorado (Edwards Coll., also Strecker); Fort Collins, Colo., June 22 (Baker); Lincoln, Nebr., June 6 (Bruner, U. S. Nat. Mus.); Colorado (French); Colorado, Nebraska, June (U. S. Nat. Mus.); New York, Colorado (French); *elegans* var. *grisea*, Miles City, Mont. (Dyar).

So far as known, confined to the Appalachian subprovince and to the Rocky Mountain region of the Campestrian.

Lophopteryx camelina Linn.

Lophopteryx americana Harv., Can. Ent., ix, p. 95, May, 1877.
Grote, New Check List Lep. N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 606, 1892.
Lophopteryx capucina Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 196, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 115, Sept., 1894.

Moth.—"♂. Eyes hairy; antennæ short, with long pencils of bristly hair from each joint. Primaries with uneven external margin. Bright brown in color, allied to *camelina*, but less rusty or reddish. Nervules interruptedly marked in very dark brown. Transverse anterior line single, forming two approximate obtuse teeth on the cell, dentate below cubital vein. Transverse posterior line double, obliterate, with included paler shades which traverse the wing obliquely, marked on costal region: a series of anteapical pale dots; purplish brown subterminal shade. Median space diffused, shaded with purplish brown, more apparently so before the outer line, and inferiorly where the median lines approximate; a terminal brown line, interrupted on the veins opposite to the extremities of which the exserted fringe is dark brown. Hind wings ochery, with concolorous fringes, becoming brown toward anal angles; a median pale shade, which intersects at internal margin a blackish patch. Beneath, yellowish immaculate, the dots on costa of primaries before apices repeated; fringe brown. Body rusty brown. Tooth on internal margin of primaries not prominent. Expanse, 36 mm. Collection Buff. Soc. Nat. Sci."

"This seems to be a stouter and broader winged form than the European, in which it would conform to Dr. Speyer's law of variation in the Noctuæ. The outer line is less distinct than in the European species, of which it may be a modification." (Harvey.)

I have received a ♂ from Mr. O. S. Westcott, taken in Wisconsin, and he writes me: "I got the name *Lophopteryx americana* Harv. from Grote." I can not see that it differs from the European *L. camelina*.

Geographical distribution.—Found by Mr. C. A. Blake in New Jersey, near Philadelphia (Harvey). The following localities have been sent me by correspondents in whose collection the species is contained: New Jersey (Professor French); New Jersey, Pennsylvania (C. Palm); Chicago (A. Bolter); Racine, Wis. (Westcott); Manhattan, Kans. (E. A. Popenoe). In Europe and Asia *L. camelina* ranges from central and southern Europe to Turkey, Siberia, and Amoor.

Larva.—We copy the following account from Hellins in Buckler's Larvæ of British Butterflies and Moths (ii, p. 162).

I have no notes of the egg or young larva. By the time the larva is 10 mm. in length it has a good deal of the adult appearance, colors brighter than afterward, no red dots yet on the spiracular line. The full grown larva is about 33 mm. in length, stout in figure, tapering slightly forward, the head much deeper and a little wider than 2; there are no humps; on 12 a pair of very prominent warts, the places of the usual dots marked by hairs; to use Albin's words, "in repose it always lifts up its hinder part," and also throws back its front part till the back of the head and segment 2 are quite bent over segments 5 and 6. There are several varieties of coloring; one mealy whitey-greenish on the back, with the dorsal vessel like a blue thread, a subdorsal line of a faint bluish tinge, the side below more green, the spiracular line, which extends around the anal flap, yellow, edged above with violet, and bearing a red spot behind each spiracle; the spiracles black, the belly green, with a tinge of plum color, and showing the usual ventral dots distinctly of a pale yellow, the head smooth, green, the mouth yellow, with a black line, the warts on 12 bright red, thoracic legs pink, ventral prolegs green with red feet.

Another variety had the head and sides of a pale yellowish pink, "the back after 3 more whitey-pink, with a darker tinted dorsal thread;" the warts on the eighth abdominal segment full deep pink, the spiracular line yellowish, with the red spots behind the black spiracles.

This larva is remarkable for the double twinned high conical tubercles on the eighth abdominal segment, whereas in Pheosia the horn is single. Possibly the double tubercles of *Lophopteryx camelina* is the primitive condition, the single hump of *L. cucullina* "ending in the twin points," being intermediate between the twin tubercles of *L. camelina* and Pheosia. It will now be a matter of great interest to discover the larva of our American *Lophopteryx elegans*. In England the food plant of *L. camelina* is the poplar, oak, alder, and hazel (Hellins). It should be observed that the larva of the European *L. carmelita* is smooth, noctuiform, with no hump on the eighth abdominal segment.

Pheosia Hübner.

(Pl. XLII, fig. 3, venation.)

Notodonta (in part) Ochs., Schmett. Eur., iii, pp. 15 and 63, 1810.
Pheosia Hübn., Verz. Schmett, p. 145, 1816.
(*Leiocampa*) Boisd., Gen. et Ind. Meth., p. 86, 1840.
Zetterstedt, Insecta Lapponica, 1840.
Leiocampa Stephens, Ill., Brit. Ent. Haust., ii, 24, 1829.
Duponchel, Cat. Méth. Lép. Eur., p. 91, 1844.
Drymonia (in part) H.-Sch., Samml. aussereur., Schmett., p. 66, 1856.
Notodonta (Leiocampa) Staudinger, Cat. Lep. Eur., p. 72, 1871.
Pheosia Grote, New Check List N. Amer. Moths, p. 19, 1882.

Smith, List. Lep. Bor. Amer., p. 30, 1890.
Kirby, Syn. Cat. Lep. Het., p. 607, 1892.
Pheosia and *Notodonta*, (in part) Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 195, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 115, Sept., 1894.

Moth.—Head moderately prominent, much as in Notodonta, rather small, front narrower than usual. Antennæ in ♂ narrowly pectinated to the tips, with fine short pectinations, not being simple. Palpi unusually small, rather slender, not reaching to the front, porrect. Eyes naked.

Thorax not very stout, subglobose; not tufted.

Fore wings unusually long and narrow; costal edge very convex, apex much produced and rounded subacute; outer edge very oblique, in ♀, more convex than in the ♂; inner edge full at the base, straight toward the angle, the slight tuft on this angle being continuous with the edge and projecting outward rather than downward. The hind wings reach when expanded three-fourths of the distance to end of abdomen; produced toward the rounded apex; costa nearly straight; internal angle much produced on the end of Vein VI, with a well-marked tuft.

Venation: No subcostal cell, though the first subcostol venule approaches its main vein very closely at the origin of the fifth; anterior discal vein very oblique, directed inward; in the hind wings, venation much as in Notodonta, except that both discal veins are directed inward, forming a V, whereas in Notodonta the two form one straight line directed outward.

Legs not very stout; tibiæ with a flat broad tuft. Abdomen cylindrical, rather long, tip obtuse, rounded.

Coloration: The species are whitish and brownish, with dark brown longitudinal intervenular streaks; no cross wavy lines or discal spots.

The genus is characterized by the ♂ antennæ being pectinated to the tip, by the small palpi, by the long wings pointed at the apex, and by the small tuft on the edge of the fore wings.

Egg.—Hemispherical; shell ornamented with dense microscopic granulations.

Larva.—Head rather small, narrower than the segments behind; body gradually increasing in width to the eighth abdominal segment, which is either humped or bears a horn; suranal plate long, lunate, coarsely granulated; skin smooth, polished; no distinct stripes or bands. *Freshly hatched larva:* Head rather large, flattened, subcordate; a broad black prothoracic plate; on the eighth abdominal segment a single dorsal oval wart; end of the body held up in walking.

Cocoon.—A subterranean cell lined with silk.

Pupa.—Body rather slender; cremaster divided into two very short divergent spines.

Geographical distribution.—This genus is common to Europe and temperate North America from the Atlantic to the Pacific; occurring in the North American region, including both the Humid and Arid provinces, but not yet known to inhabit the Austroriparian or Mexican (Sonoran) subprovinces.

Pheosia dimidiata (Herrich-Schaeffer).

(Pl. VII, fig. 11.)

Drymonia dimidiata H.-Sch., Samml. ausserenr. Schmett., p. 66, fig. 515, 1856.
Pheosia rimosa Pack., Proc. Ent. Soc. Phil., iii, p. 358, 1864.
Notodonta californica Stretch, Ill. Zyg. and Bomb. N. Amer., i, p. 116, Pl. IV, fig. 5; larva, plate 10, fig. 9, 1872.
Pheosia dictaa Lintner, Ent. Contr., iv, p. 76, June, 1878.
Notodonta (Pheosia) *rimosa* Tepper, Bull. Brooklyn Ent. Soc., i, p. 3, 1878.
Pheosia rimosa Grote, New Check List. N. Amer. Moths, p. 19, 1882.
Pheosia dimidiata Grote, New Check List N. Amer. Moths, p. 19, 1882.
Pheosia californica Grote, New Check List N. Amer. Moths, p. 19, 1882.
Pheosia rimosa Pack., Fifth Rep. U. S. Ent. Comm., p. 455, 1890. (Fig. of larva in text.)
Pheosia rimosa Smith, Cat. Lep. Bor. Amer., p. 30, 1891.
Dyar Psyche, vi, p. 128, 1891.
Kirby, Syn Cat. Lep. Het., i, p. 607, 1892.
Pack., Journ N. York Ent. Soc., i, p. 63, 1893. (Life history.)
Pheosia portlandia Edwards, Ent. Amer., ii, p. 168, 1886.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Dyar, Psyche, vi, pp. 351-353, Nov., 1892.
Notodonta dscherei Neumogen, Can. Ent., xxiv, p. 227, September, 1892.
Pheosia dimidiata Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 195, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 115, Sept., 1894.

Larva.

(Pl. XX, figs. 1-7.)

Stretch, Ill. Zyg. and Bomb. N. Amer., i, p. 116, pl. 10, fig. 9, 1872.
Lintner, Ent. Contr., iv, p. 76, 1878.
Tepper, Bull. Brooklyn Ent. Soc., i, p. 3, 1878.
Goodhue, Can. Ent., xiv, p. 73, 1882.
Packard, Fifth Rep. U. S. Ent. Comm., Ins. Inj. Forest Trees, p. 155, 1890. (Fig.)
Proc. Bost. Soc. Nat. Hist., xxiv, pp. 522–523, 1890. (Stage III–V.)
Journ. N. York. Ent. Soc., i, pp. 65–68, 1893.
Dyar, Psyche, vi, pp. 194–196, Dec., 1891.
Psyche, vi, pp. 351–353, Nov., 1892. (Description in full of egg and of the five larval stages of var. *portlandia*.)

Moth.—Thorax and head cinereous; the tuft on the patagia or shoulder tippets tipped with dark brown. Fore wings rounded and somewhat produced toward the apex; of a delicate frosty white and brown. Along the ends of the subcostal venules of the fore wings are long streaks of brown; in the apical and subapical spaces are two long, longitudinal, broad streaks, oblique and parallel to the costa, which terminate just below the apex; middle of the wing white. A long, broad line extends from the base to just above the inner angle on the outer margin, lined below with white, and deflected upward along the outer edge. Tuft cinereous. Beneath, cinereous, costa darker. The female darker than the male. Hind wings white, the region of the internal angle and tuft dark brown. Legs and abdomen cinereous.

Four examples from Colorado are slightly darker and less fulvous than in Wisconsin and New England individuals.

A ♀ ? from Franconia, N. H., received from Mrs. Slosson, is very large, expanding 60 mm. It has more dark brown on the fore wings than usual, a large costo-apical dark brown patch containing a white slash and a large wide brown region on the internal edge, extending up the outer edge to near the apex, the ends of the independent and cubital venules white; but it is not nearly so dark in the middle of the wing as in var. *portlandia*.

The imago of Stretch's *californica* does not seem to differ from the Eastern form, and by Messrs. Lintner and Dyar it is regarded as cospecific with the Eastern form. In respect to *P. portlandia*, I also regard this as only a climatic, melanotic variety of the Californian and Eastern *dimidiata*. I am indebted to Mr. Dyar for a specimen, though it is somewhat rubbed.

The Oregon form is much darker and slightly larger than the Eastern form, and thus conforms to the law in geographical distribution which obtains in the Geometrids, that on the Pacific Coast, where the climate is humid, there is a tendency to greater size and darker, almost melanistic coloration. Var. *portlandia* is a melanotic form, and is dark mouse or sable-brown. The fore wings are marked precisely as in the normal forms, but the brown marks and slashes are blacker, and the ground color of the wings smoky or dusky, not being frosted with white scales. Hind wings dark mouse color on the inner edge, forming a broad band, extending to the heavy dark patch at the inner angle, while the rest of the wing is sordid or smoky white, not frosty white. While the length of the fore wing of my type from Maine is 25 mm., that of *portlandia* is 26 mm., the entire expanse being 54 mm.

I find that the venation of *portlandia* does not differ from that of the Eastern *dimidiata*.

Mr. Lintner gives at length his reasons for regarding our *dimidiata* (*rimosa*) as cospecific with the European *dictæa*. Specimens were sent by Mr. von Meske to Dr. Speyer, who did not doubt that the two species were identical, the difference being very slight. He also gives at length the results of his own comparisons. He likewise refers to the fact, which I have verified, that there are two forms of the larva, both in Europe and in the United States, both on the Atlantic and Pacific coasts, one being without and the other with a yellow lateral stripe. I should not hesitate to regard the species as common both to Europe and America, were it not that the European species is without a horn.

In the figures of the British larva of *dictæa* in Buckler's work, published by the Ray Society, (his fig. 1*b*, Pl. XXXV) the stripe is present on the eighth abdominal segment, while the large horn of our form is represented by only a hump. In one of Buckler's figures the hump of the green variety is almost obsolete, and the black line is wanting. In Buckler's figures of the allied *dictaoides* there is only a hump. Judging by the figures, none of the British species seem identical with ours. In Duponchel and Guenee's Iconographie et Histoire Naturelle des Chenilles t. ii, the larva is very well figured, but there is no horn, not even a marked lateral black line, and the hump is not particularly well developed. We have not seen other figures of the European caterpillar.

Mr. Meske also wrote me in 1877 as follows:

> The imago of *Notodonta rimosa* Packard stands very near to the European *Notodonta dictaea* Linné, but the larvae of those two species are entirely different. The larva of the former is very slender, light green, and has a caudal horn like a sphinx larva; it feeds on *Populus tremuloides*. This is the second case in the North American fauna where the imago stands very near to its allied European form, while the larva is entirely different. The first case is *Acronycta occidentalis* as compared with *Acronycta psi* Linné.

It is well to keep the species thus distinct to emphasize the fact that the full-fed European larva is more like the younger stages, having lagged in its development behind the American form.

Egg.—Diameter, 1.3 mm. Low hemispherical, about one-half as high as broad. Under a Tolles triplet the micropyle in the center is distinctly seen, and the snow-white shell is distinctly, though very finely, pitted or granulated. Under a $\frac{1}{5}$ inch objective the markings are seen to be very peculiar, the surface not being divided into polygonal areas, but studded with microscopic beads, which form near the micropyle at the apex radiating series, and lower down lines of beads more or less parallel with the equatorial diameter. From three to seven eggs are laid on a single leaf. Probably the moth flies from one plant to another, laying a few eggs at a time.

Freshly-hatched larva, Stage I.—Described a few hours after hatching, before they began to feed. Length, 3.5–4 mm. The head is rather large, shining black, smooth, and considerably wider than the body; not spherical in shape, but somewhat flattened and subcordate or bilobed, as the occiput is deeply indented. A large, broad, but antero posteriorly rather short, black, mostly smooth, prothoracic plate, with slight roughnesses near the front edge where the hairs take their origin; the hinder edge slightly indented on the median line. On each side of the plate is a lateral black piliferous wart. The second and third thoracic segments each with a pair of conspicuous, oval, black, flattened, piliferous warts, and two small, round ones on each side, the lower one being about one-half as large as the upper. Abdominal segments 1 to 6 each with four dorsal, piliferous, flattened black warts, the hinder ones a little farther apart than the anterior ones, but yet close to the latter. On segment 7 the four corresponding warts are arranged in a regular trapezoid, the two anterior ones being much nearer together than the two hinder ones. On the eighth segment is a single central dorsal, black, oval, moderately prominent wart, which is twice as large as the largest on the ninth segment; it is transverse, bearing a bristle at each end, thus having plainly originated from what was once two separate warts. The latter segment bears four black warts, arranged in a regular trapezoid. The ninth and tenth segments are held up when the larva walks. The anal legs are black and a little smaller and shorter than the middle abdominal legs. The black suranal plate is subtriangular, being obtusely pointed in front; the surface is rough, bearing a rough, low tubercle in front on which are minute piliferous warts. The body is somewhat flattened, being broader than high, and of a peculiar, pale glaucous or sea green, the skin being polished like porcelain.

The hairs under a $\frac{1}{5}$ inch objective are seen to be slightly bulbous at the tip, and therefore glandular, but under a lower power appear to taper like ordinary setae. In Stage II the hairs are also slightly bulbous, and clear at the tip.

At the end of Stage I.—Length, 5–6 mm. The body is much longer than before, so that the tubercles are farther apart, and now the eighth segment has the dorsal wart surrounded by an amber-yellow spot, rendering it more conspicuous, and also the lateral concolorous line has appeared; the same tint occurs on the base of the abdominal legs.

(Specimens described in part from life, August 2.) Length at the end of the stage, just before exuviation, 6 mm. The head is moderately large, in the single larva observed not so wide as the body, as it was about to molt, the prothoracic segment being greatly swollen. (In alcoholic specimens the head and black piliferous tubercles of the larva in the next stage can be seen through.) The head is now black and slightly bilobed, and 1.5 mm. wide.

The prothoracic plate is rather broad, but quite short antero posteriorly, with four piliferous warts on the front and four on the hinder edge. The piliferous warts on the succeeding segments are large, distinct, black, and bear but a single hair. The tubercles on the second and third thoracic warts are arranged in a straight transverse row; the two dorsal ones are slightly larger than those on the third thoracic segment. On the abdominal segments the four dorsal tubercles are all of the same size and arranged in a trapezoid, which becomes longer, going backward to segment 7. On the eighth segment there is a double large black tubercle bearing two bristles; the tubercle is several times larger than any of the others, and is evidently the result of the coalescence of the homologues of the two dorsal warts occurring on the segments in front. The ninth segment with the four dorsal tubercles arranged in a square, with the lateral ones farther up on the back than the homologous ones in front, and in a subdorsal position. The suranal plate is black brown, nearly three-fourths as long as broad, bearing six marginal and two dorsal median hairs. The thoracic legs are black; the abdominal legs pale, with an external dark chitinous plate above the planta.

The general color of the body is glaucous green, being of the same hue as the color of the underside of the aspen leaf, on which it feeds. There is a brown dorsal spot on the eighth abdominal segment, on which the tubercle rests, while along the sides, low down, at the base of the abdominal legs, and in corresponding places where the legs are wanting, is a row of irregular reddish spots. The skin under a ½-inch objective is seen to be studded with fine, dark, short, conical setæ or granulations which are largest and thickest on the sides of and at the base of the middle abdominal legs. The hairs over the body are glandular, slightly bulbous, and about half as long as the body is thick.

The two tenant hairs on the thoracic feet are knife shaped, somewhat as in *Ichthyura inclusa.* The plantæ of the abdominal legs have a much larger number of crochets than usual in larvæ of Stage I, as there are twenty-six of them, forming a nearly complete but broken circle, and the crochets themselves are rather short and blunt.

Stage II.—Length, 8 mm. Molted August 3. The Pheosia characters are now declared, owing to the transformation of the dorsal tubercle on the eighth abdominal segment into a fleshy cone or low horn. The larva feeds on the edge of the hole which it eats out of the leaf, and at first sight may be mistaken for a sawfly larva, owing to the dark reddish brown spots and band on the sides, which resemble abdominal legs and assimilate it in appearance to the edge of the hole, which turns dark after it has been eaten out by the caterpillar.

The prothoracic shield has now disappeared.—The head slightly narrows above and is slightly bilobed, smooth, and shining, a little wider than the body, which narrows a little toward the end; it is a dark chestnut-brown on the sides, pale chestnut in front. The body is pale green above, still of the same hue as the underside of the leaf. The underside is peculiar in the thoracic and short, thick abdominal legs being dark livid brown; with a large chestnut-brown patch on the base of each, and on the first and second abdominal segments is a dark brown blotch where the base of the legs would be if they were present; farther along in the space between the fourth pair of legs and the anal legs is an irregular dark brown broad line extending along the side of the body to the sides of the anal legs. The latter are used in creeping, but are about half as large as the middle ones.

The hump on the eighth abdominal segment is now *well developed, high, conical, and fleshy, slightly inclined backward,* dark at tip, and still bearing two bristles, though the dark chitinous spine is obsolete; the horn-like tubercle is half as high as the segment is thick. The body behind the "caudal horn" narrows rather rapidly to the end of the suranal plate, which is larger than before, but pale and of the same color as the body.

The anal legs are used, but are about half as large as the middle ones and with much fewer crochets, which are very numerous in the middle legs, forming a nearly complete circle. The piliferous warts in general are now very much smaller and paler than in Stage I, being green, like the body, and scarcely visible under a strong lens. The hairs are sparse, only one arising from a wart, and they are short and fine.

In this stage the subprothoracic eversible gland was observed in an alcoholic specimen. It forms a large transverse sack, bleached white by the alcohol, and contrasting with the red skin of the side of the segment. It sends off two lateral siphon-like long and slender finger-shaped diverging tubes, out of which the spray is probably forced. Their ends do not reach to the sides and are not visible from them, but the gland is much as that of Cerura as figured by Poulton (Trans. Ent. Soc. London, 1887, Pl. X, fig. 7.)

Stage III.—August 6. Length, 11 mm. The head is now pale amber, but still dusky on the vertex, and it is also still wider than the body. On each side of the body is a faint whitish subdorsal line. The "caudal horn" is dark brown, now nearly as long as the eighth segment is thick vertically. The horn is slightly retractile in this stage, and the base is movable, being capable of withdrawal and extension and is distinctly nutant, the apex sometimes hanging over backward. The sides of the body along the base of both the thoracic and abdominal legs are now dark reddish chocolate brown, being of the same color as the horn.

The lateral yellow line is well marked. The body beneath is pale green. The spiracles form a dark dot surrounded by pale greenish.

Stage IV.—Length, 20 mm. August 25. The body is now thicker than before. The head is distinctly bilobed, rounded, narrowing a little toward the vertex. The caudal horn is now larger, higher, and more acute than in the preceding stage: it is freely elevated or allowed to fall over backward, is soft and flexible, but very slightly retractile, and bears a few scattered fine bristles. It has a blackish shade extending up from a point above the last spiracle to the apex, which is dark. The body is chocolate colored; the head redder, finely mottled with paler reddish. The suranal plate is well rounded behind, the surface roughened, with no piliferous warts, and this and the anal legs are more reddish than the body, being of a reddish pink hue. The spiracles are much larger than in Stage III, and are blackish, surrounded by a broad, pale, flesh-colored ring. The middle abdominal legs have a shining chitinous black patch above the planta, there being no such patch on the anal legs. The thoracic legs are dark, pitchy amber.

Mature larva.—Length, 40 mm. The head is usually of the reddish color of the body, but lighter and mottled. Now all the characters of the larva are assumed. The body is of a peculiar pearly hue, with a porcelain like polish, the head being of the same tint as the body. The head is smooth, not quite so wide as the prothoracic segment, which is much smaller than the somewhat swollen second thoracic segment. All the segments are slightly swollen in the middle. The eighth abdominal segment is swollen dorsally, and is surmounted by a high, rather stiff, well-developed horn, which is not granulated, but somewhat annulated; it is black, this tint extending as a black lateral line below and behind the spiracle. The suranal plate is of peculiar shape, being long crescentic, and bearing a small knob in front, the surface of the whole plate being coarsely granulated, rust-red, becoming greenish in front. The thoracic feet are deep amber-red or salmon color. Of the abdominal feet the first four pairs are large and thick, conical, blackish in the middle, while the anal pair are very small, with a rust-red callous spot externally. On the underside of the abdominal segments is an irregular greenish median line. Spiracles conspicuous, black, ringed with yellowish white or nearly white. One observed August 30, immediately after molting, had a very large head, nearly twice as wide as the slender body, and the suranal plate was enormous, very wide in proportion to the width of the body. Horn freely movable, wrinkled around the base, very black, and the black line on each side descends nearly to the spiracle, and is very distinct on the purplish reddish skin.

Recapitulation.—1. (Congenital characters.) The median dorsal tubercle or incipient "horn" on the eighth abdominal segment is in Stage I plainly seen to be double, the result of the coalescence and specialization of what were originally two dorsal warts. In Stage II this tubercle becomes a well-developed, high, conical, fleshy horn.

2. (Acquired or adaptational characters). The prothoracic plate of Stage I disappears in Stage II.

3. Appearance in Stage II of the dark reddish brown spots and band on the sides of the body.

4. Appearance in Stage III of traces of a whitish subdorsal line, while the lateral yellow line is well marked.

5. Horn in Stage IV becoming much as in the last stage, though more flexible.

Cocoon.—While Mr. Goodhue states that "the transformation takes place in a slight cocoon of dead leaves fastened together with a few silken threads, on the surface of the ground, much in the manner of *Darapsa myron*," Mr. Tepper remarks that the caterpillar enters the ground to pupate.

Dr. Dyar, in his account of the Californian insect, states that "the larvæ turn bluish and enter the ground to pupate, forming a cell lined with silk."

Pupa.—Dark brown. Head case smooth, deeply incised between the abdominal segments. Anal segment large and smooth, the cremaster ending in two short points "projecting almost laterally from the last segment, which, nevertheless, hold to the silken web with considerable firmness. Length, 26 mm.; width, 8 mm." (Dyar).

Food plants.—Feeds on the poplar, aspen, Balm of Gilead, and willow, both in Maine and in California.

Habits.—I first found the singular sphinx-like caterpillar of this moth over twenty-five years ago at Brunswick on the Balm of Gilead, September 28. The general color was a purplish lead; head and first segment greenish; the horn on the eighth segment black, the dark shade prolonged into a lateral line; a kidney-shaped spot on the last segment; spiracles black, encircled with white; below a yellow line. Beneath greenish and yellowish straw. October 6 it pupated.

The remarkable larva recalls those of the Sphingidæ, and I confess when I first saw it I was uncertain whether to regard it as a Sphingid or not. The horn is slightly retractile, and thus being movable, must add to its efficiency as a terrifying appendage, while the black streak on the sides heightens the effect of the horn. The spiracles also are so large and conspicuous that it is possible that they may add to a visage not altogether prepossessing to those insects or birds which may desire to be too intimate with it. Many years ago, when a boy, I found this larva on the Balm of Gilead poplar, and well remember the peculiar porcelain polish and lilac tints of the glaucous green skin and the prominent horn. Dr. Lintner (Ent. Contr., iv, 76) has given an interesting account of this caterpillar, which he found both on the aspen and the willow, and he also at first, as he says, mistook it for some Sphinx larva.

Dr. Dyar has described (Psyche, Vol. VI, p. 196) at length all the stages (five) of this species (*P. dimidiata* H. S.) from California, where it feeds on poplar and willow. His larvæ were found in the Yosemite Valley, California, and he says that in that region there are two broods a year, the winter being passed in the pupa state. (In New York there seem to be also two broods, from the statement of Mr. Tepper, given below.) It seems to differ in Stage I from the normal form in the eighth abdominal segment having "a single large dorsal dot instead of row i, but it bears two setæ" (p. 351).

In Maine I observed the eggs and freshly hatched young on the underside of the leaves of the aspen the 26th of July and 1st of August. The female lays usually three eggs near together on a leaf. The larva does not appear to eat them up, as the eggs are found throughout the month, with simply the hole gnawed by the larva in making its exit. The young larva is solitary, and eats a patch on the underside of the leaf. The larva in the second and later stages were unusually frequent in Maine in 1890.

The larva has been described by Mr. C. F. Goodhue, who has found it on the poplar and willow in New Hampshire late in September. "The transformation takes place in a slight cocoon of dead leaves fastened together with a few silken threads, on the surface of the ground, much in the manner of *Darapsa myron*." The moth appears in spring, as well as in August; it occurs throughout the Eastern and Middle States.

Mr. F. Tepper has raised the caterpillar which occurred on the willow in New York June 22; it went under ground a few days after, and the moth emerged August 22.

Geographical distribution.—Occurs in the Appalachian and Campestrian subprovinces. Orono, Me. (Mrs. Fernald); Brunswick, Me. (Packard); New Hampshire (Goodhue); Amherst, Mass. (Mrs. Fernald); Albany, N. Y. (Lintner, Meske); Plattsburg, N. Y. (Hudson); Seattle, Wash. (Johnson); Victoria, British Columbia (Neumoegen).

Var. *portlandia*, Portland, Oreg. (Behrens, Dyar); normal form Chicago, Ill. (Westcott); Racine, Wis. (Meske); Colorado (U. S. Nat. Mus.); Alaska, Maryland, Colorado, Ohio, and Nebraska (U. S. Nat. Mus.); Canada, Maine, New Hampshire, Massachusetts, Rhode Island, New York, North Carolina, Los Angeles, Cal., Michigan (Cook, Mus. Comp. Zool.); Fort Collins, Colo., June 20, at light (Baker); New Jersey, Pennsylvania, Nebraska (Palm).

Notodonta Ochsenheimer.

(Pl. XLI fig. 6; XLII, fig. 1, venation.)

Notodonta Ochs., Schmett. Eur., ii, p. 45, 1810.
Hübner, Verz. Schmett., p. 146, 1816.
Hylesia (in part) Hübner, Verz. Schmett., p. 186, 1816.
Notodonta Boisd., Gen. et Ind. Meth., p. 86, 1840.
and *Peridia*, Duponchel, Cat. Meth. Lép. Eur., p. 91, 1844.
Notodonta Herr.-Schaeffer, Syst., Bearb., Schmett., Eur., ii, 1845.
Walk., Cat. Lep. Het. Br. Mus., v, p. 995, 1855.
Pack., Proc. Ent. Soc. Phil., iii, p. 356, 1864.
Staud., Cat. Lep. Eur., p. 72, 1871.
Grote, Check List N. Am. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 599, 1892.
(in part) Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 181, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 113, Sept., 1894.

Moth.—Head not prominent; front rather narrow, its vestiture long and loose, forming a median crest between the antennæ; the latter pectinated to near the tips, often with short stout branches which are ciliated at the end; the joints in ♀ simple; a tuft of scales at the base of each antenna. Maxillæ slender, about the length of the front. Palpi porrect, reaching to the front, moderately stout; third joint not very distinct from the second, which is hairy beneath. Eyes hairy. Thorax smooth, not tufted. Fore wings a little less than one-half as broad as long; costa convex near the base and toward the apex much more rounded than usual; outer edge oblique, nearly as long as the internal edge; the apex much more rounded than usual; internal edge full near the base, with a prominent tuft in the middle. Venation: Costal region rather wide; no subcostal cell; fourth subcostal venule long; discal vein transverse, not oblique, each vein curved; those of the hind wings oblique, both in the same line, not being oblique to each other. Legs densely hairy. Abdomen rather full, simple at the end. Coloration of the species usually gray, with reddish brown markings, and usually a discal spot.

The species of this genus differ from those of the allied genera in the well-rounded apex of the fore wings, the feebly pectinated antennæ, the branches being short and ciliated, in the tuft on the inner edge, and in the presence or lack of a subcostal cell, while the outer edge of the wings is not scalloped.

I find that although our *N. stragula* in its larval and most of its adult structural characters is closely related to the European *N. ziczac*, yet the latter has no subcostal cell, though one is present in *N. stragula* (three ♂ examined). In *N. simplaria*, however, there is no cell. In larval characters our *N. stragula* agrees with the European *N. dromedarius*, *tritophus*, and *ziczac*.

Larva.—Head large, square; a large high nutant hump on second and a lower one on third and a very prominent one on eighth abdominal segment, the latter ending in two tubercles. Anal legs long, but used in walking. The European species have from three to five humps. In the European *N. ziczac* there are, judging by Buckler's figures, as in our species, but three humps; in *N. tritophus* there are four, while the larva of *N. dromedarius* most approaches Nerice in having five humps, four on each of the four basal abdominal segments and one on the eighth.

Pupa.—No distinct cremaster, the body being smooth and rounded at the end.

Geographical distribution.—It is interesting to notice that in the European forms (and in Europe there are more species than in North America) there is a tendency among the species, which vary in the number of dorsal humps, to fill up the gap between the genus Notodonta and Nerice. In fact, the latter genus exists in northeastern Asia,[1] and this fact adds another point of resemblance between the fauna of northeastern America and northeastern Asia.

SYNOPSIS OF THE SPECIES.

Fore wings rounded, mouse-gray, with reddish brown spots; no cross lines; tuft narrow, pointed; a distinct linear discal spot .... *N. stragula*
Ash-gray, with no brown; fore wings with two dark scalloped lines .... *N. simplaria*

[1] *Nerice davidi* Oberthur, from the north of China.

Notodonta stragula Grote.

(Pl. IV, fig. 1.)

Notodonta stragula Grote, Proc. Ent. Soc. Phil., iii, p. 93, Pl. XI, fig. 2, ♂, 1864.
Pack., Proc. Ent. Soc. Phil., iii, p. 357, 1864.
Grote, Check List N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 601, 1892.
Notodonta pacifica Behr, Proc. Cal. Acad. Sci., 2d ser., iii, p. 206, April, 1892.
stragula Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 185, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 113, Sept., 1894.

Larva.

(Pl. XIX, figs. 1–3.)

Tepper, Bull. Ent. Soc., Brooklyn, i, p. 10, 1878.
Edwards and Elliot, Papilio, iii, p. 129, 1883.
Packard, 5th Rep. U. S. Ent. Comm. on Forest Insects, pp. 156, 163, 1890.

Moth.—Anterior wings slaty gray, shaded with pale buff along internal margin, with a chestnut-brown basal patch and some brown streaks and spots in the terminal space; internal margin crested. Extreme base of the wing brownish; basal line distinct; subbasal space large, grayish at costa, rich chestnut-brown below the cubital vein, pale buff along the internal margin, which latter shade extends from base to internal angle. A very dark brown streak extends from the basal line to the transverse anterior line below the median vein, and a similar streak at internal margin. Transverse anterior line dark brown, grayish at costa, undulate, bordered anteriorly by a pale buff shade from below subcostal vein to internal margin. Median space widest at costa, narrow at internal margin, grayish, with an elongate pale discal spot with dark brown center. Transverse posterior line cinereous, indistinct, subdentate, continued. Terminal space with a series of rich chestnut-brown streaks between the veins; two more, linear, near the apex. Posterior wings pale cinereous with two indistinct median bands; anal angle touched with brownish. Thorax and collar brownish; tegulæ grayish; abdomen cinereous, slightly brownish above. Under surface of thorax and inside of legs brownish; outside of legs and sides of thorax clothed with cinereous hairs. Expanse of wings, 1.60 inches. (Grote.)

Dr. Dyar writes me that he has seen Behr's *N. pacifica*. "It is just like *N. stragula*, but darker, the thorax most black." I have also seen a poor specimen in Mr. Dyar's collection. It may be compared with *Pheosia portlandia*, which I regard as a melanotic form of *P. dimidiata*. I copy Behr's description.

Anterior wings; basal third brown, bordered by a darker line, preceded by a dilution; from these the anterior half ashy gray, the posterior half brown; the second line convergent and almost touching the first line that borders the basal third of the wing, preceded by a discal linear mark, which is followed by a diluted shade, ending with a well-darkened apical mark, divided by two nerves into three spots. Near the external margin a diluted fulvous shade. Hind wings grayish.

Found in Placer County, Cal.

The species is similar to *N. ziczac*, but the thorax is darker than the anterior wings.

Type in collection of the California Academy of Sciences.

Larva.—Dr. Dyar has sent me the following description of the early larval stages from his notes:

"*Stage I.*—On hatching the larva runs to the apex of the leaf and sits with the anterior half of its body projecting. It eats the upper surface of the leaf. Head round, pale brown; width, .5 mm. Body shining, sordid greenish, a subdorsal whitish line which becomes broken into oblique segmentary lines on the abdomen, a whitish lateral line. Segments 6 and 12 slightly enlarged dorsally. Thoracic feet and leg plates black. Cervical shield pale brown, transverse. Tubercles distinct, black, normal i–v, vi absent, a long one on the leg plate. (It is structurally not different from Nerice in Stage I, and has the same habits.

"*Stage II.*—Head high, narrowed toward the vertex, flattened before; smoky blackish mottled with pale in front in two ill-defined vertical bands. Body dark purplish with a blackish dorsal band and a pale shade on the side of the hump on abdominal segment 8 and slight pale lateral oblique lines. Prominence on abdominal segment 2 very slight. Thoracic feet black. Setæ short and obscure.

"*Stage III.*—Head narrowing toward vertex, with an angle between the front and sides; clypeus rather large; sutures evident, the median depressed at vertex. Body cylindrical, abdominal segment 8 enlarged dorsally, sloping off rapidly to segment 9, which is small; anal feet used, about the same size as the other abdominal ones. On abdominal segment 2 a dorsal fleshy hump, low, conical, nutant; a very slight one also on abdominal segment 3. Color lilac-white, diffusely marked along the sides with a darker shade. A brown-black dorsal band narrowing out and disappearing on abdominal segments 4–6, but distinct again posteriorly. Thoracic feet dark, a faint white stigmatal line.

"*Stage IV.*—Head higher than prothorax, concolorous with body, with a purplish band from the palpi narrowing to the vertex of each lobe. Some nearly concolorous mottlings, especially laterally posteriorly. Body lilac-white; the darker lateral streaks become oblique subdorsals, but are faint, as is the white stigmatal line. Dorsal band continuous, but very narrow on abdominal segments 4–6, velvety brown-black on the nutant hump on abdominal segment 2, reddish on the hump on 8. Venter heavily shaded with purple-brown. Legs all dark; a white line on the one on abdominal segment 6. Tubercles small, concolorous with very fine short setæ. Seta i is borne on the hump on the eighth abdominal segment, but only on the bases of the horns on abdominal segments 2 and 3. Altogether similar to the last (fifth) stage." (Dyar.)

Dr. Dyar has reared the larva, and finds that there are five stages. The widths of the head are (in the larva examined) 0.5, 1.1, 1.6, 2.35, 3.5 mm.

Larva before last molt.—Head large, oval, flattened in front, narrowing toward the vertex, which is slightly bilobed; the head is wider than the thoracic segments; the body is thickest on the second and third abdominal segments, on each of which is a thick, fleshy, conical, soft tubercle, the apex falling over backward; they may be elevated and somewhat enlarged or depressed, the anterior tubercle the larger of the two; the body is much humped dorsally on the eighth segment; supraanal plate smooth, much rounded; the anal legs slender, not nearly so thick as the other abdominal legs. General color pearly, glaucous, whitish gray, somewhat marbled with brown; head of the same color, marbled with brown; a broad, faint, lateral band shaded behind with white. A brown dorsal line extends from behind the head to apex of second tubercle on third abdominal segment; thence a faint vascular line extends to end of supraanal plate. The hump on eighth segment pale rust, yellowish red on sides, deeper above in the middle. A pale pinkish stigmatal line. Length, 20 mm.

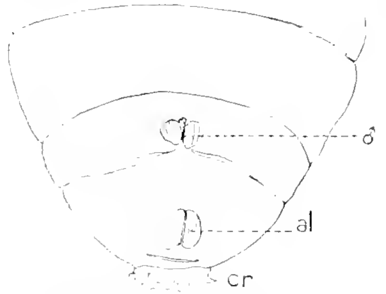

FIG. 66.—End of pupa of *Notodonta stragula*. *al*, anal legs; *cr*, the vestigial cremaster.

Mature larva.—Length, 40 mm. Does not differ except in size from previous stage. The head is rather square on the sides, narrowing above, and scarcely bilobed above; it is of the same general shape as in Schizura and Janassa. In this species, instead of a single hump on the first abdominal segment, there is a large, high, soft, movable hump on the second, and which nods backward, besides one a little stouter and shorter on the third. The humps are simple, with no traces of a fork or of bristles, and they are both brownish, of the hue of a dead dry leaf. The very prominent hump on the eighth abdominal segment bears two slight low tubercles, but no bristles. The anal legs are long and slender, but the planta is well provided with crochets. Underside of body dusky; the pale lilac lateral line sends a branch down the middle of the feet on the sixth abdominal segment.

I add Mr. Edwards's description of the full-fed caterpillar:

Head slate color, mottled with black, and with a pale stripe on each side. Mouth parts with a greenish tinge. Body pale lilac, with the exception of the eleventh and twelfth segments, which are dull golden. The seventh and eighth segments have raised prominences, which are also golden, that of the seventh being the largest. Laterally there are some pale oblique streaks somewhat similar to those of many Sphingidæ; these do not meet on the back, where there is a faint slate-colored line. Between the second and sixth segments, and common to all of these, is a darker dorsal shade which reappears on the eleventh and twelfth segments. The spiracles are white, with a black ring, and the lower lateral line is paler than the rest of the body. The twelfth segment bears a hump, and the sides of the eleventh, twelfth, and thirteenth segments are pale brown, mottled with orange. Abdominal legs dull slate color, mottled with black; thoracic legs black. Length, 55 mm.

Pupa.—♂. Body rather slender, much as in Lophodonta. Head rounded as usual. Abdominal segments smooth, sparsely and finely pitted; end of the abdomen smooth, ending in a short, very broad, cremaster, bearing near the outer edge on the underside four or five short spines and with two spines, one on each side, at the end. Vestiges of the larval male sexual aperture with an oval area on each side. Length, 17 mm.

Food plants.—Willow and poplar.

Habits.—The caterpillar of this moth has been reared by Mr. Tepper in New York. It was found on the poplar July 1, the moth appearing July 27. (Bull. Ent. Soc. Brooklyn, i, 10.) Messrs. Edwards and Elliot have found the food plant to be the willow.

This singular caterpillar is not uncommon at Brunswick, Me., late in August. It has the peculiarity of raising and depressing the two large dorsal horns in the middle of the body; when at rest they are depressed, appearing simply as humps; when erect they are somewhat larger and evaginated, with their pseudojoints like those of a telescope; probably they serve to frighten away ichneumons. My specimens molted for the last time August 31.

A caterpillar of this species was observed feeding on the extremity of a partially eaten leaf of poplar, and its oblique markings bore a striking resemblance to the twisted, partly dead, and dry portion of the leaf. The larva stood feeding in a very conspicuous position, and would easily be mistaken for an end of the poplar leaf.

The larva occurs in March, May, June, July, August, and September. (Riley MS.)

Geographical distribution.—This species is not uncommon in Maine, Canada, and southern New England, inhabiting the Appalachian subprovince. Orono, Me. (Mrs. Fernald); Brunswick, Me. (Packard); Amherst, Mass. (Mrs. Fernald); Brookline (Shurtleff); Williamstown, Mass. (Nason *fide* Grote); New Jersey (Palm); Chicago, Ill. (Westcott); Brooklyn, N. Y. (Tepper, Elliot); Plattsburg, N. Y. (Hudson); New York, Canada, Pittsfield, N. H.; Maine (U. S. Nat. Mus.); Canada, Maine, Massachusetts, Wisconsin, Tiffin, Ohio; Champaign, Ill. (French). The dark form *pacifica* Behr occurred in Placer County, Cal.

Notodonta simplaria Graef.

(Pl. IV, fig. 6.)

Notodonta simplaria Graef, Bull. Ent. Soc. Brooklyn, iii, p. 95, 1881, pl. 1. (The figure scarcely recognizable.)
Grote, Check List N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 601, 1892.
Pheosia simplaria Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 195, 1894; Journ. N. Y. Ent. Soc., ii, p. 113, Sept., 1894.

This is a true Notodonta. The antennæ are pectinated in the same manner. Fore and hind wings a little sharper at the apex, especially the hind wings, hinder edge of collar and inner edge of patagia black, and a black spot over the scutellum. Thorax gray, dark behind.

Fore wings granite ash-gray, and rather dark, blackish at base. On the inner third of the wing is a transverse scalloped line, the end of the line oblique, directed inward, and ending on the short broad tuft. A distinct linear discal spot encircled by whitish scales. Extradiscal line much excurved, so as to reach a point halfway between the discal spot and the apex of the wing; it is not wavy in its oblique course in the median interspace, but scalloped on the submedian space, and ending on the hind edge in a distinct, not wavy line, exactly parallel with that ending on the tooth. A submarginal row of dusky intervenular round spots; fringe white, with seven black dots. Hind wings whitish, a linear diffuse discal discoloration, but with no transverse diffuse median band.

Underside of the wings uniformly pale whitish gray, a diffuse dark extradiscal line, with discal spots. (Description drawn up from a ♂ compared by Mrs. Slosson with Mr. Graef's type.)

Expanse of wings, ♂, 48–50 mm.; length of body, ♂, 19–20 mm.

Geographical distribution.—Catskill, N. Y., August (Graef); St. Johns, New Brunswick (H. Edwards); New York (French).

Note.—*Notodonta plagiata* Walk., Cat. Lep. Het. Br. Mus., vii, p. 1749, 1856, belongs to the European *N. tritophus* (fide Grote and Robinson), with an erroneous locality.

LARVA OF PSEUDOTHYATIRA CYMATOPHOROIDES GROTE.

(Pl. XIX, fig. 5, *5a*, *5b*.)

This beautiful and interesting larva was detected on the yellow birch at Brunswick, Me., August 14. It was dark horn-brown, the tail upturned, and the body when disturbed twisted into a partial spiral. The next day it molted. I had supposed it might be a Notodontian, but Dr. Dyar on reading my description thinks it is almost surely a Noctuid, and that it has been described by R. Thaxter. The following description was made two days after it had molted and before the body had filled out, as it tapered slightly to the end:

Stage III?—Length, 8–9 mm. The head is large and broad, somewhat rounded, but seen from in front somewhat square, being about as broad as long; it is much wider than the body, the latter not yet being filled out; it is pale, raw sienna brown, with dense reddish brown spots arranged in two broad diffuse median and two broad diffuse longitudinal bands; it is slightly bilobed and much rounded on the vertex, not angular, and with no tubercles. The segments of the body are transversely wrinkled. The body above is of a peculiar dark sea-green hue, and below this runs into a dark umber brown. The first thoracic segment has no tubercles or marks, but is dark brown on the sides and on the back, with irregular scattered pale spots. On the second thoracic segment is a prominent transverse ridge, with a small tubercle at each end; it is dark on the anterior slope, but on the summit and on the posterior slope whitish ash. This pale area extends back to the first abdominal segment, but does not include it, though it passes down to the side of that segment and extends backward, forming a lateral diffuse, rather irregular spiracular band, from which a pair of oblique pale stripes extend upward upon the back, not quite reaching the fine median blackish line; posteriorly it forms the pale edge of the suranal plate. A decided dorsal hump on the eighth abdominal segment, which is dark velvety umber-brown with the hinder edge below whitish. The end of the body is decidedly elevated, and the dark anal legs are as large as the middle set of abdominal legs, which are flesh colored. The thoracic legs are dark green, concolorous with the thoracic segment.

Ellida Grote.

(Pl. XLII, fig. 4, venation.)

Ellida Grote, Can. Ent., viii, p. 125, July, 1876.
Cymatophora Walk., Cat. Lep. Het. Br. Mus., ix, p. 18, 1856.
Ellida Kirby, Syn. Cat. Lep. Het., i, p. 597, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 187, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 208, Sept., 1894.

Moth.—Head much as in Notodonta; the front shaggy, moderately wide; the hairs abundant; eyes naked. The male antennæ broadly pectinated; "female antennæ more shortly and finely bipectinate" (Grote). The palpi much as in Notodonta, being short and broad, the third joint short and conical, but distinct, and reaching slightly beyond the front. The thorax is smooth, not tufted.

Fore wings not broad, the costa regularly convex; the apex not produced and rounded as in Notodonta, but moderately acute; outer edge short; inner edge simple, not tufted. Venation much as in *L. basitriens*, there being no subcostal cell. The costal region is rather wide; six subcostal branches, the second very short; the sixth arises nearer the discal vein than in *L. basitriens*. The arrangement of the discal veins is much as in *L. basitriens*, their course being nearly straight. Hind wings somewhat pointed toward the apex. The subcostal does not fork so far out near the outer edge of the wing as in Notodonta, while the two discal veins taken together make a regular curved line.

The abdomen is smooth, not tufted at the end, but conical. Legs moderately stout, pilose; a pair of discal spurs on the hind tibiæ not projecting far beyond the hairs.

Coloration somewhat as in *Schizura leptinoides*, reminding one at first of that species; fore wings ash-gray, with transverse lines, but the venules only slightly marked with dark spots and streaks. A distinct curvilinear discal spot and just within it three short parallel distinct brown lines, which are most distinct in the median space. Hind wings ash-brown. Collar dark.

The genus differs from Notodonta in the more strongly pectinated antennæ, in the more pointed, less rounded wings, and in the venation. The palpi are nearly the same.

Larva.—Unknown.

Geographical distribution.—So far as known, confined to the Appalachian subprovince.

Ellida caniplaga (Walk.).

(Pl. IV, fig. 21.)

Cymatophora caniplaga Walk., Cat. Lep. Br. Mus., ix, p. 18, 1856.
Edema transversata Walk., Cat. Lep. Br. Mus., xxxii, p. 427, 1865.
Bombycea caniplaga Grote, Bull. Buff. Soc. Nat. Sci., ii, p. 5, 1874.
Ellida gelida Grote, Can. Ent., viii, p. 125, July, 1876; New Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 527, 1892.
Smith, Cat. Lep. Superfamily Noctuidae, p. 29, 1893.
Ellida caniplaga Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 208, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Moth.—Two ♂. Head, palpi, and prothoracic collar vandyke brown, the front part of the thorax contrasting with the mouse-gray hinder portion. Fore wings uniform ash gray; no distinct transverse line at the base, but just before the middle of the wing are three vandyke-brown parallel close-set lines which begin on the costa, but are most distinct and heavy between the subcostal vein and above the median fold; the outermost and innermost of the three lines extend to the inner edge of the wing, but the middle one is obsolete. The outermost of the three lines is situated very near the dark vandyke brown, distinct, curvilinear discal spot, and this distinguishes the species from any other Notodontian. On the outer fourth of the wing are two faint scalloped dark lines, represented by venular dots; a marginal row of irregular brown spots.

Hind wings and abdomen dark ash-gray, and both pairs of wings beneath of the same hue. The underside of the costa is not checkered with light and dark spots, as it is in Schizura and other genera.

Expanse of wings, ♂ 37–42 mm.; length of body, ♂ 15 mm.

At first this species might be mistaken for a variety of *Schizura leptinoides*, as the shape of the wing, the discal spot, and the lines are similar, but in no other species is the linear dark discal spot situated so near the transverse lines, these three lines being heavier and most distinct in the middle of the wing. Also the dark brown collar is peculiar, the thorax not being tufted. The pectinated ♂ antennæ will separate the genus from any except Notodonta, to which it is nearest allied.

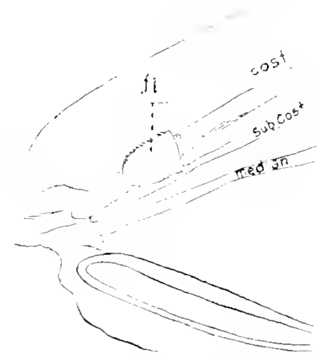

FIG. 67.—Frenulum loop on the costal vein of the fore wing of *Nerice bidentata*.

Professor Smith includes this genus in the Noctuidae, placing it in Bombycia, but its venation is that of the Notodontinæ, as it has but three branches of the cubital vein, and the subcostal venules are as in the Notodontinæ. He also remarks: "The type is in the Saunders collection at Oxford, England. A figure sent me by Mr. Schaus proves it to be '*Edema transversata* Walk., *Ellida gelida* Grt.'" (Cat. Noctuidae, p. 29, 1893.)

Geographical distribution.—New York (Dyar); St. Catherines, Canada (Norman); Canada (French); Kittery, Me. (R. Thaxter); Plattsburg, N. Y., April 29, May 15, 16, 30 (G. H. Hudson).

Nerice Walker.

(Pl. XLIII, figs. 1, 1*a*. Venation.)

Nerice Walk., Cat. Lep. Het. Br. Mus., pt. v, p. 1076, 1855.
Pack., Proc. Ent. Soc. Phil., iii, p. 358, 1864.
Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 487, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 187, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 114, Sept., 1894.

Moth.—Head moderately prominent; front squarish, moderately broad, the scales on it evenly cut, rather short; the tuft at the base of each antenna rather prominent. Antennæ not quite half as long as the fore wings, and in ♂ well pectinated to the tips; the branches four times as long as the antennal joints, and ciliated. Palpi large and stout, ascending, curving up in front of the clypeus, and reaching well beyond the front of the head: the hairs beneath thick and spreading; third joint small, conical. Maxillæ short, not reaching out to the palpi. Thorax with a high pointed median tuft, sloping behind.

Fore wings a little less than one-half as broad as long; costa convex, especially toward the apex, which is rounded; outer edge oblique, slightly convex to the internal edge. Venation: A long narrow subcostal cell; second and third subcostal venules unusually short, the apical space between the costa and subcostal vein being very narrow; in this respect the genus is much as in Lophodonta (especially *L. basitriens*); the third subcostal venule is one-half as long as the second. The venation is otherwise as in Notodonta, the discal veins being the same, and vein VI looped at base, as in Notodonta.

The genus differs from Notodonta in having no tuft on the inner edge. The hind wings differ from those of Notodonta in being shorter and rounder and in the apex being more produced, while the venation differs in the costal vein being longer and turned up at the end on the costa; otherwise the venation is much as in Notodonta.

The legs are much as in Notodonta, being rather slender, the femora and tibiæ densely pilose, the latter with moderately large tibial spines. Abdomen blunt at the end, with a small anal tuft.

Coloration: The only North American species is whitish gray, with brown between the cubital vein and the costa, sending two prominent teeth toward the internal edge. There are no transverse lines of any sort. The hind wings are chocolate-brown.

This genus is distinguished by the antennæ being pectinated to the end, and with longer branches than in Notodonta; by the large palpi extending well in front of the head; especially by the high prominent median thoracic tuft, and by the well-rounded apex of the fore wings. It differs from Notodonta not only in the more broadly pectinated antennæ, but in the much longer palpi and the squarer fore wings, the outer edge being less oblique, while the internal edge is simple, not bearing a tuft. The hind wings are also a little shorter and more rounded at the apex than in Notodonta.

Larva.—The larva differs from that of Notodonta, or any other genus of the family, in the abdominal segments being nearly all provided with a dorsal hump, the abdominal segments 1 to 8 having each a "large anteriorly directed prominence ending in a bifid ridge, the incision being transverse, the anterior portion being curved backward and larger than the posterior part, the two looking very much like the bill of an eagle, and susceptible of being opened and closed." (Marlatt.) It is silvery green, with dark bluish green subdorsal and lilaceous lines on the thoracic segments. It is evidently adapted for protection while feeding on the edge of an elm leaf, the serrations of the body resembling those of the edge of the leaf of its food plant.

Pupa.—Body rather stout, somewhat pointed at the end, which bears an unusually long, slender, smooth, round cremaster, armed with very short curled setæ, and ends in two up-curved slender, hooks. The surface of the body with shallow and sparse pits; on the sutures of the abdominal segments very finely shagreened.

Cocoon.—Formed of thick, brownish silk, situated within folded leaves or under some slight protection at the surface of the soil. Concealed by particles of earth. (Marlatt).

Geographical distribution.—Besides a single species inhabiting the Atlantic and Central States of North America, including Kansas, Walker describes a species (*N. pallida*) from Nepaul, and Oberthur describes and figures *N. davidi* from the north of China, which is very similar to our *bidentata*. The genus is not represented in western Asia, southern India, or in Europe.

Nerice bidentata Walker.

(Pl. VII, fig. 15.)

Nerice bidentata Walk., Cat. Lep. Br. Mus., v, p. 1076, 1885.
Pack., Proc. Ent. Soc. Phil., iii, p. 358, 1864.
Grote, Check List N. Amer. Moths, p. 19, 1882.
Marlatt, Trans. of 20th and 21st meetings of Kansas Acad. Sc. for 1887–88, xi, p. 110, 1889.
Pack., Fifth Rep. U. S. Ent. Comm. Ins. Inj. Forest and Shade Trees, p. 267, 1890.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Bor. Amer., i, p. 187, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 187, June, 1894; Jour. N. Y. Ent. Soc., ii, p. 111, Sept., 1894.

Larva.

(Pl. XIX, fig. 4, and Pl. XXIII, figs. 1, 1*a*, 1*b*, 1*c*, 1*d*.)

Marlatt, Trans. 20th and 21st meetings Kansas Acad. Sc. for 1887–88, xi, p. 110, 1889. (Figs. of egg, larva, pupa and moth.)
Packard, Proc. Bost. Soc. Nat. Hist., xxiv, p. 525, 1890.
Soule, Psyche, vi, p. 276, June, 1892. (Egg, five larval stages, and pupa described.)

Moth.—Three ♂. Head, prothorax, and thoracic tuft sable-brown, the rest of the thorax and the internal border of the fore wings cinereous, edged in front with silvery white; this latter portion of the wing is twice deeply indented by an inner, small, rounded tooth and an outer, large, broadly triangular projection. The dark brown median portion shades into cinereous toward the costo-apical portion; two short oblique brown lines margined below with cinereous are situated, each in an intervenular space, just above the middle of the outer margin. The hind wings, as well as both pairs beneath, are very light brown. A faint median diffuse darker line crosses both wings.

Length of body, ♂, 15 mm.; expanse of wings, ♂, 40 mm.

Egg.—"0.9 by 0.55 mm. Shape, hemispherical, with a broad flattened base, irregularly encircled by a whitish cement fastening to the leaf. Surface shining, apparently smooth, but when highly magnified is found to be covered with raised lines inclosing minute polygonal, usually six-sided, areas. Color, honey-yellow; after hatching, nearly white." (Marlatt.) "Very like the egg of *Nadata gibbosa*." (Soule.) (For Larval stages I–IV see Appendix A.)

FIG. 68. *Nerice bidentata*: *a*, moth; *b*, larva; *c*, pupa; *d*, folded leaf inclosing the cocoon all natural size; *e*, the egg enlarged with outline of the surface pattern much magnified. C. L. Marlatt *del.*

Larva.—"Length, 1.25 inches. General color, polished bluish green. Head narrower above than below and larger than segment 1; head of the same polished green hue as the body, with four perpendicular silvery green lines, the two outer ones running parallel to the triangular piece and then taking its V-shaped form. A row—four to six—of minute black eye-spots at base of palpi. Three thoracic segments, above pale silvery green, interrupted, however, by a straight dorsal and wavy subdorsal line of the dark bluish green general color. Segments 4 to 11, inclusive, each with a large anteriorly directed prominence ending in a bifid ridge, the incision being transverse, the anterior portion being curved backward and larger than the posterior part, the two looking very much like the bill of an eagle and susceptible of being opened and closed. Segments from 1 to 6 gradually increasing; 6 to 9 about of a size, or showing but a very slight decrease; 10 and 11 somewhat smaller and of a size, though the prominence on 11 is more pointed and higher than that on 10. Steep decline from 11 to anus, with but a very slight prominence on 12. The upper half of the body, including prominences, is silvery-green, with the dark lines already mentioned on thoracic segments, and an oblique dark line running on the other segments from anterior base of prominence to the posterior portion of the following segment. Summits of prominences yellowish, with extreme edges brown. Spiracles yellowish with a lilaceous annulation. Thoracic segments with a lilaceous line, bordered above with yellow immediately above the legs; segments 4 and 5 with a distinct and the rest of the segments each with an indistinct patch of the same two colors in a line with it, frequently becoming confluent and forming another line from 10 to anal legs." (Riley.)

This larva, judging by the figure and description of Mr. C. L. Marlatt,[1] is an exaggeration of

[1] Trans. 20th and 21st annual meetings of the Kansas Academy of Science, 1887–88, xi, 1889, 110.

the appearance of the European *N. dromedarius*, as each abdominal segment from the first to the ninth bears a large, fleshy, two-toothed hump, the three largest on segments 3 to 5. Thus the outline of the back is serrate, and perhaps mimics the serrate edge of the leaf of the elm on which it feeds. The body is greenish, with the upper half of the sides washed with white, with crimson spots and bands, the tip of the dorsal protuberances being also crimson.

Mr. Marlatt does not state whether the dorsal tubercles are movable, or whether the caterpillar is protected by mimicking the outlines or the colors of the leaves of its food plants. Further observations are needed on this point.

Cocoon.—"The cocoon is formed on the surface of the earth, and consists of loose, yielding silk and earth." (Riley.) Marlatt states that the caterpillars spin "cocoons of stout, brownish silk in folded leaves or under some slight protection at the surface of the soil, concealed by particles of earth.

Pupa.—The body is rather thick, the cremaster very blunt, with a long, slender, acute point bearing very short curled setæ, and divided at the end into two minute forks. Surface of the body with shallow sparse pits; on the sutures of the abdomen very finely shagreened. Length, 16–18 mm. "The pupa was very active, rolling a foot or more at a time." (Soule.)

I am indebted to Miss Caroline G. Soule for the excellent colored figure of the larva on Pl. XIX.

Habits.—Mr. Marlatt has published in the Transactions of the Twentieth and Twenty-first Annual Meetings of the Kansas Academy of Science (1887–88) an account of the habits and transformations, with the accompanying figures, of this singular Notodontian. It appears to be double brooded, as the moths appeared in Kansas from May to June, and the females deposited their eggs at that time, a second brood of moths probably appearing about the 1st of August, as the caterpillars became fully grown September 14 to 21. They spin cocoons of stout, brownish silk within folded leaves (fig. 66*d*) or under some slight protection at the surface of the soil, concealed by particles of earth.

I once found the larva on the elm at Providence fully grown September 3, but failed to describe it: it pupated September 6, and the moth appeared in May of the following year.

We are indebted for the following notes on the larva to Professor Riley:

> Found September 16, 1869, at Bellville, on the common elm, a most singular caterpillar. September 26, 1869, they all descended to the ground and formed their cocoons in the same corner of the breeding cage. It issued the following May 1, 1870. From a larva found feeding on the elm August 26 the moth issued September 21. (Fifth Rep. U. S. Ent. Comm. p. 267.)

Mr. Dyar writes that he has found the larva in its second stage early in the summer (June) in its "perch," at Keene Valley, Essex County, N. Y.

Food plant.—It has not yet been found on any other plant than the elm.

Geographical distribution.—The genus ranges through the Appalachian into the eastern portions of the Campestrian subprovince, not having yet been observed west of the great plains.

Franconia, N. H. (Slosson); Brookline, Mass. (Miss Soule); Amherst, Mass. (Mrs. Fernald); Trenton Falls, N. Y. (Doubleday); Providence, R. I. (Packard); New York (Grote); Missouri (Riley and Miss Murtfeldt); Eastern Kansas (Marlatt); Topeka, Kans. (Popenoe); Canada, Maine, Massachusetts, New Hampshire, Wisconsin, Ohio, Carbondale, Ill. (French); Plattsburg, N. Y. (Hudson); New Jersey, Pennsylvania (Palm); Chicago, Ill. (Westcott).

Dasylophia Packard.

(Pl. XLII, figs. 5, 5*a*, 6, venation.)

Phalæna Abbot and Smith, Nat. Hist. Lep. Ins. Georgia, p. 167, Tab. LXXXIV, 1797.
Notodonta Harris, Cat. Ins. Mass., p. 73, 1835.
Datana? Walker, Cat. Lep. Br. Mus., v, p. 1062, 1855.
Datana? Morris, Synopsis Lep. N. Amer., p 247, 1856.
Dasylophia Pack., Proc. Ent. Soc. Phil., iii, p. 362, 1864.
Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Halima Kirby, Syn. Cat. Lep. Het., i, p. 569, 1892.
Dasylophia Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 200, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 116, Sept., 1894.

Moth.—Head large and rather prominent, vertex with two high pointed erect tufts, the tips of which meet over the vertex, reaching to the level of the thorax in ♀, a little shorter in ♂. Antennæ with long slender pectinations on the basal two-thirds, while the remaining third is provided with lateral setae: in ♀ simple. Palpi slightly ascending; third joint passing beyond the front, second joint slightly curved upward, the scales beneath the joints being short; third joint half as long as the second, porrect, being directed forward at a slight angle with the second joint.

Thorax short; the scales of the prothorax distinctly marked.

Fore wings hardly one half as long as broad: costa very slightly concave in the middle, toward the tip a little convex; outer margin oblique; internal angle obtuse; the inner edge near the base of the wing is full in ♂, in the ♀ straight. Venation: A short subcostal cell, the discal vein of both wings forming a regular curve. Hind wings with the costa long and straight, apex subrectangular; from thence the outer margin is longer than usual and slowly rounded to the not very distinct internal angle. The wings reach to the basal two-thirds of the abdomen.

Legs pilose, the anterior femora densely so, those of the ♀ with longer scales, and more irregularly and thickly pilose.

Abdomen long, cylindrical, with lateral tufts, and tip of ♂ slightly tufted.

In coloration the species are generally gray, with dark streaks running parallel to the venules. There is a distinct basal longitudinal mesial streak and an outer very distinct geminate curved line

The long, slender, acute palpi, the high conical tufts on the vertex of the head, the shape of the wings, their markings, and the venation are sufficiently diagnostic of this genus.

Egg.—Shape of a flattened spheroid, the upper pole somewhat concave, a little broader at the base than at the top. Surface of the shell covered with polygonal areas, which vary somewhat in shape, size, and distance apart, the interspaces being rather broad.

Larva.—Head round; body elongated, rather slender, of nearly uniform thickness, with a low rounded black dorsal knob on the eighth abdominal segment; no other armature except a pair of subdorsal black warts on the first abdominal segment. Anal legs slender, uplifted. Three lateral black lines, and base of all the legs with a black patch. Freshly hatched larva: Head very large, body tapering behind; end of body with the slender anal legs, which are hookless and slightly reversible, held up while in motion. Two subdorsal conspicuous papillae on the first abdominal segment, and two similar but much smaller ones on the eighth, which in the last stage form the single dorsal knob. Glandular hairs unusually long, thick, clavate, black, clear, and colorless at the end.

Cocoon.—Thin, loose but somewhat tough, covered with bits of earth, etc., and spun on the surface of the ground.

Pupa.—Cremaster conical, cleft at the end, each fork blunt, and bearing three hooked setae.

Geographical distribution.—Of the two species known, one (*interna*) is confined to the Appalachian subprovince and the other ranges through the Appalachian and the Austroriparian subprovinces.

Œdemasia senata Druce (Biol. Centr. Amer., p. 235, pl. 25, fig. 1), from Jalapa and Panama (volcan de Chiriqui), has the shape of fore wings and the markings of a Dasylophia, and I am quite of the opinion that it is not an Œdemasia (Schizura); the two black round spots near the inner angle are just as in *D. anguina*. In fact I regard it as very closely related to *D. anguina*, and hence as a representative species.

Mr. Neumoegen has kindly shown me *Nystalea amazonica* Stand., from Brazil, and which is a genuine Dasylophia very closely related to our *D. anguina*. If this is so, then the genus ranges through the Mexican ("Sonoran") subprovince and the Central American region to Brazil. *N. indiana* Grote I am inclined to regard as a Noctuid.[1]

SYNOPSIS OF THE SPECIES.

Body and basal region of fore wings white; a distinct black line along cubital vein............ *D. anguina*

Body and wings mouse-brown; no black line; basal region of fore wings tawny brown .... *D. interna*

[1] I copy from Neumoegen and Dyar's Revision the following description of this moth, which I have been unable carefully to examine:

"*Nystalea indiana* Grote, Papilio, iv, p. 7, 1884.

"Anterior part of thorax with a dull yellowish patch as in Datana, bordered by black; the rest gray. Fore wings much elongated; antennae simple, ciliate, the cilia longer at base, a tuft on each joint at each side. Primaries cinereous, paler on the disc, distinctly mottled; subbasal line faint, T. a. and t. p. lines close together, straight, parallel, narrow, blackish-brown, equidistant from the indistinct black discal ringlet. On veins 2–3 (viii$_2$–vii$_1$), near the base, a black patch; another between veins 3–4 (vi$_2$–v$_1$) just outside t. p. line. Subterminal row of small black dots, two in each interspace, and terminal black shaded spots. Secondaries blackish, pale at base. Expanse, 40 mm. Hab. Florida."

Dasylophia anguina (Abbot and Smith).

(Pl. IV, figs. 10, 11.)

Phalæna anguina Abbot and Smith, Nat. Hist. Lep. Ins. Georgia, p. 167, Tab. LXXXIV, 1797.
Notodonta anguina Harris, Cat. Ins. Mass., p. 73, 1835.
Datana? anguina Walk., Cat. Lep. Het. Br. Mus., v, p. 1062, 1855.
Drymonia cucullifera H. Sch., Samml. aussereur. Schmett., p. 66, fig. 381, 1856.
Datana anguina Morris, Synopsis Lep. N. Amer., p. 247, 1862.
Dasylophia anguina Pack., Proc. Ent. Soc., Phil. iii, p. 362, 1864.
Heterocampa punctata Walk., Cat. Lep. Het. Br. Mus., xxxii, p. 420, 1865 (*fide* Grote and Rob.).
Dasylophia anguina Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891; var. Trans. Amer. Ent. Soc., xx, p. 11, 1893.
var. *punta gorda* Slosson, Can. Ent., xxiv, p. 129, 1892.
Hatima anguina Kirby, Syn. Cat. Lep. Het., i, p. 569, 1893.
Dasylophia anguina Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 200, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 116, Sept., 1894.

Larva.

(Pl. XXI, figs. 1-6.)

Abbot and Smith, Nat. Hist. Lep. Ins. Georgia, p. 167, Tab. LXXXIV (colored figure of larva with pupa and moth).
Harris, Ent. Corresp., p. 301, Pl. I, fig. 12, 1869 (col. fig.).
Dyar, Ent. Amer., v, p. 55, 1889.
Packard, Proc. Bost. Soc. Nat. Hist., xxiv, p. 528, 1890, Pl. III, figs. 1-8 (figures of all larval stages). Fifth Rep. U. S. Ent. Comm., p. 366, 1890 (Pl. XXXII, fig. 3).

Moth.—Two ♂, one ♀. Ash gray, mixed with snow-white scales on the head, thorax, and costa and base of fore wings. Basal region of fore wings whitish and inclosing a conspicuous long black line, extending along the cubital vein to the origin of the third cubital venule, and a shorter one diverging from it situated in the discal space and ending at the base of the first cubital venule; also a brown slash in the second cubital interspace. No transverse line on the basal third of the wing. Near the apex of the wing are three subparallel black longitudinal streaks. A transverse line on the outer fourth of the wing, which is obsolete on the inner edge of the wing and faintly marked on the costa, with fine black specks on each side, and inclosing a row of minute black dots. The veins and venules are speckled with black scales; two black spots larger than the others are situated in the subcubital space inside of the cross line, and a larger round black spot in the second cubital interspace, near the outer edge, besides a smaller one in the first cubital interspace; they are encircled with whitish scales. A faint submarginal zigzag brown line not reaching the apex of the wing and fading out near the internal angle.

Fringe of both wings white, with a pair of black twin dots at the ends of the venules; on the outer edge of the fringe a dark slash situated opposite the ends of the venules.

Hind wings sordid white, becoming dusty on the outer fourth. In one ♀ the hind wings are entirely dark.

Expanse of wings, 35–36 mm.; length of body, 17–20 mm.

I copy Mrs. Slosson's description of *D. punta gorda*, which appears to be a variety of *D. anguina*. (See Pl. IV, fig. 10.)

Male.—Head and thorax appearing palest gray from admixture of pure white with cinereous. Abdomen, secondaries, and ground color of primaries sordid white. Primaries streaked longitudinally with blackish, which contrasts violently with ground color. A diffuse, heavy, blackish shade runs obliquely from apex inward. A curved blackish line, reaching neither costa nor internal margin at outer three-fourths of wing. Submarginal row of distinct, blackish spots, two of which are much larger than the rest and margined with white. Costa interrupted near apex by white spots. Fringe sordid white, interrupted by blackish. Somewhat smaller than *D. anguina*, S. & A., and differing markedly from that species in its sharp contrasts of color, which make it appear like a purely black and white insect. It has no ocherous shade. The antennæ resemble those of *D. anguina*, the pectinations not as long as in those of *D. interna* Packard. Described from two males taken at light, Punta Gorda, Fla.

I received a few of the eggs of this moth from Miss Emily L. Morton, of Newburg, N. Y. The young hatched July 25, and were fed on locust leaves.

Egg.—Shape of a flattened spheroid, the upper pole somewhat concave, a little broader at the base than at the top. (Dyar says: "Evenly rounded, flattened above and below.") The shell is very thin and transparent, so that the larva, with its yellowish head and red lines, can be distinctly seen through it. The surface is covered with polygonal areas, which are not very distinct, though as much so on the upper pole as on the sides. The areas vary somewhat in shape, size, and distance apart, the interspaces being rather broad, and there are no beads like those on the surface of the eggs of Schizura. Diameter, 0.7–0.8 mm.

Larva of first stage, just after hatching.—July 25. Length, 3–4 mm. The head is very large, nearly twice as wide as the body behind the middle, rounded, and with a fine, narrow black stripe along the hinder edge; it is honey-yellow, with scattered black hairs. Body moderately slender, gradually diminishing in width to the end, the anal legs being long and slender, larger than in the young of Schizura. They are forked, long, and slender; the terminal third evaginate, nearly as large at the end as at the base, and are held lifted up, together with the two preceding segments, at an angle of about 15 degrees. The claws are entirely absent, the tip being soft, retractile, and extensile, and the leg itself being provided with 12–13 stiff, dark, acute setæ. They differ but slightly from those of the fully fed caterpillar. The end of the leg is retracted by three slender retractor muscles, one being single, the two others united near their insertion into the retractile portion.

The other abdominal legs are provided with a semicircle of ten hooks each, the inner two hooks of one set being very short. All the legs, both thoracic and abdominal, are dull greenish. The body is deep pea green, the surface shining. The first abdominal segment shining red, with two slender, papilliform, nonpiliferous subdorsal deep red tubercles, situated in or just below the subdorsal lines. There are two similar but much smaller piliferous red warts on the eighth segment. Body behind the head with five red or reddish black lines; the single dorsal and the two subdorsal lines narrow, nearly continuous, scarcely broken. The lateral line is slightly interrupted like the others at the sutures. Below the spiracles is a much interrupted line of heavier dark red, somewhat curved or sinuous slashes, situated at the base of the legs, becoming less distinct behind the fourth pair of abdominal legs.

The hairs are stiff and black, mostly thick and clavate, and pale at the extreme tip. Those on the head are slightly knobbed. On the prothoracic segment is a chitinous plate or shield from which arise four of these hairs, of which two are about one third longer than those of the meso- and metathoracic segment; they are about as long as the body is thick; those on the second, third, and fourth abdominal segments are larger and longer, more distinctly clavate than those elsewhere; they are smooth, black, but clear and colorless at the extreme tip.

Second stage, after first molt.—July 28. Length, 6–7 mm. The head is now more distinctly amber colored and smaller in proportion than before. Body pale green, the dark brown stripes, especially the dorsal one, being more distinct; the dorsal line is continuous, the two lateral ones somewhat broken. The hairs are black, not so much club shaped as before. The markings show little change from the first stage, but the reddish first abdominal segment has grown paler. The tubercles on the eighth abdominal segment have each lost their single hair.

Third stage, after second molt.—August 5. Length, 15 mm. The larva has now dropped the club-shaped setæ, or "glandular hairs," all the hairs being minute, tapering, and very short, while the lateral humps on the eighth segment are decidedly larger than before and marked with two parallel reddish brown lines, so that in respect to these humps the characters of the fully grown larva are nearly assumed, while the tubercles on the first segments are still slightly larger in proportion than in the mature larva.

The head is of moderate size, but little wider than the body, rounded, and orange-reddish. The body is smooth and shining, straw yellow, the line blackish; the dorsal black line ends on the smooth black knob on the eighth segment. The three lateral black lines are more or less interrupted, situated in a broad whitish band, the middle line being the faintest, which incloses on the first abdominal segment a jet-black tubercle. Low down is an infraspiracular row of twelve black spots situated at the base of the legs, when present. There are four black spots on the front part of the suranal plate, while the double reddish black slashes on the lateral humps of the eighth abdominal segment are more pronounced than in the earlier stages. The extensile, uplifted anal legs are black at the tips.

Fourth stage, after third molt.—August 10–11. Length, 22–24 mm. In this stage the larva only differs from the preceding one in the deeper, more distinct colors of the body and its markings, while the body itself is larger and thicker. The black tubercles on the first abdominal segment are slightly smaller than before.

Fifth stage, fully fed larva.—Length, 55 mm. Head rounded, greenish amber; body smooth, of nearly uniform thickness, with a low rounded jet-black knob on top of the eighth abdominal segment, in front of which is a narrow black dorsal line; anal legs very slender, uplifted. Three lateral black lines close to each other and forming a broad, dark, wavy band. Base of all the legs black, but the legs themselves pale; ground color of body, deep pink, flesh color. Differs from the fourth stage in the rather thicker body, slightly shorter anal legs, and the smaller first abdominal black dorsal tubercles, while the black spots on the eighth abdominal segment are more pronounced.

Recapitulation.—(1) The larva hatches with the generic characters already established, viz, with the long slender retractile anal legs, unprovided with hooks, and with the pair of hairless dorsal tubercles on the first abdominal segment. (2) The two dorsal tubercles on the eighth abdominal segment lose the hairs at the first molt and begin to assume the shape and coloration seen at the last stage. (3) The clavate hairs disappear with the second molt. (4) In the third stage the coloration and markings of the species begin to appear, the body changing from pea-green to straw yellow, the skin smooth and shining, and the lines and spots blackish, while the reddish tint of the first abdominal segment, characteristic of the first stage, is discarded.

The earliest stages of Dasylophia are very different from those of *Symmerista*, the latter apparently lacking the clavate hairs and tubercles of the former genus.

It is probable, though further field work is needed to prove it, that by the third stage the caterpillar is exposed to the same dangers and escapes them in the same way as the larva in its final stage. Observations as to the position of the larva while feeding on the locust or wild indigo leaf are needed in order to show how the reddish head, shining straw-yellow body, and blackish stripes and markings assimilate it to its habitat; also whether ichneumons are repelled by the movements of the anal legs, and whether such motions of the end of the body are sufficient to drive away ichneumons and Tachinæ from its otherwise unprotected, smooth body.

These remarks will also apply, though less strongly, to the caterpillar of *Symmerista albifrons*, which has similar shape and coloration, though its anal legs are not retractile nor so long and slender, and hence not so well calculated to frighten away unwelcome insects. Experiments should also be made to ascertain whether the two larvæ in question are distasteful or not to birds.

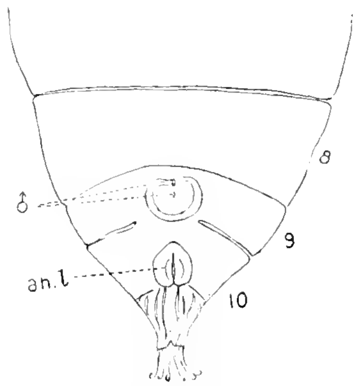

FIG. 69.—Pupa of *Dasylophia anguina*. *an. l*, vestiges of anal legs.

It may be here observed that although many insects, according to the recent views of Exner and Plateau, may not distinctly perceive the outlines of bodies, yet all insects doubtless see objects in motion. Hence any ichneumon or Tachina, or the carnivorous beetles or bugs, may be frightened away by the sight of a moving or nodding tubercle like those on many Notodontians, and still more by the movements of the filamental or even the slightly elongated legs of other forms, or by the upturned abdomens of Datana caterpillars.

Cocoon.—"It formed a cocoon of leaves and silk of thin loose texture" (Harris Corresp., p. 306). "Pupa enveloped in a thin, but a somewhat tough, cocoon composed of silk and bits of earth, etc., constructed at the surface of the ground." (Dyar.) The cocoon is loose, rather irregular, with sand, etc., adhering to the outside, forming a thin network of coarse silk, just the sort of structure to which the cremaster hooks would adhere to hold the pupa in place, 23 by 12 mm.

Pupa.—"It is 23 mm. long, 8 mm. in diameter, shining dark chestnut-brown; cremaster short and blunt, terminating in several hooklets." (Dyar.)

One ♂. Body rather long, moderately thick, upper surface of thorax finely corrugated. Abdominal segments only punctured near the sutures and finely granulated on hinder edge of segments 5 to 7. Two ♂ sexual openings or scars on segment 9 instead of one. End of body tapering to a point. Cremaster conical, cleft at the end; surface longitudinally corrugated, each fork or spine truncate, and bearing three long setæ, which are curved at the end as in fig. 67. Length, 20 mm. (U. S. Nat. Mus.).

Habits.—Harris found the larva on *Podalyria tinctoria* August 3. "Its position when at rest is like the gregarious caterpillars (*Pygæra*) of the apple tree, the head and tail being elevated." He found another caterpillar on *Lespedeza capitata*. "August 9 to 10 it formed a cocoon of leaves and silk of thin loose texture; August 13, became pupa," the moth appearing the following June.

Dyar, writing in New York, states: "The duration of each stage was about four days, with the exception of the last, which was six days. The eggs hatched August 17 and the larva ceased feeding September 6. They became pupa in a few days after constructing their cocoon, and passed the winter in this stage. There are two broods of this insect in a season, those here described being of the second brood."

The eggs of this rather rare moth were sent me by Miss Morton, of Newburg, N. Y., having been laid about the 20th of July. The larva hatched at Brunswick, Me., July 25: the first molt occurred July 28, the second August 6, the third August 10 to 11, and the fourth August 20 to 22. Riley has found the larva as late as in October, the moths in March, April, and June.

Food plant.—Usually the wild indigo plant (Harris, Bridgham, at Providence); sometimes the locust (Harris, Miss Morton); clover (Dyar); *Lespedeza capitata* (Harris); locust and *Baptisia tinctoria* (Riley).

Geographical distribution.—Occurs in both the Appalachian and Austroriparian subprovinces, extending from southern Maine and from Massachusetts to Florida and Georgia, as well as Texas.

Kittery, Me. (Thaxter); Boston, Mass. (Harris); Brookline, Mass. (Shurtleff); New York, Providence, R. I. (Bridgham, Dearden); New York (Miss Morton, Dyar); Plattsburg, N. Y. (Hudson); Michigan, New York, District of Columbia (Riley); Georgia (Abbot and Smith); Georgia (Riley); New York, Wisconsin, Georgia (French); New York, Arkansas (Palm).

Dasylophia thyatiroides (Walker).

(Pl. IV, fig. 9.)

Heterocampa thyatiroides Walk., Trans. Ent. Soc. London (3), i, p. 79, 1862.
Dasylophia interna Pack., Proc. Ent. Soc. Phil., iii, p. 363, 1864.
Heterocampa tripartita Walk., Cat. Lep. Het. Br. Mus., xxxii, p. 419, 1865 (*fide* Grote and Rob.).
Xylina signata Walk., Cat. Lep. Het. Br. Mus., xxxiii, p. 758, 1865 (*fide* Smith, Can. Ent., xxiii, p. 121).
Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Hatima interna Kirby, Syn. Cat. Lep. Het., i, p. 569, 1892.
Dasylophia thyatiroides Dyar, Can. Ent., xxvi, p. 69, March, 1894.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 200, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 116, Sept., 1894.

Moth.—Two ♂. Light mouse-brown; palpi above blackish; sides of the tuft on the vertex of the head grayish; prothorax with a faint dark line. Middle of the fore wings grayish, dusted coarsely with brown. Differs from *D. anguina* in having a zigzag or scalloped cross line on the basal third of the wing within which the wing is tawny brown, not white, as in *anguina;* also a double scalloped line ending just within the inner angle. Costa toward the apex interrupted by gray spots, which are more distinct on the underside. A submarginal row of very oblique dark linear spots between the venules, succeeded by lighter, longer streaks of light tawny white. Fringe gray, with dark spots. Pectinations of the antennæ a little longer than in *D. anguina.* Tarsi tipped with lighter scales. Hind wings mouse-brown.

Expanse of wings, ♂, 36 mm.; length of body, ♂, 16 mm.

This species differs decidedly from *D. anguina* in having a zigzag cross line on the basal third of the fore wing within which the wing is tawny brown, not white; also a double scalloped line ending just within the inner angle. Besides, there are no black lines, and the body is mouse-brown in hue.

Dr. Dyar has kindly lent me a colored sketch of Walker's type of *H. thyatiroides* in the Oxford Museum, received from Colonel Swinhoe. There seems to be little doubt but that it is my *D. interna.*

Food plants.—*Dasylophia interna* Pack.! Carya (R. Thaxter, Can. Ent., xxiii, p. 34, February, 1891.

Geographical distribution.—Orono, Me. (Mrs. Fernald); Kittery, Me. (Thaxter); Dublin, N. H. (Leonard, in Harris Coll. B. S. N. H.); New York (Mrs. Fernald); New York, July, moth (Riley); Maine, New Hampshire (French); Plattsburg, N. Y. (Hudson).

Symmerista Hübner.

(Pl. XLIII, fig. 2, 2*a*. Venation.)

Phalæna Abbot and Smith (in part), Nat. Hist. Lep. Ins. Georgia, p. 159, Tab. LXXX, 1797.
Symmerista Hübn., Verz. Schmett., p. 248, 1816.
Edema Walk. (in part), Cat. Lep. Het. Br. Mus., v, p. 1028, 1855.
Morris, Synopsis Lep. N. Amer., p. 242, 1862.

Pack., Proc. Ent. Soc. Phil., III, p. 358, 1864.
Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., I, p. 572, 1892.
Symmerista Neum. and Dyar, Trans. Amer. Ent. Soc., XXI, p. 187, June, 1894; Journ. N. Y. Ent. Soc., II, p. 114, Sept., 1894.

Moth.—Vertex of the head with two large tufts uniting and forming a large, high, prominent vertical tuft just above the insertion of the antennæ. The pectinations of the ♂ antennæ are a little longer than the joints, becoming gradually obsolete toward the tips; the pectinations are densely ciliated; in the ♀ the antennæ are entirely simple and thread like. Eyes naked. The palpi are usually long and slender, extending a third of their length beyond the front, and conniving at their tips; third joint unusually long, equaling in breadth the width of the second joint. The maxillæ are very short, not reaching out as far as the palpi. The thorax is moderately robust, and is not tufted.

The fore wings are unusually broad and square at the apex, being about half as long as broad; costa straight; the apex somewhat pointed and square; outer edge near the apex nearly straight, thence gradually rounded to the internal edge, which is not tufted. Venation: Quite unlike that of Dasylophia and Notodonta; a small short subcostal cell, and a second, minute one beyond; the fourth subcostal venule ends on the costa within the apex; the discal venules are situated well beyond the middle of the wing, and the two together form a nearly straight line; the independent vein arises nearer the subcostal vein than usual.

Hind wings longer than usual, the outer two-thirds of the costa straight; the outer edge regularly rounded, slightly bent in the middle. Venation: The subcostal vein divided about halfway between the discal veins and the outer edge; the independent vein (III_2) arises much nearer the subcostal than usual, and the discal veins taken together form an oblique (not curved) line.

Legs rather slender; femora and tibiæ pilose; the hind tibiæ with long hair-like scales; the tibial spurs rather stout, with the ends sharp and naked.

Coloration: The species gray, with cross lines and the costal edge white.

The genus may be recognized by the high conical vertical tuft on the head, by the unusually long palpi, and by the straight costal edge and square apex of the fore wings, with their two subcostal cells, and by the peculiar style of coloration.

Egg.—"Subglobose, slightly concave at the base, smooth, shining." (Beutenmüller.)

Larva.—Body increasing in width from the prothoracic to the eighth abdominal segment, the head rounded, but slightly wider than the segment behind it. Skin smooth, shining; richly and conspicuously banded with yellow or reddish bands and black lines; on the eighth abdominal segment a large, shiny, coral-reddish hump. Suranal plate distinct, crescent-shaped.

Young larva.—Anal legs smaller than the other abdominal ones; body moderately thick; a slight dorsal hump on the eighth segment, with minute, short, slightly bulbous hairs; a lateral dark brown line and a yellowish spiracular band and a subdorsal dark line.

Cocoon.—"Made a cocoon in a roll of paper" (Harris Corresp.). "Spins a thin, white web" (Abbot and Smith); spins a thin, white web, through which the pupa can be seen.

Pupa.—The abdomen ends in a short, cremasteral spine, which is flattened vertically, deeply cleft, with tubercles, from which arise from three to four curved setæ on each side, the entire apparatus retaining a firm hold on the end of the mass of silk by which it adheres to the leaves.

Geographical distribution.—So far as known, the species found in the United States are confined to the Appalachian and Austroriparian subprovinces of North America, extending from Maine to Florida and thence westward to Texas.

In Presidio,[1] Mexico, lives *S. mandela* (*Edema mandela* of Druce, Biol. Centr. Amer. Het., I, p. 235, pl. 25, fig. 3), which in the shape of the fore wings is allied to *S. albifrons*, but differs decidedly in the marking, not having the white costal region.

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[1] By Presidio we suppose is meant Presidio del Norte, which is in northern Mexico, on the southern bank of the Rio Grande, just over the Texas border. This species should therefore be looked for in southwestern Texas and southern New Mexico.

We retain the name *Symmerista* because the first of the two species mentioned under it by Hübner is his *S. albicosta*; the other species is *S. politia* (Cramer). On examining Cramer's figure of *politia*, though evidently poorly executed, we find that it differs generically from *albifrons* and *albicosta*. Mr. Druce, in Biologia Centr. Americana, Heterocera, i, p. 239, adopts Symmerista for *S. politia* Hübner, and retains Edema for *albifrons*. This does not seem to us to be justifiable, and we think another name should be given to the genus of which *politia* Cram. is the type. Moreover, Druce's *Symmerista pinna*, from Panama (fig. 9, tab. 25), is represented as of the shape and with the marking of a Dasylophia. *Edema Mandela* Druce loc. cit. (pl. 25, fig. 3), from Mexico, is allied to *S. albifrons*, and is a true Symmerista, as we have restricted the genus.

Walker's *Edema producta*, from St. Johns Bluff, in eastern Florida, is, as Mr. A. G. Butler kindly writes me, "a Noctuid of the genus *Ingura*, and identical with *I. abrostoloides*." In Druce's Heterocera, i, p. 235, it is still retained under Edema.

Symmerista albifrons (Abbot and Smith).

(Pl. IV, figs. 13, albicosta; 14, albifrons.)

Phalæna albifrons Abbot and Smith, Lep. Ins. Georgia, p. 159, Tab. LXXX, 1797, fig. 1.
Edema albifrons Walk., Cat. Het. Lep. Br. Mus., v, p. 1028, 1855.
Morris, Synopsis Lep. N. Amer., p. 242, 1862.
Pack., Proc. Ent. Soc. Phil., iii, p. 358, 1864.
Symmerista albicosta Hübn., Verz. Schmett., p. 248; Noct., p. 110, 1816; Eur. Schmett. Noct., fig. 110, 1801?
Herr.-Sch. Syst. Bearb. Schmett. Eur., ii, fig. 131, 1845.
Staudinger, Cat. Lep. Eur., p. 75, note. 1871.
Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 572, 1892.
Symmerista albifrons Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 187, June, 1894; Journ. N. Y. Ent. Soc. ii, p. 114, Sept., 1894.

Larva.

(Pl. XXII, figs. 1–4.)

Abbot and Smith, Lep. Ins. Georgia, p. 159, Tab. LXXX, 1797. (Larva, pupa, and moth figured.)
Emmons, Nat. Hist. N. York, v, p. 242, Pl. XXXVII. (Larva and pupa figured.)
Harris, Ent. Corresp., p. 304, 1869.
French, Trans. Dept. Agr. Ill., xviii, Appendix, p. 120, 1880.
Beutenmüller, Ent. Amer., vi, p. 75, April, 1890. (Egg, all six larval stages, and cocoon described.)
Dyar, Psyche, v, p. 421, Nov.–Dec., 1890.
Packard, Proc. Bost. Soc. Nat. Hist., xxiv, p. 525, 1890. (Stages I–V described.)

Moth.—Six ♂ and two ♀. Cinereous; head and prothorax tawny and whitish in front; paler in ♀. Palpi brown on the sides. On the crest above, a brown line; behind is a median whitish spot, with tawny scales, behind which are some brown scales; the rest of the thorax is dark ash. Fore wings with two dark lines situated within the middle of the wing; the first basal one is light, with two scallops, one on the costa margined within with dark; the outer one is situated within the middle of the wing, and is a double dark line curved suddenly outward in the discal space; behind, it is dislocated on the subcubital fold; it ends on the beginning of the white portion of the costa, which is one-toothed just beyond the brown, pale-edged discal spot. From this tooth[1] an obsolete third line runs parallel to the second to beyond the middle of the internal edge. The white costal margin is contracted upon the middle of the fourth subcostal venule, and thence runs directly to the apex. The region below the white portion of the costa may be dark ash, tinged more or less with fuscous. The submarginal region is a little lighter, inclosing a submarginal series of inwardly oblique or black linear lunate spots. Hind wings smoky white. Beneath, the wings are uniformly whitish; the submarginal row of spots appear through. On the underside of the hind wings is an obscure fuscous median line. On the first segment of the abdomen is a dark, round spot. Expanse of wings, ♂, 36–45 mm.; length of body, ♂, 16–18 mm.

[1] My description is based on the sharp-toothed form, or *albicosta* Hübn. (Eur. Schmett., fig. 110); the round-toothed form is Abbot and Smith's *albifrons*. Whether these variations also extend to the larva remains to be seen.

Egg.—"Pale green, subglobose, slightly concave at the base, smooth, shining. Length, .80 mm.; width, .50 mm. Duration of this stage, thirteen days. Laid in small masses on the underside of leaves." (Beutenmüller.)

For the description of the early stages of this caterpillar I have not full notes drawn up from living specimens, but have to depend on alcoholic examples of the different stages and the excellent colored sketches of Mr. Bridgham, so that this notice is in part provisional, as we have yet to see the eggs, although one of the commonest caterpillars on the oak.

First stage, larva just hatched.—Length, 5–6 mm. August 24. Just before the first molt the body is moderately thick and of a pale yellowish tint; the head is brown,[1] not deep amber, as in the subsequent stages. The anal legs are decidedly smaller than the other abdominal legs and somewhat uplifted, or rather extended horizontally. They are slightly retractile, and probably bear a few hooks. The large dorsal hump on the eighth abdominal segment, so characteristic of the genus Symmerista, is already well developed, so that the chief generic characters of the larva appear at birth. The hairs are minute, short, sparse, and very slightly thickened at the end, all of the same length and arising from minute, microscopic warts. The dark dorsal line is only faintly indicated; the lateral dark brown line well marked, most distinct on the prothoracic segment, interrupted at the sutures, and faded out on the eighth abdominal segment. The large hump on this last-named segment is large and high, but scarcely differs in tint from the rest of the body, though slightly darker. On each side of the ninth segment is a large black comma-shaped spot, the point directed forward and downward, while behind them is a median black dot. There is a broad yellowish spiracular lateral band; above it a pale, dirty white band, edged above by the lateral, or rather subdorsal, black line; the underside of the body, including both the thoracic and abdominal legs, is whitish. The anal legs bear about six hooks.

Second stage, after the first molt.—Length, 6–8 mm. August 27. The head is still very large in proportion to the body. The hump on the eighth abdominal segment is larger, more pronounced, and orange-yellow, sometimes red; the head is dull amber. The dorsal line is now distinct, and the subdorsal line is triplicated on the two anterior thoracic segments and duplicated on the eighth abdominal. Behind the dorsal hump there are two, instead of one, median black dots, one placed behind the other, and two black spots are added on the side of the body near the base of the anal legs, i. e., two on the ninth and two on the tenth segments. On the pro- and mesothoracic segments are two parallel, short, sinuous, blackish red lines. The spiracular band and underside of the body as in the previous stage, but deeper straw-yellow. The anal legs have a longitudinal reddish stripe on the outside or are reddish near the tip. The hairs are longer and slenderer than before, taper a little, but are docked at the tip, and arise from warts, those on the back arranged in a trapezoid.

Third stage, after the second molt.—Length, 20 mm. September 6. The general shape of the body of the mature larva, with its large, smooth dorsal hump and peculiar shining banded skin, is now assumed; the specific characters having apparently now appeared, though we have none of the other forms (*albifrons* and *packardii*) with which to compare it. The head is still large, wider than the body, which does not yet grow smaller toward the head as it does in the fully grown larva. The body is now richly and very conspicuously banded so that already in this stage the caterpillar becomes a very showy object. How it is regarded by birds and ichneumons remains to be observed. The narrow thread-like dorsal line and the lateral line are now inclosed in a broad, dull, whitish-gray band bordered on each side by a faint, dark line. There is a subdorsal straw-yellow broad band. The spiracular deep straw-yellow band is bordered below by a double blackish-red broken line. The dorsal hump is bright coral red, so bright and conspicuous as to suggest that when the end of the body is suddenly moved at the presence of an ichneumon the movements of the bright red mass may frighten away the unwelcome visitor. The black spots and slashes on the ninth and tenth segments have increased in number. The two median reddish black dots of the second stage have coalesced and formed a long stripe, flanked on each side by a shorter stripe, and an outer dot on the ninth segment. On each side of the ninth and tenth segments are two blackish spots.

[1] Beutenmüller says "jet-black, shiny" (p. 75).

Fourth stage, after the third molt.—Length, 30 mm. The markings and colors are the same as in Stage V, but the larva at this period only differs from the third stage in being longer in proportion, though with a greater number of black lines and spots, as described under the last stage.

Fifth and last stage.[1]—September 12. Length, 40–50 mm. The body now increases in width from the prothoracic segment to the eighth abdominal, the head being much rounded, but a little wider than the prothoracic segment and more pitchy red. The arrangement of the markings is mainly as in the third and fourth stages, but the straw-yellow bands are now deep orange, often almost coral-red. The number of blackish lines have increased. There are five instead of three dorsal lines, the outer line on each side being the heaviest and most continuous and scarcely broken at the sutures. The black spots and slashes on the sides at the base of the abdominal legs are more distinct and numerous than before, as are the black spots on the eighth, ninth, and tenth segments, behind the dorsal hump. On the hinder edge of the eighth segment are eleven black spots, varying in size and shape. On the ninth segment are three sublinear dorsal and two oblong black lateral spots, and on the tenth segment are three dorsal coarse black dots, and on each side a black dot and oblong black spot. The supraanal plate is distinct, crescent-shaped, and deep honey-yellow, like the anal legs. There is a median ventral, interrupted black line, also indicated in the third stage.

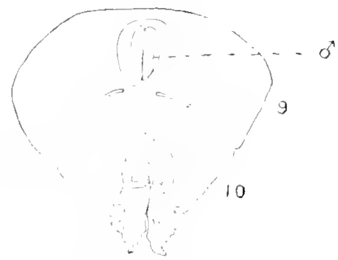

Fig. 70.—End of body of ♂ pupa of *Symmerista albifrons* (sharp toothed form).

In this genus, then, we have a return to the functional anal legs, armed with hooks, the end of the body not being more or less permanently uplifted or extended horizontally. Instead of this deterrent or terrifying feature we have the showy coral-red hump and the bright black and red bands on a shining, glistening skin (already indicated as early as the third stage), which may be danger signals to birds to whom this caterpillar may be distasteful.

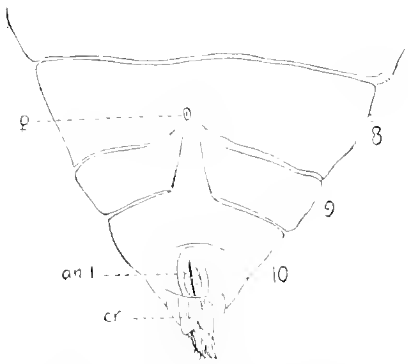

Fig. 71.—Pupa of *Symmerista albifrons*. *anl*, anal legs; *cr*, cremaster (sharp toothed form).

Cocoon.—A thin, white, irregularly oval, tough web, through which the pupa is partly visible. Beutenmüller says: "The cocoon is irregularly oval, and is of a tough, sordid white texture, and is spun on the ground amongst leaves" (p. 26). Miss Soule writes me that "of five specimens, three spun flat circular cocoons between leaves and two pupated with no attempt at spinning."

Pupa.—Body moderately stout, rather long, the end moderately blunt; the surface, except at the end of the abdomen, coarsely punctured, and the sutures rather coarsely shagreened. The cremaster (fig. 70) is peculiar in being double or deeply forked at the end, each fork or spine being stout, flattened, rugose, but with the tip smooth, polished, and slightly directed outward. The spines are longitudinally ridged at the base, and transversely so toward the smooth tip, and the inner side bears three long slender setæ, curved at the ends. These setæ are often broken off, and their presence would not be suspected. The two spines vary in distance apart, being in two out of three examples closely contiguous, while in another specimen they are opened wide apart, this difference being probably due to difference in contraction of the muscles at the time of death. Length, 17–23 mm.

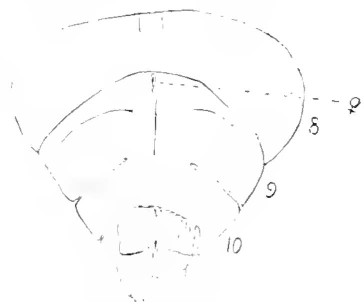

Fig. 72.—Pupa of *Symmerista albifrons* ♀.

Habits.—This is perhaps the most common notodontian caterpillar to be found on the oak. At first the caterpillars are gregarious, but after the first or second molt they begin to scatter over the tree. In Georgia, according to Smith and Abbot, the caterpillar "spun itself up in a thin white web between the leaves October 28, and came out on the

[1] Beutenmüller describes six stages.

wing the 18th of February. Others spun on the 29th of March, and came out on the 2d of May. The whole brood feeds together, especially when small."

Mr. James Fletcher reports that in 1884 the caterpillars appeared in great numbers and were most injurious to both oaks and maples at Ottawa, Canada. (Rep., 32.)

It is common on white oaks in Rhode Island and Maine late in August and through September, those observed at Providence spinning a thin cocoon between the leaves early in October and until October 20–28. October 5 I found some small larvæ (probably next to the last stage) with the stripes straw-yellow instead of orange. The moth appears in June in the northern States.

Mr. Beutenmüller publishes the following notes on its transformations: "The eggs from which my observations were made were laid on June 19, and the young larvæ emerged on July 2. The first molt took place on July 9, the second molt on July 17, the third molt on July 24, the fourth on July 30, and the last molt on August 4. The larvæ were fully grown on August 12." He adds that it is single-brooded. His observations were made in New York, while, as will be seen by Abbot's statement, there are two broods of larvæ in Georgia.

Riley states that, according to W. W. Daniels, "When young the larvæ feed in a phalanx, as it were, lying parallel on the leaf and as close together as they can." His specimens occurred at Woodstock (Missouri), September 19, on the burr oak (*Q. macrocarpa*), some full grown and others just undergoing the third molt. "Entered the ground during the latter part of September and transformed to chrysalids, appearing as moths the following April." (Fifth Rep. U. S. Ent. Comm., p. 153).

Food plants.—Various species of oak; observed at Brunswick, Me., on the beech.

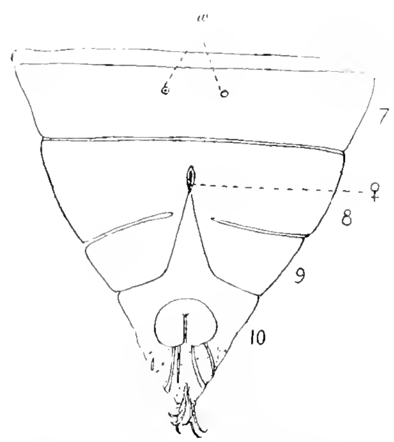

FIG. 73.—Pupa of round-toothed form (*albifrons*), from Florida; *a*, little black, irregular warts.

Geographical distribution.—Common in the Appalachian and Austroriparian subprovinces.

Ottawa, Canada (Fletcher); Orono, Me. (Fernald); Brunswick, Me. (Packard); Massachusetts (Harris, Fernald); New York (Lintner, Beutenmüller); Plattsburg, N. Y. (Hudson); New Jersey (Packard Coll.); Missouri (Riley); Manhattan, Kans., not rare (Popenoe); Racine, Wis., Chicago, Ill. (Westcott); Chicago, Ill. (Daniels); Ames, Iowa, "plentiful" (H. Osborn); St. Anthony's Park, Minn. (Lugger); Georgia (Abbot and Smith); Vermont, Wisconsin, New York, District of Columbia, Virginia, Texas, Missouri (U. S. Nat. Mus.); Maine, New Hampshire, Massachusetts, New York, New Jersey, Wisconsin, Texas (French); Seekonk, Mass., Taunton, Mass., Lawrence, Mass., Andover, Mass. (Mus. Comp. Zool.); New Jersey, Pennsylvania, Arkansas (Palm).

While in Florida, in April, I collected at Crescent City on the live or water oak a fully grown caterpillar which I supposed to be *Symmerista albifrons*. Bringing it to Providence in a tin box, it spun a well-defined, quite dense cocoon between the leaves late in April, but the moth did not emerge until September 30. Although the summer was a warm one, and the room in which it was kept had a warm exposure, the moth was evidently retarded in its appearance by a change to a cooler climate. Unfortunately, I did not make a description of the larva. It also occurs at Dallas, Tex. (Mus. Comp. Zool.). This form is *albifrons* A. and S., and (Pl. IV, fig. 14) seems to represent a variety of this species. It differs from several specimens of *S. albicosta* slightly but distinctly; it is smaller, and the white costal band is a little shorter and broader; inside of the discal spot it is not oblique, but straight, *and the tooth bounding the outer, costal side of the discal spot is larger, rounder, and fuller, less conical than in S. albicosta.* The submarginal scallops are less curved, and the space in front of the discal spot is filled in more densely with reddish brown. Expanse of wings, 35 mm.

The pupa (fig. 71) differs in the cremaster being consolidated, not forked, and the setæ are well developed. Length, 18 mm. In a Providence pupa of *albicosta*, however, the cremaster is partly consolidated, only forked at the end, and the six setæ are well developed.

Mr. Dyar writes: "I have taken the form *Symmerista albicosta* in New York and Florida, the typical *albifrons* also in New York, but much more rare (Poughkeepsie). But Professor Lintner, at Albany, takes only *albifrons*."

Symmerista packardii (Morrison)

(Pl. IV, fig. 12.)

Edema packardii Morr., Ann. Lyc. Nat. Hist., N. Y., Vol. xi, p. 92, 1875.
Symmerista packardii, Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 187, June, 1894; Journ. N. Y. Ent. Soc. ii, p. 114, Sept., 1894.

Moth.—"Expanse of wings, 31 mm.; length of body, 16 mm.

"The ground color of the anterior wings gray, sprinkled with black atoms and with white and faint brownish and ocherous stains, the half line and the interior line absent; the orbicular spot present as a geminate, blackish, upright, lunate mark, preceded by a white stain; the reniform a similar but simple and more distinct mark surrounded by a faint ocherous annulus; the median shade passes between the spots; it is thickened below the reniform, forming a black spot, but is afterward lost; the exterior line is only present in the central part of the wings; it is geminate, dentate, and forms a particularly prominent indentation opposite the reniform spot; a contrasting apical white shade, below which appears a diffuse blackish shade clearly cut above, and the black distinct subterminal line formed of oblique marks between the nervules; fringes long.

"Posterior wings uniform dark fuscous, with lighter fringes. Beneath, gray, with numerous black atoms; the lines and discal dots are obsolete." (Morrison).

"Habitat, Waco, Tex., March 9;" Texas (French).

Morrison's type is in the museum at Cambridge, Mass.

NOTE.—*Edema producta* Walk., Cat. Lep. Het. Br. Mus., v, p. 1031, 1885, and *Edema fuscescens* Walk., loc. cit., p. 1031, are species of Ingura, a genus of Noctuidæ, according to Grote and Robinson. *Edema? plagiata* Walk., Cat. Lep. Het. Br. Mus., xxxii, p. 427, 1865, "belongs to *Parorgyia* Pack." (Grote and Robinson, Trans. Amer. Ent. Soc., July, 1868).

Subfamily VI.—HETEROCAMPINÆ.

Moth.—The head is tufted on the vertex, so as to have a triangular-shaped hollow on top of the head. The male antennæ are filiform in their distal fourth. Fore wings usually long and narrow (in Hyparpax, broad and short), with the outer edge very oblique, rather more so than usual; a subcostal cell usually present, and long and narrow.

Larva.—Compressed or round, and, as the name of the typical genus suggests, varying greatly in shape, markings, and coloration; either noctuiform, with moderately long legs, becoming in *Heterocampa unicolor* very long, and in Macrurocampa forming true stemapoda like those of the Cerurinæ; body either smooth or armed with high mutant tubercles on first, fifth, and eighth, or first and eighth, abdominal segments. Larvæ in stage I often with large antlers.

Larvæ usually spinning a slight, thin cocoon.

Pupa.—Stout, full, with the spine of the cremaster well developed.

SYNOPSIS OF THE GENERA

A. Antennæ of ♂ almost or quite plumose nearly to the tip; palpi and legs long and slender. fore wings broad and short; body and wings pink. Larva like that of Schizura, with a double hump on first and eighth abdominal segments .... *Hyparpax*

Like Hyparpax, but fore wings longer and narrower and more acute at apex; tip of ♂ antennæ more filamental .... *Euhyparpax*

Like Schizura, but the fore wings scalloped; palpi rather slenderer and shorter; fore wings long and narrow. Larva with end of body raised; a large double tubercle on first and a decided hump on eighth abdominal segment .... *Xylinodes*

B. End of ♂ antennæ filiform; vertex tufted; palpi short and thick; wings often long and narrow, outer edge more or less oblique. Hind wings longer and more pointed than in Heterocampa.

Larva; body somewhat compressed, with two or three abdominal humps, often a V-shaped, silvery dorsal mark in front of the last tubercle .... *Schizura*

Differs slightly from Heterocampa in the venation, the subcostal cell being very long and narrow. Larva in last stage smooth, unarmed, noctuiform, very closely resembling that of *H. manteo* .... *Seirodonta*

Fore wings produced toward the apex, outer edge usually very oblique; a long subcostal cell; hind wings short and rounded; ♂ antennæ filamental at the end. Larva varying from being simply noctuiform to having long substemapodiform anal legs .... *Heterocampa*

Like Heterocampa, but with no subcostal cell. Larva with the anal legs converted into true filamental processes (Stemapoda) like those of Cerura .... *Macrurocampa*

Hyparpax Hübner.

(Pl. XLIII, figs. 3, 3*a*. Venation.)

Hyparpax Hübner, Samml. Exot. Schmett. Bd., ii, pl. 168, 1806.
Datana? Walk., Cat. Lep. Br. Mus., v, p. 1062, 1855.
Hyparpax Pack., Proc. Ent. Phil., iii, p. 355, 1861.
Grote, New Check List N. Amer. Moths, p. 18, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 585, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 186, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 114, Sept., 1894.

Moth.—Front of the head rather narrow, densely pilose between the antennæ, the scales being long. Antennæ almost plumose in ♂, being pectinated to the tips, with unusually long branches; in ♀ subsimple. Palpi very slender, porrect; second joint a little pilose beneath; third joint slender, acute. Eyes naked. Thorax with a slight low tuft.

Fore wings two-thirds as broad as long, broad subtriangular; costa a little full at base, beyond straight; apex rectangular, not falcate; outer edge equal in length to the internal, not scalloped, convex. Venation: The costal region is quite broad, and the first to the fourth subcostal venules arise very near to each other and end at the costal edge very near together; there is a long narrow subcostal cell, and the second subcostal venule arises a little beyond the middle of it, while in Xylinodes it arises near the distal end; fifth subcostal venule shorter than usual; the discal veins are situated beyond the middle of the wing, and the course of the two is unusually oblique, the hinder one not being curved as it is in Xylinodes, but oblique; the origin of the first cubital venule (III$_3$) is unusually remote from that of the second.

Hind wings short and broad, much rounded at the apex. Venation: The subcostal vein divides farther out from the discal vein than in Xylinodes and much farther out than in Schizura, and the common origin of the hinder discal and first cubital venule (III$_3$) is remote from that of the second cubital venule (IV$_1$). The internal vein (VII) is very short. The legs are very long and slender, hinder pair of tibiæ with two pairs of very long spines. The tip of the abdomen is in the male pointed and slightly tufted when the claspers are outspread.

Coloration: Ocherous or pinkish ocherous, with pink lines and scales; a long discal line.

This genus is characterized by the broadly pectinated or plumose antennæ, the branches extending nearly to the tip; by the long slender palpi and legs, with the two pairs of long tibial spurs; by the plain unscalloped fore wings, the plain, not tufted, thorax, and the peculiar style of coloration. By its venation and larval characters it stands near Xylinodes and Schizura, although the general appearance of the moth would not perhaps lead to this view.

Larva.—Closely allied in its general shape and style of coloration to Xylinodes and Schizura. A double red hump on the first and a tubercle on the eighth abdominal segment; the dorsal region between these two segments green.

Freshly hatched larva.—Much like the young of Schizura in shape and in the position and shape of the conical tubercles. Body thrice ringed with red, the dorsal tubercles of first and eighth abdominal segments scarcely larger than those on the other segments.

Pupa.—Subterranean, the larva spinning no cocoon.

Hyparpax aurora (Abbot and Smith).

(Pl. 7, fig. XXIV.)

Phalæna aurora Abbot and Smith, Nat. Hist. Lep. Ins. Georgia, ii, p. 173, Tab. LXXXVII, 1797.
Hyparpax aurora Huebner, Samml. Exot. Schm., ii, pl. 168, 1806.
Datana? aurora Walk., Cat. Lep. Br. Mus., v, p. 1062, 1855.
Morris, Synopsis Lep. N. Amer., p. 217, 1862.
Hyparpax aurora Pack., Proc. Ent. Soc. Phil., iii, p. 356, 1864.
Pack., Rep. V. U. S. Ent. Comm. on Forest Insects, p. 156, 1890. (Larva, Pl. III, figs. 6, 6*a*.)
Kirby, Syn. Cat. Lep. Het., i, p. 585, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 186, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 114, Sept., 1894.

Larva.

(Pl. XXIV, figs. 1–6.)

Abbot and Smith, Lep. ins. Georgia, p. 163, Tab. LXXXII. 1797.
Edwards, Ent. Amer., iii, p. 169. Dec., 1887 (3 larval stages).
Packard, Journ. N. York Ent. Soc., i, p. 73, June, 1893.

Moth.—Two ♂, 1 ♀. Ocherous yellow and roseate. Head and body rosy pink. Base of the fore wings roseate, bounded externally by a pink line bent at a right angle upon the first anal vein (VI). Between this line and the outer one the wing is ocherous yellow; outer edge of the wing pink. Hind wings white, either unspotted or with a pink line along the edge; a slight pinkish discoloration at the internal angle. Abdomen roseate at the end. The legs are tinged externally with roseate. Length of body, 15–20 mm.; expanse of wings, 36 mm.

The young were reared from eggs kindly sent me June 26 by Miss Emily L. Morton, of New Windsor, N. Y.

Larva, Stage I.—Length, 2.5 mm. The head is very large and broad, about twice as wide as the rather slender body, and dull honey-yellow or chitinous in color; with a few long light hairs in front near the vertex. On the prothoracic segment are two rather large acute conical dorsal tubercles of the same color as the head and larger than those on the first or eighth abdominal segments, though all the dorsal tubercles on the body are unusually large, larger in proportion than in the first stage of Schizura; those on the second and third thoracic segments are well developed, but considerably smaller than those in front. Those on the first abdominal segment are situated close together, while those on the first thoracic segment are rather wide apart. The two on the eighth abdominal segment are not quite so large as those on the first abdominal segment. The glandular hairs arising from these tubercles and those on the side of the body are long, varying in length, and distinctly bulbous at the end, those on the thoracic and posterior thoracic segments being longer than those in the middle of the body, or in the allied genus Schizura.

The body above pale yellow, with a greenish tinge, the sides of the body being cherry-red. The first, third, and eighth abdominal segments are cherry-red all around, including the tubercles, so that the body is thrice ringed with red. All the dorsal abdominal tubercles are quite large, those on the first and eighth segments scarcely larger than those on the other segments. The end of the body is uplifted, both when walking and at rest. All the abdominal legs are reddish, and the thoracic legs are dark.

Stage II.—Just molted, July, 1891. Evidently delayed in its growth. Length, 6 mm. Head moderately large (now wider than the body, as the larva has not begun to feed); it narrows slightly above, and bears on the vertex two piliferous warts which are somewhat larger than those below on the face, of which there are five, rather large conical warts, arranged in two rows, each bearing a bulbous tipped glandular hair; the head is pale sere-brown (burnt sienna), with six whitish spots arranged in two vertical rows. The clypeus and labrum are whitish. The first thoracic, first, third, and eighth abdominal segments each bear two large high dorsal warts, which are dark at the tips; they are flanked by subdorsal and lateral warts which are but a little smaller; the dorsal ones in question are much larger and higher than those on the other segments, and the segments themselves are a dull pale cherry-red. Thoracic segments 2 and 3 and abdominal segments 2, 4, 7, 9, and 10, together with the tubercles, are bright yellow. The legs are all pale, though the anal ones are darker and redder. The glandular hairs are still bulbous in this stage, rather short and even; those on the first thoracic and first, third, and eighth abdominal segments being longer than those elsewhere.

These hairs are seen under a ⅛-inch objective to be unusually large, distinctly flattened at the end, which is broad and square, the tips being flattened and transparent. In a few of the hairs the expanded tip appears to be ragged and broken, or toothed, and in one case deeply forked.

The descriptions of the following stages are drawn up from Mr. Bridgham's excellent colored figures, those of the two earlier stages having been compared with my descriptions and found to be accurate in form and color. His examples of Stage I (from eggs I sent him) were drawn July 3 to 7; of Stage II, July 12; of Stage III, July 18; Stage IV, July 23; Stage V, and last, July 28.

Stage III.—Length, 20 mm. The head is somewhat angular, spotted with whitish, and the tubercles are larger than before. The body has more of a lilac tint, and the tubercles, which were yellow in the previous stage, are now still deeper yellow, tinged with white, rendering them more conspicuous; a distinct lateral stigmatal line extends along eighth and ninth segments and along the edge of the suranal plate. The end of the body is raised high up; there is no green on the body.

Stage IV.—Length, 25 mm. In the greater thickness and shape of the body, as well as the bright green color, the larva of this stage closely resembles the caterpillar in its final stage. The head is now smoother, the tubercles smaller, and the dorsal tubercles on the three thoracic segments, as well as those on the second to seventh abdominal segments, are smaller than before, while those on the first and eighth abdominal segments are now larger than before and very prominent. The body is now of a deep delicate pea-green, with a large reddish brown triangular patch extending from the prothoracic segment next to the head and ending at the anterior base of the tubercles on the first abdominal segment. Behind the said tubercles a broad reddish brown patch extends to the large tubercles on the eighth segment, the band being edged with whitish yellow; from the rear of the tubercle a similar-colored band extends to the end of the suranal plate. The underside of the body in front and the middle abdominal legs are brownish.

Stage V.—Length, 35 mm. In shape and coloration just as in Stage IV, but the head is a little darker, and the back of the larva between the two great abdominal tubercles, and also behind the last tubercles on eighth segment, is green, not reddish brown, and this area is edged with irregular reddish thread lines on a white field. Also a lateral infrastigmatal line is present along the end of the body. In Miss Morton's figure, copied in my Forest Insects (Pl. III, figs. 6, 6*a*) the larva has the same style of coloration.

I have not yet seen the fully fed larva, and we need a detailed description of it, as compared with the final stage of Schizura and Janassa. (See, however, Appendix A.)

Cocoon.—The larva enters the ground, forming a subterranean thin case of dirt. (Abbot and Smith.)

Habits.—"The caterpillar was taken on the timber white oak, but feeds also on other species of oak. It went into the ground and inclosed itself in a thin case of dirt July 15, appearing on the wing August 7. Sometimes this species also buries itself in autumn, and remains till the spring, at which season the moth may now and then be observed sitting on the oak branches." (Smith and Abbot.)

Food plants.—Different species of oak.

Geographical distribution.—Ranges through the Appalachian and the Austroriparian subprovinces, and is rare in New England, but not uncommon in the Southern States.

Orono, Me. (Fernald); Cambridge, Mass. (Harris Coll.); Newburg, N. Y. (Miss Morton); Massachusetts, New York (French); Plattsburg, N. Y. (Hudson); North Carolina (Morrison); Georgia (Abbot and Smith). Its western limits are unknown.

Hyparpax perophoroides (Strecker).

Cosmia perophoroides Strecker, Proc. Acad. Nat. Sc. Phil., p. 152, 1876.
Hyparpax aurostriata Graef, Entomologica Americana, iv, p. 58, June, 1888.
Smith, Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 585, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 187, 1894; Journ. N. Y. Ent. Soc., ii, p. 111, Sept., 1894.

Moth.—Eight ♂, 1 ♀. I have examined two males of this form, kindly presented by Mrs. Slosson, who captured them in Florida. I am not quite sure as to their specific distinctness from *H. aurora*, which is a somewhat variable moth. Whether this form is a local variety or a distinct southern species remains to be proved.

In one example the body and wings are uniformly pale ashen ocherous. The inner bent line on the fore wings are exactly as in typical *aurora*, and the oblique long linear discal mark is as in that species; the outer line, however, is not so wavy as in *aurora*. The middle region of the wing is of the same shade as the base and outer edge of the wing.

The other example, apparently from the same locality and captured at the same date, is dull roseate all over the fore wings, and thus approaches the normal form.

Mr. Graef's specimens were received from Texas. He remarks: "I received more than a dozen specimens from Texas, and they are all of this form and constant; *H. aurora* is a totally different species." I took it for granted that this form was distinct from *aurora*, but renewed examination makes me inclined to regard it as a variety.

Mrs. Slosson, who tells me she has seen in Florida hundreds of the normal *H. aurora*, thinks this variety is distinct. The following description of *H. perophoroides* is drawn up from eight ♂ and one ♀ in her collection. In life Mrs. Slosson has noticed that the thorax is bathed with a glaucous green tinge, which extends to the base of the fore wings, but disappears as the moth dies. Antennæ plumose. Head in front and markings on the wing rich pale wine red; head above, thorax, and ground color of the wings fawn-brown. Fore wings uniformly fawn-brown, two deeply stained, wine-red, narrow, distinct transverse lines, nearly parallel, passing from the inner side of the wing to the costal edge, and a third concolorous line starting from the junction of the median vein and the inner line and ending on the costal edge nearly halfway from base of wing to the end of the line it joins. (These lines are situated exactly as in the normal examples of *H. aurora*.) Hind wings suffused with pale wine-red on the outer fourth.

In two ♂ the entire fore wings are uniformly suffused with pale claret-red, and in one ♂ the wings are suffused with the same tint, but the space between the three lines are deep, dull, wine, brick red, like the lines themselves, the band being about twice as broad on the costal as on the hind edge.

Underside: Fore wings deep wine-red, paler along the outer margin; hind wings whitish, with reddish scales on the costal edge.

Geographical distribution.—Florida (Mrs. Slosson) and Texas (Belfrage, Graef Coll.); Texas (French).

Hyparpax venus Neumoegen

(Pl. VII, fig. 18.)

Hyparpax venus Neum., Can. Ent., xxiv, p. 226, Sept., 1892.
Palm, Journ. N. York Ent. Soc., i, p. 20, March, 1893 (Pl. I, fig. 4).
Neum. and Dyar, Trans Amer. Ent. Soc., xxi, p. 186, 1894; Journ. N. Y. Ent. Soc., ii, p. 114, Sept., 1894.

Moth.—"Head yellowish with rose center; antennæ light brown; eyes black; collar, thorax, patagia, as well as primaries, of beautiful light rose color; nerves concolorous; fringes whitish. Beyond median cell, from costa to inner margin, a transverse white line, slightly bending inwardly at its center.

"Secondaries and nerves white, with a rose-colored marginal line along costa and margin to anal angle. A rose tint along anterior margin, fading toward center.

"Abdomen yellowish-white, with rose anal tuft.

"Below, primaries and secondaries of yellowish white, with concolorous nerves and fringes. Costa rose and broad marginal rose tints, especially so on primaries, fading toward center.

"Legs rose colored; prominent yellowish-white tibial spines.

"Expanse of wings, 30 mm.; length of body, 9 mm.

"Habitat: Colorado. Type, ♂, Coll. B. Neumoegen.

"It seems to be a rare species, for Mr. Bruce only caught one last year, and this summer only five specimens, among which one ♀, which, as he writes me, tallies in all details with the ♂. Its name is warranted by its beauty."

Euhyparpax Beutenmüller.

Euhyparpax Beut., Bull. Amer. Mus. Nat. Hist., v, p. 19, Feb., 1893.

"Primaries twice as long as broad; costa almost straight, very slightly concave about the middle; apex pointed; outer margin slightly rounded; inner angle obliquely rounded. Secondaries reaching to the inner angle of the primaries, apex acutely rounded, outer margin almost oblique, hind angle rounded. Body (♂) slender, extending beyond the secondaries; anal tuft obsolete. Legs pilose, femora and tibiæ covered with long ciliated hairs, tarsi covered only with very short scales. Head depressed, palpi very short and barely visible, owing to the scales covering the same and the thorax. Antennæ half as long as the primaries; stalk stout, with the pectinations to about the middle of equal length, when they very gradually decrease in length to about 2 mm. before the apex, which portion is without pectinations. The genus is allied to *Hyparpax*." (Beutenmüller.)

Euhyparpax rosea Beut.

(Pl. VI, fig. 24.)

Euhyparpax rosea Beut., Bull. Amer. Mus. Nat. Hist., v, p. 19, Feb., 1893.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 204, June, 1894; Journ. Amer. Ent. Soc., ii, p. 117, Sept., 1894.

"Head, thorax, and body pale ocherous, slightly tinged with pink. Primaries pinkish ocherous, inclined to be rose colored, with a very narrow undulated transverse line of a deeper color beyond the middle of the wing. This line is somewhat curved before reaching the costa. Beyond this line, before the outer margin, is a row of very indistinct spots of the same color. At the end of the discal area is a faint indication of an ocherous spot. Secondaries rose colored, with the cilia paler. Undersides of all the wings wholly rose color, without any markings. The legs and body are also tinged with pinkish. Stalk of antennæ, above, whitish with the pectinations deep ocherous, of which color are also the antennæ beneath. Expanse of wings, 40 mm."

Fig. 74.—Venation of fore wing of *Euhyparpax rosea*. (Dyar del.)

Fig. 75*a*.—Venation of part of hind wing of *Euhyparpax rosea*. (Dyar del.)

"One male, West Cliff, Custer County, Colo. (T. D. A. Cockerell). Coll. Hy. Edwards, Am. Mus. Nat. Hist." (Bentenmüller.)

I have not had an opportunity of carefully examining this moth, and am indebted to Dr. Dyar for the figures of the venation.

Xylinodes Packard.

(Pl. XLIII, fig. 1, venation.)

Ianassa Walk., Cat. Lep. Het. Br. Mus., v, p. 1101, 1855.
Xylinodes Packard, Proc. Ent. Soc. Phil., iii, p. 366, 1864.
Janassa Grote, New Check List N. Amer. Moths, p. 19, 1882.
Phya Druce, Biologia Centr. Amer., p. 242, June, 1887.
Janassa Smith, List Lep. Bor. Amer., p. 31, 1891.
Ianassa Kirby, Syn. Cat. Lep. Het., i, p. 570, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 200, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 116, Sept., 1894.

Moth.—♂ and ♀. Head as in Schizura, prominent; front when denuded subtriangular as in Schizura, and tufted as in Schizura, a porrect tuft of scales on the vertex. Palpi as in Schizura, short, stout, porrect, hardly reaching the front, tips of the third joint obtuse, beneath densely clothed with short scales, conniving throughout. Male antennæ rather broadly pectinated to the distal third, the branches rather long, stout, each tipped with a tuft of ciliæ; in the ♀ simple. Thorax moderately stout, scales of the pronotum distinct; not crested above; beneath with unusually long hair-like scales, with a longer prosternal tuft arising from beneath the eyes.

Fore wings broad, long, and narrow, being a little more than one-third as broad as long; costa nearly straight, but yet more convex than in Schizura; outer margin very long, distinctly scalloped; internal angle rounded, and a little within the middle of the inner margin is a prominent tuft of dark scales: outer edge scalloped.

Venation: The second and third subcostal venules are very near each other, the subcostal cell very narrow, linear; the fourth subcostal vein arises within the middle of the subcostal cell. The upper branch of the third subcostal is very short and passes straight to the costa just before the apex. The upper discal vein is curved somewhat obliquely inward to the origin of the fifth subcostal venule, then passing very obliquely, and uncurved, to the middle of the discal space, where it meets the lower discal vein, which is perpendicular to the cubital venule from which it arises. The venation of both wings is in fact just as in Schizura. Hind wings a little more pointed at the apex than in Schizura; costa straight, bent down somewhat at the apex; outer edge oblique, not very full, bent slightly on the first median interspace.

Legs: Femora buried and concealed in the long scales of the breast; fore tibiæ densely pilose, presenting a flat expanse on each side; the middle and hind tibiæ with two long sharp, nearly equal spurs.

Abdomen long, cylindrical, the tip square, scarcely tufted.

Coloration: Gray with darker streaks obliquely crossing the costa. The single species of our fauna is more slashed and streaked than any of our other Notodontians.

This genus, both in its larval and adult characters, is so near Schizura that it seems scarcely necessary to regard it as separate, and it may ultimately be found best to unite it with that genus. It only differs in the scalloped fore wings, the rather stouter and shorter palpi, the stronger pectinations of the antennæ, the distinctly scaled pronotal pieces, and the long hairs on the breast; the fore wings are also longer and narrower than in Schizura, and the outer edge more oblique, while the inner edge has a slight tuft. Our generic name, Xylinodes, was given to it from the resemblance of the markings of the fore wing to the noctuid genus Xylina, in which the fore wings are also decidedly slashed. The name Ianassa should be dropped, since it was proposed by Münster in 1839 for a genus of sharks (Beitr. Petref., i. 1839). Mr. Druce (Biol. Centr. Amer., p. 242) points out the fact that Ianassa is preoccupied, and apparently ignorant that I had proposed the name Xylinodes for the genus, changed the generic name to Phya.

Egg.—"Globular and smooth" (Dyar). Further observations are needed.

Cocoon.—A regularly oval thick earthen cell lined with silk, the larva transforming either on the surface or within the earth.

Larva.—Head bilobed; on first abdominal segment a hump supporting a large double tubercle, and on the eighth segment a decided hump bearing two small piliferous warts. End of body and anal legs raised, much as in Schizura. Freshly hatched larva: "Tubercles on first abdominal segment brown; anal feet partly aborted." (Dyar.)

Geographical distribution.—This genus is peculiar to the New World, extending through the Appalachian and Austroriparian into the eastern portion of the Campestrian subprovince, as far west as Colorado, South Dakota, and Salt Lake, Utah. This genus also occurs in the Mexican (Sonoran) subprovince as Mr. H. Edwards has described (Ent. Amer. i, p. 129). *Janassa laciniosa* is from Jalapa (Schaus) and Mazatlan.

Xylinodes lignicolor (Walker).

(Pl. IV, fig. 15.)

Ianassa lignicolor Walk., Cat. Lep. Het. Br. Mus., v, p. 1101, 1855.
Xylinodes virgata Pack., Proc. Ent. Soc. Phil., iii, p. 367. 1864.
Grote, New Check List N. Amer. Moths, p. 31, 1882.
Smith, List Lep. Bor. Amer., p. 31, 1891.
Ianassa lignicolor Kirby, Syn. Cat. Lep. Het., i. p. 570, 1892.
Exarcta lignigera Walk., Cat. Lep. Het. Br. Mus., xxxii, p. 423, 1865 (*fide* Grote and Rob.).
Edema transversata Walk., Cat. Lep. Het. Br. Mus., xxxii, p. 427, 1865 (*fide* Grote and Rob.).
Ianassa lignicolor Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 200, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 116, Sept., 1894.
Ianassa coloradensis Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 200, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 116, Sept., 1894.

Larva.

(Pl. XXV, figs. 1, 1*a*, 1*b*, 1*c*, 1*d*, 1*e*, 1*f*.)

Dyar, Ent. Amer., v, p. 91, 1889, (full life history, egg to moth).
Packard, Fifth Rep. U. S. Ent. Comm., p. 157, 1890 (full-fed larva, pupa).
Proc. Bost. Soc. Nat. Hist., xxiv, p. 541, 1890.

Moth.—Two ♂, 1 ♀. Pale cinereous. Pronotal scales discolored with ligneous brown. A broad median thoracic dusky line, succeeded on the abdomen by a dark spot. Fore wings whitish ash-gray, with brown scales arranged in streaks; on the costa the streaks are directed obliquely toward the outer margin, ending upon the subcostal vein. Toward the apex there are two distinct brown streaks, which are parallel to the costa; between and below the second streak there are two whitish streaks. A dark brown discal dot is situated upon the lower discal venule; beyond it is a brown streak; in the middle of the discal space is a light line which passes over the discal dot and continues along the lowest subcostal space to near the outer margin. Below the median vein the wing is slightly tinged with ocherous. Just below the basal portion of the median vein is a brown streak, and the internal border is mottled and streaked with dark cinereous. The tuft is dark brown. The outer edge of the wing is also darker than the discal portion. There are no transverse streaks or lines. Hind wings white, the costa slightly discolored with ashen scales. Abdomen nearly concolorous, being a shade darker than the hind wings. Beneath, of an ashen hue, with a distinct median black line. Tarsi broadly ringed with dark scales.

Expanse of wings, ♀, 57 mm.; length of body, ♀, 23 mm.

Edwards's *Janassa coloradensis* is a pale silver white variety of his *Schizura perangulata*, as I find by a comparison with his type in the American Museum of Natural History.

Egg.—"Globular and smooth" (Dyar). (For a more complete description, see Appendix A.)

This caterpillar has been already well described in all its five stages, by Mr. H. G. Dyar, in Entomologica Americana (v, p. 91, May, 1889). The points of special interest, noticed by Mr. Dyar are (1) that only five eggs in the case observed were deposited on the same plant; (2) the larvæ feed singly and during Stages I and II they "eat only the upper portion of the leaf, and their yellowish-brown color well simulates its withered appearance; (3) subsequently they devour the entire leaf, with the exception of the largest veins and rest on its edge, where they might be mistaken for a curled and discolored portion."

Of the structural features and shape of the first stage, as compared with the last stage, Mr. Dyar gives no detailed account, except referring to a "hump on joint 5," i. e., the first abdominal segment. He now informs me that the tubercles are flat, distinct, with long glandular hairs.

In the second stage the head is said to be "slightly notched on top." In Stage III the important observation is made that "the markings of the mature larva now begin to be assumed." This is in accordance with what appears to be the rule in this group, i. e., that when the larvæ reach Stage III they feed more conspicuously and then begin to arise the special protective shape and colors of the last stage and also the terrifying movable warts or spines, if present at all.

As regards the second stage of this larva, the following notes on some alcoholic specimens, kindly loaned me by Professor Riley and collected by Mr. Bruner in Nebraska, may be of interest.

Second stage.—Length, 6–7 mm. Head large, deeply indented on the vertex, each lobe bearing near the end a piliferous wart. The two dorsal piliferous tubercles on each thoracic segment are nearly of the same size, but those of the prothoracic pair are considerably larger than the mesothoracic, and the latter are larger than the metathoracic pair. The tubercles on the first abdominal segment are a little larger than those on the prothoracic segment. Those on the eighth abdominal segment are as large at the base, but not so high as those on the first abdominal segment; and those on the ninth segment are quite large, being about two-thirds as large as those on the eighth abdominal segment. All the setæ arising from the dorsal and lateral tubercles are decidedly clavate at the end.

Compared with *Schizura ipomeæ* of the same stage and size, the head of Janassa is seen to be larger and the lobes above more pointed. The shape and proportions of the thoracic and abdominal segments are nearly the same, but the paddle-shaped setæ are shorter, while the body, generally, is stouter. At this stage the two larvæ appear to be scarcely generically distinct.

Last stage.—Mr. Dyar has quite fully described this stage, but there are some structural features to which we would call attention. The head is distinctly bilobed, with no warts, but a bristle on each side of the vertex. The markings of the head have been well described by Mr. Dyar. From the first abdominal segment arises a large, double tubercle, undoubtedly movable as in Schizura, and serving to frighten away parasitic insects. From the hump arise two dark, smooth tubercles, which are directed forward and give rise each to a bristle.

On the eighth abdominal segment, where the spiracles are nearly twice as large as the others on the abdomen, is a decided hump, bearing two small, piliferous warts. The anal legs and end of the body are much as in Schizura, being raised at times.

The larva closely approaches those of the species of Schizura, having essentially the same style of coloration and the same arrangement of terrifying humps and tubercles, but not the peculiar V-shaped dorsal marks of Schizura. The markings of the moths are quite different, and while the two genera are quite distinct, they are more closely allied than any other two genera.

I add the description drawn up from examples observed in Providence:

Head not very large, not so wide as the prothoracic segment; pale, almost whitish ash-gray; an irregular dark ash band on each side in front passing up from the mandibles and meeting on the vertex, where a branch is sent out at right angles, uniting with its fellow in the median line of the head; no median line above the apex of the vertex, but two spurs are sent out above the vertex from each side, which nearly reach the median line of the head, and inclose a clear round space. Prothoracic segment pea green on each side above the spiracle. Meso and metathoracic segments bright deep pea-green, bordered with reddish below; a long, narrow, triangular dorsal light-brown band, slightly forked on the prothoracic segment, extends from the head to near the base of the large dorsal tubercle on first abdominal segment: this tubercle is sensitive and retractile as in the other species of this subfamily; it is large but not forked, the end being very slightly cleft, blackish in the middle, and each small terminal wart has a dark hair which is bent downward and forward. First to third abdominal segments pale gray and reddish brown, the first less marbled and watered with gray than the second and third; the back of the fourth to ninth segments clear deep pea-green, with a round sinus in front on the fourth segment, and on the sixth and front edge of seventh inclosing a watered, gray, elongated, irregular patch. On the eighth segment a small dorsal tubercle tinted with brown; the eighth spiracle much larger and more conspicuous than the others; around the seventh pair of spiracles are clear white patches. The abdominal legs 1 to 4 are thick and fleshy, with a reddish brown circular line incomplete above; anal legs small and slender, about one-third as large as the others. Length, 35 mm.

Pupa.—Body short and thick; "minutely but sparsely punctured. At the posterior edge of the thorax is a row of granular square elevations, extending across in a curved line between the wing cases." (Dyar). Tip of abdomen unusually blunt; cremaster partly rudimentary, not projecting beyond the tip, and consisting of two widely separate, flattened, squarish spines, terminating in two small spines. Length, 18 mm.

Cocoon.—"Tough and parchment-like, semitransparent, similar to that of *Schizura unicornis*. After forming its cocoon, the larva fades to a nearly uniform whitish color, and the change to pupa does not occur till about a month before the emergence of the imago in the spring." (Dyar.)

Habits.—The caterpillar of this moth occurs on the oak at Providence from the middle to the last of September. The larva is very characteristic and allied to those of Schizura. In Professor Riley's collection are the regularly oval, thick, earthen cocoons lined with silk, and about three-fourths of an inch in length, the caterpillar transforming on the surface or within the earth.

Riley records finding larvæ in March, and from July to September, and the moths as flying in March, April, May, June, July, and August.

Food plant.—Different species of oak; on beech in September, Brunswick, Me.; New York, white birch (Dyar).

Geographical distribution.—Brunswick, Me. (Packard); Franconia, N. H. (Mrs. Slosson); Cambridge, Mass., (Hyatt); Providence, R. I. (Packard); Lansing, Mich. (Miles); Eastern New York, (Dyar); Plattsburg, N. Y. (Hudson); St. Anthony Park, Minn. (Lugger); Georgia, (Edwards); Nebraska (Bruner); Volga, S. Dak. (Truman, larvæ on oak); New York, Pennsylvania, Arkansas (Palm); Maine, New York, Nebraska, Missouri, District of Columbia, Georgia, and Texas (U. S.

Nat. Mus.): Maine, Rhode Island, New York, Michigan, Champaign, Ill. (French); Dallas, Tex. (Boll, Mus. Comp. Zool.).

Schizura Doubleday.

(Pl. XLIV, figs. 1-5. Venation.)

Phalæna Abbot and Smith, Nat. Hist. Lep. Georgia, p. 1797.
Hyboma (in part), Hübner, Verz. Schmett., p. 200, 1816.
Schizura Doubleday, Entomologist, p. 59, 1841.
Heterocampa Div. III, Walker, List. Lep. Ins. Br. Mus., v, p. 1025, 1855.
Œdemasia Pack., Proc. Ent. Soc., iii, p. 359, 1864.
Cœlodasys Pack., Proc. Ent. Soc., iii, p. 363, 1863.
Schizura Pack., Proc. Ent. Soc., iii, p. 363, 1864.
Hatima Walk., Cat. Lep. Het. Br. Mus., xxxii, p. 450, 1865.
Œdemasia Grote, New Check List N. Amer. Moths, p. 19, 1882.
Schizura Grote, New Check List N. Amer. Moths, p. 19, 1882.
Cœlodasys Grote, New Check List N. Amer. Moths, p. 19, 1882.
Schizura (including Cœlodasys) Pack., Psyche, v, p. 53, May, 1888.
Œdemasia Smith, List Lep. Bor. Amer., p. 30, 1891.
Schizura (including Cœlodasys) Smith, List Lep. Bor. Amer., p. 31, 1891.
Œdemasia Kirby, Syn. Cat. Lep. Het., i, p. 567, 1892.
Schizura Kirby, Syn. Cat. Lep. Het., i, p. 567, 1892.
Schizura (including Œdemasia) Pack., Psyche, vi, p. 522, Sept., 1893.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 201, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 116, Sept., 1894.

Moth.—♂ and ♀. Head more prominent than usual, on the vertex two tufts inclosing a triangular hollow and projecting out between the antennæ. Eyes naked. Antennæ well pectinated on basal two-thirds, the outer third filiform (thicker and more ciliated in *S. apicalis* than usual); in ♀ simple. Palpi short, thick, blunt at the end, not extending beyond the front; second joint hairy beneath, the terminal scales reaching even with the tip of the third joint and meeting beneath; the third joint small, short. Maxillæ well developed (in *S. unicornis*), united, and as long as the palpi.

Thorax not regularly tufted, but the ends of the tegulæ are slightly upturned and dark, and on the underside below the head and in front of the legs is a large triangular tuft of long hairs, the ends of which are even with the front of the head.

Fore wings a little less than one-half as broad as long, costa nearly straight, slightly convex toward the apex, which is more pointed than usual; outer margin slightly angulated on the fifth subcostal venule, becoming more oblique below. Venation: A short or long subrhomboidal subcostal cell; costal region rather wide, the subcostal venules 1–4 not closely crowded; the third subcostal venule (II_3) shorter than usual, otherwise the venation of both wings is much as in Heterocampa.

Hind wings somewhat produced or pointed at the apex, much more so than in Heterocampa; the costa nearly straight, slightly bent downward near the apex; outer edge long, the lower half disposed to be parallel with the costal edge of the primaries.

Legs rather short; femora and tibiæ densely hairy, the hind tibiæ are shorter than usual and with a broad tuft; the first pair of tibial spurs small and slender, the outer one of the apical (discal) spurs twice the size of the inner one. Tarsi small.

Abdomen much slenderer than usual, with a distinct anal forked tuft, characteristic of the genus.

Coloration: The species usually with dark ash-gray longitudinal slashes, costo-apical white and black spots, transverse wavy lines, and a curvilinear discal spot, except in *S. concinna*, where the spot is a small black dot. The hind wings of the males are usually sordid white and those of the females dusky or mouse colored.

The genus is recognized by the filiform end of the male antennæ and the distinct male anal tuft; by the peculiar vestiture of the head; by the short, thick palpi, as well as the prominent head; characters in which it approaches Heterocampa, as well as the venation, though the hind wings are longer and more pointed than in Heterocampa.

On a careful revision of the generic characters of Œdemasia I do not find any of sufficient value to separate it from Schizura. *Œ. concinna* has all the adult characters of Schizura except the style of coloration, the palpi of this species do not seem to be generically different from those of the species usually referred to Schizura. An examination of the figures illustrating the venation of *S. ipomeæ* and *concinna* will show a general agreement in the plan of venation.

When we come to the larval characteristics it would seem unreasonable to unite such a peculiar species of larva as that of *concinna* with the species of Schizura as formerly limited by us; but the same difficulty is met with in Heterocampa. Œdemasia might be retained as a subgenus or section of Schizura, but at present it seems best to at least unite the two genera. Undoubtedly the old genus Œdemasia is partially evolved, and to some it may seem best on account of its larval characters to retain it as a distinct genus. Before this is done, however, we need more exact knowledge of the larval histories of the subfamily. At all events, the differences which separate the adult *S. concinna* from the other species of Schizura are not at all so marked as those which separate the other genera of the family as we have defined them.

Egg.—Hemispherical, the surface marked with microscopic polygonal areas, becoming obsolete toward the apex, so that it is smooth.

Larva.—Head and body somewhat compressed, head high, narrow, not so wide as the body. The eighth to tenth abdominal segments uplifted, with rather long and slender anal legs, a high nutant, slightly eversible, forked dorsal tubercle on the first abdominal segment; two high twin fleshy tubercles on fifth abdominal segment, not quite so large as similar ones on the eighth segment. Colors green on sides of the thoracic segments; the rest of the body russet, with fine, irregular, reddish lines, and a characteristic silvery white dorsal V-shaped mark in front of the last tubercle. In *S. concinna* the entire first abdominal segment is swollen and red, while the piliferous warts are converted into long, solid, black, stout, blunt spines.

Freshly hatched larva.—Head very large, rounded; body studded with large piliferous conical dorsal warts, those on the prothoracic segments as large as those on the first and eighth abdominal segments, and those on the other segments large and well developed.

The glandular hairs long and bulbous at the tips. Body pale greenish yellow, with a pale reddish band around the prothoracic and first, third, and eighth abdominal segments.

Cocoon.—A regularly oval earthen or thin silken web, with bits of leaves, etc., on the outside.

Pupa.—Moderately stout, end of abdomen obtuse; the cremaster with the spine deeply cleft, each fork well developed, rather long, not much flattened, ending in a point and throwing off near the end a short branch which nearly meets its fellow on the opposite fork.

Geographical distribution.—The species range throughout the Appalachian, Campestrian, and Austroriparian subprovinces, but are most numerous in the Appalachian and Austroriparian subprovinces. No species have yet been found in Mexico.

SYNOPSIS OF THE SPECIES.

A. Discal spot linear. Transverse lines more or less distinct.
- Fore wings with pointed apex; more or less distinct transverse lines; a linear dark discal spot inclosed in a pale patch; no reddish brown markings; largest species of the genus.................. *S. ipomeæ*
- No transverse lines; linear spot distinct; fore wings pointed at apex, whitish frosty gray, with no reddish or brown lines and shades, except a faint extradiscal line; a hollow black low triangular mark on end of thorax.................... *S. leptinoides*
- Size of markings of *unicornis*; fore wings more pointed; light brown with whitish scales, no greenish yellow scales; cross lines distinct; lunate discal mark very distinct.................... *S. apicalis*
- Fore wings squarish at apex; markings white, reddish, black and brown, distinct, and cross lines distinct, the middle and extradiscal lines consisting of reddish brown lunules; two black subapical slashes, a short white longitudinal streak in the second median interspace.................... *S. unicornis*
- Shape of *unicornis*, wings slightly broader, thorax very dark brown, fore wings reddish, and a broad longitudinal reddish shade beyond the distinct linear discal mark.................... *S. badia*
- Fore wings grayish white, with a fawn-colored shade along internal margin.............. *S. perangulata*

B. Discal spot, a small round black dot; no transverse lines.
- Closely resembling *concinna*, but larger, and fore wings much more produced toward apex; oblique dark costal bands.................... *S. eximia*
- Fore wings squarish at apex; tawny ashen, with reddish brown patches; thorax pale ash; no transverse lines, and costal bands obsolete .... *S. concinna*

SYNOPSIS OF LARVÆ (THAT OF S. APICALIS UNKNOWN).

A. With two or three large high dorsal abdominal forked tubercles.
  Head striped; sides of second and third thoracic segments greenish; a whitish dorsal patch between the first and second dorsal tubercles; conspicuous V-shaped mark just behind the second tubercle. *S. ipomeæ*
  Three high tubercles, higher than in the other species, especially the first; body more or less russet, with no green patches. Head not striped .... *S. leptinoides*
  Only two dorsal tubercles, that on fifth abdominal segment wanting; body russet or very dark green on sides of thoracic segments behind the spiracles. Head not striped. V-shaped dorsal mark silvery white and conspicuous .... *S. unicornis*
  Three small dorsal tubercles, sides of thoracic segments green; V-shaped mark absent (Dyar) .. *S. badia*
  Resembles larva of *leptinoides* in coloring, but structurally more like *ipomeæ*. When at rest greatly bunched anteriorly, and the furcate prominence on first abdominal segment is very long (Thaxter). An additional one on preceding segment (Dyar) .... *S. eximia*
B. First abdominal segment greatly swollen above and on the sides; hairs of the other species represented by very stout, blunt spines.
  Dorsal hump coral-red; spines black; body with black and white lines before and behind first abdominal segment; yellow ocherous along the back .... *S. concinna*

I add Dr. Dyar's synopsis, as he has seen the larvæ of *eximia*. I have changed the name *nitida* to *badia*.[1]

Schizura ipomeæ (Doubleday).

(Pl. IV, figs. 16, ♂; 17, ♀.)

Schizura ipomeæ Doubleday, Entomologist, p. 59, Jan., 1841.
Heterocampa (*Schizura*) *ipomeæ* Walk., Cat. Lep. Het. Br. Mus., v, p. 1026, 1855; xxxv, p. 1931, 1866.
Heterocampa ipomeæ Morris, Synopsis Lep. N. Amer., p. 241, 1862.
Schizura ipomeæ Pack., Proc. Ent. Soc. Phil., iii, p. 363, 1864.
Cœlodasys biguttata Pack., Proc. Ent. Soc. Phil., iii, p. 365, 1864.
Cœlodasys cinereofrons Pack., Proc. Ent. Soc., iii, p. 366, 1864.
Heterocampa ducens Walk., Cat. Lep. Het. Br. Mus., xxxii, p. 417, 1865 (*fide* Grote and Rob.).
Heterocampa B. corticea Walk., Cat. Lep. Het. Br. Mus., xxxii, p. 418, 1865 (*fide* Grote and Rob.).
Heterocampa compta Walk., Cat. Lep. Het. Br. Mus., xxxii, p. 418, 1865 (*fide* Grote and Rob.).
Heterocampa restipennis Walk., Cat. Lep. Het. Br. Mus., xxxii, p. 421 (*fide* Grote and Rob.).
Heterocampa nigrosignata Walk., Cat. Lep. Het. Br. Mus., xxxii, p. 422, 1865 (*fide* Dyar).
Cœlodasys telifer Grote, N. Amer. Entomologist, i, p. 99, June, 1880; New Check List N. Amer. Moths, p. 19, 1882.
Cœlodasys biguttata Grote, New Check List N. Amer. Moths, p. 19, 1882.
Schizura ipomeæ Smith, List Lep. Bor. Amer., p. 31, 1891.
  telifer Smith, List Lep. Bor. Amer., p. 31, 1891.
Schizura ipomeæ Kirby, Syn. Cat. Lep. Het., i, p. 568, 1892.
  Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 203, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Larva.

(Pl. XXV, figs. 2, 2a–2b, 3, 3a, 3b, 3c.)

Abbot, MS. (Bost. Soc. Nat. Hist.).
Doubleday, Entomologist, p. 59, Jan., 1841. Excellent uncolored figure of mature larva. Plate facing p. 60, fig. 8.
Packard, figure of larva and moth copied from Abbot MS. in Library Bost. Soc. Nat. Hist., in American

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[1] Humped Notodontians with processes on joints 5 and 12, sometimes also on 8 and 9, the one on joint 5 often furcate and nutant; anal feet uplifted. Rest on the edges of leaves and resemble the foliage except in one instance.
Processes on joints 5 and 12 reduced, rounded.
  Conspicuously marked, brownish, with hump on joint 5 and head red; tubercles produced, black; larvæ gregarious .... *concinna*
  Largely green, resembling the green foliage; tubercles obscure; larvæ solitary .... *badia*
Processes on joints 5 and 12 well developed, that on 5 with furcate tip; larvæ solitary, resembling withered or distorted leaves.
  Sides of thorax marked with green; V-mark conspicuous. A large white dorsal patch on joints 5–8 ... *ipomeæ*
  Without white patch .... *unicornis*
  Sides of thorax not green; V-mark pinkish, tending to become obscure.
  Process on joint 5 moderate; a broad dorsal band on thorax and a distinct lateral line on body .... *leptinoides*
  Process on joint 5 long with a supplementary one on joint 4; dorsal band on thorax narrow; lateral line obsolete .... *eximia*

Packard, Amer. Naturalist, iv, p. 226, Pl. II, figs. 2, 2*a*, June, 1870.
Fifth Rep. U. S. Ent. Comm., Forest Insects, p. 155, 1890.
Proc. Bost. Soc. Nat. Hist., xxiv, pp. 531–539, 1890. Pl. IV, figs. 1–6 (Stages I–V figured).
Journ. N. York Ent. Soc., i, pp. 69, 70, June, 1893.
Riley, in Packard's Rep. For. Ins., Fifth Rep. U. S. Ent. Comm., p. 155, 1890.

Moth.—Head gray, vertical tuft above black. Thorax reddish brown, patagia blackish above. No distinct line on the prothorax. Primaries reddish brown, nervules black. Base of the costa dark, beyond cinereous with brown scales along the edge, which become indistinct waved lines continued across the wing and are more oblique beyond the discal dot. One of these scalloped lines two-thirds of the way from the base of the wings to the discal spot is more distinct than the others, with a distinct scallop in the discal space. The linear reddish brown discal dot is surrounded by gray, and below and beyond is a dark, rather broad discoloration curved around it. Beyond this the black nervules are interrupted by gray scales. There are two obscure series of reddish dots near the margin in the interspaces. Opposite the outer series of these spots the fringe, otherwise ferruginous, is of a dirty white. Secondaries sordid white, discolored with smoky brown at inner angle. The large tuft beneath the head is lilac-ashen. Beneath, the fore wings are white, smoky in the middle. Costo-apical dots distinct. Fringe white, black at the ends of the nervules; at the base are white dots in the interspace. Secondaries entirely white, except the dusky spot on the inner angle. Legs ashen, ends of the scales dark, tarsi broadly annulated with dark. Abdomen slender, whitish, a narrow mesial line beneath.

In the female the markings are more distinct. The two series of ferruginous waved or scalloped lines on each side of the median region are more distinct. The submarginal ferruginous region is more broken up by ashen scales. The secondaries and abdomen above smoky brown, with a pale mesial diffuse band ending on the inner edge in a diffuse, oblique, sordid, whitish band, bordered on each side by sordid white. There are faint traces of a slight mesial fascia across the wing. Beneath, both wings are dark smoky. A light ferruginous line on the abdomen, which is itself larger than in the other species. Expanse of wings, male, 35–43 mm.; female, 40 mm. Length of body, male, 17–24 mm.; female, 20 mm.

Cælodasys cinereofrons Pack., as stated by Grote, is undoubtedly a variety of this species, now to be referred to the genus Schizura. It differs in the costal region of the fore wings, except at the base, being ash-gray, with a slight lilac tint; the inner edge also being grayish, the middle of the wing from the base to the outer edge being dark brown. The following notes on the larva of this variety were received from Professor Riley, and published in our Report on Forest Insects, 1890, p. 155:

June 20, found on oak two very small larvæ, which entered the ground July 8 and emerged as moths July 30. Color of larva as follows: Second and third segments grass-green; the horn of the fourth segment is bifurked and the tips blood-red, also the tips of the two smaller horns on joints 8 and 11. The rest of the body and head reddish-brown.

S. telifer (Grote) is only a variety of *S. ipomeæ*, with two long, distinct, black streaks, one passing through the discal spot and the other extending along the submedian vein.

The eggs were kindly sent me by Miss Emily L. Morton, who obtained them at Newburg, N. Y., from a female *Schizura ipomeæ* (*Cælodasys biguttata* Pack.) of the normal form mated with a male of the variety *C. cinereofrons* Pack. Miss Morton informed me that a male of the normal *C. biguttata* was also attracted. The eggs were laid July 11 and hatched July 17; the first molt occurred July 19–24; the second on August 1–2; the third August 6–7; the fourth August 16–18; the date of the last molt not noted, but about four or five days later.

Egg.—One mm. in diameter. Perfectly hemispherical in shape, with the surface marked on the sides and near the base with minute polygonal areas which toward the top become gradually smaller, with minute beads at the angles; the top of the egg is smooth.

First stage, larva just hatched.—Length, 2–3 mm. It shows an approach to the characters of the fully fed larva in the uplifted small anal legs and the tubercles on the segments, though those characteristic of the last stage are not specialized.

The head is enormous in proportion to the size and width of the body, being twice as wide as the thoracic segments; it is well rounded, rather short antero-posteriorly; full and rounded on the vertex, rounded, not angulated, above, and in color dark amber.

The prothoracic segment is wider than the succeeding ones, with two very large dorsal piliferous tubercles, situated far apart, while those on the meso- and metathoracic segments are minute and situated not so near together as those on the abdominal segments. The tubercles on the first, third, eighth, and ninth abdominal segments are larger than those on the other segments. They are all darker than the body, and dull amber-brown in color.

The body in general is greenish yellow, with a pale reddish band around the prothoracic segment and around the first, third, and eighth abdominal segments. The hairs are in most cases about twice as long as the body is thick. On the head are a few scattered simple hairs, pointed at the end. Those on the segments behind the head are in general clavate at the tip. Those of the two large prothoracic tubercles and of the larger warts on the eighth and ninth abdominal segments are nearly twice as long as most of the others, and are slightly bulbous at tip Those on the meso- and metathoracic segments are about a fourth longer than most of those on the succeeding segments to the eighth abdominal.

The larva just before the first molt is nearly twice as large as when first hatched, but it can be easily distinguished by its hairs alone from those in the second stage.

The thoracic legs are black, the abdominal, including the anal legs, dusky. Before molting the larva doubles in length, finally being 6 mm. long.

Second stage, after the first molt.—Observed to molt July 19–24. Length, 7–8 mm. The larva is very different from the preceding stage. The head, though smaller in proportion to the rest of the body, is still much wider than the body, ending in the vertex in two conical tubercles, much as in the adult: color of the head brown, with four rows of large round pale spots, three in each row; the sides of the head and occiput pale. Prothoracic segment with two large black-tipped conical tubercles, and two much larger ones on the first and eighth abdominal segments, those on the first being larger than those on the eighth segment and several times larger than in the first stage; there is a smaller pair on the fifth abdominal segment. Anal legs long and slender, of much the same proportions as in the fully fed larva. Color of the body greenish, but the prothoracic and first, third, fifth, and eighth abdominal segments reddish. The piliferous tubercles on the side of the body are not so large and prominent as in Stage I.

The hairs are not quite so long as the body is thick and of more uniform length all over the body than in Stage I, and decidedly different in shape from those of the first stage: they are shorter, thicker, and somewhat shovel-shaped, being broad and flat at the end and slightly notched or toothed on the edge, the flattened portion being striated; those of the head are still simple. Those of the two prothoracic tubercles are twice as long as those on the meso- and metathoracic segments, the hairs on the latter two segments and on the abdominal being somewhat shorter than the body is thick; those of the two larger tubercles on the eighth and ninth segments are a little longer than those on the smaller tubercles at the end of the body. In nearly all the hairs the shaft is, under a $\frac{1}{5}$-inch Tolles objective, seen to be finely spinulated.

Third stage, after the second molt.—Observed to molt August 1–2. Length, 10–11 mm., finally becoming 13–14 mm. The head, tubercles, and hairs (setæ) much as before, the head retaining the same style of markings. The colors of the body, however, have changed: there is an irregular double dorsal reddish resinous line on the thoracic segments. On abdominal segments 2 to 4 is a single line, and on the same segments the dorsal tubercles are yellowish green, as are those on segments 6 and 7. The ground color of the body is yellowish green, irregularly marbled on the sides with resinous red. The anal and other abdominal legs are tinted with reddish. There is a lateral reddish line along the sides of the thoracic segments; a double dorsal reddish line on the seven terminal abdominal segments extending out on the uplifted anal legs (not developed in Stage II, though faintly indicated).

Those observed August 4 later on in this stage had changed a little since molting; have assumed more of the distinctive coloring of the fully fed larva; the yellowish green parts, especially on the thoracic segments, are now of a bright pea-green, while the silvery white V-shaped mark on the sixth to eighth abdominal segments, so characteristic of the genus Schizura, is now very distinct. (This mark is faintly indicated in the previous stage by two broad, slightly converging, whitish yellow dashes on the seventh segment and a median pointed whitish dash in front, but in the present stage these dashes are strengthened, united, broader, and colored more distinctly.)

A noteworthy step taken at this stage is the final consolidation of the two dorsal tubercles of the first abdominal segment, which now becomes a forked single tubercle.

Fourth stage, after the third molt.—Observed August 6. Length, 15–16 mm. The characters of the full fed larva are now almost wholly assumed. The head is high and narrow, the vertex bearing two tubercles. The forked tubercle on the first abdominal segment is now larger and higher than that on the eighth segment; all are reddish, tipped with black. The body is much thicker than before and marbled, except on the pale pea-green meso and metathoracic portions, with reddish lines and spots, which are much more numerous than before. The hairs are now entirely changed in shape, being simple and pointed like those on the head.

Fifth stage, after the fourth molt.—Observed August 16–18. Length, 25–27 mm., and finally 35 mm. This stage does not differ essentially from the fourth, except that the horns are a little higher. The markings and colors of the mature larva seem to be acquired in this stage.

The essential or specific characters may be best brought out by comparison with the fully grown larva of *S. unicornis*. *S. ipomœa* is larger and the hairs are longer. The head is less angular above and not so strongly marbled with the irregular network of reddish lines, and has four dark lines in two pairs extending from the vertex to the base of the mandibles. The arrangement of the four double red and yellow dorsal lines between the head and the horn on the first abdominal segment is the same in the two species, but the space they occupy is wider in *S. unicornis*, while the corresponding dorsal lines of the first behind the horn and the second and third segments are firmer, less wavy than in *S. unicornis*. The horn of the first abdominal segment is higher and slenderer, not so thick at the base as in *S. unicornis*, while those on the eighth abdominal segment are much higher and more prominent. The four pairs of dorsal oblique lines of *S. unicornis* are less distinct in *S. ipomœa* and more wavy, while the V-shaped dorsal mark just behind them is less sharp and distinct, with more red interlineations in *S. ipomœa*.

The following description of two larvæ found at Brunswick, Me., on the red maple, August 11, describes the peculiar mimicking coloration better than those hitherto published:

Full-grown larva.—Length, 28–33 mm. Wonderfully mimics a dull blood-red portion of a leaf which had been cut partly off and become somewhat twisted, so that the larva itself would easily be mistaken for such a part of a prominent terminal leaf. The deception was perfect, as I did not myself at first see it when within ten inches of my eyes, and on holding it before the eyes of an observing boy of thirteen he could not at first recognize it as a caterpillar. The same leaf had blotches of dull red, and the flesh-red abdominal feet of the caterpillar clasped the concolorous red leafstalk. One larva was much deeper blood-red in color than the other, the latter having a more faded tint.

The head is high and narrow, not so wide as the body, but wider than the first thoracic segment; it is pale livid purplish, darker down the front, with two parallel black-brown lines on each side, bordered with paler, and inclosing a clear pale purplish band. The clypeus, labrum, antennæ, and region near the eyes are pale. A minute piliferous wart on each side of the vertex. The first thoracic segment is mottled with reddish and pale flesh on the sides. A dorsal broad band, divided in the middle by a pale yellow line, becomes one-half as wide behind on the second thoracic segment and passes back to the horn on the first abdominal segment; the rest of the second and third thoracic segments are pea-green, a little paler than the upper side, and darker than the underside of a red-maple leaf, but on the whole very closely assimilated in tint to the color of the leaf.

The abdominal segments are in general faded, dull blood-red, due to fine, dark, flesh-red lines and mottlings on a pale carneous ground. On the first abdominal segment is a high, nutant, fleshy, soft, dorsal tubercle which is inclined a little backward, but on being touched bends over downward near the back; the basal half is mottled and lined like the sides of the segment from which it rises, but above becomes bright, clear, blood-red, the end being deeply forked, each fork bearing a long black bristle. A median black line passes along the tubercle, becoming forked in front and behind at the base. Two large, high, twin, soft tubercles on the fifth segment are not quite so large as the two similar ones on the eighth segment, but are situated on a much larger hump;

they are of the same blood-red hue as those on the first segment. The small dorsal tubercles on the second and third abdominal segments are minute and yellow; those on the fourth are partly blood red. The anal legs are long and slender. On the back of the abdominal segments 1–4 is a porcelain white band, bordered with faint yellow, and divided by the sutures; the portion on the first segment behind the tubercle is triangular, that on the fourth round; they each contain three deep pink lines more or less broken and irregular. The V-shaped mark consists of a white oval (acute in front) spot on the sixth segment, and the two arms of the V are formed by two converging oval spots, with a yellowish white spot between the forks. The thoracic legs are pale flesh, the middle abdominal legs of the color of the leaf-stalk, while the anal legs are paler. Beneath, the body is green on the three thoracic segments, this color being continued back as a narrow band to the first pair of abdominal legs; otherwise much as on the sides of the body.

Larva compared with that of S. unicornis.—Differs from *C. unicornis* in the head being purple and having four dark narrow lines extending from the base of the jaws to the vertex; the dorsal spine on the first abdominal segment is nearly three times as large and high as in *C. unicornis*, and ends in a deep fork, each tine of which bears a stiff truncated spine. A pair of dorsal, rounded, small tubercles on each abdominal segment 1–8, those on the fifth and eighth segments being much larger than the others and coral red in color. Coloration much as in *C. unicornis*, but the branches of the V in front of the tubercle on the eighth segment are wider and inclose a broken red line. Meso- and metathoracic segments green; body brick-reddish, slashed with pale lines, with a broad dorsal band forked on the prothoracic segment and extending upon the horn on the first abdominal segment; behind the horn are four dorsal, oval, light patches, each inclosing three red lines.

Cocoon.—Earthen, regularly oval in shape, externally covered with sand, so that it closely resembles that of *Xylinodes lignicolor*. (Riley.)

"The single specimen of the cocoon of this species in the national collection was constructed in a sandy soil, and is extremely thickly covered with particles of sand, entirely concealing the silken inner structure, which seems to be somewhat more copious and dense than in the case of *S. unicornis*. The cocoon is elongate oval, measuring about 22 mm. in greatest diameter." (Riley MS. notes.)

Pupa.—Moderately stout; end of abdomen obtuse. The cremaster deeply cleft, each spine well developed, rather long, not much flattened, ending in a point, and throwing off near the end a short branch which nearly meets its fellow on the opposite spine. Length, 21 mm.

Two ♂. Body not very stout (head not preserved in any cast shells), smooth, shining. Hinder edge of the thorax with eight square, dark tubercles, with rudiments of a ninth. Abdominal segments 5 to 7 shagreened on the hinder edge, and segments 6 to 8 punctured (these punctures acting as ball bearings?). Cremaster ending in two stout spines forked at the end, much larger than in *S. unicornis*, and transversely corrugated. Length, 18–19 mm. (U. S. Nat. Mus.)

Habits.—The following notes and descriptions are based on an examination of the material in Professor Riley's collection. The larva occurred on the oak September 24. In Virginia one was found by Mr. Koebele on the birch September 14, and it has also been bred from the blackberry. The larva makes an earthen cocoon, regularly oval in shape, covering it with sand on the outside, so that it closely resembles that of *Xylinodes lignicolor*. *C. unicornis* spins a silken cocoon, with débris collected and adhering to the exterior. It is evident that *C. cinereofrons* Pack. is only a variety of *biguttata*, there being a series of connecting forms in Riley's collection now in the United States National Museum. The moth occurred at Cambridge, Mass., June 16, and in July and August. (Harris.)

"Larvæ of this species are found from May to October at St. Louis, Mo., feeding on the different kinds of oak and on maple. The moths issued in April and August. The coloration of the larvæ is quite variable, though the most uniform marking is as follows: Color, green, speckled with purple. A faint substigmatal sulphur-yellow line, most distinct on thoracic joints. A broad pale subdorsal line, between which the dorsum is pale lilaceous, but thickly mottled with rich purple-brown and ferruginous, leaving a narrow dorsal line distinctly marked. Two elevated ferruginous warts on top of joints 4 and 11. Head large, pale green, with a distinct lateral black and white stripe." (Fifth Rep. U. S. Ent. Comm., p. 155.)

Riley has observed the larva in May, June, July, September, and October; the moths from March to August.

Food plants.—In the Northern States, different species of oak, and on maple, birch, blackberry (Riley); red maple (Packard); "Acer, Ulmus, Quercus, Betula, Vaccinium, Ceanothus" (Thaxter); in the Gulf States on *Ipomea coccinea* (Abbot); in Grand Canyon on an unknown leguminous tree (Townsend); honey locust (Beutenmüller).

Geographical distribution.—Extends through the Appalachian, Austroriparian, and the Campestrian subprovinces.

Brunswick, Me. (Packard); Massachusetts (Harris); eastern New York (Miss Morton, Grote, Dyar, Doll); Plattsburg, N. Y. (Hudson); Chicago, Ill. (Westcott); New York, New Jersey, Pennsylvania (Palm); St. Louis, Mo. (Riley); Georgia (Abbot); larva found at Grand Canyon of the Colorado, northern Arizona, July (C. H. Tyler Townsend, No. 312); Seattle, Wash. (in Coll. of Professor Johnson *fide* Dyar); Massachusetts, New York, Wisconsin, Illinois, Missouri, Nebraska, Virginia, District of Columbia, and California (U. S. Nat. Mus.); Canada, Maine, Massachusetts, New York, Wisconsin, Ohio, northern Illinois, Georgia, Texas (French); Seattle, Wash. (Dyar); var. *telifer*, Poughkeepsie, N. Y. (Dyar).

FIG. 76.—End of pupa of *Schizura ipomeæ*, showing the anal scar and male genital opening.

Schizura leptinoides (Grote).

(Pl. IV, figs. 18 ♀, 19 ♂.)

Cœlodasys leptinoides Grote, Proc. Ent. Soc. Phil., iii, p. 323, Sept., 1864, Pl. IV, fig. 2 ♀.
Cecrita ? mustelina Pack., Proc. Ent. Soc. Phil., iii, p. 359, Nov., 1864.
Cœlodasys leptinoides Grote, New Check List N. Amer. Moths, p. 19, 1882.
Schizura leptinoides Smith, List Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 568, 1892.
Cœlodasys mustelina Grote, New Check List N. Amer. Moths, p. 19, 1882.
Schizura mustelina Smith, List Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 568, 1892.
Schizura leptinoides Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 204, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Larva.

(Pl. XXVI, figs. 1, 1*a*, 1*b*, 1*c*, 2, 2*a*—2*d*, 3, 3*b*, 4, 4*a*—4*c*.)

French,[1] Can. Ent., xviii, p. 92, May, 1886 (larva of "*C. mustelina*," last stage).
Packard, Proc. Bost. Soc. Nat. Hist., xxiv, p. 539, 1890. (Stages I–III described.)
Journ. N. York Ent. Soc., i, p. 71, June, 1893.
Dyar, Ent. Amer. 1890. (Eggs and all stages).

Moth.—One ♂, three ♀. Antennæ of ♂ more broadly pectinated than in *S. unicornis*, and less so than in *S. ipomeæ*. Head and thorax ash, with a delicate, pale, olive-green tint. Front of head white, especially in ♂; vertex olive-ash, with a blackish line on each side inside of the base of the antennæ (not so distinct in ♀). Thorax behind uniquely marked with a distinct, black, low, wide, hollow triangle, the base of which extends straight across the thorax from one side to the other, the two sides of the triangle being formed by the black edges of the tegulæ.

Fore wings more produced toward the apex than in *S. unicornis* and less acute than in *S. ipomeæ*; in the male, marked much as in *S. unicornis* (the species connecting *unicornis* and *ipomeæ*); ash-gray, with no olive tint; the wings slashed with narrow linear black lines, of which there are three on the base of the wing, one on the costa, one on the subcostal venule, and one in the submedian interspace. A basal curved, indistinct broken line (obsolete in ♀) formed of longitudinal black marks, and diffusely bordered externally with whitish gray. Beyond the cross line the wing is whitish gray, becoming brownish on the inner edge of the wing. No distinct discal

[1] Dyar states (Trans. Amer. Ent. Soc., xxi, p. 204) that the larva described by French is not that of *S. leptinoides*.

mark in my male, but a long, slender, two-scalloped discal line, sending four black lines outward along the veins. In the ♀ a round, distinct discal dot. An outer, obscure, zigzag, double sordid white line, shaded externally with reddish brown, and indicated when obsolete by a double series of short, longitudinal, black venular streaks. The venules beyond marked with black scales. Fringe whitish, dusky toward the apex, and marked with dusky spots. Wings beneath, whitish, dusky on the costal region.

Hind wings in ♂ white, slightly dusky on the outer edge, and a dusky diffuse patch on the internal angle. Abdomen in both sexes olive whitish ash, becoming paler toward the end, which, in my single male, is not forked as usual in the genus.

The ♀ differs very much from the ♂, and is much more common in collections. The fore wings are uniformly of a peculiar stone-ash or leaden gray, the basal and outer lines obsolete: a minute black discal dot present. There is, as in the ♂, a broken black line at the base of the wing in the submedian space. The outer edge of the wing is clear ash-gray. A series of longitudinal black, sometimes red, wedge-shaped streaks just within the clear whiter marginal border, those opposite the discal dot being the largest.

Hind wings of ♀ uniformly mouse-gray, with no distinct dusky patch near the internal angle. Beneath, both wings uniformly dusky, becoming clearer, paler gray on the outer edge. Fore wings with four pale marks on the outer third of the costa.

Expanse of wings, ♂ 36 mm., ♀ 36mm.; length of body, ♂ 15mm., ♀ 15 mm.

This species differs from *S. ipomeæ*, besides other points noted above, in the longitudinal black streaks on the fore wings, in the absence of an inner line, in the linear black discal spot, and in the peculiar white, frosty gray hue or ground color of the fore wings, there being no reddish or brownish shades, except what is faintly shown in the extradiscal line. It differs from *S. unicornis* in the longer and more pointed fore wings and in the absence of reddish brown shades. From both it differs in the peculiar black triangular mark on the thorax. The females are at once recognized by the peculiar uniform leaden ash-gray ground color of the fore wings.

Egg.—Transverse diameter, 1 mm., of the same size and shape as those of *S. ipomeæ.* Hemispherical, moderately high, and under a high Tolles lens seen to be very finely pitted; under a half-inch objective of Tolles the surface is seen to be divided into five and six-sided areas, with a distinct raised edge; the surface smooth and more often without the bead so common in eggs of *S. ipomeæ.*

Toward and at the micropylar region the cells become longer, minuter, and more crowded, and in this respect the egg seems to differ from those of *S. ipomeæ*, in which the areas are more or less obsolete in the micropylar region.

Freshly hatched larva.—Length, 3 mm. The head is very large, nearly twice as wide as the body; deep honey-yellow.

Prothoracic segment of the same tint as the head, but green behind. The rest of the body is pale yellowish green, with rather large honey-yellow warts. The first and eighth abdominal segments are deep cherry-red, while the sides of the second to seventh segments above the legs are the same color. On the first and eighth segments is a pair of dorsal cherry-red tubercles, those on the first somewhat larger than those on the eighth segment; those on segments 2 to 7 are small, of nearly uniform size, and concolorous with the greenish yellow segments. The end of the body, including the anal legs and the ninth and tenth segments, is upheld as usual in the genus. The thoracic and first four pairs of abdominal legs are dark. The anal legs smaller than those in front, and are pale, being of the same color as the end of the body. The glandular hairs are distinctly seen to be bulbous at the tip and long and unequal in length, the two longest ones, i. e., those on the prothoracic segment, being about three times as long as the body is thick.

Compared with the larva of *S. ipomeæ* of the same stage, the two dorsal warts on the prothoracic segment appear to be a little smaller. The glandular hairs seen under a half inch objective are of the same length and general shape as in *S. ipomeæ*, but do not appear to be quite so bulbous.[1]

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[1] With the above description may be compared the following one drawn up from Riley's alcoholic specimens:

First stage.—Length, 1 mm. The larva of this stage is very similar to that of *S. ipomeæ*, the shape of the head, of the tubercles, dorsal and lateral, and of the peculiar paddle-shaped glandular hairs being identical. I can only

Within the egg the larva lies with the front of the head next the top of the dome, so that the jaws are opposite the upper side, hence when it eats its way out of the shell, the more or less bean-shaped opening is on one side rather high up, near the summit.

Fully fed larva.—In Maine, at Brunswick, the caterpillar occurred fully fed on the beech and also on the hornbeam during the first week in September.

This species is of the color of a dry, sere leaf, with no green upon the body, and is thus readily separated from *S. ipomeæ;* besides the body is thicker; it bears a striking resemblance to a part of a dead leaf, and several leaves were noticed with portions partly cut off and somewhat curled up, to which the caterpillars bore a striking resemblance, both in shape and color.

It was observed that the high dorsal tubercle on the first abdominal segment is both nutant and slightly retractile, being invaginated when irritated. The larvæ also occurred at Providence, R. I., through September on the chestnut. It is also figured in MS. by Major Leconte as living in Georgia. (Pl. XXVI, fig. 4c–4e.)

Length, 25–30 mm. The body is compressed as usual. The head is somewhat notched above, large and high, compressed, clay-yellow, with two broad dark bands in front, which are made up of irregular, wavy, dark lines and spots. The labrum is carneous. A pair of minute piliferous tubercles on the back of the third thoracic segment. On the first abdominal is a large, high, fleshy, cylindrical, nutant tubercle of the same yellowish color as the body; it nods back and forth freely as the creature walks; it bears a pair of cylindrical, chitinous, piliferous tubercles, with bases rather wide apart, and which are reddish black at the base and pale at the tips. On the fifth abdominal segment is a large, broad, fleshy hump, concolorous with the body, from which arise two low, conical, nutant, fleshy tubercles, each bearing a low chitinous piliferous tubercle. (This hump and its tubercles are not developed in *S. unicornis.*) The eighth abdominal segment is provided with a prominent, narrow, fleshy hump bearing two small piliferous warts. The anal legs are about one-half as thick as the middle abdominal legs.

The body is uniformly the color of pale unburnt or Philadelphia brick, or of the same tint as a sere, pale brown leaf, with no green upon it. There is a broad dorsal dark brown stripe along the thoracic segments, which is continued upon the base of the head, which bears a broad triangular dark spot. Behind the first abdominal hump is a long triangular flesh-colored dorsal band; on the third abdominal segment is a shorter similar patch, while a similar carneous band on the fourth segment breaks up into three diverging stripes ending at the suture. The V-shaped dorsal spot on the sixth and seventh segments is faded, pink edged with clay-yellow, and dark brown. Along the abdominal segments is a narrow, dark, supraspiracular line. The thoracic and abdominal legs are, like the body, pale, with reddish lines.

The apparent aim, or rather the result of the action of the environment, has been to produce a caterpillar whose shape and color represent a sere-brown, more or less twisted portion of a serrated leaf, such as that of a beech, hornbeam, and similar trees.

perceive a difference in the slightly smaller dorsal tubercles, especially those on the eighth and ninth abdominal segments. There are probably slight differences in color, but Professor Riley's specimens are faded out from long immersion in alcohol, so that it is impossible of course to say how the two larvæ differ in color until the two forms have been compared in the living state.

Second stage.—Length, 7 mm. Of the same size as *S. ipomeæ* of the same stage. The tubercles do not differ in shape or in size. The specific difference (besides those of color, about which I can not ascertain) is that the two vertical lobes of the head are more acute than in *S. ipomeæ*, while the surface seems to be less distinctly marked. Moreover, the paddle-shaped glandular setæ are decidedly shorter. By these marks alone alcoholic specimens of the larvæ of the two species of the present stage can be easily separated.

Third stage.—Length, 11 mm. The same differences obtain as in the preceding stages. The vertical lobes of the head are more acute in *S. leptinoides* than in *S. ipomeæ*, while the setæ, now less flattened at the end, are in shape like those of the third stage of *S. ipomeæ*, but are decidedly shorter. The dorsal and other tubercles are just as in *S. ipomeæ*. It is probable that other specific distinctions are to be sought for in this style of coloration. Indeed, as may be seen in alcoholic specimens, the head of *S. leptinoides* is simply rough on the surface and uniformly resinous, while in *S. ipomeæ* of this stage the surface in front and on the sides are divided into whitish areas bounded by brown lines. The coloration in general is much alike in the two species. The dorsal band along the thoracic segments and the V-shaped whitish yellow mark on the sixth and seventh segments are nearly as in the third stage of *S. ipomeæ*.

It differs from any other species known to me in lacking any green color on the thoracic or other segments of the body.

The larva of *S. mustelina* described by Professor French is said to be 0·80 inch in length, and "the sides of joints 3 and 4 are bright green," otherwise it appears to agree with our specimens of *leptinoides*. Probably the specimens described by French, which were under size, were in next to the last stage, or at all events had retained the green coloring of the earlier stages. He raised three moths from his larvae. (Dr. Dyar writes me that French's larva is evidently *S. unicornis*.)

Cocoon.—The caterpillar fastens leaves together for a cocoon, within which it changes. (French.) It is oval, made of silk, uniformly thin, though dense and parchment-like, and my Maine specimen spun between leaves.

Pupa.—Two ♀. Body rather stout, of the usual color. It is noteworthy from the head being pointed and ending in two stout conical spines, or cocoon-cutters, arising from the epicranium between the eyes. Cremaster ending in two stout spines, flattened vertically, and ending in four or five slightly curved, short, sharp spinules, with a minute spinule at the base on the inside. Vestiges of the anal legs small, narrow, not prominent. On hinder edge of mesoscutum is a transverse row of ten large deep pits separated by double tubercles, each tubercle being flattened above, with an impressed median line giving a double appearance to the tip, which is dull, not polished as are the sides. Length, 18 mm.

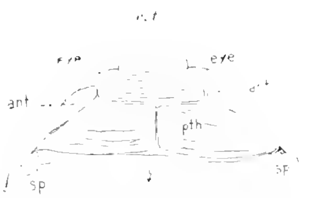

FIG. 77.—Pupa of *Schizura leptinoides*. Dorsal view of head. *c. t.*, with the cocoon cutter; *ant*, antenna; *pth*, prothorax; *sp*, spiracle.

Habits.—Professor French, speaking of the habits of *C. mustelina*, says that "three nearly grown caterpillars were found at Carbondale, Ill., on a rosebush September 18. By October 1 they had pupated, and the moths appeared on May 20, 22, and 31 following. No efforts were made to rear a second brood, but from the time the larvae were found in the fall it is to be presumed that there are two broods in a season."

The eggs here described were laid by a species of Schizura, and sent by Miss Emily L. Morton, who is quite sure that it was *Schizura leptinoides*. They were laid June 3, at New Windsor, N. Y.; they hatched June 12, all the others being out of the shell by noon of the next day. I did not carry it beyond the first stage, but have little doubt but that Miss Morton's identification of the moth was correct.

Riley has found the eggs in August; the larvae in July, August, and September; the moths in August.

The moth was collected at Cambridge, Mass., by Dr. Harris, June 15. I have found the larva on the hornbeam at Brunswick, Me.; it was uniformly pale russet-brown, the color of a sere dead leaf. It began to pupate September 12.

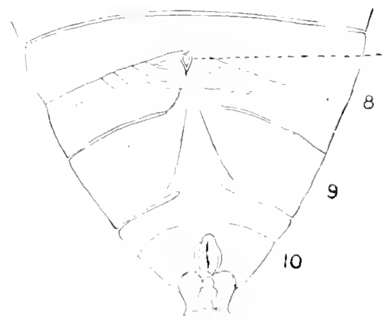

FIG. 78.—Pupa of *Schizura leptinoides*. End of body.

Food plants.—Carya (Thaxter); beech and hornbeam in Maine; in Rhode Island, the chestnut and tupelo (Packard); rose (French); hickory, walnut, butternut (Miss Morton); walnut (Pilate); Georgia (Leconte's figure, which I take to represent the larva of this species, fed on the oak. Pl. XXVI, figs. 4*c*, 4*d*, 4*e*). Abbot (MS.) figures the larva giving as its food plant *Helianthus angustifolius*. In New York, hickory and hop hornbeam (Dyar). Dr. Dyar writes that *leptinoides* is generally a hickory feeder.

Geographical distribution.—A member of the Appalachian and Austroriparian subprovincial faunae; it ranges from Maine to Georgia, and westward to Illinois.

Orono, Me. (Mrs. Fernald); Kittery, Me. (Thaxter); Brunswick, Me. (Packard); Massachusetts (Harris); ♂, Buffalo, N. Y. (P. Fisher, U. S. Nat. Mus.); Newburg, N. Y. (Miss Morton); Plattsburg, N. Y. (Hudson); Carbondale, Ill. (French); Ohio (Pilate); Savannah, Ga. (Leconte, Abbot); Wisconsin and District of Columbia (U. S. Nat. Mus.); Maine, Massachusetts, Rhode Island, New York, Pennsylvania, Ohio; Champaign and Carbondale, Ill. (French).

Schizura apicalis (Grote and Robinson).

(Pl. IV, fig. 22 ♂.)

Cœlodasys apicalis Grote and Rob., Proc. Ent. Soc. Phil., vi, p. 15, 1866, pl. 2, fig. 7, ♂.
Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 568, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 203, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Moth.—One ♂. Of the size of *S. unicornis.* Head well tufted on vertex and at the insertion of the antennæ. Body and wings fawn color or grayish brown, with white scales; ends of patagia and a parallel line on each side behind and a spot over the scutellum at the base of the abdomen, dark brown. Fore wings with the costa unusually straight, apex a little more square than in *S. unicornis*, outer edge straight, less curved than usual, moderately oblique. No basal line; extrabasal line composed of five scallops. Wings fawn color from base to this line, and inclosing a distinct black streak parallel to the cubital vein; middle of wing whitish, frosted over with white scales; discal mark large curvilinear, heavier and more curved than in *S. unicornis*. A narrow, white, wavy, extradiscal line, beginning as a very oblique white mark on the costa. Venules blackish.

Beyond the discal mark the wing is fawn-brown, with darker brown intervenular streaks and white frosted patches. Hind wings white, with a large dark patch on internal angle. Abdomen with a forked tuft. Underside of fore wings gray, white on the inner edge. Hind wings as above, but grayish at the costal edge.

Expanse of wings, ♂ 33 mm.; length of body, ♂ 17 mm.

Recognized by the large, heavy, distinct discal mark, the distinct black submedian streak, the fawn brown fore wings, and by the white bands in the middle of the wing, while the hind wings are white, being brown in *S. unicornis.*

Geographical distribution.—Kittery, Me. (French); New York (Doll); Arkansas (Palm); Florida (Slosson).

Schizura unicornis (Abbot and Smith).

(Pl. IV, figs. 20 ♂, 21 ♀.)

Phalæna unicornis Abbot and Smith, Nat. Hist. Lep. Ins. Georgia, ii, p. 170, Tab. LXXXVI, 1797.
Hyboma unicornis Hübn., Verz. Schmett., p. 200, 1816.
Notodonta unicornis Harris, Cat. Ins. Mass., p. 73, 1835; Rep. Ins. Mass., p. 307, 1841; Treatise.
Edema unicornis Walk., Cat. Lep. Het. Br. Mus., v, p. 1030, 1855.
Morris, Synopsis Lep. N. Amer., p. 241, 1962.
Harris, Treatise Ins. inj. Veg., p. 421, 1862
Cœlodasys unicornis Pack., Proc. Ent. Soc. Phil., iii, p. 364, 1864.
Cœlodasys edmandsii Pack., Proc. Ent. Soc. Phil., iii, p. 364, 1864.
Edema semirufescens Walk., Cat. Lep. Het. Br. Mus., xxxii, p. 424, 1865 (*fide* Grote and Rob.).
Edema humilis Walk., Cat. Lep. Het. Br. Mus., xxxii, p. 425, 1865 (*fide* Grote and Rob.).
Heterocampa? conspecta H. Edw., Proc. Cal. Acad. Sci., p. 2, Sept. 7, 1874.
Cœlodasys unicornis Grote, New Check List N. Amer. Moths, p. 19, 1882.
Schizura unicornis Pack., Fifth Rep. U. S. Ent. Comm. Forest Ins., p. 269, 1890.
Smith, List Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 567, 1892.
Hatima semirufescens Kirby, Syn. Cat. Lep. Het., 1892 (*fide* Smith).
Schizura unicornis Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 203, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Larva

(Pl. XXVIII, figs 1, 1*a*, 1*b*, 2, 2*a*–2*e*, 3, 3*a*–3*c*, 4, 4*a*–4*d*, 5, 6.)

Abbot and Smith, Nat. Hist. Lep. Ins. Georgia, p. 170, Pl. LXXXIII, 1797 (colored figures of larva, pupa, and moth).
Harris, Ins. inj. Veg., 1st edit., p. 307, 1841.
Ins. inj. Veg., 2d edit., p. 326, 1852.
Fitch, Third Rep. Nox. Ins. N. York, p. 363, 1856.

Harris, Treat. Ins. inj. Veg., third edit., p. 424, 1862.
Ent. Corresp., p. 302, Pl. II, fig. 8, (figure not well colored).
Payne, Amer. Ent., ii, p. 341, Oct., 1870.
Lintner, Ent. Contr., iii, 26th Rep. N. York Mus. Nat. Hist., 1872, p. 131 (extra, 1872), 1874 (plain figures with details).
French, Trans. Dept. Agr. Ill., xv, p. 191, 1877.
Marten, Trans. Dept. Agr. Ill., xviii, Append., p. 120, 1880.
Coquillet, Trans. Dept. Agr. Ill., xviii, Append., p. 181, 1880.
Packard, Bull. 7, U. S. Ent. Comm., p. 136, 1881.
Saunders, Ins. Inj. Fruits, p. 80, 1883 (larva and moth, ♀, figured).
Riley, Fifth Rep. U. S. Comm., p. 269, 1890.
Packard, Fifth Rep. U. S. Ent. Comm. Forest Ins., p. 269, 1890.
Proc. Bost. Soc. Nat. Hist., xxiv, p. 538, 1890 (plain figure of larva, Stage I).
Dimmock, Anna K., Psyche, iv, p. 279, June, 1885.

Moth.—Eight ♂, 2 ♀. Antennæ not so broadly pectinated as in *S. ipomeæ*, and fore wings squarish at the apex, not produced as in *S. ipomeæ*, the outer edge being much less oblique. Head and thorax pale ash, with numerous pale green scales, giving the body (abdomen excepted) a slight subolivaceous hue. The interantennal tuft on the vertex of the head is edged with black. Thorax with two blackish lines across the front, the hinder one sometimes much the broader; hind edge of the tegulæ black brown and hinder edge of the scutal region dark.

Fore wings ash gray, varied with whitish, reddish brown, yellowish green, and black markings. They are crossed by three well marked lines. The basal line is black, curved outward on the costal region, and again on the cubital vein; and within is a narrower parallel brown line. The base of the wing is whitish ash. Between the basal and median line is a transverse series of lunules, which are brown on the costal region, the series consisting behind the subcostal vein of four reddish lunules; the row is much curved outward between the costa and internal vein. Beyond it is a narrow parallel brown line. Between this and the basal line the wing is darker than elsewhere. A distinct black discal transverse streak, widest on the median line, where it ends. Between this and the middle line the wing is white. A faint diffuse brown line just beyond the discal line, but the true extradiscal line is a series of reddish, connected patches or lunules, beginning on the subcostal vein and ending on the internal, the series being straight, not curved. Costa white marked with black. A long black streak near the apex inside of the costa, and a similar streak in the first cubital interspace. In the succeeding space near the internal angle is a conspicuous white streak, within which is a black spot. Apical region whitish, middle region of the outer fifth of the wing reddish, region of the internal angle brownish. Fringe ash, with dusky venular spots.

Hind wings of ♂ sordid white, varying to dusky, with a whitish extradiscal broad diffuse line; a dusky patch on the internal angle; in ♀ the wings are uniformly mouse brown, with no distinct pale lines. Underside of fore wings uniformly mouse brown, with four dark and five white spots on the outer third of the costa; hind wings in the ♂ whitish, in ♀ as on the upper side. Abdomen forked at the end as usual.

Expanse of wings, ♂ 31–33 mm., ♀ 31–32 mm.; length of body, ♂ 15–17 mm., ♀ 15 mm.

This is our commonest species of Schizura, and is easily recognized by its squarish fore wings and by the variety of its markings in white, reddish, black, and brown, there being four cross lines on the fore wing, the middle and extradiscal being composed of reddish brown lunules; by the two black subapical slashes, and by the white longitudinal short streak in the second cubital interspace, in front of which is a short, black streak, and within a black, roundish spot.

Cælodasys edmandsii Pack. is evidently a synonym of *S. unicornis*. The specimen (♂) marked *edmandsii* in Mr. Edwards's collection appears to be only a small *unicornis* with narrower wings than usual. The only difference is in the dusky tawny costa of the fore wings and the similarly tinted hind wings, due perhaps to imperfect preservation. *S. conspecta* H. Edw., one ♂ type from California in American Museum of Natural History, New York, is only a climatic variety of *S. unicornis;* the position of the markings is identical in the two forms, but *conspecta* is larger, the fore wings as much produced as in any of *unicornis*. The pale area on the outer third of the wing is clear and whitish, and the hind wings are clearer and whiter than in any eastern example of *unicornis*. This appears to be a climatic variety, following the same law of climatic variation as we have already referred to.

Egg.—"Greenish to yellowish gray in color; transverse diameter, 8 mm.; hemispherical. not flattened; surface under high power, with elevated ridges forming facets. A slight irregular roughening occurs about the micropylar region." ("Deposited in captivity in Feb." Riley MS.)

Larva.—The first stage of *S. unicornis* differs but slightly from that of *S. ipomeæ*. Length, 2 mm. The head and body are of the same proportions, the prothoracic tubercles of nearly the same size, but those on the back of the meso and metathoracic segments are larger than in *S. unicornis*. The tubercles on the abdominal segments are of nearly the same proportions, but slightly larger.

The first, third, and eighth abdominal segments are bright red in *unicornis* as in *ipomeæ*, and the colors and markings in general scarcely different from those of *ipomeæ*. The anal legs are the same in size and position in the two species, but the tubercles are on the whole larger in *ipomeæ*.

The hairs are clavate in *unicornis* and of the same proportionate length as in *ipomeæ*.

It thus appears that no genuine specific differences exist between the freshly hatched larvæ of *S. ipomeæ* and *unicornis* and most probably *leptinoides*, though the caterpillars are so different when fully fed. On the other hand, though we do not know the earliest stages of the other species of Schizura, yet from our knowledge of those of *Dasylophia anguina* there seems little doubt that the generic characters are quite clearly indicated in the first stage; that is, it will always be easy to separate Schizura larvæ just after hatching from those of any other genus of Notodontians, while if specimens of *S. ipomeæ* and *unicornis* of the first stage were mixed together it would be almost impossible to safely separate them according to the species, the incipient specific characters actually existing being too slight and indecisive.

Length, 20 mm. Body much compressed; head not so wide as the body, compressed, flattened in front, elevated toward the vertex, cleft, ending in two rounded conical tubercles, pale rust red, densely marbled with a fine net-work of darker lines. Body pale rust red, with a pale pea-green patch on the side of the second and third thoracic segments, not reaching to the anterior spiracle. First abdominal segment with a large high acute conical tubercle, bearing at tip two very slender, spreading, brown cylindrical tubercles. On fifth a slight hump, bearing two small warts; eighth segment bearing a rather large dorsal hump, supporting two dark warts; in front is a broken V-shaped silver mark, the apex directed forward. Anal legs brown, held out, with end of body, horizontally. Three lateral obscure, oblique lines connecting with a dark, obscure, lateral straight line placed some distance above the spiracles. Feet all rust-reddish, thoracic feet paler.

Length, 25 mm. Has a shorter smaller dorsal retractile tubercle than in *S. ipomeæ*. Thoracic segments pea green; the dorsal V-shaped mark on the seventh segment is prolonged to the front edge of the sixth segment, this part really forming a separate narrow V, in front of the apex, of which on fourth and fifth segments each is a dusky brown patch, between the reddish brown piliferous warts.

Before the last molt the larva is the same as the mature form. Length, 15 to 18 mm.

The dorsal hump is not so soft and retractile or sensitive as in the larva of *S. leptinoides*.

"It is a very singularly shaped caterpillar. General color in sound specimens, rich reddish brown, in others grayish brown, shaded with very minute spots of a darker color, which give it a shagreened appearance. A faint line of a darker color runs along each side from the third segment. It is variegated on the back with a lighter color, somewhat in the shape of a letter W as one looks from the head, and two lines forming a V mark.

"Larvæ found on the blackberry were mostly very pale, with the white Y mark on joints 9 and 10 very plain, with much glaucous color about the back, and with the other shades of purple-brown, flesh-brown, olive and pale green, which are found on the withering blackberry bushes, all present. The glaucous and brown colors are especially noticed on the canes of this plant." (Riley in Fifth Rep. U. S. Ent. Comm., p. 269.)

Cocoon.—"Thin and almost transparent, resembling parchment in texture, and covered generally with bits of leaves on the outside" (Harris). The larva spins a silk cocoon with the debris on the outside, judging by a specimen in the United States National Museum.

"The cocoon is a rather close, fine silken one, and transparent when the outer protecting material is removed. This last may be either a leaf, folded or otherwise, excrement, or other matter which the larva entangles in the loose outer web of the cocoon for concealment and protection." (Riley MS.)

Pupa.—Like that of *S. ipomeæ*, but slightly shorter, and the spine of the cremaster a little more acute. Hinder edge of thorax, with a transverse series of nine square black tubercles; surface slightly punctured, especially on the front edge of abdominal segments 5–7, the last three segments smooth, tip rather blunt. Cremaster small, the two spines short and stout, granulated and corrugated on the surface. Length, 20 mm. (From U. S. Nat. Mus.)

This is our commonest Schizura, and occurs on the willow and thorn late in August in Maine. August 28 one had spun a slight cocoon.

"Length varying from 12 to 21 mm.; color rich shiny brown. In general characters, and especially in the row of eight blunt, tooth-like, dull, black projections from the posterior dorsal margin of the mesothorax, it resembles closely the pupæ of the two other species of this genus which have this stage described, viz. *S. leptinoides* and *S. ipomeæ*. From these species it may be distinguished, however, by the character of the two prongs to the cremaster. These are much shorter than those of *ipomeæ* (which are three times as long as wide), being scarcely longer than the width, and the inner branches or teeth are short, and the small inner basal teeth are absent or nearly so. *S. leptinoides* is readily separated by the fact that the branches in this species are themselves branched or bitoothed.

"About four days are required for pupation from the spinning up of the larva. At first the color markings of the larva are retained with considerable distinctness in the pupa, but these are soon lost and the normal brown color assumed." (Riley MS.)

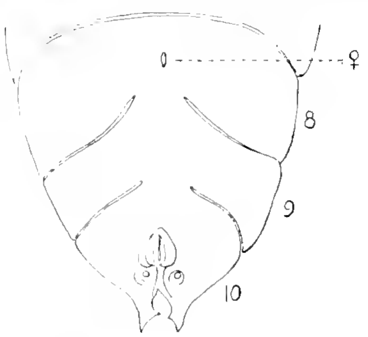

Fig. 79.—Pupa of *Schizura unicornis*.

Habits.—The caterpillar of this moth, more commonly met with on the apple tree, we have found September 6 on the elm at Brunswick, Me. At about this date, Harris says, it makes its cocoon, which is thin and almost transparent, resembling parchment in texture, and covered generally with bits of leaves on the outside. The caterpillars remain in their cocoons a long time previous to changing to chrysalids, and the moth appears the following May and June.

This and the other species of the genus are doubtless protected from the attacks of birds by their close resemblance to a dead, dry portion or blotch on the edge of the leaf, as they usually feed on the edge.

Miss Emma Payne was the first to call attention to its mimicry of leaves partly dead. We quote her interesting account:

I think this worm furnishes a wonderful instance of mimicry of the vegetable by the animal organism. The green segments just back of the head resemble a small portion of the green leaf, and the other parts admirably counterfeit the brown and russet tints of the dead leaf, while the form of the animal in its various postures aids the deception by its resemblance to a leaf partly alive and partly dead, the green mostly eaten and the brown torn. (Amer. Ent., ii, p. 341.)

I have noticed that this caterpillar feeds very conspicuously, but is protected by its resemblance to the twisted, partly dead ends of some of the leaves, the oblique markings of the larva resembling the twisted dead and russet portions of the leaf.

The following observations have been made by Professor Riley:

"The larva of the above species is found feeding on quite a number of different plants, such as oak, elm, plum, apple, dogwood, alder, winterberry, rose, and blackberry, also on hickory.

"The insect is evidently two brooded, those of the first brood spinning up at the commencement of July, while larvæ of a second brood, often only about one-fourth grown, are found as late as October 10.

"The cocoon is very thin and looks much like parchment. It frequently draws a few leaves together for this purpose, and changes to a chrysalis in about four days, which is at first of the same color as was the caterpillar, the green segments being distinctly visible, but soon changes to a shiny brown, with two points at the tail and one blunter one at the head. There are also slight elevations on the under part of the abdomen where the prolegs of the caterpillar were.

"The mimicry of the larva when on the blackberry, either stem or leaf, is perfect, and the imitative resemblance of the moth, when at rest, to the bark of a tree is still more striking. The moth always rests head downward with the legs all drawn together and its wings folded round the body, which is stretched out at an angle of about 45 degrees, the dull gray coloring of the wings with the lichen-green and flesh color giving the whole such a perfect appearance to a piece of rough bark that the deception is perfect.

"Some of the larvæ are, however, infested with Tachinids and with *Ophion purgator* Say." (Riley's unpublished notes.)

Food plants.—Apple, plum, thorn (*Cratægus*), elm, and probably poplar (Packard), *Betula alba* (Mrs. Dimmock); hazel (*Corylus americana*), *Prunus virginiana* (Lintner); *Prinos verticillatus* (Abbot); locust, cherry, dogwood, alder, ilex, oak (Beutenmüller).

Geographical distribution.—Common throughout the Appalachian and Austroriparian subprovinces. Its western limits not yet defined, though it inhabits Napa County, Cal., according to Edwards.

Canada (Saunders); Orono, Me. (Mrs. Fernald); Brunswick, Me. (Packard); Franconia, N. H. (Mrs. Slosson, and a fresh one was captured by her in the Summit House, on Mount Washington, New Hampshire, at the end of July); Boston, Mass. (Harris, Shurtleff, Sanborn); Rhode Island (Clark); New York (Grote, Lintner, Dyar); Plattsburg, N. Y. (Hudson); Racine, Wis. (Emma Payne); Manhattan, Kans. (Popenoe); Amherst, Mass. (Mrs. Fernald); Georgia (Abbot and Smith); Napa County, Cal. (H. Edwards); Canada, Kittery, Me.; New Hampshire, New York, Ohio, Wisconsin (French).

Summary of the steps in the assumption of the generic or adaptive, i. e., protective characters of three species of Schizura (S. ipomeæ, leptinoides, and unicornis).

The supergeneric features of the partly elevated, uplifted anal legs and a difference in the size of the tubercles appear at the time of hatching.

1. The head becomes marked much as in the adult in the second stage.

2. The tubercles begin to be differentiated in the second stage, when the prothoracic tubercles are much smaller than in the first.

3. The tubercles of the first abdominal segment, originally separate, become united at the base in the third, and form a single high-forked tubercle in the fourth stage.

4. The glandular hairs differ generically in the second stage from those in the first. The flattened glandular hairs appear in the second and disappear in the fourth stage.

5. The V-shaped dorsal mark on the sixth and seventh abdominal segments appears at the end of the third stage, and is due to the coalescence of three separate, whitish yellow spots.

6. The pea-green color of the meso- and metathoracic segments appears at the end of the third stage.

It thus appears that the mimetic colorational features, being those which especially enable the larva to escape observation, appear shortly before the creature is half grown, then changes occurring at the end of the third stage, while the movable terrifying tubercle of the first abdominal segment becomes developed at the same time.

When feeding on the edge of a leaf, the Schizuræ exactly imitate a portion of the fresh, green, serrated edge of a leaf, including a sere-brown withered spot, the angular, serrate outline of the back corresponding to the serrate outline of the edge of the leaf. And as the leaves only become spotted with sere-brown markings by the end of summer, so the single-brooded caterpillars do not, in the Northern States, develop so as to exhibit their protective coloration until late in the summer, i. e., by the middle and last of August.

A feature of some significance is the large size of the prothoracic tubercles in the larva of the first stage of *S. ipomeæ*, which in successive stages becomes reduced to a size no greater than those of the other thoracic segments.

Schizura badia (Packard).

(Pl. IV, fig. 23.)

Œdemasia badia Pack., Proc. Ent. Soc. Phil., iii, p. 361, 1864.
Heterocampa significata Walk., Cat. Lep. Het. Br. Mus., xxxii, p. 421, 1865 (*fide* Grote and Rob.)
Œdemasia badia Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 20, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 567, 1892.
Schizura nitida Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 204, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Larva.

(Pl. XXVII, figs. 1, 1*a*, 1*b*, 2, 2*a*–2*d*.)

Dyar (*ex. Thaxter*), Psyche, vi, p. 177, Nov., 1891; Proc. Bost. Soc. Nat. Hist., xxvi, p. 395, 1894. (Egg and stages I–V.)

Moth.—Three ♂. Head above and prothorax reddish brown. Palpi and patagia behind, blackish. Fore wings dark reddish with ashen and dark brown scales. Base of the wing reddish brown; in the discal space before the linear black discal mark a cinereous area, but this region is discolored with dark brown and continued to the outer edge as two blackish lines, one being the fifth subcostal venule, the scales over which spread out toward the apex. Outer margin with black and whitish streaks on the venules and in the interspaces. Apex white.

Hind wings whitish, becoming smoky toward the outer edge, especially on the venules. Beneath, smoky cinereous. On the outer edge of the fore wings is a row of small black dots; ends of the venules black.

Expanse of wings, ♂ 30 mm.; length of body, ♂ 13 mm.

In a well-preserved specimen collected by C. A. Shurtleff at Brookline, Mass. (Coll. Bost. Soc. Nat. Hist.), the patagia are much darker than the rest of the thorax; the middle yellowish ashen region is bordered on each side by zigzag lines; on the anterior half it is frosted over with fine whitish scales. The costal third of the wing is white. The dots of the marginal row are each succeeded within by white streaks. Abdomen pale cinereous, darker than the hind wings; the tip is not so distinctly divided as in *concinna*. *Schizura badia* may be easily distinguished by its deep reddish brown color, dark patagia, and light hind wings, and by the linear discal spot turning at a high angle outward, and by the reddish shade, or two reddish-brown lines, in the middle beyond. There are also distinct scalloped reddish brown lines at the base and beyond the discal spot. The thorax is also darker red.

Larva.—"I have found this larva on *Viburnum lentago*, and it is certainly not an *Œdemasia*. It is without the red hump and black tubercles of *Œ. concinna*, the body being smooth, with dorsal processes on the first, fourth, fifth, (?) and eighth abdominal segments; the sides of the thoracic segments are green, but the usual V-shaped mark is, I believe, absent. I have not been able to obtain the larva recently for more careful description." (Dyar in Psyche, vi, p. 177.)

I add Dr. Dyar's description of the egg and of Stages I–V. As my *nitida* is a synonym of *concinna*, Dyar's description must be that of *badia*. I am indebted to Dr. Dyar for specimens of *badia* forming the subjects of Pl. XXVII.

"*Egg.*—More than hemispherical, flat on the base, covered with shallow, rounded, hexagonal areas, not distinctly defined, and becoming obscure and punctiform around the micropyle. Diameter, 0.8 mm.; height, 0.6 mm. Laid three or four together on the under side of a leaf of the food plant (*Viburnum*).

"*First larval stage.*—On joint 2, two subdorsal setæ on enlarged bases; on joint 5 a single dorsal hump bears tubercle 1; on joints 6–11 two humps, tubercle 1 on each, becoming smaller posteriorly; on joint 12 a low single hump. Head higher than wide, the lobes distinct; pale testaceous brown. Body shining red-brown, finely mottled with yellow, this color replaced by clear yellow subdorsally on joints 3, 4, 6, 8, and 11, and subventrally on joints 6, 8, and 9; feet dark. The setæ have rather large, slightly conical, brown, chitinous tubercles, normal in arrangement (6 absent), with several on the lower part of the square brown leg plate; setæ slightly enlarged at tip. Anal feet elevated.

"*Second stage.*—Head bilobed with a tubercle at the apex of each lobe; red-brown with a rounded, pale yellow patch on each side of clypeus above, one on the side of each lobe and the clypeus itself the same color; ocelli dark; a few setæ; width, 0.7 mm. A red brown dorsal line with markings of the same color, finely yellow dotted, along the lateral area and covering the whole of joints 5, 7, 10, and 12; the rest of the body pale yellowish, especially on joint 8. The abdominal feet on joints 8 and 9 and the thoracic feet are pale. Tubercles 1 with enlarged bases, forming slight dorsal prominences on joints 2, 5, and 12. Anal feet brown, elevated. Setæ dusky with glandular tips, normal, six present with five or six setæ on leg plate.

"*Third stage.*—Head small in proportion to the body, bilobed with a large tubercle at apex of each lobe, rather flat before with several setæ; pale brownish white, shaded with brown posteriorly, with a vertical brown band before ocelli extending to vertex of each lobe, the pair connected by an angular cross band above clypeus and again, faintly, near the vertex; clypeus greenish, ocelli dark; width, 0.95 mm. Tubercles 1 with enlarged bases; a slight hump on joints 5 and 12 bearing 1 near the apex; a pair of tubercles in place of the cervical shield. Body at first yellowish, except the sides of joints 2–4, which are green. Later shining leaf-green. A purple-brown dorsal band dotted with white extends from joint 2 to the anal feet, widening a little on the middle of each segment, covering tubercle 1 on joint 5, but on joint 6, 1 is bright yellow; the brown color covers the whole of joint 7, even the foot, and stains the posterior half of joint 6 and a stigmatal patch on joint 5. Tubercle 1 on joint 8 yellow. The brown band covers 2 on joints 9 and 10 and stains the foot on joint 10, extending up anteriorly and also posteriorly on joint 11; it covers tubercle 1 only on joints 11 and 12 and, becoming very narrow on joint 13, passes to the anal feet. A faint white subdorsal band, stained with yellow, most distinct on joints 8 and 9, and forming a somewhat oblique yellowish mark on joint 11, suggesting the usual V-mark of Schizura larvæ. The green ground is partly replaced subventrally by whitish streaks. Thoracic feet pale. Setæ pale, with glandular tips.

"*Fourth stage.*—Head much as before, but a brown line extending up from the ocelli is all that is left of the brown on the sides of the lobes, and the band connecting the vertical lines above is broken. Width, 1.5 mm. Body as before in color, but the setæ stiff, distinct, not glandular. The green of the sides is considerably broken up by whitish streaks; tubercles 1 on joint 6, and 1 and 2 on joint 8, are yellow. As the stage advances the brown dorsal band partially fades out, the white subdorsal line, broken on joint 11, becomes more distinct, and its posterior part forms a distinct V-mark on joint 11. Tubercles 1 on joints 5 and 12 make slight, but distinct, furcate processes. These disappear in the next stage.

"*Fifth stage.*—Head small, flat before, rounded, higher than wide; white, with a faint yellowish tinge; from each side of base of clypeus a band extends to vertex of each lobe, cut by a small spot of the ground color each side of the clypeus and a larger one opposite apex of clypeus and narrowly bordering clypeus above; this band is purple-brown, mottled with round dots of the ground color; a similar fainter band behind the ocelli. A very slight prominence on joints 5 and 12, low, scarcely even a hump; otherwise the body is smooth, tubercles absent, setæ small, dark, but tubercle 6 and those on the leg can be distinguished; anal feet elevated. Body green, clear on the sides of joints 2–4 with a dorsal purple-brown band mottled with white, which tapers and ends at joint 5. A white subdorsal shade on joints 5–13, diffuse downward and cut by oblique lines of the ground color (green), broken on joint 11, the posterior part continued forward from joint 11 on joint 10 and becoming yellow, forms a V-mark supplemented by a few dots on joints 9 and 11. A distinct yellow patch surrounds tubercle 1 on joints 6–8 with a yellow dotted dorsal shading; the spots 1 on joint 8 separated by a Y-shaped brown mark (in some cases the sides of joints 5–8 are more or less covered with dark brown, mottled with whitish, being remains of the brown marks of the previous stage), and the brown usually prevails in a band from the spiracle on joint 5 back to the abdominal feet. Bases of the feet around tubercle 6 waxy white, this area bordered by a rather irregular brown mark. Anal plate and feet dark. Spiracles pale brown. Thoracic feet tinged with reddish."

Food Plant.—*Viburnum lentago.* (Dyar.)

Habits.—Besides the facts already given, the moth occurred in New York in August. (Riley.)

Geographical distribution.—Boston, Mass. (Sanborn, Shurtleff, Harris, Coll.); Dutchess County, N. Y. (Dyar); Orono, Me. (Mrs. Fernald); Kittery, Me., Massachusetts, Illinois (French); New York (U. S. Nat. Mus., Dyar); New York, New Jersey (Palm).

Schizura perangulata (Edwards).

(Pl. VI, fig. 4 ♂, 5 ♂, 6 ♂.)

Œdemasia perangulata H. Edw., Papilio, ii, p. 125, Oct., 1882.
Smith, List Lep. Het. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 567, 1892.
Pack., Psyche, vi, p. 522, 1893.
Janassa lignicolor, var. *coloradensis*, H. Edw., Ent. Amer., i, p. 17, April, 1885.
Pack., Psyche, vi, p. 522, 1893.
Schizura perangulata Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 202, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Moth.—"Primaries grayish white, with a fawn-colored shade along the internal margin, especially toward the base of the wing. The anterior lines are obsolete, the posterior is broken on the costa, but its course may be traced by a series of imperfect streaks, nearly to the posterior margin, thence about the middle of the wing it forms a very acute angle to the center of the internal margin, and is slightly dentate outwardly. There is a conspicuous discal mark, some streaks near the apex of the costa and others near the internal angle, blackish brown, fringe fawn color. Secondaries sordid white, with a blackish blotch on anal angle, and the fringes and margin dusky. Beneath, the wings are sordid white, shading into dusky on the costa, the primaries broadly so, and inclosing some blackish streaks. Antennæ fawn color. Thorax brownish fawn color, mottled with darker shade, the collar brown-black. Abdomen sordid white, shading into fawn color at the base. Legs fawn color, mottled with brownish.

"Expanse of wings, 38 mm. One ♂, Colorado, Coll. H. Edwards." (Edwards in Papilio, ii, pp. 125, 126, Oct., 1882.)

This species may be easily recognized, and differs from its nearest ally, *S. eximia*, by the distinct linear discal mark. It has on the fore wings near the internal angle a series of brown slashes and a row of whitish-gray and dark slashes on the costa, near the apex, otherwise the Utah example is like it. The hind wings are white, with a dark spot on the internal angle; the wings are not dusky, nor with a whitish diffuse line such as is present in *S. eximia*. A ♂ in Mr. Neumoegen's collection from Canyon City, Colo. (Pl. VI, fig. 6), has the reddish colors of *S. eximia*, but it may be at once separated from it by the large linear discal mark. The fore wings are crossed by reddish zigzag lines. The large dark shade or blotch beyond the discal mark is present, and the black slashes on the costal region and at the internal angle are well marked. The long black streak on the base of the wing, along the cubital vein, is present and very distinct. A ♂ specimen from Ogden, Utah (U. S. Nat. Museum, Pl. VI, fig. 5), is much bleached, without the reddish-brown zigzag lines, and the fore wings are very pale silvery white on the costal region; the veins are darker, the linear discal mark is indistinct, and beyond it is the usual dusky patch. The black stripes at the base of the wing extending along the cubital vein, and also along the inner edge, are distinct. The hind wings are white, with a dusky discoloration along the internal angle.

Expanse of wings, ♂ 41–43 mm.; length of body, ♂ 20–21 mm.

Geographical distribution.—A member of the Campestrian subprovince, it is not known to exist either east or west of the Great Basin and Colorado Plains.

Denver, Canyon City, Colo. (Bruce, in Neumoegen collection); Salt Lake, Utah (Edwards); Ogden, Utah, June 20, 1885 (U. S. Nat. Museum), Colorado (French); State of Washington (Strecker). I have examined this specimen, which extends the distribution of this species to near the Pacific Coast unless it occurred in a locality in the State east of the Cascade range.

Schizura eximia (Grote).

(Pl. VI, fig. 7 ♂.)

Œdemasia eximia Grote, Bull. U. S. Geol. and Geogr. Surv. Terr., Hayden, vi, p. 275, Sept. 19, 1881.
Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 567, 1892.
Schizura eximia Packard, Psyche, vi, p. 522, Sept., 1893.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 202, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 116, Sept., 1894.

Larva.

Pl. XXVII, fig. 3.

Thaxter, Can. Ent., xxiii, p. 34, 1891. (Food plant given.)
Thaxter, quoted by *Dyar*, Psyche, vi, p. 177, Nov., 1891. (Brief description of larva.)
Dyar, Proc. Bost. Soc. Nat. Hist., xxvi, p. 397, 1891. (Stage IV described.)

Moth.—Three ♂. Very closely related to *S. concinna*, differing chiefly in the more produced fore wings, with the outer angle more oblique, and in its larger size. Head above and thorax ash-gray, with a slight olive-green tint, behind reddish brown, as in *S. concinna*. Fore wings much produced toward the apex, the outer edge very oblique. The markings and shades and discoloration absent, exactly as in *S. concinna*, including the costal region, the internal region, and the position, shape, and color of the round black discal dot. The internal region or margin of the wing is less black than in *S. concinna*, and more as in *S. badia*, but darker and claret reddish; the costal region is more distinctly marked with oblique dusky streaks than most of my examples of *S. concinna*, and in this respect the costa is marked more as in *badia*. The long narrow blackish basal streak on the submedian fold as in *S. concinna*. Hind wings whitish, with a large dusky patch at the internal angle. The underside of both wings pale whitish and marked as in *S. concinna*.

Expanse of wing, ♂ 48 mm.; length of body, ♂ 18 mm.

Grote, in his description, compares this moth with *S. badia*, and does not refer to its close resemblance to *S. concinna*. It differs entirely from *S. badia* in its round discal dot, that of *S. badia* being long and linear; the thorax and wings are less reddish brown, and the wings are much more elongated toward the pointed apex.

Larva.—Dyar, who regards (Psyche, November, 1891, p. 177) this species as "improperly referred to Œdemasia," and places it "next to *S. leptinoides* and near *Janassa*," quotes the following brief description of it from a letter from Dr. Thaxter:

Œdemasia eximia resembles *Cœlodasys leptinoides* in coloring, but structurally is perhaps more like *biguttatus* (*ipomeæ*). When at rest it is greatly hunched anteriorly, and the furcate prominence on segment 4 is very long. I should say it was surely a Cœlodasys.

I copy Dyar's description of Stage IV of this species. He states that the "larva superficially greatly resembles *Schizura leptinoides*, and was at first mistaken for it."

"*Fourth larval stage.*—Head high, slightly bilobed, flat before; sordid whitish with a vertical band on each side composed of brown-black dots confluent in streaks, continuous on its posterior edge but breaking up inwardly, the pair connected across the median suture by three more reddish but similar bands, which are indented on the suture and, joining there, border the clypeus. Markings on side of head also reddish, dotted, confusedly, broadly reticulate. Width, 2.3 mm. A long, nutant process on joint 5 preceded by an elevation on joint 4; a slight hump on joint 9 and a little larger one on joint 12, bearing the whitish tubercles I. Sides of joints 2–4 sordid whitish, confusedly reticulate with bands of reddish dots which become blackish stigmatally and dorsally, forming a narrow stigmatal and dorsal band. Body pale brown, faintly marked with dots of red-brown or blackish. V-mark distinct, pale yellow, with no inclosed dot. There is a velvety brown-black subdorsal shade, irregularly touching the region of tubercles 1 and 2, beginning in a narrow line on the side of the process on joint 5, becoming more and more pronounced posteriorly till it fills in all the space around the V-mark. Joint 12 is again lighter, the brown shade forming a pair of narrow lines on the anterior side of the hump, but obtaining again on joint 13. Trace of a lateral line, but broken and diffuse. A distinct substigmatal line. Abdominal feet on joints 7–10 pale, marked with reddish mottlings, the claspers vinous. An oblique brown line runs from base of the horn on joint 5 to the anterior side of the foot on joint 7, and another, subventrally, from below the hump on joint 12 to the posterior side of the foot on joint 10 and, continued back subventrally, ends on the anal foot. Setæ short, rather dark.

"*Fifth stage.*—Much as before, but the process on joint 4 is pronounced, leaning backward to touch the horn on joint 5; width of head, 3.5 mm. There is a trace of a hump only on joint 8. V-mark distinct, *pinkish*, with centering red lines, but remaining narrow, not diffuse. Dorsal shade mossy olivaceous brown, distinct only on joints 9–13, often quite greenish on joints 10 and

11; joints 6-8 suffused with pinkish dorsally. The area on the sides of joints 2-4 and the bases of the feet on joints 7-10 below the substigmatal line translucent whitish, with sparse, dotted, brown reticulations. Horn 6 mm. long, tapering, the distal half slender. When full grown the larva becomes paler throughout, though different individuals vary in shade. Feeds solitary on the edge of a leaf."

Food plant.—Salix, Populus (Thaxter); white birch (*Betula papyrifera*), maple, beech; apple, (Beutenmüller); "a larva was found on the ground under an elm tree" (Dyar); "a more general feeder than *leptinoides*" (Dyar).

Geographical distribution.—So far as yet known, an inhabitant of the northern portion of the Appalachian subprovince.

Franconia, N. H. (Mrs. Slosson); Roxbury, Mass., (Sanborn, Bost. Soc. Nat. Hist.); Kittery, Me. (Thaxter, French); Plattsburg, N. Y. (Hudson); New York (H. Edwards); northern Kentucky (Sanborn, Mus. Comp. Zool.); Massachusetts, New York, Champlain, Ill. (French); New York (Dyar); Seattle, Wash. (Dyar); Pennsylvania, British Columbia (Palm); Keene Valley, New York (Dyar).

Schizura concinna (Abbot and Smith).

(Pl. VI, figs. 1 and 2, ♂, 3, ♀.)

Phalæna concinna Abbot and Smith, Nat. Hist. Lep. Ins. Georgia, ii, p. 169, Pl. LXXXV, 1797.
Notodonta concinna Harris, Rep. Ins. inj. Veg. Mass., p. 309, 1841; Treatise on Ins. inj. Veg., third edit., pp. 425, 426, larva fig. 210, Pl. VI, fig. 11, 1862 (colored fig. of moth).
Edema concinna Walk., Cat. Lep. Het. Br. Mus., v, p. 1030, 1855.
Notodonta concinna Fitch, Third Rep. nox. Ins. N. York, p. 342, 1856.
Edema concinna Morris, Synopsis Lep. N. Amer., p. 242, 1862.
Œdemasia concinna Pack., Proc. Ent. Soc. Phil., iii, p. 360, 1864.
Œdemasia nitida Pack., Proc. Ent. Soc. Phil., iii, p. 360, 1864.
Notodonta concinna Riley, Amer. Ent., ii, p. 27, Sept. and Oct., 1869. (Figures larva, pupa, and moth, the latter copied from Harris.)
Heterocampa salicis Edwards, Proc. Cal. Acad. Sci., vii, p. 121, 1876.
Œdemasia concinna Grote, New Check List N. Amer. Moths, p. 19, 1882.
Œdemasia nitida Grote, New Check List N. Amer. Moths, p. 19, 1882.
Riley, Report Entomologist U. S. Dept. Agr. for 1884, p. 411, 1885.
Packard, Fifth Rep. U. S. Ent. Comm. Forest Ins., p. 457, 1890.
Notodonta concinna Dimmock (Anna K.), Psyche, iv, p. 279, 1885.
Dryocampa riversii Behr., Proc. Cal. Acad. Sc. (2) ii, p. 94, 1890. (*S. salicis*, *fide* Dyar in letter).
Œdemasia concinna Smith, List. Lep. Bor. Amer., p. 30, 1891.
Œdemasia salicis Dyar, Psyche, vi, p. 177, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 567, 1892.
Œdemasia nitida Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 567, 1892.
Schizura concinna Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 202, June, 1894; Journ. N. Y. Ent. Soc, ii, p. 116, Sept., 1894.

Larva.

(Pl. XXVI, figs. 5, 5a-5f.)

Abbot and Smith, Nat. Hist. Lep. Ins. Georgia, ii, p. 169, Tab. LXXXV, 1797. (All stages figured.)
Fitch, Third Rep. Nox. Ins. N. York, p. 342, 1856.
Harris, Treat, Ins. inj. Veg., 3d edit., p. 425, 1862, moth, Pl. VI, fig. 11, larva, fig. 210 in text.
Ent. Corresp., p. 303, Pl. I, fig. 3, 1869. (Larva).
Marten, Trans. Dept. Agr. Ill., xviii, Append., p. 120, 1880.
Saunders, Can. Ent., xiii, p. 138, 1881; 12th Rep. Ent. Soc. Ontario, p. 21, 1882; Ins. inj. Forests, p. 63, 1883 (compiled, figs. copied from Riley and Harris).
Edwards and Elliot, Papilio, iii, p. 130, 1883.
Beutenmüller, Entomologica Americana, iii, p. 157, 1887. (List of food plants.)
Riley, Rep. Ent. U. S. Dept. Agr. for 1884, p. 411, 1885 (figs. of larva, pupa, and moth).
Dimmock, Anna K., Psyche, iv, p. 279, 1885.
Packard, Fifth Rep. U. S. Ent. Comm. on Forest Ins., p. 457, 1890. (Larval Stages II, III, V.)
Proc. Bost. Soc. Nat. Hist., xxiv, p. 531, 1890. (Egg and larval Stages II, IV, V.)
Journ. N. York Ent. Soc., i, p. 68-69, June, 1893. (Larval Stages I, II.)
Dyar, Psyche, vi, p. 177, 1891. (Stages III to V of *Œdemasia salicis*.)

Moth.—Three ♂, five ♀. Head ash, tawny ashen, with reddish brown discolorations, thorax ash color with reddish brown scales behind. Fore wings very pale tawny in the middle of the wing, between the cinereous costa and the brown inner margin. No transverse lines. At the base along the cubital vein is a dark streak; there are three dark spots on the costo apical region; another faint linear minute streak in the apical interspace; in the two spaces below are two faint, long, linear slight lines between the dark venules. A minute but distinct discal dot succeeded by a linear streak reaching to the outer margin. Near the internal angle are two unequal linear spots. A faint row of marginal brown lunules. Near the internal angle is a brown geminate discoloration. Hind wings in ♂ white with a dusky discoloration on the inner angle. Wings beneath pale; fore wings a little dusky externally; the three costo-apical dots and the spotted fringe visible beneath. Fringe brown on the venules.

Female: Base of the fore wings fuscous; beyond ashy; a distinct submedian dark basal streak, a minute discal dot, with a faint brown streak beyond. Two twin costo-apical streaks, more distinct than in the ♂, so also two larger, broader spots near the internal angle. The marginal row of spots more distinct. Hind wings dark, ashy, reddish brown.

Expanse of wings, ♂ 30 mm., ♀ 30–31 mm.; length of body, ♂ 16 mm., ♀ 17 mm.

It differs from *badia* in the wings being narrower and longer; the base of the fore wings is less reddish, rounder, not lunate. The fringe is whiter on the edge; there is no reddish tinge on the hind wings. It is a slender species. After a careful examination I am unable to perceive any difference between what I have decided to be *nitida* and this species. This species, like the rest of the genus, is remarkable for the difference in the color of the hind wings in the two sexes.

A ♂ in the United States National Museum, labeled "240 L, from Cœur d'Alene City, Idaho, August 29, 1891," is, though rubbed, evidently paler on the fore wings, with less reddish brown than the Eastern individuals. There is no doubt about the species, as the basal longitudinal reddish stripe is present, and it does not differ materially otherwise. It is no larger, the alar expanse being 30 mm.

Var. *salicis* Edw. (one ♂. Type, California. I also have a ♂ given me some years since by Mr. Edwards). I can not, after repeated examination, really perceive any difference between this and the Eastern *concinna;* it only differs in size, being a little larger and with slightly more pointed fore wings, as one would expect to find it, in accordance with the facts pointed out in my Monograph of Geometrid Moths (p. 587), where a list of twenty-five species of Geometrids, which grow larger on the Pacific than the Atlantic Coast, is given. The three last stages are described by Mr. Dyar, and show that the larva is closely similar in each stage to the Eastern *concinna.* Mr. Edwards's description of the mature larva agrees exactly with our Rhode Island examples.

Egg.—Diameter about 6 mm. Low hemispherical, the height being about half the diameter. The shell is thin, smooth, and under a triplet not seen to be pitted, but under a half-inch objective the surface is seen to be divided into regular, moderately large, flat polygonal areas, with slightly raised but distinct edges. No micropyle visible, and no specialized arrangement of the polygons on the apex of the egg.

Freshly hatched larva.—Length, 3 mm. Head large, globular, smooth, and unarmed, a third wider than the body, deep dark, honey-yellow. The body is greenish yellow above, cherry-reddish on the sides; the prothoracic dorsal tubercles are larger and higher than those on the second and third thoracic segments and connected by a chitinous band, becoming more distinct in Stages II and III. The first and eighth abdominal segments are reddish, including the pair of dorsal tubercles, which are of the same size. The end of the body is held up, much as in the fully grown larva, and I mistook it for a Schizura larva, like the ordinary species, until after it had molted, as the tubercles are conical in this stage as in freshly hatched Schizura of other species. In some individuals the greenish dorsal tubercles are dark at the tip. The glandular hairs are bulbous at the tips, and a few at each end are nearly one-half as long as the body.

Three days after, June 27, they became 5 mm. in length, the head now small, and the larvæ were preparing to molt, and July 29–30 three cast their skins.

Stage II.—Length, 4–5 mm. at first. Now the body is like dark opaque varnish in color. The head is dark reddish varnish or pitchy in hue, and decidedly narrows above, bearing two blunt knobs on the vertex; it is now wider than the body. The prothoracic shield is larger than before. The sides of the second and third thoracic segments are yellowish with reddish lines, and on the sides of the seventh abdominal segment is a pair of lobed bright straw yellow spots converging behind, and lower down are three yellow tubercles tipped with brown. There is a similar single yellow tubercle on each side of the ninth segment. The prothoracic dorsal tubercles are somewhat smaller than those on the first abdominal segment, and the eighth pair are also a little smaller, but all the other dorsal tubercles are still large and conspicuous.

The same stage.—Length, 6 mm. Head reddish amber, not dark coral-red as in the mature larva; angular on the sides, with two thick, stout, rather large, black tubercles on the vertex, bearing a hair; there are also five or six piliferous warts on each side of the head. Body with large piliferous warts, those on the prothoracic and first abdominal segments much larger (about three times) than the others, those on the prothoracic a little slenderer than those on the first abdominal segment; those on the eighth segment broader at the base, and rather larger than those on the first abdominal segment; those on the mesothoracic slightly larger than those on the metathoracic; those on the second abdominal very slightly larger than those on abdominal segments 3 to 6, the latter slightly decreasing in size from before backward, and all considerably smaller than those on the ninth and tenth abdominal segments. All the tubercles, except those on the head, bear slender hairs which are about one-third as long as the body is thick, and which are broad and flattened at the end, which is abruptly truncate. All the tubercles on the body are of the same color as the body, which is of a general mottled reddish hue, with no distinct traces of longitudinal bands, except along the base of the legs; the skin is minutely dotted with white specks and with small lateral black piliferous warts.

The only bright spots are the light straw-yellow bases of the dorsal tubercles on the second and third thoracic segments, besides a pair of latero-dorsal oblique bright yellow patches on the seventh abdominal segment and a small bright yellow spot on each side of the base of the tenth segment. All the legs, both thoracic and abdominal, are concolorous with the body. The anal legs are normal, but smaller than the others, with numerous hooks, and are held slightly uplifted.

Third stage.—Length, 9 mm. The body is rather stouter than in the previous stage. The head is black, and all the tubercles on the head and body, together with the thoracic legs, and the scale on the outside of the end of the abdominal legs are black. All the tubercles end in a hair, now acute and simple, while the tubercles themselves are higher and more pronounced than before. There are traces of a subdorsal and two lateral lines (these are effaced by the alcohol).

Fourth stage.—Length, 13 mm. The head is still black, with the two large black tubercles present, though smaller in proportion than before. All the tubercles on the body are much as in the last stage in their relative size and shape; those of the third thoracic segments are of the same size and height, the pair on the first abdominal segment being longer and larger than the others, and those on the eighth abdominal segment have not increased proportionately in size, but are still nearly twice as large as those on the seventh segment. The body is still reddish, with (in the alcoholic specimen) traces of three or four reddish lines on each side, which are bordered more or less regularly with whitish.

Fifth and last stage.—Length, 23–30 mm. Some notable changes have occurred in the coloration, while the shining black spines are much larger and more imposing than in the earlier stages, all these changes adapting the caterpillar more completely to its exposed mode of life.

The head is now deep coral-red, smooth, with no traces of the tubercles characteristic of the previous stages, the vertex being smooth and simply bilobed. The two prothoracic dorsal spines, instead of being larger than the other thoracic spines, as in Stage II, are much smaller, being only about one-fourth as long or as high as the mesothoracic pair; the latter are sometimes a little thicker but shorter than those on the third thoracic segment. Those on the first abdominal segment are very long, rather slender, and arise from a deep coral-red, soft, swollen hump, whose soft, red, swollen sides descend so as to embrace the spiracle. The dorsal spines of the second abdominal segment are of the same size as those on the third thoracic segment (smaller in specimens 30 mm. in length), those of the following segments decreasing in size to those of the seventh segment, while those on the eighth are slightly larger than those on the tenth segment.

The suranal plate is rounded, lozenge-shaped, with a row of four large piliferous warts extending across the middle, while around the hinder edge are four smaller ones. On each side of the black dorsal line are seven wavy black lines alternating with white ones, so that the caterpillar is very conspicuously banded and spotted. The small black tubercles on the side of the body all bear a single hair. The anal legs are normal, about a third smaller than the other abdominal legs, and with numerous hooks. The end of the body is often uplifted.

Until we know more of the exact structure and markings of the first stage, it would be premature to attempt to recapitulate the leading points in the ontogeny of this curious larva.

What we have taken to belong to the second stage of *concinna*, and whose exact coloration we failed to note when collected, shows that even probably when hatched from the egg the larva is provided with its full complement of spines, and even more, there being two on the head, which are lost in the last stage. Without specimens of all the other species for comparison, we can not properly interpret the nature of the singular ornamentation, so unlike that of any other Notodontian of the American or European fauna.

To recapitulate, it is to be noticed that:

1. The head is deep dull amber in Stage II, becoming black in Stages III and IV, and deep coral-red in the last stage. The head is angular or squarish in Stages II–IV, bearing on the vertex a pair of tubercles which disappear at the final molt. Of what use these tubercles are in the early stages, and why if useful at that period of the insect's life they are not retained in the last stage, is difficult to understand, though the smooth shining dark coral-red head may, and doubtless does, make the creature more conspicuous.

2. The hairs in the second stage are, as usual, enlarged at the end, being flattened and suddenly truncated.

3. A swollen coral-red dorsal hump arises in the last stage on the first abdominal segment, bearing two very long, black, blunt spines, which can be moved by the larva so as to terrify its enemies.

4. The great dorsal spines along the entire body, and the large lateral ones, like elongated hobnails, have in general grown larger from the second to the last stage, rendering the creature probably still more distasteful and repulsive to birds and less open to attack from parasitic insects.

5. It is worthy of notice that in this species the dorsal tubercles and spines are separated widely, while in other Schizuræ those of the first and eighth abdominal segments grow together and form a single more or less movable terrifying spine. Xylinodes is intermediate, the tubercles on the hump being in pairs.

6. On account of these unique characteristics and its system of conspicuous markings and noticeable appendages, which all unite in giving warning to birds that it is inedible, and the entire absence of protective mimicry, this larva occupies an unique place in the Notodontian group. In other Schizuræ we have a mixture of two properties; the larva is both disguised so as to resemble a part of a brown-spotted green leaf, and has a movable deterrent spine on the back. In Symmerista the larva is so gaily colored as to at once indicate to birds that it is distasteful, but there are no deterrent spines or bristles. It is obvious that experiments should be made by feeding Symmerista, Schizura, and Dasylophia larvæ to birds in order to see if they would be rejected or not.

The young, at least after the first molt, are so spiny that it is difficult to say from what existing form this caterpillar may have descended, though the stem-form was a Schizura, as Stage I shows.

Cocoon.—Resembling that of *S. unicornis*. (Harris.) "The cocoon is formed of very close fine glossy silk, the leaves of the plant being drawn around it so as to conceal it entirely. It is almost egg-shaped and very symmetrical." (Edwards.) A cocoon given me by Mr. Beutenmüller is regularly oval, of silk, rather thin, semitransparent, and 15 mm. in length. It was spun between leaves. Two broods in New York; the spring brood spinning on leaves, the winter brood in the earth (Elliot).

Pupa.—"Short, broad, bright chestnut brown, very glossy and shining, the abdominal portion showing the few hairs of the larval tubercles." (Edwards.)

Habits.—Abbot states that in Georgia it breeds twice a year, the first brood making its cocoons toward the end of May, the moths appearing fifteen days afterwards. As is well known in the Northern States, the caterpillars of this species are common and conspicuous, feeding in clusters in a very exposed manner on apple leaves.

Harris states that the eggs are laid during July "in clusters on the underside of a leaf, generally near the end of a branch." He then observes: "When first hatched they eat only the substance of the under side of the leaf, leaving the skin of the upperside and all the veins untouched, but as they grow larger and stronger they devour whole leaves from the point to the stalk, and go from leaf to leaf down the twigs and branches" (Treatise, p. 425). He adds: The fully grown caterpillars "rest close together on the twigs, when not eating, and sometimes entirely cover the small twigs and ends of the branches. The early broods come to their growth and leave the trees by the middle of August, and the others between this time and the latter part of September. All the caterpillars of the same brood descend at one time and disappear in the night. They conceal themselves under leaves, or just beneath the surface of the soil, and make their cocoons, which resemble those of the Unicorn Notodonta. They remain a long time in their cocoons before changing to chrysalids, and are transformed to moths toward the end of June or the beginning of July" (Treatise, pp. 425–426). This habit of feeding exposed and living gregariously up to the time of pupation proves the almost entire immunity enjoyed by this caterpillar from the attacks of birds. We have also noticed in Providence the simultaneous and sudden disappearance of a whole brood from an apple tree at the end of September.

Regarding the habits of this species in California, Mr. Edwards states that he detected the caterpillars in the fall of 1875 "feeding upon willows in the neighborhood of Mount Shasta. Six caterpillars taken, all feeding close together, upon a dwarf willow, their brilliant colors giving to the plant at a little distance the appearance of a raceme of showy flowers. In a few days they began to undergo their change, and by the 27th of August had all transformed. The perfect insects began to appear on the 22d of December, a second followed on the 9th of January, and the third on the 16th of March. The remaining specimens all died in the chrysalis state." Mr. Dyar found the larvæ he describes on the maple in the Yosemite Valley in August.

The moth has been bred by Mr. Elliot from the willow, and I have found it in different stages of growth on the willow at Brunswick, Me., in August and September. It also feeds on the aspen and blackberry in Maine. I have also found the caterpillar feeding on the huckleberry (*Vaccinium*).

I found the eggs with the larvæ just hatching on the leaves of the willow at Brunswick, Me., June 21. The eggs were in this case somewhat scattered and few in number, and the larvæ did not feed gregariously. The larvæ continue to hatch till the early part of August in Maine, as August 14 I found the larvæ in Stage II and also fully grown on the aspen.

"This curious and well known caterpillar was received in August from Oregon. Mr. F. S. Matteson, of Aumsville, states that he found it in large numbers on a young apple tree, entirely denuding the branches of leaves. This mention is made as bearing upon the geographical distribution of the species. The gregarious habits of these larvæ when first hatched admit of an easy remedy in hand picking." (Riley, Rep. U. S. Dept. Agr., 1884.)

After the second molt some of the larvæ are ichneumoned. September 2 an ichneumon larva had issued from the ventral side of the caterpillar and spun a white thin cocoon; the nearly dead caterpillar was fastened by its back to the cocoon. After a day or two the caterpillar died and turned whitish, the rows of black warts becoming conspicuous.

Riley has observed the eggs in June; the larvæ from June to October; the moths in May and August.

Food plants.—Apple, cherry, plum, rose, thorn, pear, *Betula alba*, willow, aspen, blackberry, bramble, huckleberry (*Vaccinium*). I have found the larvæ in Maine most commonly on the willow, and it is probably from this tree that the insect has migrated to our fruit trees. In California it feeds on the willow (Edwards) and maple (Dyar).

In Beutenmüller's list, besides the fruit trees already mentioned and different species of willow, he has found it on the flowering dogwood, sweet gum, persimmon, snowdrop tree, bayberry, and three different species of hickory. Apricot, wistaria, oak, locust, hickory, persimmon, poplar. (Riley.)

Geographical distribution.—This species has a wide range, extending throughout the Appalachian, Austroriparian, and Campestrian subprovinces from Maine and Canada to Missouri and southward to Texas, Georgia, and Florida.

London, Canada (Saunders); Quebec (Fyles); Brunswick, Me., common (Packard); Boston, Mass. (Sanborn, Harris); Amherst, Mass. (Mrs. Fernald); Newburg, N. Y. (Miss Morton); Plattsburg, N. Y. (Hudson); New York (Doll); Brooklyn, Long Island (Hulst); Providence, R. I. (Clark, Bridgham, Packard); Janesville, Md. (M. C. Z.); southern Illinois (French); Missouri (Miss Soule); Manhattan, Kans., "common on apple" (Popenoe); Aumsville, Oreg. (Matteson *fide* Riley); Kansas, Missouri, Idaho, California, Oregon, Iowa, New York, District of Columbia, and Virginia, Cœur d'Alene City, Idaho, August 29 (U. S. Nat. Mus.); *salicis*, Mount Shasta (H. Edwards), and Yosemite Valley (Dyar): Normal form. Florida (Palm); Canada, Kittery (Me.): Massachusetts, New York, Maryland, North Carolina, Georgia (French); var. *salicis* California (French).

Seirodonta Grote and Robinson.

(Pl. XLV, figs. 1, 1*a*, and 1*b*, venation. Pl. XLVIII, fig. 10, palpus.)

Cecrita? (in part) Pack., Proc. Ent. Soc. Phil., iii, p. 359, Nov., 1864.
Heterocampa (in part) Walk., Cat. Lep. Het. Brit. Mus., Part xxxiii, p. 419, 1865.
Edema (in part) Walk., Cat. Lep. Het. Brit. Mus., Part xxxii, p. 426, 1865.
Seirodonta Grote and Rob. (inedited), List. Lep. N. Amer., p. xi, Sept., 1868.
Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, pp. 569, 929, 1892.
Cecrita, in part, Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 206, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Moth.—♂ and ♀. Head prominent, not quite as large as in Heterocampa; vertex broad, triangular, with a flattened tuft in front of each antenna. Clypeus square, full in the middle, and toward the vertex a median elevation. Antennæ of ♂ pectinated three-fourths to the tip, as in Heterocampa; in ♀ simple, with a few ciliated scales beneath. Maxillæ well developed, twice as long as the head, united and coiled up. Palpi porrect, extending well beyond the front; second joint rather narrow and long, with a few spreading scales below; third joint of moderate size, rather short, distinct, conical. Thorax not tufted, but the prothorax with long dense hairs beneath. Fore wings not quite half as broad as long; costa slightly convex at the base and apex, straight between, not bent at the apex; outer edge oblique, not angulated, but little shorter than the internal edge.

Venation: A long narrow subcostal cell, much as in Heterocampa (*H. manteo*), and the venation otherwise scarcely differs from that of *H. manteo*, except that the discal veins make a regular curved line. In the hind wings the costa is full near the base, more so than the species of Heterocampa; apex a little more pointed than in *H. manteo*; the outer edge slightly bent in the middle, while the costal vein is shorter, ending much nearer the middle of the costa than in Heterocampa. Legs rather long, with only a single pair of tibial spurs, the outer one being twice as long as the inner.

The genus differs from Heterocampa chiefly in the venation, the discal venules forming a line much curved in. I confess that these characters seem to me quite trivial, especially when we take into account the very close similarity of the larva to that of *H. manteo* and the great difficulty of distinguishing one from the other. I had concluded to unite it with the *Heterocampa*, but regard it provisionally as a distinct genus. The style of markings is not as we find it in *Heterocampa*, there being two definite lines on the fore wings, arranged, however, much as in *H. manteo*.

To place this species in the genus Cecrita, close by *guttiritta* and *biundata*, is scarcely allowable, since the larvæ seem to differ so much, though the earliest stages of *bilineata* have yet to be observed.

Larva.—Body cylindrical, head smooth, rounded, no wider than the body, which is marked almost precisely as in *Heterocampa manteo*, with two pale subdorsal lines, which diverge on the prothoracic segment, are close together on the second and third thoracic segments, and again widely separate from the front edge of the first abdominal segment to the end of the body; sometimes the space between is reddish and extends down on the sides of the third and sixth segments. A yellow or white spiracular line. A pair of small dorsal piliferous tubercles on the first and eighth abdominal segments; the other minute, much reduced. Anal legs long and slender.

Geographical distribution.—The single species known is confined to the Appalachian subprovince, but since it occurs at Franconia, N. H., may be found in the Hudsonian fauna.

Seirodonta bilineata (Packard).

(Pl. VI, Fig. 8 ♂.)

Cecrita? bilineata Pack., Proc. Ent. Soc. Phil., iii, p. 359, 1864.
Seirodonta bilineata Grote and Rob. (Inedited. Grote in letter.)
Heterocampa turbida Walk., Cat. Lep. Het. Brit. Mus., xxxii, p. 419, 1865 (*fide* Grote and Rob.).
Notodonta (Gluphisia?) ulmi Harris, Ent. Corresp., p. 302, 1869.
Edema? associata Walk., Cat. Lep. Het. Brit. Mus., xxxii, p. 426, 1865 (*fide* Grote and Rob.).
Seirodonta bilineata Grote, New Check List N. Amer. Moths, p. 19, 1882.
Pack., Fifth Rep. U. S. Ent. Comm. on Forest Insects, p. 268, 1890.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 569, 1892.
Cecrita bilineata Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 207, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Larva.

(Pl. XXIX, figs. 1, 1*a*. Pl. XXXV, figs. 1, 1*a*–1*c*; 2, 3.)

Harris, Ent. Corresp., p. 301 (Pl. II, figs. 2, 3), 1869. (Scarcely recognizable colored figures of larva.)
French, Can. Ent., xviii, p. 49, March, 1886. (Mature larva described.)
Packard, Fifth Rep. U. S. Ent. Comm. on Forest Insects, p. 268. (Uncolored figure, Pl. XXXII, fig. 4. Desc. ex Harris.

Moth.—Two ♂, two ♀. Body and wings uniformly mouse-colored. Upper side of the palpi and end of the patagia dark.

Fore wings crossed by two distinct, dark brown, scalloped lines edged with gray, the inner situated on the basal third of the wing and the outer forming the usual extradiscal line, the two approaching each other on the submedian fold.[1] The inner line is bent inward near the internal edge of the wing on the internal vein (VI), then curved outward between this vein and the subcostal vein. The outer line is bent outward on the internal vein and curved inward on the submedian fold, and thence by a series of scallops ends, after making a great curve on the outer fourth of the costa. The space between the two lines is slightly darker than the rest of the wing. A linear black, not very distinct, discal mark. Toward the apex are four dark costal marks. A very faint submarginal line.

Hind wings and abdomen a little paler than the thorax and fore wings; a dusky patch near the internal angle. Underside of the wings uniformly mouse-colored and concolorous with the upper side of the hind wings.

Expanse of wings, ♂ 40 mm., ♀ 35–40 mm.; length of body, ♂ 15 mm., ♀ 15–17 mm.

This plain, quakerish-in-garb species may be known by its uniform shining mouse tint and the two narrow distinct curved and scalloped dark lines which cross the fore wings, and by the pale mouse-colored hind wings.

Young and older individuals feeding on the elm were kindly sent me by Mr. Tallant, from Ohio, and were received July 10. A fully fed one (not mentioned, however, in the following description) was found under an elm at Bath, Me., in August.

Larva, Stage II.—"Head slightly bilobed, narrowed above, median suture deep; shining brownish black, the clypeus pale; width, 0.9 mm. Body with anal legs elevated, a little enlarged dorsally on abdominal segments 1 and 8. Where the large black tubercles of row i are uniform light green a yellowish subdorsal line faintly seen; anal legs reddish. Two dorsal purple-brown patches (in this individual) on segments 2–5 and 10–12, respectively, incised or almost broken at the intersegmental furrows. Setæ rather coarse, blackish, single from normal concolorous tubercles. Legs all pale. Length at end of stage about 9 mm. Calculated series of widths of head in 5 stages: I, .62; II, .95; III, 1.44; IV, 2.18; V, 3.3." (Dyar MS.)

Larva, Stage III (?).—Length, 10 mm. The head is much broader than the body, the front broad and flat, pale yellowish green, with long dark hairs, and on each side a curved black-brown line, not edged with white. The body is pale straw or lemon yellow, the sides below more greenish, with red specks and short curved lines in front, there being very few behind the first abdominal segment. The dorsal brick-red stripe is arranged as follows: On the prothoracic segment are

[1] This fold is the vestige of Vein V.

two thread lines which converge a little to meet the broad single band on the second and third thoracic segments, and including the two concolorous tubercles, which are dark at the tip, and are of the same size but farther apart than those on the eighth segment. On the first abdominal segment the red band breaks up into two subdorsal lines which pass into the blood-red, transverse, broad band on the third abdominal segment, which extends down each side of the segment. On the fourth and fifth segments are two parallel red lines, and on the sixth the broad single dorsal band passes down on each side, forming a lateral lobe not quite so large or so full and rounded as that on the third abdominal segment. This broad median, blood-red band contracts on the seventh and eighth segments, where it ends. The anal legs have a reddish line on each side. A fine irregular lateral yellowish line passes along the lower end of the spiracles, and there are faint indications of an upper lateral parallel yellowish line, which are most marked in front.

Piliferous warts: None on the first thoracic segment; two minute dorsal ones, all of the same size, on the second and third thoracic segments. Those on the first and eighth abdominal segments are large and equal in size; those on the second and third abdominal segments are a little larger than the others. The hairs on the dorsal warts are dark, those on the sides pale.

Stage IV (?).—Length, 15 mm. About to molt. The head with its dark lateral lines as before; the tubercles as before, but those on the first abdominal segment are rather larger and more prominent than those on the eighth segment. The two lateral lines on the second abdominal segment are much wider, so that the inclosed space is very narrow, and the broad transverse reddish band on the third abdominal segment is interrupted in the middle by a whitish green band which extends back more or less interruptedly to the seventh segment, on which it forms a broad, green, oblong spot, the green edged with white and inclosing a median line. The reddish band extends on each side of the ninth segment, and on the suranal plate is a lateral reddish, fine, broken line and a median whitish line. The anal legs are much as before. Two well-defined lateral yellow lines, while the body is more spotted along the whole length than before. The spiracles are pale reddish. The thoracic and abdominal legs are green. This larva is much like the drawings made by Bridgham (Pl. XXXV, fig. 3). It molted, after two days' rest, July 14; on July 26 it began to pupate when 25 mm. long.

Last stage.—Length, 25 mm. Head pale greenish, with a single dark purplish curved line on each side, not edged with white. Sides of the body greenish, speckled with reddish. (As the markings are not yet distinct, a further description could not be made.)

Full-fed larva.—One occurred on the elm August 30, at Providence (Bridgham); length, 27 mm. Head clear pale pea-green (not mottled with purplish), but the dark purple and white line is present on each side. No broad purplish discal band, the space inclosed by the white lines being whitish pale pea-green, and with a median white line beginning on the third thoracic segment. The dorsal and lateral piliferous warts are yellowish. The two subdorsal white lines extend out to the tip of the anal legs.

A full-grown larva received from Miss Caroline G. Soule July 24, from Brookline, Mass., on the 26th of July began to form a cocoon on the bottom of the breeding box. Length, 30 mm. Head greenish, finely mottled and netted with purplish; a faint dark purple line broadly edged behind with white. Two white subdorsal lines, very distinct on the abdominal segments and inclosing a broad purplish dorsal band, the two lines finely and faintly edged with reddish purple, and contracting a little on the somewhat humped eighth abdominal segment. The retractile anal legs have on each side a reddish purple line. The piliferous warts are all white, the hairs pale brown. A single yellowish spiracular line, most distinct on the thoracic segments. A second one not so distinctly marked and wanting the white edging of the lines on the head.

I have introduced these descriptions of *Seirodonta bilineata* and very carefully compared the alcoholic larvæ with those of *Heterocampa manteo* without as yet being able to detect any difference between these, except that in some individuals there are but two segments red on the side, where, as in *H. manteo*, there are three segments thus marked, though the moths differ in generic and specific characters.

On Pl. XXXV are represented the earlier larval stages of what I suppose to be this species rather than any of Heterocampa, as it fed on elm leaves. It will be seen that in the earlier stages this genus is a Schizura rather than a Heterocampa, and it is thus a connecting link between the two genera, and this justifies our placing it in a genus apart from Heterocampa, though its late larval and imaginal characters are closely similar to those of Heterocampa.

Cocoon.—Subterranean, or spinning a slight cocoon when in confinement. "This is a silken affair, loosely constructed (judging from fragment in collection), and with earth and sand incorporated and forming its predominating constituents." (Riley MS.)

Pupa.—Length, about 20 mm.; rather slender; reddish brown in color, shining; punctuation fine and not dense; dorsal teeth at suture between meso- and metathorax 10 in number, not large, nearly twice as wide as long, central one largest. Tip of abdomen with two strong spurs as in *S. ipomeæ*, bifurcate at tip, the inner branches approximating so as nearly to inclose a somewhat oval space. Spurs more or less tuberculate.

"Described from two pupal shells evidently of undersized individuals." (Riley MS.)

Food plants.—Elm (Harris, French, and myself), beech.

Habits.—This insect was known by Dr. Harris to inhabit the elm as early as 1837. The caterpillar is found from August until October. Professor French has also described the larva found on the elm. (Can. Ent., xviii, p. 49.) The larva which Harris (Ent. Corresp., p. 302) found under a sycamore and reared on sycamore leaves is evidently the young of *Heterocampa unicolor*. He found the caterpillar at Cambridge, Mass., on the elm in September and October, and observed it on fences August 28 and September 9, showing that the larva had then left its food tree. I probably was in error in stating in the footnote on page 268 of my report on Forest Insects that the figures of Harris in Pl. II "represent *Lochmæus manteo*," as the latter species is not known to feed upon the elm.

Professor French's excellent description was based on thirteen individuals, all taken on a young elm tree at Carbondale, Ill., September 29. "By October 5 all but one had disappeared for the purpose of pupation, going beneath the surface of the dirt in the breeding cage. Nine imagines were produced the following spring, the times of emergence ranging from May 24 to June 7. There seem to be two broods in a season, for larvæ were found on elms during the early part of summer, but these were not reared to find out the period of the summer brood."

Riley records the moths as occurring in April, June, July, and August.

Geographical distribution.—Not yet known beyond the limits of the Appalachian subprovince. Franconia, N. H. (Mrs. Slosson); Orono, Me. (Mrs. Fernald); Bath, Me. (Packard); Portland, Me. (E. S. Morse, Mus. Comp. Zool.); Boston, Mass. (Harris); Amherst, Mass. (Mrs. Fernald); Plattsburg, N. Y. (Hudson); Providence, R. I. (Packard); Columbus, Ohio (Tallant); Maine, Massachusetts, New Hampshire, Carbondale and Champaign, Ill. (French); New York, District of Columbia, Missouri, Arkansas, Texas (U. S. Nat. Mus.); Lawrence, Kans. (F. H. Snow, Mus. Comp. Zool.); Manhattan, Kans. (Popenoe); Chicago, Ill. (Westcott); Fort Collins, Colo. (Baker); Arkansas (Palm).

Heterocampa (Doubleday).

(Pl. XLV, figs. 2-4; XLVI, figs. 1-5; XLVII, figs. 1-3, venation; Pl. XLVIII, fig. 6, front of head; figs. 11, 12, palpi.)

Lochmæus and Heterocampa Doubleday, Entomologist, p. 57, 1841.
Misogada Walk., Cat. Lep. Het. Br. Mus., v, p. 992, 1855.
Heterocampa (in part), Walk., Cat. Lep. Het. Br. Mus., v, pp. 1022–1026, 1855.
Cecrita Walk., Cat. Lep. Br. Mus., xxxii, p. 419, 1855.
Stauropus? Doubleday, Harris Corresp., p. 131, 1869.
Lochmæus and Heterocampa Pack., Proc. Ent. Soc. Phil., iii, pp. 368, 370, 1864.
Litodonta Harvey, Can. Ent., viii, p. 5, Jan., 1876.
Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 563, 1892.
Heterocampa Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 563, 1892.
Heterocampa and *Cecrita* in part, Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, pp. 204, 206; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Moth.—♂ and ♀. Head larger and more prominent than in any of the foregoing genera, but smaller than in Cerura; vertex triangular; front rather narrow, subtriangular, narrowing below. Eyes naked; on each side of the eyes a long broad flat tuft, and on the head a dense tuft of long scales. Eyes naked. Antennæ well pectinated on the basal two thirds, beyond filiform; the branches more or less ciliated; the joints above not densely scaled. Palpi much larger and rather wider than usual, stout, ascending, reaching a little beyond the front; second joint longer than the first and rather longer than usual; the scales on the upper side short and dense, below much longer and uneven; third joint conical, often rather short, small, not always very distinct, being more or less concealed by the long loose hairs of the second joint.

Maxillæ longer than usual and very well developed, forming several coils. Thorax not crested. Fore wings rather less than one-half as long as broad; costa nearly straight or slightly convex; apex somewhat rounded or pointed or (in *hydromeli*) squarish, (in *unicolor* abruptly bent), but usually somewhat produced; outer edge long, oblique, convex (in *unicolor* sharply bent on first cubital venule, III_3). Hind wings shorter and more rounded at the apex than in any other genus of the family, outer edge shorter, more regularly rounded than usual; costal and inner edge of nearly the same length. Wings not tufted.

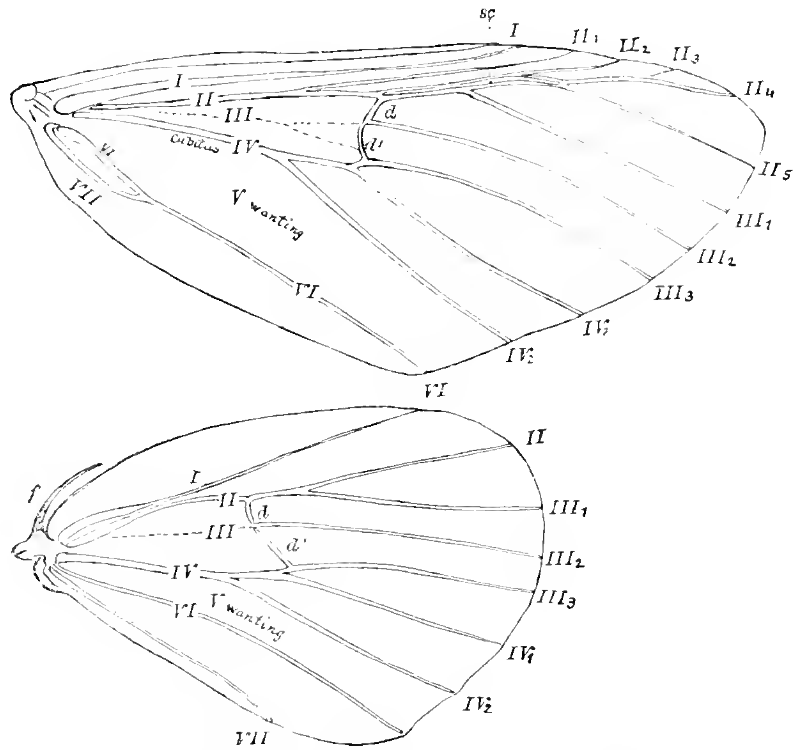

Fig. 80.—Venation of *Heterocampa obliqua*, the names of the veins as designated on p. 86. *d*, anterior, *d'*, posterior discal vein, *f*, frenulum, *sc*, subcostal cell.

Venation much as in Schizura, but quite variable: usually a long narrow subcostal cell, though it is sometimes open in individuals of the same species; the third subcostal venule is very short, and the cell between it and the fourth is minute; in the *superba* and *hydromeli* group the subcostal venules tend to be bent up at their end toward the costa, and so in *astarte* and *biundata*, but usually they are diverted more toward the apex, and then more parallel with the costa: the discal venules vary in length and direction: the anterior one is usually short and diverted obliquely inward to where it meets the sixth venule; the hinder discal venule either forms a regular curvilinear line, or is broken into two portions forming an angle with the apex, pointing inward, from which the median discal fold passes to the base of the wing; the first cubital vein (III_1) usually more or less detached at its origin from the second and at the bend throwing off the hinder discal venule (d').

Hind wings with the venation quite uniform, the first and second subcostal venules separating a short distance beyond the origin of the anterior discal venule, the first being a little shorter than the second branch (in *manteo* the second originates halfway between the first and the independent);

discal venules either situated nearer the base of the wings than usual, either forming a quite regular curvilinear line (*subrotata* and *guttivitta*), or the hinder venule is decidedly bent inward (*hydromeli* and *unicolor*) or regularly curved inward (*biundata*).

Legs rather stout, with thick, long tufts of scales; fore tibiæ with flat spreading tuft; hind tibiæ with two pairs of large, nearly equal, long, sharp spurs. Abdomen long, cylindrical, not tufted at the end, nor densely woolly, as in *Cerura*.

Coloration: The species are quite variable, but more or less dull gray, with indistinct scalloped transverse lines and an obscure linear or a twin discal spot; hind wings gray, with a faint interrupted diffuse outer line, or whitish; in the *subrotata* group the fore wings are pale ash, with tawny blotches at the base, and diffused over the wing, while the dark markings are more distinct.

The genus is characterized by the unusually short hind wings, with their well-rounded apex; the front of the head is rather narrow, the palpi stout and usually broad; the thorax very hairy beneath. The species are nearer those of Schizura than any other genus of the family, showing no near relationship to Cerura in adult characters, except the width of the head on the vertex. The limits of the genus are doubtful, and some authors may in the future decide to divide it into several, perhaps retaining Lochmæus and Cecrita as genera. I have been inclined to do this both from the venation and the larval characters, but when we take into consideration the unusual amount of individual variation in the venation such a course seems hazardous. If any division were to be made it must be to retain *Lochmæus* for a single species, *manteo*.

The genus may be divided into five subgenera, which are, however, more or less artificial, and appear to be perhaps incipient subgenera the result of the specialization of the type in different directions.

Subgenus 1 Fore wings long, apex squarish; hind wings well rounded; in the hind wings the second subcostal venule arising half way between the subcostal and independent .... *H.* (*Lochmæus*) *manteo*

Subgenus 2. Fore wings rather long, apex pointed; hind wings rounded, short; palpi not very thick and stout; fore wings gray, with olive-green or reddish tints, and obscure scalloped inner and outer lines; discal mark diffuse and indistinct; discal venules in both wings forming a regularly curved line.
H. (*Cecrita*) *umbrata, obliqua, astarte, guttivitta, biundata, and plumosa*

Subgenus 3. Antennæ with longer pectinations than in the other species: fore wings short, broad and square at the apex (*subrotata* and *hydromeli*); venation variable, the discal venules together forming an oblique curve. *subrotata*

Subgenus 4. Discal venules forming a rather sharp angle directed inward, and situated between the independent venule and the first cubital venule. Female antennæ nearly as well pectinated as in the male.
H. (*Litodonta*) *hydromeli*

Subgenus 5. Fore wings moderately long, with the outer edge bent, the fore wings very uniform in color, and without distinct markings of any kind; venation nearly identical with that of *astarte* and *obliqua*.
H. unicolor

The generic characters of *Litodonta* given by Harvey were these: "It differs by the antennæ being pectinate in both sexes. 'The thorax is more brushily tufted behind; the head more appressed; the abdomen shorter.'" It seems to us that these characters are not of generic value, as *H. subrotata* is very near *H. hydromeli*, but others may prefer to retain the genus as distinct, at least until something is known of the larval history.

Larva.—Body usually thickened in the middle; head with a red lateral band edged with white or with white and yellow, with equal red lines, the space between clear green, or filled in on first, third, and sixth abdominal segments with red, which in some species extends down on the side; anal legs either normal or long and slender. In Stage I larva either normal, unarmed, or with from one to nine pairs of deer-like antlers; anal legs with normal or (*H. unicolor*) with long, slender, eversible ends.

Cocoon.—Regular oval, translucent, like very thin parchment in color and structure; spun between leaves.

Pupa.—Body usually thick and plump: front of head with two parallel, slightly marked ridges between the eyes; cremaster armed with two stout, large, conical spines, differing much in shape in the different species.

Geographical distribution.—The genus is confined to the New World and the species range from Nova Scotia and Maine to Mexico, Central America, Surinam, and Brazil. At present more species are known to inhabit the Appalachian and Austroriparian subprovinces than any other region, and none have yet occurred on the Pacific Coast above Mexico. The genus is possibly of South American origin. I have also in my collection a species structurally and in style of coloration quite near *H. biundata* collected on or near the coast of Brazil by the late Prof. C. F. Hartt.

SYNOPSIS OF THE SPECIES.

1. (Subgenus *Lochmæus.*) Fore wings long; discal squarish black mark inclosed in whitish gray.
   Fore wings pale ash, crowned by four distinct scalloped lines....... *H. manteo*
2. (Subgenus *Cerita.*) Fore wings rather short, especially in ♂; apex squarish; discal mark diffuse, indistinct, gray, with olive green tint, and obscure scalloped inner and outer lines.
   Palpi short, partly black; fore wings ash-gray, often without a greenish tint; transverse lines indistinct, discal mark usually inclosed in a large, diffuse lunate pale ashen patch.......... *H. guttivitta*
   Palpi larger, blacker; body and fore wings more uniformly and persistently olive-green than in *guttivitta*, scalloped lines more distinct; no whitish ash discal patch; body and wings sometimes reddish instead of greenish.......... *H. biundata*
   Antennæ plumose; outer edge and fore wings oblique; brown-gray, markings much as in *biundata*; submarginal series of sublunate brown spots much as in *biundata*.......... *H. lunata*
3. (Subgenus *Heterocampa.*) Antennæ with long pectinations; discal mark curvilinear, black; wings greenish or brown, with distinct black stripes and lines.
   a. Fore wings produced toward apex, outer edge very oblique.
   Body and wings brown, the latter with black marks and reddish brown patches; a large oblique subapical white shade.......... *H. obliqua*
   Body and wings green; inner line on fore wings less curved than in *obliqua*; marginal black lines more deeply scalloped; a thoracic crest.......... *H. astarte*
   Without the subapical white shade; a heavy, broken, scalloped submarginal line; hind wings with a whitish line.......... *H. pulverea*
   Submarginal shade as in *pulverea*, but more dislocated.......... *H. belfragei*
   b. Fore wings short and square.
   Body and fore wings either uniformly ocherous or brown, with a broad, white, subapical shade, and a broad, curved, dark shade behind the distinct discal mark.......... *H. subrotata*
4. (Subgenus *Litodonta.*) Antennæ of ♀ heavily pectinated.
   A thoracic crest; thorax and fore wings marked with sea-green.......... *H. hydromeli*
5. (Subgenus *Stemmatocampa* (new).) Outer edge of wing oblique; no definite markings; of a pale ash or reddish brown hue.
   Two faintly marked scalloped lines on fore wings.......... *H. unicolor*

SYNOPSIS OF THE KNOWN LARVÆ.

A. Larvæ with normal anal legs and young larvæ with normal piliferous warts.
   A broad reddish band, extending from the side of first, third, and sixth abdominal segments.. *H. manteo*
B. Young larvæ armed with horns; anal legs longer in full-fed larvæ.
   Freshly hatched larva with nine pairs of horns; prothoracic pair of horns represented by tubercles in stages II–IV; spots on the side of first, third, and sixth abdominal segments either absent or small. *H. guttivitta*
   Young larva (Stage I) with a single pair of horns, persisting as tubercles through Stage IV. A large oblique russet spot on side of first, third, and sixth abdominal segments.......... *H. biundata*
   Full-grown larva with two prothoracic dorsal tubercles.......... *H. pulverea*
   Body of full-fed larva thickened in the middle; two dorsal red lines diverging on the first and widest apart on second abdominal segment, then converging only slightly toward the fourth and fifth, diverging very slightly again on sixth and seventh; in Stage I with six pairs of horns... *H. obliqua*
C. Body with long black anal filaments in Stage I; in last stage reduced to nearly normal length.
   Body green; a dorsal broad yellow and red band; no lateral lines.......... *H. unicolor*

Heterocampa manteo (Doubleday).

(Pl. V, fig. 1 ♂; VII, fig. 21 ♂.)

Lochmæus manteo Doubleday, Entomologist, p. 58, Jan., 1841.
Harris, Ent. Corresp., p. 131, 1869.
Heterocampa manteo Walk., Cat. Lep. Het. Brit. Mus., v, p. 1021, 1855.
Tadana cinerascens Walker, Cat., Lep. Het. Br. Mus., v, p. 991, 1855. (Fide Grote and Rob.).
Heterocampa manteo Morris, Synopsis Lep. N. Amer., p. 240, 1862.
Heterocampa subalbicans Grote, Proc. Ent. Soc. Phil., iii, p. 336, Dec., 1863, pl. 8, fig. 2 (a good figure); New Check List N. Amer. Moths, p. 19, 1882.
Packard, Fifth Rep. U. S. Ent. Comm., p. 158, 1890.
Smith, List Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het. Br., i, p. 564, 1892.
Heterocampa manteo Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 206, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Larva.

(Pl. XXIX, figs. 2–10.)

Doubleday, Entomologist, p. 58, Jan., 1841. (Uncolored figure of mature larva, plate facing p. 60, fig. 6; pupa, fig. 7.)
Comstock (J. H.), Rep. U. S. Dept. Agr. for 1880, pp. 259, 260, 1881.
Riley, Fifth Rep. U. S. Ent. Comm., pp. 158, 159, 1890.
Packard, Fifth Rep. U. S. Ent. Comm., p. 158, 1890.
Proc. Bost. Soc. Nat. Hist., xxiv, pp. 515–518, 1890.

Moth.—Three ♂, two ♀ (and others seen). Uniformly pale ash-gray, with three wavy diffuse darker lines crossing the fore wings, and a large, heavy, black discal mark, becoming in rubbed specimens two twin black dots inclosed in a pale ash spot. (Two very fresh and distinctly marked ♂ from the United States National Museum used in this description.) Male antennæ moderately well pectinated, but less so than in most of the species. Head and thorax light ash-gray; thorax behind over the mesoscutum darker. Fore wings ash-gray, varying from pale, almost whitish, ash to a darkish ash, and crossed by four usually distinct, deeply scalloped, dark lines, the scallops more or less filled in with pale gray. At the very base of the wings a short line composed of one scallop, which is deflected on the cubital vein and passing out along the internal vein becomes confluent with the second line. This second line is double, consisting of two parallel, four-scalloped, dark lines, which pass straight across the wing, ending the same distance from the base both on the costa and internal edge. A large, very conspicuous, transversely oblong, black discal spot, which in old rubbed specimens usually appears as two thin black dots inclosed in a pale area, and which is diagnostic of the species. Extradiscal line double, composed of about ten scallops; where it ends on the costa dislocated and set in from the subcostal portion. A little more than halfway from this to the edge of the wing is a dark, sharply zigzag, diffuse line. A marginal row of about seven distinct black dots.

Hind wings dark mouse colored, with a faint, diffuse, whitish line, and a dusky patch on the internal edge.

Underside of the fore wings like the upper side of the hind wings, with the costal edge on the outer third pale, with four dark spots. Hind wings sordid whitish; outer edge dusky, like the fore wings. Fringe pale gray, with the venular spots alternating with the more distinct marginal dots.

Hind legs very hairy, with two pairs of tibial spurs nearly equal in size.

Expanse of wings, ♂ 40–45 mm., ♀ 43 mm.; length of body, ♂ 21–23 mm., ♀ 20 mm.

This is the most common species of the genus, being sometimes abundant enough to be actually destructive to oaks in the Southern States. The species differs from the others of the genus in the large, black, wide discal spot, in rubbed specimens represented by two black dots in a pale field, in the uniformly pale ash color of the fore wings, and the four distinct, deeply and numerously scalloped lines.

Egg.—"About 0.8 mm. in diameter, hemispherical, shining; under high power, irregularly hexagonally sculptured, the sculptures consisting of raised lines. Color of dried specimen a dull pink." (Riley MS.)

From the inspection of the figure by Doubleday (probably copied from Abbot's colored drawing) of the larva of *Lochmæus manteo* Doubleday, I feel sure that *Heterocampa subalbicans* Grote is a synonym. Indeed, it has been referred with a doubt by Mr. Grote to his species. I am indebted to Professor Riley for an opportunity of examining and describing a series in alcohol of the larvæ in all the five stages (No. 2759 from box 12, 155), and have myself collected the caterpillar in its last two stages, while Professor Riley has given me a blown specimen and the opportunity of examining his own series.

Larva, Stage I.—Length, 4-6 mm. The head is very large, nearly twice as wide as the body, and flattened in front, the outline seen from in front being somewhat six-sided. There are six to seven minute piliferous warts, the black setæ arising from them being unusually large and stiff, and tapering at the end; around the base of the warts are brown discolorations, and the row of warts on each side of the median line, together with the outer row, are connected by an irregular, faint, brownish band.

The body narrows in width to the end. The dorsal and lateral tubercles are well developed, the dorsal ones being quite high, but on the whole rather small and all of the same shape; those on the prothoracic and first abdominal segments are of about the same size, and only a little larger than those on the second and third segments; the two dorsal ones on the eighth abdominal segment are of the same size as those on the first abdominal segment, but are nearer together and with somewhat larger bases. The ninth and tenth segments are rather long, with well developed tubercles. The supra-anal plate is well developed, being rounded, not so long as broad, bearing on the edge eight hairs, of which the two posterior ones are bristle-like and black; near the middle of the plate are two black dorsal bristles. The paranal lobes are large and full, each bearing an excrementiferal bristle. The anal legs are long and slender, being as long as the ninth segment, and are slightly retractile. The four anterior pairs of abdominal legs bear on the plantæ from sixteen to eighteen crochets. The setæ arising from the dorsal and lateral tubercles are long and large, and though apparently tubular, taper, some to a point, while others are slightly docked, but they do not, as usual, end in a broad clear tip. But along the extreme lower side of the first and second and seventh and eighth abdominal segments is a series of singular battledoor-like setæ, a pair to each of the segments named, and arising from the lowest tubercle on the side of the segment.

These battledoor hairs, which are modified secretory setæ, are very short, only from one-third to one-half as long as the other setæ, and have a slender pedicel enlarging into an elongate bulbous expansion, the surface of which is striated or wrinkled longitudinally, while the tip appears under a half inch objective to be clear. There is also a pair of remarkable foliaceous oval appendages at the end of the thoracic legs, which we have not seen in the few other larva whose feet we have specially examined. These are described and figured in our paper on the "External structure of caterpillars."[1]

The colors, being well preserved in the alcoholic specimens examined, may be described in the absence of the living. The head is amber, mixed with resinous. The body is whitish above; the tubercles and their bases pale straw-yellow, as are the anal region and anal legs; the setæ are brownish, and there are pinkish stains at the base of the prothoracic and first and eighth abdominal dorsal tubercles. Hence it seems that in the first stage of this species the mode of coloration of the final stage (V) is already indicated.

Second stage.—Length, 10-11 mm. The head is now proportionately smaller than before, the dark spots more exaggerated, and the twin dorsal tubercles on the prothoracic and first and eighth abdominal segments, while not much larger than the others, are much darker reddish brown, with pink stains around their bases, and thus contrast with the others, which are yellow. The two double dorsal pink lines, connecting the prothoracic and first abdominal tubercles, also the four short lines in front of and behind the tubercles on the eighth segment, are now distinct; also the subdorsal, white, lateral band on the outer side of the dorsal tubercles, while the subspiracular, narrow, pale yellow line is distinct. The stigmata on the eighth abdominal segment is twice as large as the others. The hairs are very long, black, and tapering. I can not see any battledoor setæ in this stage. The anal legs are provided with crochets.

[1] Proceedings Bost. Soc. Nat. Hist., 1890.

Third stage.—Length, 12–15 mm. The characters of the final stage now appear. The head has changed its shape and style of markings to that of the last stage; it is flatter in front, with a lateral brown line edged with white, while the large, conspicuous, dark spots have disappeared, and the color of the head is dull opaque-amber. The four red, parallel, dorsal lines on the second and third thoracic and seventh and eighth abdominal segments are now distinct. All the dorsal tubercles except those on the prothoracic and first and eighth abdominal segments have much diminished in size, while the others have remained stationary.

Fourth stage.—Length, 18 mm. The piliferous warts in general are smaller than in Stage III, and those on the prothoracic and first and eighth abdominal segments are smaller than before. The eighth abdominal segment is slightly humped, and the anal legs are normal, though about one-half as thick as those in front. The body is green, with a broad subdorsal and two narrow lateral yellow lines, as in the last stage, the lower being the infra-spiracular line. The sides of the three thoracic segments are dotted with reddish pink, and there is a reddish streak on the outside of the anal legs. The subdorsal yellow lines diverge on the prothoracic segment, and along the next two segments succeeding are edged within with pink-red lines. Behind the two dorsal tubercles on the first abdominal segment they are much farther apart, extending to the supra-anal plate, and are whitish yellow, narrowly bordered with deep, straw-yellow, and inclose a narrow, yellow dorsal line. (This line in the next stage extends to the prothoracic segment.)

Fifth and last stage.—Length, 30–32 mm. It differs in the dorsal piliferous warts on the first thoracic and first and eighth abdominal segments being smaller than in the fourth stage, being now no larger than those on the other segments, and the hump on the eighth segment has almost disappeared. There is, as in the fourth stage, a conspicuous red dash on each side of the third abdominal segment, and the other lines are as described in the fourth stage.

RECAPITULATION.

1. Head large, with dark spots and connected lines in Stages I and II.

2. The spots disappear, and the peculiar lateral dark line edged with white characteristic of the final stage appears in Stage III.

3. The piliferous tubercles on first thoracic and first and eighth abdominal segments attain their maximum in Stage II; the tendency after this stage is to return to a simple, smooth body, without excessive ornamentation or any decided change in coloration.

4. In Stage III all the other tubercles diminish in size.

5. The style of coloration of Stage V is indicated in Stage II.

6. In Stage IV the tubercles almost reach their minimum, becoming still smaller in the final stage.

7. The few tenant hairs present in the first stage are battledoor-shaped.

It is interesting to notice, in reviewing the larval history of this species, the strong tendency shown after the second stage to a diminution in size of the tubercles, so that by the fourth stage the body becomes smooth and free from all projections, humps, and spines, and thus more noctuiform. At the same time the yellow and whitish stripes and pink blotches become indicated at an earlier stage than usual, as if the aim were to adapt the caterpillar to the ribs and parallel greenish and yellowish lines or shades of the leaf on which it feeds.

This is perhaps, as regards the other species, the most generalized and simple form in its early larval stages, there being no horns and the dorsal warts of nearly uniform size.

In the group comprising *H. biundata*, *guttivitta*, and *obliqua* there is a singular degree of hypertrophy and specialization of the dorsal tubercles, while in the group represented by *H. unicolor* the process of hypertrophy and specialization takes another direction, i. e., the anal legs, the larvæ becoming cerura-form.

REMARKS.—Pl. XXIX, figs. 2, 2*a* represent what may prove to be the young larva of this species. It was found by Mr. Bridgham on the walnut at Providence, R. I., July 5. I have no notes on it. The following descriptions have been drawn up from Comstock's specimens, the types of his description in his report as United States Entomologist for 1880. His No. 219, "Notodonta on oak, September 23, 1879," is equal to var. *c*. of his description. I am indebted to Professor Riley for an opportunity of examining the specimens when they were in the collection of the United States Entomologist, Department of Agriculture, Washington.

Stage II?—Length, 6 mm., probably not long before molting, as the head is as wide as the body; it is rounded, of abnormal shape, not squarish on the sides. The piliferous warts on the head are minute, but bearing long bristles, and connected by broad, dark brown bands. Forming a rude Greek cross on each side of the vertex and on the side below are three dark spots, two on the back side and one near the clypeus; the sides of the latter dark, forming a V.

On the body the piliferous warts are rather large and high, especially the dorsal ones. The dorsal prothoracic tubercles are conical, rounded, twice as large as those on the second and third thoracic segments, and deep reddish around the base. The two dorsal warts on the first abdominal segment are as large or slightly larger than those on the first thoracic segment, and somewhat forked at the tip, which is dark, giving rise to two bristles. The eighth abdominal segment is gibbous on the back, bearing the dark red tubercles, which are slightly larger than those on the prothoracic segment, and which are simple, not forked, and reddish above the base. The suranal plate is rounded, bearing a few high slender conical setiferous warts. The anal legs are long and slender, reddish, extending well beyond the suranal plate. The body is green, with yellow markings, with two interrupted broad yellow bands, which are in fact broken into a series of irregular spots. From the first thoracic segment two parallel, nearly contiguous, red dorsal lines extend to the dorsal tubercles on the first abdominal segment, and inclosing a fine broken yellowish line. A similar pair of red lines, but broader and more diffuse, on the last third of the body. The setæ are glandular, slightly enlarged at the tips. (The specimen, alcoholic, is not well preserved.)

Stage III.—Length, 10 mm. The head is rather large, broader than the body, while the sides are now somewhat squarish. The origin of the lateral dark and white line is now seen to be thus: The front is rather broad and flattened; on each side is a slightly curved row of about five dark piliferous warts, which are connected by an irregular dark band, which begins on each side of the vertex and curves around to the sides of the labrum. This line is broadly bordered by a whitish band, and outside of this are three black blotches. The sutures of the apex of the clypeus are broadly stained with black-brown, forming a V, as in the second stage. Piliferous tubercles as in Stage II, but now the bristles taper to a point, though large and coarse, and the bases of those of the first thoracic and first abdominal tubercles are reddish, those of the others yellowish. The twin dorsal reddish lines are more distinct, and now there are two distinct, broad, subdorsal white bands, containing on the inner side the dorsal tubercles, whose bases are yellowish. A spiracular, narrow, straw-yellow line, passing just above the spiracles and partly inclosing them. The anal legs are reddish, but no reddish spots or dots yet appear on the sides of the body, as they do in the next stage. On the third abdominal segment is a large, dark, setiferous tubercle, which is reddish at base; it is one-half the size of that on the first segment.

The following description is drawn up from Comstock's type (No. 4455, "From eggs on oak, D. C., June 24, 1889"), var. 6. One or two were in the fourth stage and the others fully grown. Length, 32–34 mm. They (the full-grown ones) have the dorsal region between the subdorsal lines deep, continuous carmine or dull blood-red. The six thoracic piliferous warts are yellow, the dorsal lines white, the subdorsal one white, more or less tinged with straw-yellow, two well-marked lateral yellow lines, the supraspiracular being narrower than the lower ones. Below the lower line the sides of the body are more continuously blotched with carmine-red than usual. The lateral lines on the head are as usual black, edged externally with white. The base of the mandibles and of the antennæ are tinged with yellow. The bristles are as usual long and stiff.

In two full-grown *H. manteo*, 35 mm. long, Department of Agriculture, "No. 359, C." (pl. XXIX, figs. 3, 3*a*), kindly lent by Dr. Riley, the colorational characters often, though not always, seen in Stage IV are retained, the red filling up the space between the subdorsal lines, passing far down in great lobes on the sides of the abdominal segments 1, 3, and 6, those on segments 3 and 6 being the largest, and partly inclosing the spiracles. The tubercles are small and normal, i. e., as in the mature larvæ generally.

In one larva, 359*b*, 45 mm. long, the space between the two subdorsal lines is filled in solidly with deep, dull blood-red, only interrupted by the dorsal yellow line, while the two lateral yellow lines are distinct.

H. manteo var.—("On birch, Virginia, September 14, 1882," Department of Agriculture.) Two blown specimens, full-grown larvæ. (Pl. XXIX, figs. 5, 5*a*.) Length, 30 mm. The head is moderate in size, shaped as in that of normal *manteo*, with a lateral, narrow, brown line, bordered externally with white. The head is rather freer from bristles, and is paler than in normal *manteo*; in fact the whole body is paler, like the underside of a birch leaf, compared with the other blown specimens. In one of the examples there is a fine, narrow, reddish V-shaped mark, the arms of the V being situated outside of the clypeus.

On the prothoracic segment are two flattened, yellowish, piliferous warts, connected by a slight low ridge. There are four dorsal smaller conical piliferous warts on the second and third thoracic segments. (These are just as in *H. manteo*.) On the first abdominal segment are two cylindrical, conical, coral-red dorsal tubercles, arising from smaller bases, and are (in one example) deep blood-red, forming an oval spot, situated mostly on the outside of the tubercles. These tubercles are of the size of those in Stage IV of normal *manteo*, and the conical nipples are themselves larger than in some of the fourth stage of normal *manteo*, but of the same size as in the others; in fact, these tubercles vary much in size in different individuals of normal *manteo* of Stage IV, which shows that they are comparatively suddenly produced or are a lately acquired character, and are thus inconstant. The third abdominal segment is much as in normal *manteo*, Stage IV, but in one of the specimens is a large, deep blood-red, irregular, oval, subdorsal spot of the length of the segment itself, and in the subdorsal line on the sixth abdominal segment is a much smaller blood-red spot. The eighth segment is dorsally decidedly gibbous, and bears two distinct, but small, yellow, piliferous, flattened dorsal warts. The dorsal yellowish and the two subdorsal yellowish white lines are of the same width and arrangement as in normal *manteo*, but the red inner border is nearly obsolete.

What at once strikes the eye are the three pairs of unequal, deep blood-red, subdorsal spots, which are partly inclosed by the subdorsal lines. On the sides of the body are thickly scattered red spots, running sometimes into very short curved lines.

There is a spiracular yellow line extending from next to the head to the second abdominal segment, beyond which it is obsolete. The abdominal feet are tipped with reddish; the anal legs with two parallel reddish stripes beneath, while the lateral piliferous warts are yellow.

It varies much in the three pairs of subdorsal, abdominal, dark blood-red spots, as they are entirely wanting in one of the specimens. It is plainly derived from normal *manteo*, and is adapted for existence on the pale yellowish green underside of the birch leaf, while the deep blood-red spots are similar in color to those of the birch twigs or leafstalks.

A larva near L. manteo, if not of that species.—Three blown specimens, "No. 350, on linden, October 17, 1874," were loaned me by Professor Riley. (Pl. XXIX, figs. 4, 4*a*.)

I can not see any difference between these specimens and *H. manteo*. Length, 34 mm. The head is deep amber, with a broad, black, lateral band bordered externally with a rather narrow whitish band. The dorsal tubercles are as in *H. manteo* of the last stage. Those on the first abdominal segment are small, low, flattened and red around the base. The eighth segment is gibbous, with the piliferous warts small, normal, and yellow. The yellow dorsal line is distinct, and the subdorsal lines are, as in *H. manteo*, broad and white, tinged with yellowish on the upper edge, and broadly but very irregularly bordered with reddish inside, this edging broken up into red scattered spots. The spiracular line is yellow, situated just below the spiracles, which, as usual in this genus, are partly merged in the upper edge of the line.

Cocoon.—In confinement spinning "a very slight, elastic, silken cocoon," some "a tough silken cocoon, others one made only of a few threads, while some had no cocoon at all, but had made a smooth cavity in the earth" (Riley). According to Comstock's informant, in nature the mature caterpillar entered the ground, where they laid most of the winter before transforming.

Pupa.—♂ (head wanting). Length, 18 mm. End of body less blunt than in Schizura. Last four segments smooth, polished; cremaster ending in two stout foot-like spines, the toe very long and pointed, the heel pronounced; the surface transversely densely corrugated; vestiges of anal legs swollen and quite distinct; two ♂ sexual openings, the hinder one being the smaller of the two. (Drawn up from Riley's No. 249.)

Pupa.—"Length, 16–22 mm. Body only moderately robust; shining, dark reddish brown; dorsal teeth at posterior margin of mesothorax, 12 in number, gradually decreasing in size from the center laterally, nearly rectangular, and without central indenture; two spines at tip of body rather long and narrow, somewhat roughened, and each with an inner subapical tooth or branch, in this respect somewhat similar to the pupæ of Schizura. The slender outer branch is irregular in length and direction, which, however, is generally outward." (Riley MS.)

Fig. 86.—Pupa of *H. manteo.*

Habits.—During 1880 a great amount of damage was done to the foliage of oak forests in at least two counties of Arkansas by this worm, which appeared in immense numbers in January. The following extract is taken from Professor Comstock's account in his report as United States Entomologist (Agricultural Report, 1880):

There are probably two broods of the variable caterpillar in the course of the season, although but one, the fall brood, seems to have been noticed. The moths appear in the latter part of April or in early May, and between that time and late September, when the principal damage is done by the worms, there is abundant time for two broods of caterpillars.

In the District of Columbia for the last two years these larvæ have been noticed very abundantly upon oak, hawthorn, and basswood, and doubtless feed upon other plants. In late September they had reached their full size and entered the ground, where, as we gather from Mrs. Thomas's letter, they lie most of the winter before transforming.

Professor Riley has sent us the following notes on its habits and food plants, which appeared in our report on Forest Insects:

Two larvæ of a Notodonta were found feeding on oak and persimmon, in Virginia, June 18, 1882. Another one was found June 20, also in Virginia, feeding on walnut; and two more July 19, feeding on oak. (It also feeds on the white, post, and laurel oak, and linden.) One of the first found larvæ spun up between leaves July 19, and another one pupated on the surface of the ground July 21. The first moth issued August 5 and the other one August 12.

Larvæ of a second brood were again found August 30, feeding on apple and black birch, and another full-grown one September 3, feeding on persimmon.

Octorer 11, 1870: S. S. Rathvon describes it as injurious to the linden trees, stripping them and going from one tree to another in the village of Lititz, near Lancaster, Pa. They went into the ground about the 1st of September. The specimen he sent had fifteen large Tachina-fly eggs attached transversely across the end and third joints. The white margin to the black stripe was missing, and the dark purple dorsal band extends to stigmata on joints 6 and 9 and to subdorsum on 4 and 11 (box 3, No. 29), also a variety in box 3, No. 53.

October 17, 1870: Bolter found 2 under oak leaves, both of them like that I found on oak October 2, 1870.

April 30, 1871: One has issued from an exotic oak in Shaw's Gardens [St. Louis, Mo.]. The markings are much more diffused, with a large whitish discal spot on primaries. That marked 45 from burr oak—Muhleman, issued May 25, 1871. It is a variety and perfectly deceptive, like *N. unicornis*, taking the same tubular position.

Very abundant in 1873. October 12, leaves falling, obtained many from post oak. Three most persistent forms blown, *a* (1 in cage 12), *b* (11 in cage 11), *c* (1 in cage 10).

July 6, 1874: The imagines have been issuing very irregularly. To-day I sieved the cages, and especially 17, in which there were a number of all three forms. They now are all alike, and the head is the only characteristic part. All the color is gone from the body, which is now of a uniform paris green, more or less mottled with a pale and dark shade, the vascular line dark and broken. Many of these are now crawling about quite actively, while others are in the pupa state and others issuing. They were all in a very slight elastic silken cocoon.

September 20, 1874: A number of all sizes on oak, separated into three lots—*a*, in cage 12; *b*, in cage 10; *c*, in cage 5. They are very variable, and there are specimens intermediate between these three forms. Some have the colors very bright and distinct, and others less so. A lot found on linden, but afterwards feeding well on oak, are all of the light form *a* in cage 13.

November 21, 1874: In sieving the cages containing forms *a*, *b*, and *c*, they were found still in the larval state, some having made a tough silken cocoon, others made one only of a few threads, while some had no cocoons at all, but had made a smooth cavity in the earth. In cage 5 were found two large Tachina larvæ, certainly from form *c*, one of which is preserved in box 7–40. April 10, 1875, one Tachina fly issued, marked 359. One moth issued April 16, 1875, the larva of which was found on linden, but fed also on oak in cage 13, where there are many more in the ground. Braconid parasite bred October, 1874. October 26, 1875: Nine from oak, all near form *b*.

"*Eggs* in August, *Larva* in April, June, July, September, and October (winter as larvæ, transforming sometimes as late as July). *Adults* in April, May, June, July, August." (Riley MS.)

Food plants.—Different species of oak, including the white, post, burr, and laurel oak; hawthorn, basswood, persimmon, walnut, apple, black birch; in Georgia it lives on *Pinckneya pubens* (Abbot's MS. drawings, Gray copy, Bost. Soc. Nat. Hist.); linden, oak (Riley MS).

Geographical distribution.—Ranges through the Appalachian and Austroriparian subprovinces and the eastern portion of the Campestrian (Nebraska), not having occurred west of the eastern borders of the great plains. Two specimens only have been recorded from any of the New England States, where others will probably be discovered, though rarely. It seems to abound most from Pennsylvania southward to Georgia. Orono, Me. (Mrs. Fernald). Lawrence, Mass. (Mr. Treat, Mus. Comp. Zool.); Detroit, Mich. (Mus. Comp. Zool.); Trenton Falls, N. Y. (Doubleday); Plattsburg, N. Y. (G. E. Hudson); Pern, near Lancaster, Pa. (Coll. Amer. Ent. Soc. Phil.); Washington, D. C., Virginia, Georgia (Riley), Tallahassee, Fla. (Koebele); St. Louis, Mo., Nebraska, Arkansas (U. S. Nat. Museum); Canada, Maine, Massachusetts, Pennsylvania, Ohio, Wisconsin, Champaign, Ill., Texas (French).

Heterocampa guttivitta (Walker).

(Pl. V, fig. 2 ♂, 3 ♀.)

Cecrita guttivitta Walk., Cat. Lep. Het. Brit. Mus., v, p. 992, 1855.
Drymonia mucorea Herr.-Schaeffer, Samml. aussereur. Schmett., fig. 514, 1856.
Lochmæus cinereus Pack., Proc. Ent. Soc. Phil., iii, p. 372, 1864.
Misogada sobria Walk., Cat. Lep. Br. Mus., xxxii, p. 450, 1865.
Heterocampa doubledayi Scudder, in Harris Ent. Corresp., p. 134, 1867.
Heterocampa guttivitta Grote, New Check List N. Amer. Moths, p. 19, 1882.
Heterocampa pulverea Pack., Fifth Rep. U. S. Ent. Comm., p. 159, 1890.
Lochmæus olivatus Pack., Fifth Rep. U. S. Ent. Comm., p. 39, 1890.
Heterocampa guttivitta Smith, List. Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 561, 1892.
Cecrita guttivitta Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 207, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Larva.

(Pl. XXXI, figs. 1, 1*a*, 1*a*–1*d*, 1*d*, 1*d*, 2, 2*a*, 3, 3*a*, 4, 4*a*, 5, 5*a*, 6, 6*a*, 7, 7*a*; XXXIII, figs. 1, 1*a*, 1*c*, 2, 2*a*, 3, 3*a*.)

French, Can. Ent., xii, p. 83, 1880.
Sixth Ann. Rep. S. Ill. Normal Univ., p. 661, 1880.
Packard, Bull. 7, U. S. Ent. Comm. Ins. Inj. Forest Trees, p. 46, 1881. (Quotes French's description.)
Fifth Rep. U. S. Ent. Comm. on Forest Insects, p. 159, 1890. (*H. pulverea* by error.)
Fifth Rep. U. S. Ent. Comm. on Forest Insects, p. 397, 1890.
Proc. Bost. Soc. Nat. Hist., xxiv, p. 548, 1890. (*H. pulverea* by error.)
Dyar, Psyche, vi, p. 178, 1891. (Fourth and last larval stages; cocoon and pupa.)

Moth.—Four ♂, four ♀. Ground color pale olive-greenish ashen, with white scales and patches. Head above greenish ash, in front ash, and the palpi ash-colored, and generally with no black scales on the outside, though in some examples there is a streak of black, but less than in *H. biundata*. Thorax varying from pale to dark ash, with dark olive-green scales; a dark line across the hinder edge of the collar; over the mesoscutum dusky brownish, and on base of abdomen a brown patch; the tegulæ edged with pale ashen scales.

Fore wings with the basal line indistinct, the scallop not so distinct and pointed as in *H. biundata*; middle line doubly scalloped; the spaces between the dark scallop filled with whitish scales. Discal mark a distinct curved dark line inclosed in a large conspicuous lunate or oval pale patch; in some individuals on the inner side of this patch and extending below it is a dark brown patch.

The outer line is sinuous, the scallops shallow; the line curves outward deeply opposite the origin of the cubital venules and loses itself toward the costa in a diffuse greenish costal patch. There is a distinct submarginal series of about eight subtriangular dusky spots, the largest one situated on the first cubital interspace; this line is scarcely dislocated as compared with *H. biundata*. Hind wings ash, whitish in spots; traces of an outer dusky band, distinct in the center, where it is externally shaded with whitish; a diffuse sordid whitish band crosses the wing, but is quite faint and best marked on the costa and at the internal angle. Beneath, the lines and spots do not reappear, and both wings are uniformly ash-brown, the line at base of fringe dusky, the fringe whitish ash, spotted with dusky.

Expanse of wings, ♂ 44 mm., ♀ 35–52 mm.; length of body, ♂ 20 mm., ♀ 20 mm.

This is a very variable species, and it is difficult to separate some cabinet specimens, when not fresh, from those of *H. biundata*. It is distinguished by the stouter palpi, the second joint being broad and bushy at the end, while the third joint is shorter than in *biundata*; the second joint is either ashen or with a narrow blackish line on the outside, while in *biundata* the side is almost wholly black, and the third joint is much longer. It is best characterized, however, by the usually not very distinct, linear, curved discal mark being inclosed in a large, diffuse, lunate, pale ashen patch. In the well-preserved and fresh and rather melanotic Franconia specimens received from Mrs. Slosson this spot is small and obliquely oval. It also differs from *biundata* in the less distinct transverse lines of the fore wings. Rubbed and worn specimens are never so uniformly olive-green as in *biundata*, and have never been observed becoming ocherous yellowish or reddish, as occasionally occurs in *biundata*. Many individuals are smaller than in *biundata*.

The specimens collected by Mrs. Slosson at Franconia, N. H., and they are very fresh and well preserved, are decidedly darker than those from the Southern States and from near the coast, while the lines and discal mark are rather more distinct. In the Franconia examples there is a diffuse whitish patch extending from the middle of the wing beyond the extradiscal line to the apex, including the two dark subapical spots or streaks.

In a ♀ example reared from the larva figured on Pl. XXXIII, fig. 2, 2*a*, the cross lines on the fore wings are obsolete and the wings are very pale whitish, with a slight olive tint, and the outer half of the wings are whitish, while both wings beneath are very pale ashen in hue. The shape of the wings is much the same in both species; in *guttiritta*, however, the costa of the fore wings is a little more full, the wings being a little more produced toward the apex.

For my identification of this species I depend on a fairly well-preserved large ♀ from Brooklyn, N. Y., which, in 1889, I compared with and which well agreed with Walker's type in the British Museum. Mr. R. Thaxter also regards this as the *guttiritta* of Walker's description. It is *Lochmæus cinereus* of my Synopsis of the Bombycidæ of the United States (Proc. Ent. Soc. Phil., iii, p. 372). The type of this species was formerly in the Museum of the Peabody Academy of Sciences, but became lost or mislaid. It was much rubbed, not showing the characteristic markings, the description being that of a worn specimen. It is the *Lochmæus olivatus* of my report on Forest Insects (p. 397), being erroneously determined as that species, and not the *olivata* of my Synopsis.

This is also *H. pulverea* of Riley and of my report on Forest Insects, p. 159, and elsewhere; the *pulverea* of Grote and Robinson is quite a different species, as I have ascertained from an examination of their type in the American Museum of Natural History at New York.

Larva (Pl. XXXI, figs. 1, 1*a*—1*d'*).—Found on the sugar maple, July 10, at Brunswick, Me., feeding on the underside of the leaf, eating out a little irregular patch; no eggs were to be discovered.

Stage I.—Length, 5 mm. Head large, rounded, much wider than the body; pitchy chestnut, or dull, dark amber. The body tapers gradually from the prothoracic segment to the end of the body, which is elevated, as usual. Anal legs slender and as long as the eighth segment is thick; paler at tips; cylindrical, and the tips are slightly eversible. The skin of the body is smooth and shining, of a uniform pitchy, dull reddish color, with fine, narrow, thread-like, greenish yellow, wavy lines. The dorsal region between the first thoracic and the eighth abdominal segments is greenish yellow.

The larva is the most remarkable of its family, in possessing at this stage an extraordinary armature of nine pairs of enormous horns like those of a deer. (Fig. 83, III, *a, b, c, d*). The prothoracic pair are nearly three times as large as those on the first abdominal segment, and arise from a dark piceous plate; each horn is stout, about twice as long as the body is thick, with two stout acute tines reaching forward and outward, and a third upward, with a fourth small sharp one projecting in front near the base; each tine bears a hair arising from near the end. The tines are more or less rough and finely spinulose, especially on the opposing bases of those projecting upward and backward. The second and third thoracic segments are smooth and unarmed and much wrinkled transversely. On the first abdominal segment is a pair of long, slender horns with the distal third smaller and bent forward and outward, with the end thickened and bearing two or three minute spinules and a single long hair; this pair arises from a large black dorsal, undivided plate, while those behind (on second to seventh segments) arise from a more rounded black plate, divided into two half-moon-shaped pieces by a distinct greenish yellow space. Those of the second abdominal pair are much smaller than the pair in front and those behind. Those of the third abdominal segment are not so large as the first, but much longer than those behind. The pair on the eighth abdominal segment are of the same size and shape as those on the first abdominal segment, but are slightly shorter. The suranal plate is rounded, convex, shining black, giving rise to a pair of black horns shorter than the shortest ones in front. Thoracic legs blackish; the middle abdominal legs of a pitchy color.

It molted July 19, being perhaps belated, as are most in the next stage.

Stage II.—Length, 5–6 mm. Head and body uniformly liver-colored or reddish brown. Head conical, rounded, entirely liver-red, like the body, with no lateral bands or any markings. *Now there is only a single pair of very short horns or tubercles situated on the prothoracic segment, with no traces of the others.* These prothoracic tubercles are cylindrical, short, square at the end, which is dark and no longer than one-third the length of the anal legs, with no branches. The end of the body is uplifted; the anal legs are concolorous with the body. The body gradually tapers to the end, with no traces of any markings.

I found, July 11, other larvæ on neighboring maple trees, of which the following is a description, and think it is the same species:

Stage III.—Length, 10 mm. *The head is now very large, subtriangular*, rising higher than the body behind, and much wider than the body; greenish, with a broad, pale reddish band on each side, meeting on the vertex. The prothoracic horns are now represented by the conical piliferous tubercles of moderate size, dark reddish at the end, from each of which a reddish line passes back to the first abdominal segment. The third abdominal segment is pale reddish above, the hue passing down to the base of the first pair of abdominal legs. Along the back of abdominal segments 4 to 6 is a pale reddish band interrupted by the sutures. On abdominal segments 7 to 9 is an elongated, reddish, diamond-shaped, dorsal, pale red band, including the suranal plates; a faint reddish lateral spot on the side of the sixth abdominal segment. Abdominal legs yellowish, concolorous with the body. Anal legs long, slender, upheld; thoracic legs pale; the sides of the body just above their base discolored with pale reddish. A distinct subdorsal yellow line on each side of the body, not so distinct on the last three abdominal segments.

In three specimens, with little doubt of this species, which were 15 mm. in length, there are two parallel red lines extending backward from the prothoracic tubercles and diverging, as in the smaller specimens, on the first abdominal segment. On the third abdominal segment is a crescentiform dorsal red spot, the horns pointing anteriorly; on the segment behind is a median triangular red patch, and on the five succeeding ones collectively is a much smaller one, cleft behind. In this specimen the hollow of the crescentiform spot is filled with a yellow curved spot, but in one of the other examples there is in place of it a white patch, and the crescentiform spot is represented by two short parallel lines. There is another reddish dorsal patch common to the seventh and eighth segments. Indeed there is much variation in the markings. The suboval yellow lines are distinct. There are four small, short, lateral, oblique, reddish patches on the side of the body, one at the base of the third pair of thoracic legs, another at the base of the fourth pair of abdominal legs, and in one of the specimens one at the base of the first pair of abdominal legs.

Stage IV.—Length, 18–20 mm. Head large, wider than the body, flattened in front. The band on each side is rather short and broad, not reaching to the base of the antennæ and not meeting above on the vertex; it is composed of lines of four colors, being black within, then white, then a broad pink band broadly shaded externally with yellowish. No tubercles on the top of the prothoracic segment, but a yellowish patch containing two lines forming the beginning of the two parallel reddish sienna-brown lines, which end on the first abdominal segment. Behind this spot are three yellow dorsal lines which end on the hinder edge of the third abdominal segment. On this and the next segment is a conspicuous forked sienna-brown line, inclosing on the third segment a white triangular patch. The two subdorsal yellow lines are broad and distinct, edged within with reddish on the eighth segment and on the suranal plate. Sides of the body with scattered black specks. Spiracles yellow, finely edged with black. A slight, short, narrow oblique line on the side at the base of the legs of the third thoracic and sixth abdominal segments. A reddish line on the inside of the anal legs. A black dot on the middle of the thoracic legs.

It molted, passing into the last stage August 9-10.

Last stage.—Length, 35 mm. Head as in *H. biundata*, with a short lateral four-colored band of black, white, pink, and, externally, of yellow. *Body with no reddish brown spots on the side*, though quite thickly speckled with dark red brown. The rudiments or vestiges of the prothoracic horns are very slight, forming a yellowish, slightly swollen area. Dorsal band snow-white, fading into yellowish on the side, where there is a series of fine dark red black dots; the line is widest on the second and third abdominal segments, and at the suture, between the fourth and fifth segments, the anterior part of the band connects by a narrow neck with the posterior division of the band, which contains a whitish vascular line, bearing reddish dots on each side. Each side of the body on abdominal segments 7 to 10 snow-white, including the upper part of the anal legs, which are marked with a red line. The thoracic legs are green, with a black dot in the middle.

Description of another larva on the red maple (Pl. XXXI, fig. 1, 1*a*).—The egg was found July 3 on the red maple at Brunswick, Me., and it hatched July 11 or 12. The caterpillar eats the surface of the leaf when first hatched.

Larva, Stage I.—Length, 6 mm. Head moderately large, a little wider than the body, rather short, smooth, with a few scattered hairs, pale cherry red. The body is moderately thick, a little compressed, tapering from the prothoracic segment to the anal legs, the end of the body being upheld, the anal legs long and slender, but not so long as the tenth abdominal segment is wide. It bears a remarkable series of large black forked dorsal horns, so as to appear like a young Ceratocampid. The first thoracic is slightly wider than the third thoracic segment, and bears a large shining black cervical plate, which is nearly twice as wide as long, the posterior edge being straight and blacker than in front. From this plate arise two large black horns, each with three large, long branches or tines, which are thick, acute, ending in a dark bristle; the trunk of the spine is short, the tines being three times as long as the undivided trunk, while there is a fourth minute spur below the others; the two anterior tines rise high and arch over the head.

The second and third thoracic segments are unarmed, smooth, with no tubercles, but wrinkled. From each abdominal segment (1 to 8) arises a pair of large high dorsal black horns. Those on the first abdominal segment are nearly twice as large as those on the succeeding segment, and arise from a large black plate which is entire, undivided; the horns in these, as all the abdominal ones, are a little bent beyond the middle, at the end sending off a minute sharp spine, while they end in a short black bristle. The six succeeding black dorsal plates are divided into two halves, each half lunate in shape. The third pair of abdominal horns are nearly as large as the first pair, while the three pairs following are of the same size as the second pair. The last pair of horns arise from the tenth segment, which are not quite so large as those on the eighth, and the segment bears a large undivided black plate which extends down the sides and to the base of the anal legs, the latter being slender, rather long, shining black, and held extended out horizontally. There are no horns on the ninth segment.

The body is transversely wrinkled and the ground color is pale yellow, but the sides are so densely covered with fine, short, wavy, cherry-red lines as to appear red. Between the horns on the sixth and seventh abdominal segments is a large clear yellow dorsal area. The thoracic legs are black; the middle abdominal legs cherry-red, becoming blackish toward the plantæ.

At times it jerks its head rapidly from side to side, as if to scare away an enemy.

Another larva (Pl. XXXIII, fig. 1, 1*a*).—This was a rather belated larva with the body somewhat shriveled, which occurred on the oak at Providence September 20–24. Length, 15 mm. Head moderately high and narrow; on each side of and rather remote from the distinct median suture and nearly parallel to it is a dark thread line, the frontal space inclosed being clear of dots. The ground color of the head is like new parchment; on each side are dark specks, forming a band on each side between the antennæ and the prothoracic tubercles. The antennæ are bright yellow. *First thoracic segment with two twin contiguous yellowish humps from which arise two pale raw sienna brown tubercles, each ending in a piliferous tubercle, rising quite high over the head; below, not quite near the end, are two minute tubercles, the remnants of the tines of the horns of the earlier stage.* On all the posterior segments of the body the piliferous tubercles are obsolete, and can not be detected with the lens. Two thoracic dorsal brown parallel lines beginning between the prothoracic tubercles, converging to the second thoracic segment and separating so as to form a large oval whitish spot on the second and fourth abdominal segments, and ending on the hinder edge of the fourth, and beginning again on the fifth, then separating again so as to inclose a long oval dorsal space on abdominal segments 5 to 8; then contracting and ending on the suranal plate between the bases of the anal legs.

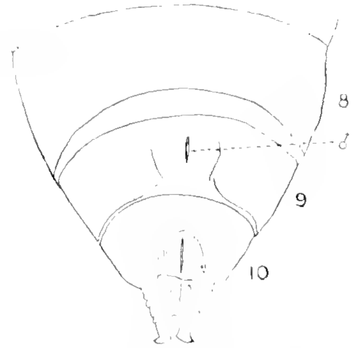

FIG. 81.—Pupa of *H. guttivitta*. *. End of body.

The oval white spots inclose two parallel faint reddish median lines. The body is somewhat compressed, tapering to the end; the anal legs are long, outstretched, slender, with a reddish line on the outside and cherry-red at tips. Sides of the body flesh colored, with reddish dots and short lines. Thoracic legs pale, with a cherry red stripe on the outside. The middle abdominal legs pale flesh, with a few short wavy reddish-pink lines and specks on the outside.[1]

Pl. XXXIII, figs. 2, 2*a*, represent a larva from which I reared the moth, a female of normal appearance.

Pupa.—Body rather stout and thick, the head rounded, much as usual, coarsely corrugated, with two very faintly indicated low parallel vertical ridges between the eyes. The abdominal segments are sparsely and not very coarsely punctured; the last three segments as usual, smooth and polished. Behind the mesoscutum are six square, flattened, dull, unpolished, black tubercles, not having any median impression to give them a double appearance (like that of *Schizura leptinoides*). The cremaster ends in two stout spines, which are larger and stouter than in *H. biundata*, and of quite different shape, the terminal spine being broad and somewhat foot-like, the end being square, with the heel pointing inward and the toe upward at right angles to the main spine. Vestiges of the anal legs rather prominent, rounded, smaller than in *H. biundata*. Vestiges of the sexual opening longer than in *H. biundata*. Length, 19 mm.

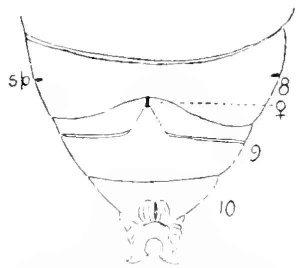

FIG. 82.—Pupa of *Heterocampa guttivitta*. ♀. *Sp.* spiracle.

Habits.—The eggs were found at Brunswick, Me., as early as July 3, and it hatched July 11 or 12. Other larvæ, as observed in Maine, hatched about the 8th to 10th of July, feeding on the underside of the leaf, at first eating away a little irregular patch. Stage I lasts nine days, Stage II probably four or five days. The last stage is reached a month later, August 9–10; my belated individual occurred on the oak at Providence as late as September 20 to 24. The larva has the habit of jerking its head rapidly from side to side, as if vexed or to scare away some assailant.

[1] Dr. Dyar sends me the following account of a variety of *C. guttivitta* larva (mature):

"I have twice found a peculiar variety of *guttivitta* (one at Woods Holl, Mass., one at Jefferson, N. H.), in which a large brown *dorsal* patch was retained in the last stage. The following is a full description of it:

"Head oval, higher than wide, flattened in front, smooth, green; a purplish band on a whitish ground, preceded by a narrow black line from base of jaw to vertex, joining the one or the other side; a short, similar band on the posterior lateral angle of the head at ventral side; ocelli and jaws black; palpi yellowish; width about 3.5 mm. Body smooth, the minute, black, normal setæ arising from whitish spots; anal feet slender, slightly used. Body slightly smaller at the extremities, appearing enlarged centrally in the usual position of the larva. A broad white subdorsal band, narrowly black-bordered above, broken on joints 2 and 11. Dorsal area yellowish green, lateral area leaf-green, brown-dotted, spiracles salmon color. On anterior edge of joint 2 a narrow yellow line, containing two purple-brown spots. A narrow white dorsal line edged with black, linear to joint 4; on joint 5 it divides into three, all coming together again on joint 8, forming an elliptical area; on joint 9 it again divides, each side branch joining the subdorsal line on joint 11 posteriorily to the break, the central line running to joint 13. These lines are yellowish white, scarcely black-bordered posteriorly to joint 4. Besides these normal markings are the following dark purple brown patches: (1) a narrow oblique linear subventral patch on joint 4 from base of foot upward and backward; (2) a subdorsal pyriform patch on joint 7 between the dorsal and subdorsal lines; (3) a single dorsal cordate patch, the depression anteriorly, situated on joint 8, dividing the dorsal line and barely reaching the subdorsal. In front of this heart-shaped spot the junction of the dorsal lines forms a white spot. In the second example these brown patches were somewhat larger, and there was in addition a subventral patch above the foot on joints 7 and 10, the latter sloping the other way from the one on joint 4."

Riley notes larvæ as occurring in July, and captures of the moths in May, June, July, and August.

Food plants.—Rock or sugar maple, red maple, and the oak. Mr. Bridgham found a larva in the third stage (10 mm. in length) on the apple at Providence, July 20. It is the same as that represented on Pl. XXXI, figs. 4, 4*a*. He also found other larvæ on chestnut, maple, beech, and viburnum.

Geographical distribution.—Orono, Me. (Mrs. Fernald); Brunswick, Me. (Packard); Portland, Me. (E. S. Morse, Mus. Comp. Zool.); Franconia, N. H. (Mrs. Slosson); Natick, Mass., May 25, Stratton (B. S. N. H.); Rhode Island (H. L. Clark); Plattsburg, N. Y. (Hudson); Iowa, June (U. S. Nat. Mus.); Racine, Wis. (Westcott); Washington, D. C., Georgia (A. Oemler, U. S. Nat. Mus.); Punta Gorda, Fla. (Mrs. Slosson); "St. Johns Bluff, East Florida, March and April" (Doubleday); New York, Maryland, Washington, D. C., Florida, Georgia (U. S. Nat. Mus.); Maine, New Hampshire, New York (French); Fort Collins, Colo. (Baker).

This species probably ranges from the southern limits of the Hudsonian fauna southward through the Appalachian and Austroriparian subprovinces, and very rarely occurs in the Campestrian (Colorado).

Heterocampa biundata Walker

(Pl. V, figs. 4 ♂, 5 ♀.)

Heterocampa biundata Walk., Cat. Lep. Het. Brit. Mus., v, p. 1025, 1855.
Lochmæus biundata Pack., Proc. Ent. Soc. Phil., iii, p. 370, 1864.
Lochmæus olivata Pack., Proc. Ent. Soc. Phil., iii, p. 371, 1864.
Heterocampa biundata Morris, Synopsis Lep. N. Amer., p. 240, 1862.
Grote, New Check List N. Amer. Moths, p. 19, 1882.
Heterocampa semiplaga Walk., Can. Nat. and Geol., vi, p. 37, 1861.
Stauropus viridescens, Walk.,[1] Cat. Lep. Het. Brit. Mus., xxxii, p. 416, 1865. (Fide Grote and Rob.)
Cecrita biundata Druce, Biol. Centr. Amer. Het., i, p. 234, May, 1887.
Cecrita obliqua Druce, Biol. Centr. Amer. Het., i, p. 234, May, 1887.
Cecrita viridescens Druce, Biol. Centr. Amer. Heterocera, i, p. 234, May, 1887
Lochmæus cinereus Pack., Fifth Rep. U. S. Ent. Comm. on Forest Insects, p. 398, 1890.
Heterocampa biundata Smith, List Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 564, 1892.
Cecrita biundata Dyar, Ent. News., iv, p. 34, Jan., 1893.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 206, 1894; Journ. N. Y. Ent. Soc., iv, p. 117, Sept., 1894.

Larva

(Pl. XXXII, figs. 1, 1*a*–1*d*; 2, 2*a*, 2*b*, 3, 3*a*, 3*b*, 4.)

Packard, Fifth Report U. S. Ent. Comm. on Forest Insects, p. 398, 1890. (Larva not described.)
Proc. Bost. Soc. Nat. Hist., xxiv, p. 543, 1890, fig. 2. (Erroneously referred to *H. guttivitta*.)
Dyar, Ent. Amer., vi, p. 209, 1890. (By error as Heterocampa subrotata.) (Life History.)

Moth.—Five ♂ and six ♀. Antennæ of ♂ well pectinated on the basal two-thirds, filiform at the end; the body and wings ash gray, often greenish ash, the wings more or less olive sea-green in tint. Head ash-gray, sometimes greenish on top, ashen in front; palpi wide, bushy, ashen, black on the sides; third joint thick, distinct, shorter than in *guttiritta*. Thorax ashen, greenish on the sides at the insertion of the wings, sometimes entirely olive greenish, except behind insertion of the fore wings; on front edge of the thorax a dark brown transverse stripe; a more distinct transverse stripe behind, and the hinder edges of the tegulæ dusky; between the

[1] *H. viridescens* (Walk.) is simply the female of *H. biundata*, as Mr. A. E. Butler kindly informs me, and as had previously been determined by Mr. Grote. It is mentioned by Mr. Druce, under the name above, with the remark: "I do not agree with Messrs. Grote and Robinson in regarding this insect as synonymous with *C.* (*Heterocampa*) *biundata*."

H. dardania Druce, Biologia Centrali-Americana, p. 237, from Jalapa, Mexico, appears by the figure to be very near *H. biundata*, and may prove to be a variety of it.

H. alector Druce, (l. c., p. 238) also, judging by the colored figure, seems to be very near the ♀ of *H. biundata*, rather than *pulverea* G. and R.

two oblique tegular stripes the hinder part of the thorax is dark brown, including a small tuft on the hinder edge of the thorax and a large two lobed flattened tuft, which covers the base of the abdomen, the posterior edges of the double tuft becoming blackish.

Fore wings long, the apex produced as in *H. guttiritta:* the wing with usually distinct scalloped bands; two distinct unequal scallops at the insertion of the wing (obsolete in some before me); middle double scalloped line well marked; the scallops uneven, two in median space, the largest one rectangular; a short acute scallop in front of the median vein and extended outward along it: two nearly even-sized scallops on the costal edge; a clear space between the middle and outer scalloped lines; outer scalloped line very irregular, scallops deep and heavy black-brown, and the line of scallops curving inward from the cubital vein to near the apex on the costa. The costal edge on outer third with three distinct narrow linear black spots, the venules marked with black and whitish gray scales (in some males this outer line is almost obsolete). A submarginal row of eight blackish spots, three of which are situated behind the last median venule; this series is plainly dislocated, the subapical three being set farther inward than those below, and this is a ready means of separating the species from *H. guttiritta.* In three females the fore wings and thorax are yellowish green, while in the male of a clear sea-green.

Hind wings uniformly mouse-colored or dusky ashen, yellowish on the costa, on the outer third of which is the beginning of an outer whitish line, forming two scallops; the wing is sometimes pale, almost whitish at base, but dusky toward and at the margin.

Beneath, the fore wings are clear ash, the costa a little dusky, with fine blackish linear marks toward the apex; the submarginal row of blackish spots appear through, but the series is not dislocated; hind wings not marked, except by three submarginal dusky spots behind the second median venule at the internal angle; abdomen ash, with a faint yellow-green tint.

Expanse of wings, ♂, 45 mm.; ♀, 55 mm. (2.10 inches); length of body, ♂, 20 to 21 mm.; ♀, 23 mm.

This species may be known by the fore wings being slightly more produced toward the apex than those of *H. guttiritta*, by the clear space between the distinct middle and outer scalloped lines, and by the dislocated series of submarginal dusky spots; the wings in the male are uniformly sea or olive green, while in some individuals the hind wings are yellowish green or rather brown. (My original description in third vol. Proc. Ent. Soc. Philadelphia is defective, as the type specimen was rubbed and without the greenish tint of fresh specimens.)

From *H. guttiritta* it is distinguished by being more uniformly olive-green and by the lack of whitish discal patches. The discal spot is almost obsolete, and with only a slightly marked dusky patch beneath, this blackish patch being sometimes large and conspicuous in some examples of *H. guttiritta.* The palpi are also larger, the third joint longer and slenderer, and the second joint is black externally; the scalloped lines are more distinct, and this holds for old rubbed specimens, while in *H. guttiritta* they tend to become obsolete.

The Franconia, N. H., specimens are less dark than those of *H. guttiritta.* In these specimens the body and wings are suffused with ocherous yellow scales, while in one from Florida, kindly given me by Mrs. Slosson, the body and wings are decidedly reddish brown, including the thorax and end of the abdomen. This and *guttiritta* have given me more trouble than almost any other Notodontians, as they are so liable to be confounded.

Larva.—The caterpillar of this species has been found by Professor Riley feeding on the maple, and closely resembling in the last stage the caterpillar of *H. guttiritta* Packard. The type of my original description was captured by myself in Brunswick, Me.; Professor Riley's was bred in Washington, D. C., the moth appearing May 28. Mr. Howard L. Clark has found it not uncommonly in Rhode Island. My original type was from Maine.

Stage II.—The larva was received from Mr. Joseph Bridgham, of Providence, R. I., July 1 (Pl. XXXII, figs. 1, 1*a*). Length, 7 mm. Easily recognized by the pair of three-forked dorsal prothoracic reddish brown horns, while on each abdominal segment is a pair of sharp conical brown spines.

The head is rounded, reddish brown, with no tubercles or markings. A pair of large, high, thick, three-forked, reddish brown horns, like those of a deer, the lowermost tine smaller than the two others above. There are no markings on the second and third thoracic segments, but on each abdominal segment there is a pair of acute dorsal brown spines, those on the first and eighth segments being almost twice as large as the others. A pair is also situated close together on the ninth segment. The end of the body is elevated, the anal legs small, slender, reddish brown. The body is pale greenish yellow. A dorsal reddish brown band beginning from between the horns, and widening so as to inclose the two spines on the first abdominal segments, then breaking up into two lateral lines so as to inclose a greenish yellow area extending from the middle of the first to the middle of the third segment; farther back it again breaks apart so as to inclose a pale yellowish spot on the sixth and seventh segments; from thence the bands extend out upon the anal legs.

The thoracic and middle abdominal legs are pale, like the body.[1]

Stage III.—Length, 10 mm. It is green, smooth, with two large dorsal, conical, prothoracic spines, not, however, much exceeding the vertex of the head. The head is narrow toward the vertex and as wide as the body in its thickest part—i. e., the middle; it is yellowish green, with a double red line on each side, the outer line being much broader than the inner. The body tapers to the end, and the anal legs, though long and slender, are used in creeping. The body is pea-green; the prothoracic spines are yellowish at base, reddish brown at the tip; from the end of each spine a narrow reddish thread line passes back and the two unite on the back of the prothoracic segment to form a broad median dorsal line ending on the third thoracic segment. On the fourth abdominal segment is a shield shaped, bright brick-red spot; on the seventh a double linear, coalesced oval reddish spot. A pair of widely separated, reddish, narrow, parallel dorsal stripes on the top of the eighth abdominal segment, while the abdominal legs are striped externally with red; all the other legs are pale greenish. A pair of broad, subdorsal, yellow, long lines extending from the sides of the prothoracic segment to the side of the anal legs. There are no other spines than on the segment next to the head.

Another larva of this species was found feeding on the rock maple, at Brunswick, Me., July 21, 1893; it molted August 2. It shook its head rapidly from side to side when disturbed.

Stage II.—Length, 10 mm. Body moderately slender, somewhat compressed. Head and the entire body reddish livid brick-red. The horns as in Pl. XXXII, fig. 1, 1*a*, and dull reddish.

The body is covered with fine reddish and yellow, short, irregular lines, which are somewhat confluent, but the effect is dull reddish. On the first to third and on the fifth, sixth, and seventh abdominal segments is a dorsal, median, bright yellow spot, which becomes on the seventh segment forked, and resembles the similar spot in Schizura (these spots are not present in *gutticitta*, which is entirely reddish, and in this stage it has two tubercles representing the horns of its first stage).

July 28. It is now 12 mm. in length; it has not yet changed, but now there is much more green on the sides of the body, and the yellow dorsal spots are larger and more whitish. There is a short white line between the base of the horns. There are two whitish dorsal patches on the ninth abdominal segment in front of the suranal plate. It molted August 2.

Stage III.—Length, 15 mm. The horns are still retained in this stage. It is, perhaps, a little stouter than before. It wags its head rapidly from side to side when disturbed. The head is now

[1] On examining Dr. Dyar's specimens I find that *H. biundata* differs in Stage I from *H. gutticitta* in having the dorsal spines on abdominal segments 1–8 all of about the same size, those on segment 1 and 8 being no longer than those on segments 2 to 7.

Another larva sent by Mr. Bridgham perhaps represents Stage III immediately after molting. The following is a description of it:

Length, 8 mm. The head is very large, much wider than the body (not yet filled out), and produced toward the vertex; on each side of the front is a dark, narrow, distinct line, outside of which is a dull reddish diffuse line. The body tapers to the end, and is flesh colored, with greenish and yellowish lines. The two large conical prothoracic spines are flesh colored or very light brown, becoming reddish brown at the end. A dark, diffuse, vandyke-brown dorsal line, double between the tubercles, uniting behind them and then diverging so as to inclose a whitish oval area, containing a pair of minute, short, parallel reddish dashes; finally the band unites to form a dark patch on the fourth and fifth abdominal segments; this divides again and stops before reaching the eighth segment, on which is a diffuse dark patch more or less spotted with pale marks. The sides of the body are more or less mottled and streaked with reddish brown.

high, conical, reddish brick, with a broad yellowish stripe in front, including the clypeus, and extending backward on the vertex to the occiput; sides of the head behind yellowish.

The body is now yellowish green, with broken dull reddish lines on the sides and a faint reddish patch on the sides at the base of the third thoracic and first abdominal segments, and also on the third and sixth abdominal segments. Between the base of the horns is a broad whitish green band. The back is reddish, inclosing a white dorsal broad line, widening rapidly behind, edged with yellowish; this line ends on the fourth abdominal segment. Another band of the same color begins on the fifth segment and forks on the seventh segment. Anal legs now a little longer than before and lined with reddish on the outside. The anal legs are rather long and slender, and slightly retractile at the end.

At the end of the penultimate stage, when about to molt, the prothoracic horns are about as long as the head is wide.

There is an oblique spot on the side of the first abdominal segment which is directed forward, ending at the base of the third thoracic leg; also a large lateral brown spot on the side of abdominal segments 3 to 5, passing down upon the base of the first pair of abdominal legs, and another oblique russet or sere-brown spot on the side of the seventh abdominal segment, reaching to the base of the pair of middle abdominal legs. The dorsal median band is snow-white, and the anterior portion is connected by a narrow neck at the suture between the fourth and fifth abdominal segments with the posterior portion; the upper side of each anal leg is also white. It molted August 11.

Mr. Bridgham has figured the larva now to be described, and which he found on the oak at Providence, September 10 (Pl. XXXII, figs. 3, 3*a*). I also found it at Brunswick, Me., September 8.

Stage IV.—Length, 20 mm. The head is deeply bilobed on the vertex, each lobe ending in a large conical rounded lobe; it is dull lilac, and is much paler, almost rosy, up and down the front. The first thoracic segment shows no signs of horns, these now being represented by two minute dark tubercles, which do not seem to bear a hair. There are no other tubercles on the body, as the hairs are fine, minute, and arise from very minute microscopic warts. The body tapers to the anal legs, which are long, slender, and retractile, the small plantæ being entirely so. The suranal plate is scarcely separated by suture from the ninth segment; it is smooth, and narrows toward the end, where it is regularly rounded; at and below the end are two round tubercles situated above the base of the anal legs. The body is delicate green, with a yellowish hue. A dorsal broad, very white band originates between the prothoracic tubercles, broadens to the third abdominal segment, ending in a triangular point on the fourth segment opposite the apex of another broad white line, which begins on the fifth abdominal segment and splits into two on the hinder part of the seventh segment, forming two broad subdorsal lines which extend to the end of the anal legs, the inner aspect of which is reddish pitch in color. A similarly colored median stripe on the suranal plate, inclosed between the white subdorsal bands. On each side of the first abdominal legs is a dark oblique blood-red patch inclosing the spiracle and extending to the third pair of feet, widening at the end. A large lateral, roundish, oval patch on the side of the third segment; it is dark and paler red and extends down to the plantæ of the first abdominal legs. On the sides of the sixth abdominal segment and inclosing the spiracles is a dark blood-red spot, like coagulated blood, inclosing the spiracles, and in front bearing a light pink irregular patch, and continued upon the base of the fourth pair of abdominal legs. The spiracles are deep orange-brown. The thoracic legs dark red, greenish at the sutures. The three last pairs of middle abdominal legs with a reddish crescent-shaped dash above the plantæ.

Another caterpillar (Pl. XXXII, figs 2, 2*a*) was found in two successive years on the red maple at Brunswick, Me., August 20–25. It rests on the underside of the leaf on the midrib, the head touching the leaf and the anal legs outstretched and holding on to the midrib. It was about to molt, as the prothoracic segment was swollen.

Stage IV.—Length, 25 mm. The head is pale flesh colored, narrow, the vertex prolonged above into two rather acute piliferous cones, each with a brown line behind. The larva may be readily recognized by a pair of prothoracic horns which are long and high, being about half as long as the body is wide, with three prongs; they are light brown in color. The body is very narrow, compressed, pale green, the color of the leaf on which it feeds. Along the body is a broad white dorsal stripe, contracting toward the horns, becoming narrow behind them, but widening to the third abdominal segment, contracting to a yellowish point on the hinder edge of the fourth segment, where a second white band begins in a yellowish point, and is widest on the sixth segment, becoming forked on the last four abdominal segments. The suranal plate is white above; the anal legs white above, lined with red. On the sides of the third thoracic segment is a short curved red line. A large, broad oblique stripe, lined with red and white, on the side of the fourth abdominal segment. The thoracic legs are stained with pale red; the middle abdominal legs are pale green, stained with red above the plantae. The sides of the body are finely dotted with dark blood red.

Last stage.—Described August 11. Length, 24 mm. Head high, conical, ending on the vertex in two rounded tubercles, which are blackish; sides of the head reddish brown, the color of a dead maple leaf; extending up and down the front is a white median band, including the labrum and clypeus, and extending back over to the white dorsal band beginning on the prothoracic segment. Body of a delicate pea-green, with the characteristic white dorsal band, and on the sides of the third thoracic and first abdominal segments the oblique sere-brown patch inclosing the first abdominal spiracle. A second large sere brown patch on the side of the third abdominal segment, extending forward upon the second, and backward, forming a larger spot on the fourth segment. A third oblique sere brown patch is situated on the side of the sixth segment, inclosing the spiracle and partly, like those in front, edged irregularly with a darker reddish brown tint. The white dorsal band is as before, but more pronounced, being wider and more continuously edged with reddish brown. There are fine concolorous dots scattered over the sides of the body.

A larva which Dr. Dyar thinks may be a variety of *H. biundata* was observed on the red oak at Brunswick, Me., August 27. Length, 35–40 mm. The head is not so wide as the body, greenish, with a pink stripe on each side. The body is thickest in the middle, a double dorsal pinkish brown stripe inclosing a median white line and extending upon the first abdominal segment. There are two subdorsal yellowish stripes which are interrupted on the third abdominal segment, which is pinkish brown on the sides, but not above, while the succeeding segment is brownish above but not on the sides, being bounded laterally by a yellowish line. On the fifth abdominal segment is a broad dorsal, V-shaped, brown spot, the apex pointed anteriorly. Segments 7 and 8 with a dorsal brown patch. On the last segment are two narrow brown lines. The sides of the anal legs are rusty reddish brown; an oblique reddish brown band extends from the first abdominal upon the third thoracic segment and incloses the first abdominal spiracle; the third spiracle is included in an oblique brown band extending from the brown dorsal spot above. An oblique lateral brown band on the sixth abdominal segment, and on the seventh and eighth is a lateral oval concolorous spot connecting the two segments. The ground color of the body is pea-green, speckled finely and densely with black.

The rust-red brown spots are of almost exactly the same hue as the rusty sere spots on an oak leaf, and it is thus at first difficult to detect the larva when feeding on the edge of a leaf.

This larva is, I am quite sure, the final stage of *H. biundata* (Pl. XXXII, figs. 2, 2*a*), as I have found it during the past season on the red or rock maple. One found August 28 was without the oblique pale brown line on the third thoracic and first abdominal segments, and also without the brown spot on the side of the sixth abdominal segment.[1]

[1] The following description is drawn up from a specimen sent me by Dr. Dyar, which proves to be *H. biundata:*

Length, 35 mm. The head is not so wide as the body. Width, 4 mm. It narrows above more than usual, so that at the vertex it is scarcely more than one-fourth as wide as below. The sides are angular. The vertex is bilobed, ending in two well-marked conical tubercles, which are black at the end, but not piliferous.

The head is whitish, polished greenish, with a faint purplish tinge. The region in front and on each side of the clypeus and from there to the vertex is polished greenish, without the purplish tint.

The body in general is entirely free from piliferous warts or humps. There are four minute piliferous warts on the first thoracic segment, which is normal. The body is spindle-shaped, tapering toward each end, posteriorly to the anal legs, which are small, weak, and polished faint purplish. The suranal plate is small, rounded behind, smooth, with two dark dorsal stripes. The body is pale green. As the example before me is full-fed and about ready to pupate, it is faintly marked with sere and brown, pale raw sienna on the sides of the first abdominal segment, with a small patch, and on the sides of the sixth abdominal segment, while the sides of the third and fourth, the whole of the third, the spot encroaching a little on the second segment, are washed with the same pale brown or raw sienna tint. (Dr. Dyar suggests that the white dorsal marks must have been lost on account of the approach of pupation.)

Two young with horns exactly as in Pl. XXXII, figs. 2, 2*a*, were found on the maple August 20–29; one of them molted August 27, and then appeared as in Pl. XXXII, figs. 3, 3*a*. When first found they were stretched out motionless along the midrib on the underside of the leaf.

In the last stage the larva differs from that of *H. guttivitta* in having the three pairs of lateral sere brown patches, the difference being simply colorational rather than as regards the armature.

The last stage.—Length, 30 mm. The head is still high, bilobed, narrowing toward the vertex, with two black lines in front extending from each side of the clypeus and ending on the vertex near the tubercles, and another behind one on each side extending from the antennæ and mandibles back halfway up the back side of the head.

The antlers of the early stage are now replaced by two high, conical, rounded, polished knobs, each bearing a minute bristle, and from them on the inside two parallel lines extend backward.

The anal legs are shorter than in the early stage, being about as long as the well-rounded supraanal plate. Doubleday probably gives the characteristic attitude of this caterpillar when not walking, its legs being moderately elevated.

I add a fuller description of this larva when fully grown.

Mature larva.—Length, 35 mm. Head high, narrowing from below to the vertex, which is very slightly bilobed. Two black lines ascend from the antennæ and approach each other on the vertex, the space between the lines slightly roseate: outside the head is light uniform brown with a slight greenish and lilac tinge; the clypeus is small, while the median suture of the epicranium in front is very distinct. On the prothoracic segment behind the vertex are two contiguous, thick, conspicuous, large, conical, bright red tubercles, dark at the tip; there are no other humps, and none at the end of the body, which is thickest at and a little behind the middle, the body tapering gradually to the long anal legs, which fork widely and are longer than the others, but are constantly used. Supraanal plate unusually small. Color of a peculiar brownish green dotted with black points and specks, with a white spot between the prothoracic tubercles. Body above finely marbled with dark brown, with a broken, pale, flesh-colored line, beginning on the mesothoracic segment, and on the first to third abdominal segments suddenly expanding into a large, broad, sublozenge shaped spot, suddenly succeeded, over the segment bearing the first pair of abdominal legs, by a rounded spot. On the top of the fifth segment begins another dorsal patch of the same color, which widens and extends down the sides of the third segment from the end. Along the middle of this patch are two parallel dark lines; and two broader dark lines of speckles begin on the fourth segment from the end of the body, converging and uniting on the second segment from the end, forming on the last two segments a broad median dorsal line. Thoracic legs reddish; abdominal legs reddish flesh color. Anal legs slender, reddish. On the oak at Providence, October 9.

To recapitulate:

1. The pair of prothoracic antlers of the early stage of this larva, and those of *guttivitta obliqua* and *umbrata*, is certainly the most unique and unexpected feature to be found among Lepidopterous larvæ, and the object evidently is to render the creature frightful to its assailants.

2. The rest of the body is without large horns and markings, the latter of which appear in the later stages and are such as to completely adapt it to a maple leaf late in summer or in the autumn when portions begin to wither and to turn brown. Hence the horns, if present, would then only serve to attract attention to it, and thus they are modified into much less prominent tubercles. It should be observed that in the full-grown larva of *H. astarte*, which has the same general colors and markings as *H. guttivitta* and *H. biundata*, and is thus protected, the prothoracic tubercles are absent.

How to account for the appearance of such enormous horns may be impossible even after we have become acquainted with the early stages of all the allied species, though it should be borne in mind that the young of *Citheronia regalis* and *Eacles imperialis*, as well as Anisota, have nearly as large spines when first hatched.

Pupa.—Body plump; of the same shape as in *H. guttivitta.* Head full and rounded, with the two parallel ridges between the eyes slightly larger and more prominent than in *H. guttivitta* (which shows that in this as well as in Schizura and perhaps some other genera of Notodontidæ there may be useful specific characters in the front of the head). Other differences may be seen by comparing our camera drawings with fig. 82. The vestiges of the ♀ sexual aperture are oval, and shorter than in *H. guttivitta*. Behind the mesoscutum the dark transverse line or band usually present is formed of six black tubercles (these in my single specimen may be somewhat deformed in this respect and not entirely normal), which are not square, but very short and transversely oblong, but otherwise as in *H. guttivitta*. Length, 18–19 mm.

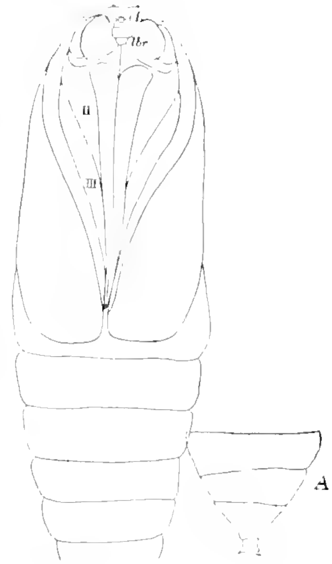

Fig. 83. Pupa of *Heterocampa biundata*.

Habits.—The habits and distribution of this species are very similar to those of *H. guttivitta*. In Providence the larvæ in the second stage occurred July 1, and the fully fed larva occurs as late as September 10.

In Maine I have found larvæ 10 mm. in length feeding on the rock maple July 21, and the fully developed caterpillars occur there late in August and during the early part of September. As in *H. guttivitta*, the young horned larva shakes its head rapidly from side to side when disturbed. The larvæ when nearly or quite fully grown are often observed resting on the midrib on the underside of the leaf. When full-fed they leave the tree and wander about before pupating. Riley has captured the moth in May and in August.

Food plants.—The red and sugar maple (Packard); "fire cherry, yellow birch, white birch, willow, witch hazel, dogwood, beech, hickory, etc. (Dyar; see also the food plants in Dyar's description referred to in Ent. Amer.")".

Geographical distribution.—Brunswick, Me. (Packard). In Franconia, N. H., which appears to be an outlier of the Hudsonian fauna, this moth is less common, fewer having been captured at light by Mrs. Slosson than of *H. guttivitta*, which is more frequently collected.

Massachusetts (Harris Coll.); Plattsburg, N. Y. (Hudson); New Jersey, Pennsylvania (Palm); Providence, R. I. (Clark, Packard); New York (Hulst); Washington, D. C., New York, Illinois, Missouri (Riley, U. S. Nat. Mus.); Kittery, Me., Tiffin, Ohio, Champaign, Ill. (French); North Carolina (Morrison); Winter Park, Fla., reddish form (Mrs. Slosson).

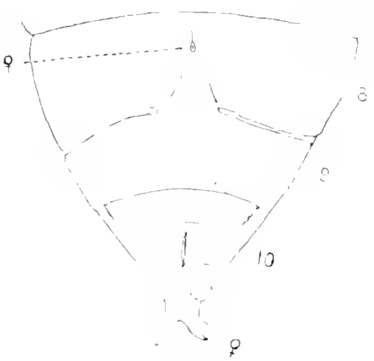

Fig. 84.—Pupa of *H. biundata*; end of body.

The southern and southwestern limits of this species are not known; it has not been discovered in Texas nor in the Rocky Mountain region. It is recorded by Druce from Jalapa, Mexico, and Volcan de Atitlan, Guatemala, 2,500 to 3,500 feet elevation; San Geronimo, Guatemala, and Panama, Volcan de Chiriqui, 2,000 to 3,000 feet elevation. Mr. Druce adds: "The Central American specimens before me agree well with Walker's type in the National collection. The female example from the State of Panama is more distinctly marked with dark brownish spots than any I have seen from North America, but specimens from Columbia in my own collection are exactly like those from New York." (P. 234.)

It seems strange that so distinct a species as *H. obliqua* should be regarded by Mr. Druce as a synonym of *H. biundata*.

The type of "*L. olivata*" is in the Cambridge Museum.

Heterocampa obliqua Packard.

(Pl. V, figs. 7 ♂, 8 ♂, 9 ♀.)

Heterocampa varia Walk., Cat. Lep. Het. Brit. Mus., p. 1023, 1855.
Heterocampa obliqua Pack., Proc. Ent. Soc. Phil., iii, p. 368, 1864.
Heterocampa trouvelotii Pack., Ent. Soc. Phil., iii, p. 369, 1864.
Heterocampa obliqua Grote and Rob., Trans. Amer. Ent. Soc., i, p. 178, 1867, Pl. IV, figs. 26 ♂, 27 ♀.
Heterocampa brunnea Grote and Rob., Trans. Amer. Ent. Soc., i, p. 180, 1867, Pl. IV, fig. 28 ♀.
Heterocampa obliqua Grote, New Check List Lep. N. Amer., p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 31, 1882.
Kirby, Syn. Cat. Lep. Het., i, p. 563, 1892.
Dyar, Ent. News, iv, p. 33, Jan., 1893.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 205, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Larva.

(Pl. XXX, fig. 1, 1*a*, 1*b*, 1*c*, 2, 2*a*, 2*b*, 2*c*.)

Packard, Journ. N. Y. Ent. Soc., iii, p. 27, March, 1895. (All stages. Figs. of Stages I, II, with spines of *H. guttivitta*, stage I.)

Moth.—Two ♂, two ♀. Dark brown, with darker streaks and lines, margined with reddish; a large oblique costo-apical white patch.

Head, pectoral tuft, and thorax cinereous, except the black edges of the patagia and the posterior margin of the thorax.

Fore wings of a uniform dark ashen brown; the basal half of the wing is crossed by three interrupted lines, composed of linear, black, slightly curved lines or lunules, margined on both sides with ferruginous ashen. The first or basal line is straight, and reaches only to the base of the internal angle, which is black. The middle line is double, composed of two parallel linear sinuate lines which become obsolete on the costa, is curved outward on the median vein much more than in *H. astarte*, and is obsolete on the internal edge. The third line is single and consists of the curvilinear black discal mark and a second curvilinear line below the fourth median venule. On the costa it is represented by two parallel brown lines, inclosing a white spot. Outside and parallel to the discal curvilinear mark is a line composed of two curved lunules, which are geminate, and inclose a reddish brown line. From the upper line extends toward the apex a very distinct white patch dusted over with ocherous scales. On its outer edge are three black intervenular streaks, bathed with ferruginous scales. In the middle of the wing and just below is a round rusty patch. Below the median vein and its branches the wing is lighter, and, like the costa, covered with cinereous and dark ocherous scales.

Hind wings in ♂ pearly white, base of the fringe dark; a dark discoloration on the internal angle: costa dark. In the ♀ the hind wings are dusky white at base, becoming quite dark grayish brown toward the outer edge.

Underside of the fore wings dark, except in the middle region, which is very pale. White and dark marks on the costal edge, and the costo-apical white patch appears through from above. Hind wings white, the fringe discolored on the venules.

Expanse of wings, ♂ 42 mm., ♀ 48–53 mm.; length of body, ♂ 22 mm., ♀ 20–23 mm.

This species differs from *H. astarte* in the uniform dark ash-brown hue of the fore wings, there being in the usual normal form no olive-green scales intermixed, but rather a tendency to reddish brown, as seen in var. *brunnea;* also in the larger oblique white subapical patch, the oblique black shade bordering it externally being broader, more diffuse than in *H. astarte*, and containing short intervenular black slashes, and this band is in *H. obliqua* continued to the internal edge of the wing, where is a white lunule; also in the first median spaces is a distinct round or oval white spot. The inner doubly scalloped line is much curved outward in the discal space, more so than in *H. astarte*. The marginal scalloped black line has much shallower scallops than in *H. astarte*. The hind wings are also more dusky than in the latter species, those near the apex becoming straight lines.

In var. *brunnea* the fore wings are suffused with reddish brown, and there is a distinct reddish brown patch beyond the discal mark, with less white in the usually white oblique subapical patch.

In var. *trouvelotii*, a large female expanding 55 mm., there is an olive tinge to the fore wings, but within the inner line are three brown patches, while the middle of the wing is clear olive-gray; beyond the discal mark the wing is tawny brown. It is near the normal *H. obliqua*, but much larger, and olive-gray instead of brownish gray, rendering the markings more distinct; the hind wings are smoky gray.

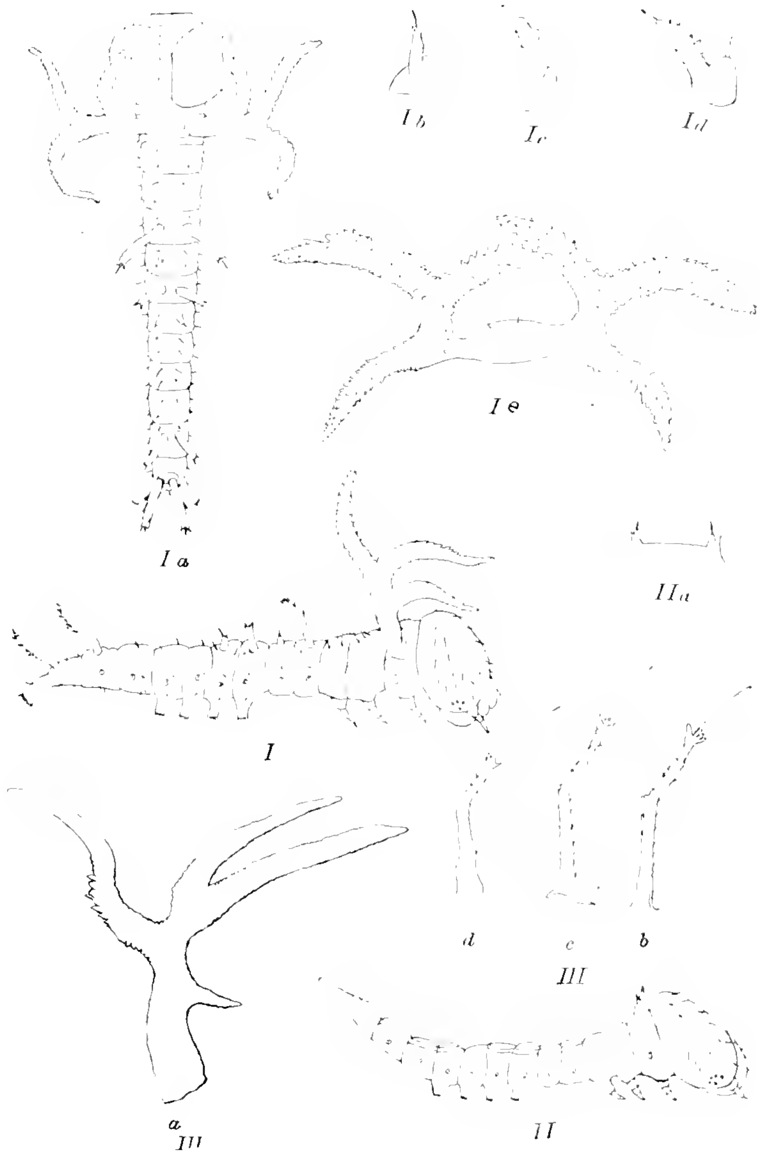

FIG. 85.—Early stages of *Heterocampa obliqua* and *H. guttivitta*.—I. *Heterocampa obliqua*. Freshly hatched larvæ; *Ia*, dorsal view; *Ib*, spine on third; *Ic*, spine on eighth; *Id*, spine on ninth abdominal segment; *Ie*, prothoracic horns of stage I enlarged. II. *Heterocampa obliqua*. Stage II. *IIa*, horns on first prothoracic segment. III. *Heterocampa guttivitta*. Horns in stage I. *a*, prothoracic horn; *b*, one on second abdominal; *c*, one on third to fifth, and *d*, on ninth abdominal segment. (The setæ are in some cases in *I* and *Ia* by oversight omitted.)

The type was from Medford, Mass., and was collected July 19 by Mr. L. Trouvelot, and is now in the Museum of Comparative Zoology, Cambridge, Mass., where is also the type of *H. obliqua*, normal form.

The eggs of this Heterocampa were received from Providence, through the kindness of Mr. W. Dearden, July 13, and hatched at Brunswick, Me., July 20–21. It feeds on the oak.

Egg.—Diameter, 0.9 mm. Of the usual hemispherical shape, moderately flattened above; shell under a lens seen to be finely pitted or shagreened; under ¼ inch, A eyepiece marked with rather large hexagonal areas, with well-marked raised edges, but not distinctly beaded. The hole eaten on one side by the larva, in escaping, of the usual elongated kidney shape.

Larva, Stage I.—Freshly hatched. Length, 3.5 mm. Head very large, much wider than the body, somewhat flattened in front; pitchy amber, smooth, unarmed, surface dull, not polished. On the first thoracic segment arising from a dark cervical plate is a pair of large branching horns with three large equal curved tines, which are pointed and densely spinose; the short, stout spinules dark, quite different from *H. guttivitta*. One tine points forward, one backward, and one laterally outward. The body is purplish reddish, with no stripes or other marks, except a small pale yellowish transverse dorsal spot in front of the base of the eighth segment. No horns on the second and third thoracic segment. On first abdominal segment is a pair of simple dark horns about as long as the segment is thick. On second segment a pair of minute setæ; on third a pair of blunt spines one half as long and large as those on first segment. A pair on eighth segment two-thirds as long and large as those on the first, and a slightly smaller pair on the last (tenth) segment. End of body carried uplifted, and the two cylindrical anal legs blunt at the end and entirely dark. Thoracic legs blackish; the four pairs of middle abdominal legs dark livid. It molted July 27. (In Fig. 83 the setæ are not in every case correctly drawn.)

Stage II.—Length, 6 mm. Head reddish brown. Now all the horns have disappeared, those on the first thoracic segment only represented by two conical acute tubercles, which are black at the tips and slightly forked, there being a small black supplementary spine on the inside of the main one. The two spines are wide apart and project out laterally. On ninth abdominal segment are two twin minute black spinules situated close together. Body pale reddish, color of an oak twig, variegated with yellowish; a distinct linear dorsal line and a broad diffuse line on thoracic segment; an irregular series of large dorsal yellowish spots, those on abdominal segments 1 to 4 and 6, 7, and 9 being the largest. Anal legs moderately long, reddish. It molted August 1.

Stage III.—Length, 8–9 mm. The head is now large, wider than the body, subtrapezoidal in front, rounded above, and slightly bilobed; pale in front, yellowish on the sides. An irregular pale reddish brown band on the vertex and on the sides inclosing in front four irregular reddish spots of the color of a dead leaf which may be called sere-brown. Prothoracic spines now stout and pale reddish, ending in three black spines. From each spine proceeds a broad reddish brown band, the color of a dead leaf, and inclosing a large oval yellowish spot which extends along the back of abdominal segments 1 to 4. The spot incloses two reddish lines which dilate four times, inclosing a roundish white spot in each dilatation. On segments 7 and 8 is a long triangular whitish spot, inclosing two short reddish lines which dilate twice, inclosing two narrow oval spaces. The back of segments 8 and 9 is reddish, the sides yellowish green, whitish; anal legs held up when at rest, greenish, with a red stripe within. The reddish portion of the body consists of irregular fine reddish and greenish yellow lines, the former predominating. It molted on the morning of August 8, and ate up the cast skin before beginning to feed upon the oak leaves.

Stage IV.—Length, 12 mm. (Two days before the molt the lateral sere-brown spots appeared as in this stage, but fainter.) By August 12 it had become 20 mm. in length. The three prongs of the prothoracic spines as in Stage III, reddish. Head a little broader and rounder than before, but with the same style of markings. The markings of the body as in Stage III, but the greenish portion of the sides speckled with black. Dorsal spots as before, an irregular lateral sere-brown spot just above the base of the third thoracic legs, and still higher up on first abdominal segment is a contiguous spot, making an oblique band, as in the other species. The reddish brown edging of the diamond-shaped dorsal spot on abdominal segments 1 to 4 extends down to the base of the first pair of the abdominal legs. In this stage there is present a straw-yellow infraspiracular line, just touching the spiracles, and best marked on the abdominal segment, and above on the second thoracic segment are similar yellow lines, not reaching the front edge of the prothoracic segment nor extending behind the oblique sere-brown band.

Stage V and last.—Described August 29. Length, 40 mm. Now there are no prothoracic tubercles, but in place of each of them a very slight, elongated, flattened callosity. Head rounded, not so wide as the body; luteous with a flesh tint and slightly purplish; an ashy irregular band on each side of the head above the ocelli, with scattered spots between. The body is thickest in the middle (much like Abbot's drawing), and pale flesh, marked with numerous irregular reddish pink wavy hair lines. The usual dorsal band is reddish, bordered with yellow, and inclosing a pale, almost whitish, band. From the prothoracic segment the two lines contract, dilating on the second thoracic segment and becoming widest apart on the second and third abdominal segments, and again widely separated on the seventh abdominal segment. The two lozenge-shaped spots thus formed inclose two parallel median pinkish lines. On the suranal plate the two lines unite to form a median pale sere brown band. Thoracic and abdominal legs pale, marked with red.

The freshly hatched larva differs from that of *H. guttivitta* in having no traces of tubercles or horns on abdominal segments 4 to 6, in the first pair having tines of quite different shape, being thicker and more spinose, these horns being dull chitinous, of the same hue as the head. The other dorsal tubercles are about one-quarter as long, not elbowed, and stouter in proportion, while those on the eighth segment are smaller.

The following description is of a larva stated by Mr. Dyar to be that of *H. obliqua*:

"*Stage IV*.—Head higher than wide, the sides rather angular, clypeus indented laterally, sutures moderate, width 2.35 mm. In the position of rest the body is contracted so as to appear enlarged at joints 7 to 10, tapering posteriorly. Anal feet 1.5 mm. long, tail-like. A pair of short prothoracic horn-like tubercles, apparently tipped with red. Color leaf green with numerous small purple-brown dots and fine white streaks. A peculiar white dorsal band, recalling in shape that of *H. guttivitta*, but without a subdorsal line. It is dilated on joint 2, narrow on joints 3 and 4, widens triangularly on joints 4 to 8, being widest on joint 6, where it extends to the lateral region. It becomes narrow in the incisure between joints 8 and 9, then widens to joint 11, and narrows again to the anal feet. It has an obscure brown border and incloses little green streaks in the anterior enlargement and others in the posterior one which almost predominate over the white color. A series of red-brown mottled blotches around the spiracles and subventrally with ill-defined edges. One on joints 4 and 5 runs obliquely forward and downward, one on joints 6 to 8 backward and downward, and others on joints 9 and 10 not oblique. There are traces of a white subventral line along the ridge, seen distinctly only on joints 12 and 13. Anal feet white, with a brown line on top and black at the tip.

"*Stage V*.—Vertex of head retracted below joint 2, not exceeding it, as in *biundata*. Head finely dotted and mottled with light red and black on a whitish ground, forming a diffuse gray band from ocelli to vertex, with a crimson tinge around the ocelli; mouth dark crimson, as are also the thoracic feet except at the joints; width, 3.5 mm. Body with a sordid white ground color (in the brown form) or lighter green (in the green form), thickly covered with white rounded red-brown dots, arranged in irregular longitudinal streaks intermixed with white streaks, the lateral patches of the previous stage largely obscured (or as before in the green form). Horns absent; the cervical shield smooth. Anal feet short, divergent, white. Dorsal band as before, all white, less thickly dotted with brown than the sides, defined by a brown shaded border and tinged with yellow where the horns were and at the sides of the central enlargement and with crimson on joint 2. (In the green form there is a faint double, rather irregular dorsal line, which is green on joints 5 to 7, 9 and 10, and forms a green wedge-shaped patch on joints 11 to 13, edged with brown and yellow, tapering posteriorly and ending in a line on joint 13. A pale yellow stigmatal line.) The border of the band is broken on joint 11, as in the pattern of *guttivitta*.

"Three larvæ on oaks (*Quercus macrocarpa*) at Plattsburg, N. Y., August, 1893, collected with the assistance of Prof. G. H. Hudson and Mr. C. F. Hudson." (Dyar.)

Geographical distribution.—This species is widely diffused throughout the Appalachian and Austroriparian subprovinces, replacing in the former *H. astarte* of the Southern and Southwestern States. According to Grote (List of 1868, footnote, p. xii), it is figured by Abbot in his inedited manuscript drawings, and hence must inhabit the Austroriparian subprovince. I also have a specimen from Georgia from Mr. Hulst; Medford, Mass. (Trouvelot); Plattsburg, N. Y. (Hudson); New York to Pennsylvania (Grote); Rhode Island (H. L. Clark); Manhattan, Kans., May 11, normal form (Popenoe); Winter Park and Enterprise, Fla. (Mrs. Slosson); Missouri, Georgia, Florida (U. S. Nat. Mus.); Massachusetts (var. *trouvelotii*); South Carolina (French); Arkansas (Palm).

Var. *perolivata* (Pl. V, fig. 7). In the collection of the United States National Museum is a finely preserved Heterocampa (No. 2801, the moth appearing in confinement August 2, 1882) from Fort Monroe, Va., which at first I regarded as probably undescribed, but which I now consider as a variety of *H. obliqua*, and somewhat similar to Grote and Robinson's figure of *H. obliqua* ♂. The larva feeds on the live oak, and was found July 28. I have prepared the following descriptions:

One ♂. Thorax and fore wings almost entirely of a beautiful pale green, with no white except two whitish costal patches, and a large white subapical oblique white patch, the black lines and marks, with the discal mark obscure. The basal and inner (i. e., that on the inner third of wing) lines as in *astarte*, rather than *obliqua;* discal mark black, elongated, obscure (on the right wing obsolete). Extradiscal treble line as in *astarte*. The large oblique white mark as in *astarte*, but the black line bordering it within is not so distinct as in *astarte*.

The marginal scalloped line as in *astarte* rather than *obliqua*, the scallops being nearly as deep as in *astarte*. Hind wings snow-white, with black scales on the costal edge and a small dusky spot on the internal angle. The intervenular dusky dots faintly shown.

Underside as in *astarte*. Abdomen pale fawn color, i. e., pale ocherous brown. The abdomen is distinctly tufted at the end, more so than usual in the genus, perhaps because of its excellent state of preservation.

Expanse of wings, ♂ 35 mm.; length of body, ♂ 18 mm.

Larva (Pl. XXIX, fig. 11).—(Described from a single ♂ specimen). Length, 32 mm. Body cylindrical, without tubercles, and of the general appearance of Doubleday's figure of the larva of *astarte*. Head rounded and narrowing above, smooth above the vertex, with no traces of vertical tubercles, and no traces of tubercles on the prothoracic segment; a reddish band on each side of the head, ending near the eyes; face in front pale, testaceous, not spotted. Body green, thickly dotted with reddish brown on the back and sides. No russet marks or reddish patches on the sides of the body. On the prothoracic segments two dark red lines converging behind and becoming parallel just behind the middle of the segment and continuing close together and parallel to each other as far as the hinder edge of the third thoracic segment: thence not very rapidly diverging and becoming farthest apart on the second abdominal segment; then converging only slightly toward the fourth and fifth segments, and ending nearly as wide apart on the ninth segment. These reddish lines are thickened on the second abdominal segment and the space between is dorsally filled in partly with red, but not enough so as to make a distinct spot. Inside of the line on abdominal segments 1 to 10 are two fine parallel median lines, interrupted at the sutures. The heavier outer or subdorsal lines are not lined or broadly edged within with yellowish white, as they are in an allied species not identified (a blown larva in the United States National Museum).

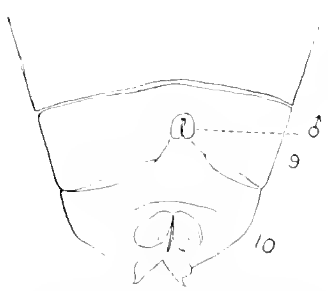

FIG. 86.—Pupa of *Heterocampa obliqua* var. *perolivata*, end of body of ♂.

Pupa.—♂ of the usual shape and color. Head much rounded. Abdominal segments coarsely punctured, the pits often confluent. The surface of the thorax is corrugated with transverse ridges. Hinder edge of the thorax singularly ornamented with about eight large, rounded, black tubercles, and the hinder edge of the eighth and ninth abdominal segments with about eight dorsal tubercles or knobs. Cremaster ending in two separate stout spines, which are simple, slightly curved, and divergent. The specimen is apparently not entirely normal in shape, being rather slender, not full and plump as usual, and the end of the body is a little abnormal, the cremaster not extending outward, probably injured in pupation. The vestiges of the anal legs are rounded and knob-like, and indicate more plainly than I have yet seen their origin from the anal legs of the caterpillar.

Heterocampa astarte Doubleday.

(Pl. V. fig. 11 ♂, 12 ♀.)

Heterocampa astarte Doubleday, Entomologist, p. 57, 1841 (*H. menas*, Harris Corresp., p. 131, 1869).
Walk., Cat. Lep. Brit. Mus., v, p. 1025, 1855.
Morris, Synopsis Lep. N. Amer., p. 240, 1862.
Pack., Proc. Ent. Soc. Phil., iii, p. 368, 1864.
Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Hep., i, p. 563, 1892.
Dyar, Ent. News, iv, p. 33, 1892; Amer. Ent. Soc., xxi, p. 205, 1894.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 205, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Larva.

(Pl. XXXIII, fig. 9, 9*a*.)

Doubleday, Entomologist, p. 57, 1841 (figure of larva and pupa), plate facing p. 60, figs. 1, 2.

Moth.—Three ♂, two ♀. Fore wings more decidedly pale olive-green than any others of the genus, with distinct black lines and markings arranged nearly as in *H. obliqua*. Palpi extending but little beyond the head, gray, black along the upper edge and on the side of the second joint; third joint rather short, acute, grayish. Thorax greenish gray; tegulæ edged with dusky brown, and a dusky brown transverse oval ring over the mesoscutum; a smoky brown spot on the base of the abdomen.

Fore wings a little sharper at the apex than in *H. obliqua*, the outer edge being oblique, as in that species, and the costal edge straight; the wing is of a decided pale olive green tint, especially in the middle of the wing. At the base of the wing is a black dot, from which a narrow black line passes out just behind the cubital vein, a little way beyond the basal line. This line is double and is represented by two black scallops, one on the costal and the other on the median space, not passing farther back across the wing toward the internal edge. A second distinct black double line on the inner third of the wing, somewhat curved in its course, and consisting of three scallops, one on the costa, one in the median space, and the third, slightly curved, scallop in the internal space. The discal mark is a conspicuous, long, curved black line, just within which is a small diffuse smoky patch, connected on the costa with a double smoky line. Extradiscal line: a double one of well-marked deep scallops curving inward behind the discal space, and ending on the outer third of the internal edge; within this curved portion is a parallel row of dusky scallops, situated directly behind the discal mark. Between the discal mark and submarginal line the wing is quite clear and greenish. A distinct black line beginning on the first cubital vein and curving forward and ending on the apex, and sending a black slash along the sixth subcostal venule. Beyond this line is a broad dusky shade bounded externally by the marginal row of distinct black scallops, which are much deeper than in *H. obliqua*. The costal edge is marked with alternate dark and light short lines.

Hind wings in ♂ snow white, with the costa blackish, and a dark dot on the internal angle; in the ♀ sordid white, with a dark line across the middle, and the outer margin of the wing dusky brown, with a black spot in the internal angle.

Under side of the fore wings dusky on the costal region, the discal mark and dusky submarginal band showing through. The rest of the wing is whitish. The hind wings are whitish, except the costal region, which is whitish, and in the ♀ the wings are more dusky. The outer margin of both wings is dusky, and the only whitish portion on the under side of the fore wings is the large oblique subapical shade, while the base of the hind wings is whitish.

Expanse of wings, ♂ 45 mm., ♀ 55 mm.; length of body, ♂ 21 mm., ♀ 23 mm.

This superb and beautifully marked species is at once recognized by the pale, rich, olive-green hue of the thorax and fore wings, with their distinct black markings, including the black linear discal mark; by the often snow-white hind wings, and by the deeply scalloped marginal black line.

It differs from *H. obliqua* not only by its olive-green tint, but by the less curved inner line on the fore wings, by the more deeply scalloped marginal line, and by the white hind wings of the male, as well as other minor peculiarities.

Pupa.—Figured by Abbot. Doubleday's figure is a copy of Abbot's.

Food plant.—Various species of oak. *Quercus nigra* (Abbot MS.).

Habits.—In Texas the moth was collected by Belfrage, April 27 and 29, and July 11, showing that in that State it is double-brooded.

Geographical distribution.—*H. astarte* appears to be confined to the Southern States, and not to extend so far north as *H. obliqua* with its varieties. It is properly a member of the Austroriparian subprovince.

St. Johns Bluff, Fla. (Doubleday); Florida (Thaxter ex Grote); Bosque County, Tex. (Boll, Belfrage, U. S. Nat. Mus.); Georgia, Florida, Texas (U. S. Nat. Mus.); Georgia (Abbot, MS.); Florida (French).

Heterocampa lunata Edwards.

(Pl. V, fig. 6, ♂.)

Heterocampa lunata (H. Edwards), Papilio, iv, p. 64, March, 1884.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 563, 1892.
Lophodonta plumosa H. Edwards, Ent. Amer., ii, p. 14, April, 1886.
Smith, List Lep. Bor. Amer., p. 30, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 563, 1892.
Heterocampa lunata Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 205, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1895.

Moth.—Two ♂. On examining the type (a ♂ from Colorado) of this species in the Edwards collection in the American Museum of Natural History, New York, I find that it should be referred to the genus Heterocampa, and that its position in that genus is near *H. biundata*. The antennæ are very plumose, the pectinations being somewhat longer than usual; the tip is simple, as usual in the genus. The palpi are as usual ascending, larger and rather broad, more so than usual, projecting well in front of the head; the third joint is concealed by the hairs of the second. The apex of the fore wings is considerably produced; the outer edge of the wing long and oblique. The shape of the hind wings, of the abdomen, and of the tufts on the thorax are as usual in Heterocampa.

Specific characters.—Head and body brownish granite gray, the tint peculiar, approaching that of *H. manteo*, but with more reddish brown scales. Palpi grayish, with a distinct black line along the upper edge. The markings of the fore wings are much as in *H. biundata*.

On the basal third of the fore wing is a faint zigzag line formed of four rather sharp scallops, the largest scallop with a small narrow one above situated both in the submedian interspace; the last scallop not directed outward, as in *H. biundata*. The linear discal spot is small, black-brown, but distinct, though only half as large as in *H. biundata*. The extradiscal line is obsolete. The outer or submarginal series of sublunate brown spots is much as in *H. biundata*, the spots becoming linear in front of the cubital vein. The fringe and the brown line at its base are much as in *H. biundata*.

Hind wings whitish, clouded on the costal margin; the fringe long, checkered, but not clouded on the internal angle of the wing.

Expanse of wings, ♂ 43 mm.; length of body, ♂ 20 mm.

On comparing Edwards's types of his *lunata* in Mr. Neumoegen's collection with his type of *plumosa* in the American Museum of Natural History, both Dr. Dyar and myself find that they are the same species.

Neumoegen and Dyar (Revision, etc.) regard Druce's *H. dardania* as a synonym of this species.

Geographical distribution.—A member of the Campestrian subprovince. Colorado (Bruce, U. S. National Museum and Amer. Mus. Nat. Hist., New York); Arizona (Morrison, Coll. Neumoegen); Colorado, Arizona (French); Fort Collins, Colo. (Baker); Mexico (Druce).

Heterocampa umbrata Walker.

(Pl. V, figs. 10, 13 ♂, 11 ♀.)

Heterocampa umbrata Walk., Cat. Lep. Het. Br. Mus., v, p. 1023, 1855.
Heterocampa pulverea Grote and Rob., Trans. Amer. Ent. Soc., i, p. 185, Aug, 1867, Pl. IV, fig. 32 ♀.
Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List. Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, pp. 563, 564, 1892.
Heterocampa athereo Doubleday, Harris Corr., p. 131, 1869.
Heterocampa umbrata Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 205, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sep., 1894.

Larva.

(Pl. XXXIII, fig. 8, 8*a*.)

French, Can. Ent., xii, p. 83, April, 1880 (last larval stage described); Sixth Ann. Rep. S. Ill. Normal Univ., p. 44, 1880.

Packard, Fifth Rep. U. S. Ent. Comm. on Forest Insects, p. 159, 1890 (copied from French). (The larva referred to in Proc. Bost. Soc. Nat. Hist., xxiv, p. 518, is not that species.)

Moth.—One ♂, two ♀. Head, thorax, and fore wings pale ash, with a slight pale olive-green tint. Palpi slender, short, black. Prothorax or "collar" with two slightly marked parallel lines crossing it. Tegulæ with white scales in the middle, while the edges and ends are bordered with white and black scales. Thorax behind with a blackish patch, succeeded on the abdomen by seven dusky short basal tufts, brownish in ♂, of which the first one is very large, the others small, the fourth one larger than the others, except the basal one.

Fore wings pale ash-gray, with a pale olive-green tint, a basal double black scalloped line at the insertion of the wing, not reaching the internal edge, which is white. On the basal fourth of the wing is a black scalloped line, followed by a broad, clear olive-ash space. Discal mark a curved, narrow (distinct in ♂, in ♀ not very distinct) line continued behind, i. e., on the cubital vein by a distinct, broad, black shade containing three parallel narrow black lines (wanting in the ♂ I have seen); this shade is much as in *H. obliqua* and curves outward, filling the second cubital space, the outer end becoming a part of the submarginal line. A large semielliptical or pear-shaped, clear, almost whitish, ash area beyond the discal mark, and traversed by a faint double scalloped dark line, the extradiscal, which entirely crosses the wing. The characteristic mark in ♀ is the black, distinct, scalloped, broken, submarginal band, which is nearly obsolete on the costa and on the internal edge, but broad and heavy between, and dislocated on the first cubital vein, the scallops being heavy, wide, and black. (In the ♂ I have seen these scallops are disconnected and lighter in hue, as well as narrower).

The edge of the wing is clear greenish ash. The fringe is of the same color, with black venular streaks. Costa with three linear black subapical marks.

Hind wings alike in both sexes, with a distinct sinuous diffuse whitish band on the outer third, this being the only species in the genus in which this line is present, and in this respect strongly recalls *H. marthesia*. Beyond this line the wing is smoky, the fringe white, dusky at the base, where is a black scalloped line. A dark spot at the internal angle.

Underside of the wings whitish, the dusky submarginal shade reproduced beneath in each wing. Fringe as above.

Expanse of the wings, ♂ 45 mm., ♀ 45 mm.; length of body, ♂ 20 mm., ♀ 19 mm.

H. pulverea is readily recognized by the lack of the subapical oblique white shade, so distinct in *H. obliqua*, by the heavy black scalloped line which is broken on the first median vein, by the pale greenish tint of the thorax and fore wings, and by the unusual whitish sinuous line on the hind wings.

My specimen, which agrees with Grote and Robinson's description and figures, also agrees with a type specimen in the American Museum in New York, and such a specimen labeled in Mr. Grote's handwriting in the collection of Mrs. Bridgham in New York.

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[1] The description of the moth does not apply to *pulverea*, but was drawn up from *H. guttivitta* by error. The references on pp. 328, 492, and 649 are erroneous. Mr. Dyar writes that he believes Walker's *H. umbrata* and *H. semiplaga* are two earlier names for this species.

Larva.—"Length, when at rest, 1.25 inches (in shape tapering slightly from the middle forward, but more rapidly from that point backward, the body deeper than broad). General color bright, clear green, a little spotted with white, marked as follows: Head gray, a little lighter through the center. Joint 1 contains two dark purplish black warts on the dorsum, reddish purple at the base, the space between them whitish. From these runs backward a bright, brownish purple line, not very dark, at first about one-sixteenth of an inch wide. This expands, reaching the subdorsum in the posterior part of joint 4, dividing in the middle in joint 3. The line runs along the subdorsal region to the posterior part of joint 6, where they unite and cover the whole of the dorsal part of joint 7 and all but a little of the posterior part of joint 8, when it again separates and runs as two lines to the posterior part of joint 9. The space on the back of joints 3, 4, 5, and 6 between the purple lines is filled with orange. On joint 4 a spur is given off from the purple line to the third thoracic leg, another runs from joint 6 to the first pro-leg, another short spur on joint 9; both of the last with oblique lines of lighter shade. On joint 9 the orange is outside the purple, extending down the lateral spurs. Joint 10 has no purple nor orange, except a little below the stigmata, but it has faint yellow subdorsal lines. Joint 11 has purple subdorsal lines which unite on the anterior part of joint 12, continuing backward as a broad dorsal line, darkest on the anal plate. The space on joint 11 between the subdorsals is filled with orange. Feet and legs purple, but the rest of the underside green; under the glass the above-described brownish purple lines are not uniform, but mottled with irregular lighter lines." (French).

From the above description it will be seen that the two prothoracic warts are retained throughout larval life, this, as Dr. Dyar has remarked to us, being the only species in the genus in which these tubercles are retained after the last molt. This fact shows that *pulverea* is the most primitive species of the genus, but until we discover the first stage of *astarte* it will be premature to construct a genealogical tree of the genus.

It is evident from the larval characters that this species should be placed below *H. guttivitta* and *H. obliqua* and *astarte*, while the moth is near *H. obliqua*, with no near affinity to *H. guttivitta* and *biundata*. As it is the only species known to us with the tubercles retained in the last stage, it is most probably the species which Doubleday has figured under the name *H. athereo*.

Habits.—All that is known with certainty is stated by Professor French as follows:

The single larva from which the above description was taken was found June 30 on the body of a white oak tree. During the few days before it pupated I fed it on the leaves of *Quercus alba* and *Q. coccinea*, both of which it ate readily. July 6 it entered the dirt of the cage to transform, and produced the imago August 6.

In a volume (Gray's copy) of Abbot's manuscript drawings (fig. 117) is a fine colored sketch of *H. pulverea*. It has well marked prothoracic tubercles, and is drawn in different attitudes as feeding on *Styrax pulverulentum*. (For stages I-V see Appendix A, p. 283.)

Geographical distribution.—Thus far it has not been met with beyond the limits of the Appalachian and Austroriparian subprovinces.

Seekonk, R. I. (Mrs. S. W. Bridgham); Lonsdale, R. I. (Dearden); Pennsylvania (Grote and Rob.); New York (Grote, Hulst, Neumoegen); Carbondale, Ill. (French); ♂ and ♀, Punta Gorda, Charlotte Harbor, Fla. (Mrs. Slosson); Georgia, (Abbot).

Heterocampa belfragei (Grote).

(Pl. V, fig. 15 ♂.)

Heterocampa belfragei Grote, Can. Ent., xi, p. 209, Nov., 1879; New Check List N. Amer. Moths, p. 19, 1882.
Litodonta belfragei Smith, List Lep. Bor. Amer., p. 31, 1892.
Heterocampa belfragei Kirby, Syn. Cat. Lep. Het., i, p. 565, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 206, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Moth.—One ♂. This is a true Heterocampa and near *H. pulverea*, and should not be included in the subgenus Litodonta, although the nature of the female antennæ is not known; it differs from *H. hydrometi* in the outer edge of the fore wings being very oblique. Thorax ash-gray; collar with two transverse black lines; tegulæ edged with black. A broad black transverse tuft on the basal segment of the abdomen.

Fore wings with a heavy distinct black line near the base, straight and ending on the median vein; basal scalloped black line on the basal third of the wing. A black costal spot in front of the discal mark, which is linear, black, curved, and distinctly defined. No line behind. Extradiscal line sinuous, doubly scalloped, inclosing whitish gray scales. Submarginal shade somewhat recalling that of *H. pulverea*, but narrower and less scalloped, much dislocated on the first median venule. Fringe concolorous with the wing, with a fine black line at the base and with linear venular spots.

Hind wings white, with a black line at the base of the fringe and with dark venular spots.

Underneath, both wings are white, a little sordid on the costal region of both pairs of wings, and the fringe of both wings is spotted with black.

Expanse of wings, ♂ 36 mm.; length of body, ♂ 16 mm.

This is a very distinct, well-marked species, and with a submarginal blackish shade as in *H. pulverea*, but narrower and more dislocated.

Geographical distribution.—"Clifton, Bosque County, Tex., March 23, April 15 and 21" (Belfrage); Texas, Arizona (French).

Heterocampa chapmani Grote.

Heterocampa chapmani Grote, Bull. U. S. Geol. and Geogr. Survey (Hayden), vi, No. 1, p. 258, Feb. 11, 1891.
Kirby, Syn. Cat. Lep. Het., p. 561, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 205, June, 1894.

I had, from Grote's description, regarded this as identical with *H. astarte*, but since then Dr. Thaxter has kindly shown me his three specimens, which were those he lent Mr. Grote, and which were his types. They were obtained at Appalachicola by Dr. Chapman. The species is figured by Abbot in his manuscript volume of drawings in the library of the Boston Society of Natural History.

One ♂, two ♀. Very similar to *H. astarte* in style and position of markings, and it may, when we know the larva, be found to be only a variety of it, though quite a distinct one. It differs from *H. astarte* as follows:

The black lines and the dusky shades and patches on the fore wings in *H. astarte* are in *H. chapmani* reddish brown, and the olive greenish shade is in *H. chapmani* pale, almost whitish ash, and on the scutellar region of the thorax reddish brown instead of dusky.

Fore wings with the basal line indistinct, reddish brown; no distinct dark, curved, black line on the internal edge of wing as there is in *H. astarte*. The two scalloped intradiscal lines as in *H. astarte*, but reddish brown. The discal line is less curved than in *H. astarte*, and not black, but deep reddish brown. The three extradiscal scalloped lines just as in *H. astarte*, but dark brown, not black. The submarginal oblique shade so distinct and black in *H. astarte* is in the present form reddish brown, as is the submarginal scalloped line, and the scallops are within filled in with spots of reddish brown; the dark spots on the fringe are reddish.

Hind wings not white at the base as in *H. astarte*, but subocherous or snuff-brown; a median shade as in *H. astarte*, the outer edge of the wing broadly shaded with pale ocherous brown, but this shade is broader than in *H. astarte*. Beneath shaded as in *H. astarte*, but the hue is ocherous brown rather than dusky or blackish. Length of body, ♀ 22–23 mm.; expanse of wings, ♀ 55 mm.

It will be seen that the difference in the two species or forms is in the color, and not in the shape and position of the markings, but at first sight the two look quite different, and provisionally should be regarded as so; this is also the view of Grote and of Thaxter. Yet it is very plain that *H. obliqua*, *astarte*, and *chapmani* have originated from a common ancestor.

Heterocampa subrotata Harvey.

(Pl. V, figs. 17 ♀, 18 ♂; 19 ♂, celtiphaga.)

Heterocampa subrotata Harvey, Bull. Buffalo Soc. Nat. Sci., i, p. 263, Jan., 1874, Pl. XI, figs. 2 ♂, 4 ♀.
Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 563, 1892.
Dyar, Ent. News, iv, p. 33, Jan., 1892.
Heterocampa celtiphaga Harvey, Bull. Buffalo Soc. Nat. Sci., i, p. 263, Jan., 1874, Pl. XI, fig. 3, ♂.
Grote, New Check List N. Amer. Moths, p. 19, 1887.
Smith, List Lep. Bor. Amer., p. 21, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 563, 1892.
Heterocampa superba H. Edw., Papilio, iv, p. 121, Sept., 1884.
Smith, List Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 565, 1892.
Heterocampa subrotata Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 206, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

This very distinct species, which connects *H. astarte* and *obliqua* with *H. hydromeli*, is easily recognized by its uniformly yellow ocherous fore wings and body, the fore wings being in the middle quite clear, by the long distinct discal mark and by the broad diffuse dark shade behind it, and by the broad white subapical shade. I copy Harvey's original description of *H. celtiphaga:*

Smaller than *H. subrotata*. antennæ pectinate, palpi dependent, thickly hirsute; thorax dark ashen; abdomen paler, becoming dark ashen toward the tip; primaries dark olivaceous ashen, almost approaching to black. All the lines light brown and narrow and similar to *H. subrotata* in their conformation; apical white shade not as extended. Fringes ashen; discal lunate mark brown; from this the scalloped transverse posterior line is externally farther removed than in *H. subrotata*. Secondaries white, with an incomplete whitish median shade; terminal line black, even; fringe ashen, pale at base, cut with darker hairs at extremity of the veins

Expanse, 18 mm. Larva on hackberry (*Celtis occidentalis*).

The specimen was received from Mr. C. V. Riley. It is the smallest species of Heterocampa yet known to science.

I have examined Edwards's type of *H. superba* (from Texas) and a male also from Texas. The following is a description of Edwards's type specimen:

It is allied to *H. obliqua* in general style of markings, but has very short wings and a square apex. The fore wings are pale tawny ocherous, clearer than in *H. astarte*. At the base of the wing behind the median vein is a short narrow black line, and a very long one starts from its base and follows the base and hind edge of wing, as in *H. astarte* and *obliqua*. Beyond this the base and middle of the wing is clear tawny ocherous. Discal mark, a curved black streak, and connected with a long straight black streak in the second median interspace, this line being inclosed in a large black diffuse patch extending below the line and inside of the discal spot; in front the blotch connects with the submarginal series of black intervenular straight streaks. Between this series and the discal spot are two parallel lines, the inner black. A faint linear submarginal scalloped line. Fringe marked with black streaks.

Hind wings as in *H. obliqua* var. *brunnea*, cloudy on the outer half with a faint pale band beyond the middle of the wing. Both wings clouded on the under side, becoming darker toward the margin, which suddenly becomes pale.

In comparing, with Dr. Dyar, *H. superba*, *subrotata* (one loaned by Mrs. Slosson), and *celtiphaga*, the latter kindly loaned by Mr. Neumoegen, we found that these are nominal species and synonyms. The specimen of *H. celtiphaga* has a white spot at the base of the fore wings, and the inner margin is edged with black. The oblique subapical shade is smaller than in *subrotata*. Mrs. Slosson's specimen of *subrotata* differs from the ones I have described in having no ocherous tint, and the black shade under the discal mark is obsolete in both examples of *subrotata* and *celtiphaga*. The latter does not present varietal differences from *subrotata*, being only a little smaller (alar expanse, 27-28 mm.), while the marks are not so distinct as in the dark non ocherous example of *subrotata* in Mrs. Slosson's collection.

We now describe what has been known as *H. subrotata*:

Moth.—One ♀ (Pl. V, fig. 17).

Fore wings short and broad, and rather square at the apex. Body and fore wings uniformly ocherous, collar and tegulæ edged with scattered dark scales. Palpi short, small, brown on the outer side of the second joint. Fore wings with black scales at the base and extending along the internal edge of the wing: a black basal line interrupted by the cubital vein: a double black line on the basal third of the wing composed of a large scallop in the discal and a larger one in the submedian space. Middle of the wing entirely clear ocherous. A long, much-curved linear discal black mark, from the inside of which a long, broad, smoky, blackish shade curves around, interrupting the extradiscal line and ending near the internal angle, behind the inner end of the whitish subapical patch; in its hinder end near the internal angle are three black slashes situated in the interspaces, and from it a short narrow black line crosses the second cubital venule, and which is bordered by a narrow white line. Extradiscal line double, a deep long scallop parallel to the discal mark, and two short scallops in the first cubital space. The white subapical patch is unusually broad, beginning on the first cubital venule and ending on the apex. A scalloped marginal black line. Fringe ocherous, with dusky venular dots.

Hind wings pale sordid whitish at base, becoming smoky externally, and crossed by a diffuse whitish line which is slightly bent in the middle of the wing. No dusky spot at the internal angle. The abdomen is pale ocherous. The underside of the wings is ocherous, the dark shade of the fore wings appearing, though faintly.

I have not seen the male of this ocherous form, but Harvey describes it as differing from the ♀ "by the subterminal line being more undulatory, by the less prominently contrasting brown and whitish shades beyond the cell subterminally, while the antennæ are pectinate."

Expanse of wings, ♂ 33 mm., ♀ 35 mm.; length of body, ♀ 16–17 mm.

Geographical distribution.—Apparently mostly confined to the Austroriparian subprovince, but occasionally met with in the Appalachian.

Central Alabama (Grote); Bastrop County, Tex. (Belfrage, U. S. Nat. Mus., the label being in his handwriting); Punta Gorda, Fla. (Mrs. Slosson). (The exact locality of *celtiphaga* was not given by Dr. Harvey); New York, Missouri, Alabama (French); *superba*, Texas (French); Chicago, Ill. (Westcott); Arkansas (Palm).

Heterocampa hydromeli (Harvey).

(Pl. V, fig. 16.)

Litodonta hydromeli Harv., Can. Ent., viii, p. 5, Jan., 1876.
Litodonta fusca Harv., Can. Ent., viii, p. 110, 1876.
——— *hydromeli* Grote, New Check List N. Amer. Moths, p. 19, 1882.
Smith, List, Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 563, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 208, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Moth.—One ♂ and four ♀ (in the Edwards Coll.). Antennæ, palpi, and vestiture of the head above and in front just as in *H. subrotata*, but the pectinations of the antennæ are a little longer, though the shape of the wings and the markings are just the same. The antennæ are white above, with a black dot at base. Front of the head more hairy and with longer hairs than in *H. astarte*, but the palpi are not so long, though very near in shape, black above and gray beneath. Tegulæ edged with black, as in *H. superba*, and the crest on the mesothorax as in *H. superba* and *astarte* and allied species. Fore wings and body of a pale and whitish gray, tinged with a decided sea or pale olive green. Thorax with two curvilinear black lines, one on each side on the prothorax, meeting in the middle of the body. Thorax behind with black cross lines, and the tufts and tegulæ tipped with black.

Fore wings short and broad, the apex more rectangular than usual except in *superba*: olive and yellow scales at base of the wing, the irregular patch interrupting the basal black line, which forms a diffuse patch between the origins of the cubital and submedian veins. Just beyond is a transverse sinuous dark line, curving suddenly inward on the costa, curving outward on the subcostal and cubital veins, and curving in again in the submedian space, then directed obliquely outward and ending on the inner edge of the wing. From the angle on the submedian fold a narrow interrupted line extends along the internal vein to the black line situated on the inner third of the wing, and which is very sinuous, and ends in a black patch both on the costal and inner edge. The discal linear black spot very distinct and prolonged obliquely to the subcostal vein, and also extending to the origin of the first cubital venule, and from that point a black line extends outward along the venule, ending in one of the submarginal series of bright sulphur-yellow intervenular spots which are situated in the faintly marked dark lunules. A series of dark brown lunules at the base of the fringe, which is white, faintly checkered with dusky at the end of the lunules.

Hind wings whitish, with a dark costal oblique streak near the apex.

Underside of the fore wings whitish, with three oblique brown streaks on the outer fourth of the wing, just before the apex.

Expanse of wings, ♂ 28–30 mm.; length of body, ♂ 11 mm.

To show that the genus Litodonta is probably not well founded, it may be said that *H. superba* is very near it, and differs mainly in the ♂ antennæ not having quite such long branches, and in the thorax and fore wings being washed with tawny yellow instead of sea-green,[1] and in having no submarginal yellow spots. Otherwise the two species are very closely allied, being of the same size and with the same shape of wings. The female has not yet occurred, so that we do not know the nature of the antennæ in that sex.

Habits.—It is two-brooded, as the moths were collected in Texas in April and May and also in July and August (Riley MS.).

Geographical distribution.—Thus far this interesting species is confined to the Southern States (Austroriparian subprovince), having occurred in Texas, where it has been collected by Belfrage, and in Punta Gorda, Charlotte Harbor, Fla. (Mrs. Slosson); Texas (U. S. Nat. Mus.); Texas (Boll, Mus. Comp. Zool.); Texas (French).

Heterocampa unicolor (Packard).

(Pl. V, fig. 20.)

Lochmæus unicolor Pack., Proc. Ent. Soc. Phil., iii, p. 373, 1864.
Lochmæus marina Pack., Proc. Ent. Soc. Phil., iii, p. 373, 1864.
Heterocampa unicolor Grote, New Check List N. Amer. Moths, p. 19, 1882.
Popenoe, 1st Rep. Kansas Exp. Stat., p. 35, 1888.
Smith, List Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 564, 1892.
Misogada cinerea Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 207, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Larva.

(Pl. XXXIII, figs. 4, 4*a*, 4*b*, 4*c*. Stage I.)

Harris, Ent. Corresp., p. 301., Pl. 1, fig. 5, 1869. (By error as *S. bilineata*.)
Edwards, Ent. Amer., iii, p. 168, 1887. (Last stage.)
Popenoe, 1st. Rep. Kansas Exp. Stat., 1888, p. 35. (Larval Stages I, II, and last, with egg, pupa, and imago ♂ and ♀, figured by Mr. Marlatt.)
Dyar, Psyche, vi, p. 95, 1891. (Life history.)
Packard, Proc. Journ. N. York Ent. Soc., i, p. 75, Jan., 1893.

Moth.—Five ♂, three ♀. Of a uniform pale cinereous, being of a faded appearance and with a faint greenish tinge, without any band or spots; or pale sea-green; dusted very minutely with ashen scales, or varying in the same brood to dark purplish gray, with transverse darker punctuated scalloped lines. Costa very straight, compared with that of *M. marthesia*. A faint series of pale longitudinal lines situated on the venules passing across the fore wings near their base. On the outer third of the wing is a rather irregular curved series of dark spots bordered externally with white; the ends of the venules are dark. With these exceptions there are no other markings, the moth thus differing notably from its congeners; no part of the wing is darker than another, and it has a faded look in very fresh examples, which is very unique in the genus.

The head, palpi, pectus, and underside of the body in general are very pale clay and whitish yellowish. The hind wings are pale ashen whitish, in some cases with a straight mesial, obscure dark spot.

[1] Dr. Dyar writes that he believes that fresh *superba* are green, and that the yellow tint is due to fading, as in *H. biundata*.

Underside uniformly pale, body and both wings almost white, and in some examples crossed by a dusky line.

Expanse of wings, ♂ 48 mm., ♀ 43 mm.; length of body, ♂ 19 mm., ♀ 18 mm.

In the straight costa, rather oblique outer edge, and lack of any definite markings, including a discal mark, this species, with its pale, faded look, differs from any others of the genus.

Specimens of the extremes of variation in a brood reared by Professor Popenoe, and which he sent me, included both unicolor and marina of my Synopsis.

Egg.—Diameter, about 0.7 mm. Regularly hemispherical, though rather flat, not being more than half as high as broad. Shell, when empty, thin, white, ornamented with dense, more or less regular, well defined polygonal areas, the edges or margins of which are very finely beaded; toward the apex they become more or less elongated and the micropyle at the apex is surrounded by a double rosette of elongated oval areas, the sharper end pointing inward, those of the inner row one-third to one half as large as those forming the outer series. The larva in escaping eats, as usual, an irregular, kidney-shaped hole near the top.

The eggs were received from Mr. Tallant of Columbus, Ohio, August 21, having been sent on the 18th, all hatching on the way.

Larva, Stage I.—Freshly hatched larva. Length, including the tails (stemapoda), 6–7 mm. The head is almost as wide as the body, somewhat heart-shaped, bilobed, dark chestnut, paler along the middle. The body is long and slender, especially elongated behind the eighth abdominal segment. The prothoracic segment in all the examples is full, as if it were about to molt, though it seems too soon after hatching. The prothoracic segment bears two diverging, rather thick appendages, which are cylindrical and rounded at tip; the segment at base and behind pale reddish and cherry-red above; the appendages are cherry-red at base, paler above, but toward the end on the distal two-thirds blackish. In front are two reddish parallel stripes. The body is pale beneath, above pale greenish yellow, the third and seventh abdominal segments cherry-red, including the sides, low down, of the sixth segment. From the first thoracic to the end of the body are three parallel lateral, linear, reddish lines, the lowermost being obsolete posteriorly. The eighth abdominal segment is convex above, but not humped. The suranal plate is small, narrow, but distinct, rough on the surface and dark, almost blackish. Behind, at the base of the tails, are two piliferous warts; the tails themselves are as long as the three last segments (8–10) taken to together, and are of uniform thickness, ringed with dark red, densely, microscopically, spinulose, with sparse fine hairs and with two or three hairs at the end. The legs each end in a cylindrical swollen flagellum, somewhat barrel-shaped, with a deep red ring in the middle, the end being clear and transparent. All over the body the piliferous warts and hairs are minute. The glandular setæ are short, slender, widening at the square end, and not being regularly bulbous.

It rests with the body curved around so that the head nearly touches the tails, the last three segments and tails being held up in the air, the latter being extended and then gracefully thrown into the air.

Stage II.—Length, 9 mm. The anal legs are still longer than before, but the prothoracic spines are much less than one-half shorter than before, while the back of the body is now reddish. (Popenoe).

Dr. Dyar has contributed the following descriptions as the proofs are passing through my hands:

Stage III.—"Head whitish green, a broad diffuse brown band on each lobe to vertex; width, 1.35 mm. Cervical horns represented by two short black tubercles; tails 2 mm. long, faintly reddish, the crimson tips a little swollen. Body green, with three to five faint white lines each side of the reddish brown dorsal band, which is distinct, covering cervical shield and anal plate, retracted at each suture and widening on joints 7 and 11.

Stage IV.—"Head about as high as wide, narrowing toward the vertex; width, 2.2 mm., marked as before, the inner white border of the brown band very broad, covering a large part of the face. Cervical horns reduced to mere points. Dorsal band as before, but of nearly uniform width, though widened on joint 11. The band is mottled with and bordered by white, becoming yellow in the segmental sutures. There is a trace of a yellow stigmatal line, and the sides have a few black specks toward the extremities."

Last stage.—In a blown full-grown larva received from Professor Riley the body is cylindrical, smooth, and the head is small and rounded, with no traces of warts on the head, which is slightly bilobed. The prothoracic and first and eighth abdominal segments are normal, with no piliferous tubercles, not even on the segments specially named. The anal legs are long and slender, but no longer than the body is thick.

The body is green, of the hue of the leaf it feeds on; along the back is a broad whitish yellow band, edged with reddish. There are no subdorsal or lateral lines or other marks.

RECAPITULATION.

1. In Stages I and II we have the high prothoracic tubercles like those of *M. marthesia* in its fourth stage.

2. There are no subdorsal or lateral lines in the last stage, and, as in *marthesia*, the movements of the anal legs must serve to deter its enemies from attacking it, being otherwise protected by its color, which is like the leaf on which it feeds.

It is evident that by their larval characters this species and *marthesia* are closely allied.

Cocoon.—"A loosely woven silken cocoon under or among the leaves and other rubbish upon the ground." (Popenoe.) The pupa is fully described by Dyar in Psyche, vi, p. 96.

Habits.—Thanks to Professor Popenoe,[1] we have the fullest account yet published of the habits and transformations of this species. It is at times destructive to the sycamore. The eggs are "laid in close groups of from fifteen to seventy-five upon the underside of the leaf of the sycamore." It appears that the "newly hatched larvæ for a time feed in company upon the leaf pulp," and in the first stage when disturbed fall or spring off and hang suspended by a silken thread. It is to be noticed that the larva "forms a loosely woven silken cocoon under or among the leaves and other rubbish upon the ground."

As the larvæ grow they no longer feed on the pulp of the leaf, but devour the woody parts and veins, when their work becomes more noticeable. When nearly fully fed the majority of the larvæ are yellowish green, marked with red as at *c*, but in the same brood, says Popenoe, "there will occur other larvæ (*d*) lighter in coloration, but transforming into moths indistinguishable from those produced by the darker form," and "the differences in coloration in the adult larvæ have no relation to the correspondingly great variation in the moths, so far as was observed." "In eastern Kansas," says Popenoe, "the larvæ occur in two broods each year, the first brood appearing in early June, the second in the first week in August. The larvæ of the first brood reach their full size in the early part of July; and within the shelter of the cocoons which they spin when full grown, the transformation to the pupal state is effected. The summer moths soon appear, and after the pairing the females lay the eggs which produce the second brood of larvæ. The larvæ of this brood mature toward the end of August, and, having spun cocoons about themselves, pass the winter unchanged, the pupal state in this brood not being reached until the following spring, a short time before the appearance of the spring moths."

From Professor Popenoe's table showing the series of changes, it appears that at Manhattan, Kans., for the first brood, the eggs being deposited June 11, the length of the egg state is four days; of larval Stage I, four days; II, three days; III, two days; IV, four days; it remained six days in the last stage (V), and was inclosed in its cocoon ten days before the pupa was seen.

In the second brood, the eggs being deposited July 27, the duration of the egg state was about four days; Stage I, three days; Stage II, three days; Stage III, three days; Stage IV, five days; Stage V, four days.

The larvæ occur in March, July, August, and September, the moths flying in May, June, and August (Riley MS.).

Food plants.—Sycamore (Riley, Pilate, Popenoe).

Geographical distribution.—Its range extends over the Appalachian and eastern borders of the Campestrian subprovinces, and with little doubt will be found to occur throughout the Austroriparian.

[1] First Annual Report of the Kansas Experiment Station for 1888, Rep. Dept. Hort. and Ent., p. 35. The illustrations were drawn by Mr. C. L. Marlatt.

Cambridge, Mass. (Harris); Seekonk, Mass. (Mrs. Bridgham); Glen Cove, Long Island (Mrs. Slosson); Massachusetts, Rhode Island, New York (French); Ohio (Pilate); Columbus (Tallant); St. Louis, Mo. (Riley); Manhattan, Kans. (Popenoe); Washington, D. C., Virginia, Missouri, Texas (U. S. Nat. Mus.); New Jersey, Arkansas (Palm).

Macrurocampa Dyar.

(Pl. XLVII, figs. 4, 4*a*. Venation.)

Lochmæus Pack. (in part), Proc. Ent. Soc. Phil., iii, p. 370, 1864.
Heterocampa Grote, Trans. Amer. Ent. Soc., i, p. 182, 1867; New Check List N. Amer. Moths, p. 19, 1882.
Smith, List. Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 1892.
Macrurocampa Dyar, Ent. News, iv, p. 31, Jan., 1893; Trans. Amer. Ent. Soc., xxi, p. 208, June, 1894.

Moth.—Male and female. Head large and prominent, a little wider than in Heterocampa. Palpi short and broad. Fore wings more produced toward the apex, which is pointed, outer edge long and very oblique, no subcostal cell (for other details of the venation see Pl. XLVII, figs. 4, 4*a*), but otherwise the venation is much as in *H. astarte* and *obliqua*. Hind wings slightly shorter and more rounded at the apex than in Heterocampa.

The fore wings are rather more clear of markings than in Heterocampa, being whitish gray with dark blotches at the base of the wing and near the outer edge. Hind wings with a diffuse whitish extradiscal line.

When we take into account the lack in the adult of the subcostal cell and the presence in the larva of perfect stemapoda and its lateral yellow bars, it seems best to separate this species from the genus Heterocampa as Dr. Dyar has done, and which I had been inclined to do for some time.

Larva.—Body long and slender, ending in a pair of twin stemapoda, as well developed as those of Cerura; no prothoracic tubercles in the last stage; body pale green, with a dorsal pink hue, and obliquely barred, sphinx like, on the sides with yellow.

Freshly hatched larva.—Stemapoda nearly as long as the body, with a pair of erect prothoracic tubercles, a slight broken dorsal line the only marking.

Cocoon.—Oval, elliptical, thin translucent.

Pupa.—Body thick, plump, head with prominent ridges on the vertex; cremaster ending in two stout diverging conical spines.

Macrurocampa marthesia (Cramer).

(Pl. V, figs. 21, 22 ♀.)

Phalæna marthesia Cram., Pap. Exot., ii, p. 3, Pl. XCVIII A, 1779.
Lochmæus tessella Pack., Proc. Ent. Soc. Phil., iii, p. 370, 1864.
Cerura turbida Walk., Cat. Lep. Het. Brit. Mus., xxxii, p. 307, 1860 (*fide* Grote and Rob.).
Heterocampa tessella Grote, Trans. Amer. Ent. Soc. Phil., i, p. 182, Aug., 1867, Pl. IV, fig. 29, ♂.
Heterocampa elongata Grote, Trans. Amer. Ent. Soc. Phil., i, p. 184, Aug., 1867, Pl. IV, fig. 30, ♀.
Heterocampa marthesia Grote, New Check List N. Amer. Moths, p. 19, 1882.
Heterocampa elongata Grote, New Check List N. Amer. Moths, p. 19, 1882.
Heteracampa tessella Druce, Biologia Centr. Amer. Het., i, p. 238, May, 1887.
Heterocampa marthesia Smith, List Lep. Brit. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 561, 1892.
Heterocampa elongata Kirby, Syn. Cat. Lep. Het., i, p. 561, 1892.
Macrurocampa marthesia Dyar, Ent. News, iv, p. 31, Jan., 1893.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 208, 1894; Journ. N. Y. Ent. Soc., ii, p. 117, Sept., 1894.

Larva.

(Pl. XXXIV, figs. 1-5; XXXV, fig. 4, 4*a*.)

Packard, Proc. Bost. Soc. Nat. Hist., xxiv, p. 550, 1890.
Dyar, Proc. Bost. Soc. Nat. Hist., xxvi, p. 157, 1894. (Life history.)

Moth.—Two ♂, four ♀. Fore wings more produced toward the apex and outer edge more oblique than in *Heterocampa obliqua*. Whitish ashen gray, head, prothorax, and patagia being thus colored, while the rest of the thorax is darker cinereous, the abdomen being a little paler. The larger part of the fore wings is of a pale whitish ashen, concolorous with the head and prothorax. Nearly the basal third is of a darker cinereous (usually almost black) than the hinder part of the thorax, and this portion embraces three unequal black linear streaks, one extending along the subcostal, the middle one the largest and following the cubital, while the shorter one runs along the internal nervure. This region is bounded externally by a pale ashen line which begins on the basal third of the costa and runs obliquely inward; it is twice zigzag before the subcostal, is bent more obtusely outward in the discal space, and again bends slowly outward, and turns at a right angle to meet the dark streak on the internal vein, and usually crosses the wing, ending in the middle of the internal edge. The discal mark is a faint curved black line, succeeded by a rather oblique, very obscure cinereous lunated line. Upon the costa just beyond is a white spot, once zigzag on the costa, edged without with black. Beyond this spot are three minute dark spots, the inner of which is succeeded by a series of four large pale lunules margined on either side with cinereous, which end on the third median, being in the third interspace replaced by a square conspicuous black spot, whose upper side is continued a little outward, while on the opposite lower side is a supplementary linear dot in the next interspace. This spot is continuous with a submarginal oblique subapical zigzag pale line, dusky within and bearing within three dark streaks in the middle of each interspace. Beyond this line the margin is dusky cinereous, with a marginal series of black linear lunules interrupted by the venules. Fringe ashen, with long black streaks, rather than dots, on the ends of the venules.

Hind wings but little paler than the abdomen, with a rather distinct pale band on the outer third, which is curved suddenly outward in the middle. Base of fringe dark, as are the venules and outer margin of the wings. The only mark on them is a single oblique costal streak a little beyond the middle of the wing.

Expanse of wings, ♂ 45 mm., ♀ 55 mm.; length of body, ♂ 20 mm., ♀ 22 mm.

This fine species is rather above the medium size, and may be recognized by the pale, almost white, fore wings, whose basal third is blackish; also by the obscure linear curved discal mark, and more especially by the squarish black spot near the internal angle, which is isolated from the submargino-apical dusky line, of which it forms a part.

The hind wings are crossed on the outer third by a diffuse whitish sinuous line not present in *H. astarte* or *obliqua*.

The species is also notable from the six dusky dorsal tufts along the abdomen of both sexes. It is liable at first sight to be confounded with *H. pulverea*, but differs in the clearer, less spotted middle portion of the fore wings.

The foregoing description applies to those examples, five or six, which I have bred at Providence. In a female expanding 60 mm., received from Mr. Hulst (Pl. V, fig. 21), and presumably collected in New York or New Jersey, the fore wings are fully as light, but the double zigzag line on the basal third of the wing is much more distinct than in the males I have reared or seen, and forms the outer edge of the blackish basal third of the wing. Beyond this line the wing is almost white, with a very faint yellowish brown shade toward the apex. Extradiscal line composed of three parallel scalloped lines, and in the second or third median space is a distinct black irregular lunule; a scalloped subapical black line.

Hind wings uniformly mouse colored, with a distinct whitish diffuse line, which enables one to readily separate this species from *H. astarte* or *obliqua*.

The form figured by Cramer is probably the present species; it is like a large ♀ (Fig. 21) in my collection. Cramer's figure is very poor and is a rude representation of this variety. My specimen is exactly like Grote and Robinson's type, which is in the American Museum of Natural History, with which I have compared it. The same specimen also agrees with their colored figure. My example is a ♀ expanding 45 mm. It differs from those described above in having a wide, curved, black shade arising from inside of the discal mark and nearly swamping it; it then curves around backward and outward, filling the second cubital space and inclosing two black curved streaks or lines, while the lunule in the first cubital space is large and distinct, and the scalloped subapical black shade beginning on the first cubital venule is broad and distinct, this shade being distinct in the types of my original description of *tessella*. In this variety the fore wings are slightly suffused with a greenish yellowish tint. Hind wings with a distinct whitish line, within which the wing is white, but beyond dusky.

The two pairs of hind tibial spurs are long and well developed. My original type is in the collection of the American Entomological Society, Philadelphia.

Egg.—Diameter, 1.2 mm. Low, flattened, hemispherical, much broader than high; in shape much like that of *H. unicolor*, but larger. Shell covered with polygonal areas, seen under ½-inch A eyepiece, with rather thin, not very distinct walls, not quite so distinct as in *H. unicolor*. Micropylar region forming a rosette of four circles of elongated, crowded, small polygonal areas.

For several eggs I am indebted to Mr. Tallant, of Columbus, Ohio. They hatched July 27, in Maine.

Larva, Stage I.—Length of body without the tails, 3.5 mm.; of the tails, 2.5 mm.; total length, 6 mm. Head moderately large, as wide as the prothoracic segment, but wider than the body in the middle. The head is unusually short, flattened in front, pale greenish yellowish and rusty brown on the sides. On the prothoracic segment are two long, high, rust reddish tubercles, which are darker at the end, conical and rounded at the tip, and bearing a light seta; they are inclined forward, and are situated far apart on the extreme side of the segment. The body behind is narrow, cylindrical, scarcely tapering to the ninth segment. The segments are not convex, but are transversely wrinkled and uniformly yellowish green. The only marking is a slight broken dorsal median obsolete line, represented by a faint elongated spot in the middle of the body and another near the end.

The tails (stemapoda) are long, like those of Cerura, being almost as long as the body and very slender. Their basal third is pale greenish; beyond, reddish brown, becoming paler just before the tip, which seems to be enlarged.

It differs from the young larva of Cerura in the prothoracic horns being vertical and laterally projecting.

Before molting the pink dorsal line becomes a little more pronounced.

July 31 it was about to molt, when the length of the body was 6 mm.; of the tails, 4 mm.; total, 10 mm.

It was found just molted on the morning of August 2.

Stage II.—Length of body, 7 mm.; of the tails, 5 mm.; total, 12 mm.

The head is now wider than the body and entirely pea-green or with a reddish hue; the body is a pea-green with a yellowish tinge. The tubercles on the prothoracic segment are nearer together at their base; they are dark coral-red, paler at base, *and from them a dark pink dorsal line extends back to the suranal plate, widening on the second, fourth, and fifth (according to the figures the third, sixth, and eighth abdominal) segments.* The tails are pale on the basal half, beyond deep pink, and interrupted near the end by a pale ring. All the legs, both thoracic and abdominal, are pale green and of the same green hue as the body. The segments are transversely wrinkled.

Stage III.—Whether the following description applies to the end of the second or beginning of the third, I am not entirely sure, but suppose it applies to the third stage. I was unable to find the cast skin.

Length of body, 10 mm.; of tails, 4 mm.; total, 14 mm.

The head is now subconical, narrowing decidedly above toward the vertex; *it now has a reddish pink stripe on each side, with yellow behind.* The dorsal red stripe is now continuous, widening on the second and fourth abdominal segments, on the fourth forming a diamond shaped spot. The two tubercles on the prothoracic segment are large, deep coral-red, and the space in front at their base is whitish, but wider than in the next stage.

A subdorsal irregular yellow line, sending an oblique narrow bar or stripe from one segment downward to the lower and hinder edge of the one behind, so that the second and third thoracic segments and abdominal segments 1 to 8 appear to have two narrow yellow oblique bars. The tails are now about one-third as long as the body, and still reddish.

The larva has now acquired the features of the fully developed larva, with the exception that the horns of the prothoracic segment are larger and prominent.

The following description is of an individual found on the underside of a beech leaf at Brunswick, Me., August 6:

Stage IV.—Length of body, 12 mm., and of tails, 6 mm.; total, 18 mm. Head yellowish green, narrowing toward the vertex, flattened in front, with two broad pink lateral bands, which meet above, and are broadly bordered behind with pale straw-yellow. Body pale, distinct green, speckled in parallel lines with reddish brown, there being ten oblique, parallel, pale yellowish, lateral stripes passing downward and backward, the first one on the second thoracic segment very short, being one-third as long as the next one. Two high, slender, conical, pinkish red tubercles on the prothoracic segment. A dorsal broad yellow band, becoming pinkish on the suranal plate; the line is broken into a series of smooth yellow swellings, four or five on a segment. The tails are greenish, with a slender internal pink thread line, the ends with the flagella (or eversible portions of the stemapods) deep coral-red.

(In some alcoholic specimens in the United States National Museum the length of body, not including the tails, is 22 mm.; of the tails, 8 to 9 mm.; length just before molting, 28 mm.; of the tails, 10 mm.; total, 38 mm. The larva is much as in the third stage; the prothoracic tubercles as before, but slightly smaller in proportion to the body. The tails are as in Stage III, the flagella nearly as long as the sheath, which is red at the end.)

Stage V and last.—Length of body, 40–42 mm.; of tails, 4–5 mm.; total, 44–47 mm.

It will now be seen that the tails are only about one-tenth as long as the body, while in Stages I and II they are about two-thirds as long as the body.

It is a large-bodied, pale green caterpillar, thickest in the middle, being somewhat spindle-shaped. The head is moderately large, flat in front, subconical, with the vertex high and conical, pale green, edged very irregularly with roseate on the sides. A small, double reddish tubercle on the top of the prothoracic segment, from which a median white or yellow dorsal stripe, here and there marked with roseate spots, passes back to the suranal plate. The anal legs are represented by two slender filaments held outstretched, which are nearly as long as the body is thick. There are seven pairs of oblique, lateral, faint yellowish, slender stripes, the last pair extending to the sides of the anal filaments. All the legs are pale green and concolorous with the body.

A great change has occurred in the prothoracic tubercles which are now two low, flattened, inconspicuous warts on the upturned or flaring edge of the segment. The anal legs are much shorter in proportion and not so long as the body is thick, being about one-third as long in proportion as in the third and fourth stages.

This caterpillar we have observed when disturbed to send out from near the head a copious shower of spray or vapor, being in this respect like that of Cerura, so carefully worked out by Prof. E. B. Poulton. The opening is hard to find. The opening of the median prothoracic gland is exactly like what we have observed in *Cerura borealis*. It is a transverse slit situated in the median line of the body, between two transverse folds directly behind the head, but yet a little way behind the front edge of the segment. It has slightly developed lips.

The points of interest in the ontogeny known to us are as follows:

The congenital characters are the enormously long stemapoda, in proportion to the body, and the pair of long, prominent prothoracic tubercles.

The acquired characters are the dorsal line, the oblique yellow bars, and the gradual reduction in the length of the tail.

Other features are:

(1) The presence of filamental anal legs exactly homologous with those of Cerura, and nearly as long, and the fact that they are much longer in the early stages than in the final one, which seems to suggest strongly the view that this genus is the ancestor of Cerura, and that the very long lashes were of more use to the ancestors of the present species than to the form we now have. It will be remembered that *M. marthesia* ranges as far south as Brazil, and that it may have originated in South America and spread northward; it is also possible that it had a set of enemies, probably ichneumons, which it has not had to contend with in temperate North America, and that the filaments have begun to diminish in size from partial disuse. On the other hand, the spraying apparatus lodged in the first segment next to the head seems to perform its function in undiminished vigor. Experiments like those made by Mr. Poulton on the fluid secreted by Cerura should be conducted with the present insect.

(2) The second point is the complete reduction in size of the two high prothoracic spine-like tubercles which takes place at the last exuviation.

(3) The head, compared with that of Cerura, is not retractile, the prothoracic segment being of the normal size.

This retractility of the head in Cerura may be an adaptive, recent character, and this feature appears to indicate that it is a later, more specialized form than *H. marthesia*.

Cocoon.—The caterpillar spins between the leaves (in the breeding cage) a symmetrical oval-elliptical, evenly woven cocoon of pale gray silk, though it is thin and translucent. It is 30 mm. in length and 17 mm. in width.

Pupa.—Two ♂, three ♀. Body full and thick, the abdominal segments 1 to 7 punctured much as in *H. guttivitta* and *biundata*. The head is full, rounded, with two well-marked, parallel vertical ridges, which are convex and smooth, passing up and down between the eyes; on the top of the head are slightly marked corrugations. In the transverse black band extending across behind and next to the hinder edge of the thorax are eight large, deep pits, the squarish tubercles between them being simple on the upper surface, which is dull, unpolished.

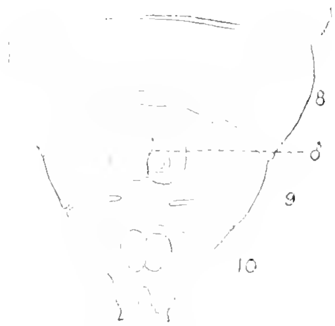

Fig. 87. Pupa of *Macrurocampa marthesia*, end of body of ♂.

Fig. 88. Pupa of *Macrurocampa marthesia*, sp., spiracle; end of body of ♀.

The cremaster bears two very stout, diverging spines, conical, corrugated on the surface; they are unarmed, being simple, with no accessory spinules, except minute rudimentary ones on the inside. Length, 18 mm.

Habits.—The caterpillar of this moth is one of the most interesting among the Notodontians, since it connects Cerura with the other genera, by reason of its two long caudal filaments, so much like those of Cerura. These appendages are simply modified anal legs, and seem to be tactile and repellant organs. This caterpillar is also interesting from its power, when touched, of forcing out a dense cloud of fine spray from a gland in the under side of the prothoracic segment near the head.[1]

In certain favorable years this is an abundant caterpillar on the oaks in Providence, R. I.

In Maine I have noticed the caterpillar in its fourth stage resting on the underside of the leaf, on a lateral rib, the dorsal stripe resembling in color and appearance the peculiar greenish yellow shade of the rib. When thus at rest the tails are not spread apart, but when disturbed it whisks its tails about, jerking them over its back just like a Cerura larva, its flagellum being everted and withdrawn as freely as in that genus. The cocoon is of silk, not very thick, spun between the leaves, and in confinement the moths issued at Providence in November, though ordinarily not due until June.

Professor Riley has observed it on oak at St. Louis, Mo., June 22, and in July; also in September, the moths issuing March 11 and 18. He has bred a Tachinid fly and a Cryptus parasite from the caterpillars.

Food plants.—The oak of various species; also found on the beech in Maine.

Geographical distribution.—Very interesting, as it occurs from Maine to Georgia and Texas, also occurring in Jalapa, Mexico, according to Druce in Biologia Centrali Americana, Heterocera, page 238, and in Surinam and Brazil. Its southwestern and western limits are unknown. It has not yet occurred in the Rocky Mountain region (Campestrian subprovince).

[1] I have deferred the description of the spraying glands of this and several other Notodontians to a future occasion. (See Journal New York Entomological Society, Sept., 1895.)

Orono, Me. (Mrs. Fernald); Brunswick, Me. (Packard); Lawrence, Mass. (Mr. Treat, Mus. Comp. Zool.); Providence, R. I. (Packard); New York (Dyar, Hulst); Plattsburg, N. Y. (Hudson); Pennsylvania (Grote, Amer. Ent. Soc.); New Jersey, Pennsylvania (Palm); Georgia (Leconte); Maryland (Mus. Comp. Zool.). Larva found on Indian River opposite Micco, Fla. (Prof. J. W. P. Jenks).

Subfamily CERURINÆ.

Head broad and full; antennæ with long, close pectinations in both sexes, in ♂ the branches being unusually long. Labial palpi reduced, three-jointed, the third and other joints when denuded not being distinct, while the scales are slender and sparse compared with those of other Notodontians. Fore wings moderately long and narrow, the outer edge either quite oblique or moderately so. Hind wings generally produced. Abdomen often broad and very hairy at the end in ♂. Color, white or pale ash, with brown-black transverse lines, sometimes eight in number; a discal ringlet; thorax and abdomen transversely striped.

Cocoon very dense, oval, flattened, the edges broad and thin; well rounded above. Often covered with bits of bark and wood. Attached to the bark of trees.

Pupa cylindrical, a little flattened beneath; rounded at each end; with no cremaster.

Larva with a broad prothoracic segment, in which the head is partially retractile, and bearing a pair of lateral tubercles. Anal legs converted into long slender filamental legs (stemapoda), each ending in an eversible flagellum. Young larva with a pair of long, horn-like prothoracic tubercles, and the stemapods a little longer than the body.

The following account of the mode of emergence of the Ceruras from their cocoons, by Dr. T. A. Chapman, will prove interesting:

Some pupæ are able to turn around in their cocoons, but I think the majority have their backs to the tree and their fronts to the exposed portion of the cocoon, and are practically fixed in their position. Then all the cocoons I have examined (thirty or forty) have a decidedly thinner place over the front of the head; it is larger than the cross section of the pupa; it contains fewer chips, and, held against the light, is quite translucent, while the rest of the cocoon is opaque. This is the portion of cocoon that is operated on for emergence.

I stated (loc. cit.) that the pupæ of our Ceruras were fairly rounded in front; in this I was decidedly in error, for *vinula* has nearly as pronounced a keel on the head as *C. multiscripta*, to which I referred. Our "kittens" are much smoother, though the same structure is indicated. It was observing this structure of *vinula* that tempted me to try to make further observations. I made a detailed description of this portion of the pupa of *vinula*, but I may omit it, as I made no observations that connected any habit with any peculiarity of this portion of the pupæ.

The dehiscence of the pupa consists in the thorax splitting dorsally and the division, proceeding to either side, separating the wings from the first three abdominal segments; the antennæ cases sometimes adhere to the wings, sometimes are separate; the leg and mouth-part coverings form a separate piece, whose apex tends to adhere to wings and abdomen. But the head covering, consisting of the ridge (or keel) and hollow on either side of it, the eye covers (including the glazed side portion), the face down to a certain incision, and a small portion below which is probably the labrum, separates as a distinct portion during the whole period of emergence and until the head is quite clear of the cocoon and often even after the moth has completely escaped, and is always found outside the cocoon. During this period the rudimentary proboscis is very visible as two short white papillæ, free from any hairs, and it is just above the base of these that the softening fluid exudes. This fluid is stated to be acid; this I did not test, but I found it to be colorless and tasteless, and it evaporated without residue; applied to the material of cocoon it softened it, but not at all rapidly. The moth makes many rotatory movements after the splitting of the pupa case, no doubt in order to smear his fluid over the necessary area of the cocoon, and we here see how little further is wanted to reach a habit similar to that of *milhauseri*, especially as the smearing process and delay for softening takes a considerable time, probably more than five minutes, possibly half an hour. This appears also from the amount of fluff rubbed about inside the cocoon in many cases. The moth keeps quite dry, and the head cover is dry outside, but moist within, when removed from the newly emerged moth; its function appears to be to protect the front of the moth during the movements of smearing and as a strong medium for applying the final breaking force to the cocoon. This use of this portion of the pupa case is by no means confined to Cerura, but is common to many moths that have to break through cocoons or out of the ground. It has, however, nothing to do with the actual distribution of the fluid, so far as my observations were decisive. I made one other observation that added a new point to be explained, viz, that when the moth emerged it often brought with it pieces of very delicate tissue that I passed over at first as being portions of the inner divisions of the pupa case; they proved, however, to be bits of the inner lining of the cocoon. The wall of a sound cocoon appears to be homogeneous; but in a cocoon where I stopped the moth before breaking it open, but after softening, this inner layer of very fine membrane is quite visible. I could not help framing several theories as to this, but as I know no more than I have stated, the theories may for the present remain in abeyance. (Entomologist, xxv, pp. 302–304, Dec., 1892. London.)

Cerura Schrank.[1]

(Pl. XLVII, figs. 5, 6, 6*a*, 6*b*, venation. Pl. XLVIII, figs. 7, 14, 15, palpus.)

Cerura, in part, Schrank, Fauna Boica, ii (2), p. 155, 1802.
Cerura Latreille, Genera Crust. et Insect. iv, p. 219, 1809.
"*Dicranura* Latreille."[2] (?)
Harpyia Ochsenheimer, Schm. Eur. Bd., ii, p. 19, 1810.
Andria Hübn., Tentamen., p. 1, 1810?
Harpyia and *Harpyias* Hübner, Verzeichniss Schmett., p. 148, 1816.
Pania Dalman, Anal. Ent., p. 92, 1823.
Dicranura Griffith, Cuvier's An. Kingdom, xv, p. 612, 1832.
Boisd., Gen. et Ind. Meth., p. 84, 1840.
Duponchel, Cat. Meth. Lep., p. 87, 1844.
Harpyia Staudinger, Cat. Lep. Eur., p. 72, 1871.
Cerura Packard, Proc. Ent. Soc. Phil., iii, p. 375, 1864.
Grote, New Check List N. Amer. Moths, p. 29, 1882.
Smith, List Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, pp. 585, 930, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 188, 1894.

Moth.—♂ and ♀. Head unusually large, front broad, subtriangular, much broader in ♂ than ♀, pilose. Antennæ short, about the length of the thorax, densely scaled above, very broadly pectinated, the branches becoming much shorter at the tips; in ♀ the branches are short but distinct. Eyes naked. Maxillæ rudimentary, separated, extending a little way beyond the scales of the front. Palpi unusually short and small, thinly scaled, and concealed by the hairy front. Scales of the thorax and patagia either close and short or loosely pilose. Fore wings rather long and narrow, less than half as broad as long; costa straight, suddenly rounded at the apex; outer edge entire, very oblique; internal angle rounded.

Venation: Subcostal cell minute; third subcostal venule short; the apical or third subcostal interspace broad, triangular; sixth subcostal (III_2) independent, arising in the middle of the discal space.

Hind wings a little produced toward the apex, reaching halfway to the tip of the abdomen costa slightly convex; outer edge oblique, the upper part straight, thence rounded; internal angle rounded. Vein II short, one half as long as in Macruroeampa. Posterior discal vein in both wings much curved.

Legs rather slender, with long sparse hairs; hind tibiæ with two minute spines. Abdomen somewhat flattened, tip broad and pilose.

Coloration: All the species white or whitish ash, with wavy transverse bands on the fore wings or a broad dark median band, and a large oblique subapical dark blotch, with discal dots or discal rings.

The species are readily recognized by the large broad head, small feeble palpi, the broadly pectinated ♂ antennæ, those of the ♀ also pectinated; the narrow wings, the white and pale gray ground color, and the peculiar markings of the fore wings.

Egg.—Flattened, hemispherical.

Larva.—Head large, broad; prothoracic segment wider than the head, with a pair of lateral tubercles; anal legs filamental, forming stemapoda, with an eversible flagellum. Freshly hatched larva with long stemapoda, slightly longer than in the last stage; the lateral prothoracic horns longer than in the mature caterpillar; body entirely brown above.

[1] Schrank in Fauna Boica, 1802, proposed Cerura for *terrifica* (*vidua* Knoch), *fagi*, *vinula*, and *furcula*. In 1810 Ochsenheimer created Harpyia, under which he first mentions *vinula*, which should be reserved for this genus. In 1810 Hübner placed *fagi* in Terasion (which preoccupies Stephen's Stauropus), and *terrifica* into Hoplitis (together with *H. meone* Cr.), and retained *vinula* together with *erminea* Esper for Ochsenheimer's genus Harpyia, which is a good genus, and then directly created Harpyias for *furcula*, *bifida*, and *bicuspis*, and an American species, for which it would be most proper to retain Schrank's first given name, Cerura, and drop entirely the rather objectionable name of Harpyias.

[2] In Latreille's Gen. Crust. et Insect., 1809, the name Cerura appears; nor is Dicranura mentioned by him in his Considérations génerales (1810), nor in his Familles naturelles du Regne Animal (1825). It is not mentioned in Agassiz's Nomenclator, nor in Scudder's Nomenclator Zoologicus. It is possibly a manuscript name adopted by Boisduval.

Cocoon.—More dense and perfect than usual in other Notodontians; elliptical, hard, and dense, flattened, the edges broad and thin, surface above well rounded; closely resembling an excrescence on the bark of trees.

Pupa.—Body cylindrical, tapering at each end. "Eyes prominent, a narrow carinated ridge runs along the head from between the eyes to back of the place of origin of the antennæ" (Dyar). End of the body rounded and obtuse; cremaster not prominent, and with no traces of a spine or hooks, since the cocoon is so dense and perfect that the pupa can not fall out or be easily disturbed.

"Pupation occurs in about two weeks after the completion of the cocoon, and the insects remain in this stage throughout the winter." (Dyar, Psyche, v, p. 395.)

Geographical distribution.—The species of this genus are to be found in the Old and New worlds; but two occur in India, however, and the two Brazilian species are doubtfully referred to Cerura by Walker.

In North America it ranges throughout the entire continent north of Mexico, excluding the arctic region, including the cold temperate subregion and warm temperate subregion and the humid provinces of the latter, and is represented by one species (*cinerea ?* Druce) in the Mexican subprovince, and also in Guatemala. Its extreme northern and northwestern range is not yet well known. Walker describes a form, perhaps *C. occidentalis*, as a variety of *C. bifida*, from St. Martins Falls, Albany River, Hudson Bay.

SYNOPSIS OF THE SPECIES.

A. Fore wings narrow, outer edge very oblique; discal mark a black dot.
- Median black band very irregular on each side, rudely hour-glass shaped; extrabasilar line consisting of four dots; no extradiscal lines .... *C. borealis*
- Median black band broad, distinctly and evenly edged on each side with black; extrabasilar line of five dots; a distinct white broad scalloped extradiscal line .... *C. occidentalis*
- Median band usually narrow, much contracted or obsolete in the middle; three extradiscal scalloped dark lines .... *C. scolopendrina*
- Like *scolopendrina*, but the band and lines faded out; thorax all gray, and body and wings whitish gray. *C. cinerea*

B. Fore wings broad, outer edge inclined to be less oblique; discal mark a ringlet.
- Fore wings with no median dark band, but crossed by nine dark scalloped lines, the third and fourth uniting to form a series of ringlets; hind wings often dusky; thorax white, with transverse black lines .... *C. scitiscripta*

SYNOPSIS OF THE KNOWN LARVÆ.

With longer cervical shield and shorter horns in Stage III than in the corresponding stage of *borealis*. *C. occidentalis*

Differs from *multiscripta* in that the dorsal reddish patch in the middle of the body does not descend so far down on the side .... *C. borealis*

Differs from *C. borealis* and *occidentalis* in the less connected and narrower dorsal lilac red patches, and in the end of the suranal plate being squarer than that of *C. occidentalis* .... *C. cinerea*

Like *borealis* but paler, more purplish, and dorsal hump distinct .... *C. scitiscripta*

Cerura borealis Boisduval.

(Pl. VI, figs. 10, 11, 12.)

Dicranoura borealis Boisd., Guerin. Icon. Regne Animal, t. 88, fig. 5, 1829, p. 519, 1844.
Griffith's Cuvier's Animal Kingdom, xv, 1832. Pl. XXXII, fig. 5, 5*a*, larva. (No description.)
Cerura borealis Morris, Syn. Lep. N. Amer., p. 238, 1862.
Pack., Proc. Ent. Soc. Phil., iii, p. 375, 1864.
Lintner, Rep. N. Y. State Museum, xxx, p. 196 (84), June, 1878.
Grote, New Check List N. Amer. Moths, p. 20, 1882.
Smith, List Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep., i, p. 588, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 189, 1894; Journ. N. Y. Ent. Soc., ii, p. 114, Sept., 1894.

Larva.

(Pl. XXXVI, figs. 1, 1*a*, 2, 2*a*, 3, 3*a*, 6; XLIX, fig. 2.)

Griffith, Eng. Edit. Cuvier's An. Kingdom, xv, 1832, Pl. XXXII, fig. 5*a*. (No description.)
Harris, Ins. inj. Veg., 1st edit., p. 305, 1841.
Lintner, Ent. Contr., iii, p. 151, fig. 11, May, 1874; Ent. Contr., iv, p. 81, 1878.
French, Can. Ent., xiii, p. 115, 1881.
Packard, Fifth Rep. U. S. Ent. Comm. Forest Insects, pp. 134, 158, 530, 597; 1890.
Proc. Bost. Soc. Nat. Hist., xxiv, p. 552, 1890.
Dyar, Can. Ent., xxiii, p. 83, April, 1891 (egg and larval Stages II, III, IV, V (and last); cocoon and pupa described.)

Moth.—Two ♂, one ♀. Female antennæ well pectinated. Head above white, each side in front black. Thorax in front to a little behind the base of the fore wings white, and behind edged with steel-blue metallic scales. Abdomen dull smoky gray, segments edged with white; end of ♂ abdomen white, fluffy, with a central dorsal black spot; end of ♀ dark brown, clothed with white and dusky scales.

Fore wings in ♂ white, in ♀ somewhat smoky. *The median black band with very irregular edges*, both within and without; the band varies in being either narrower or wider on the costa than on the internal edge, and the edges are irregular, the band contracting in the submedian space and becoming hourglass-shaped, and edged more or less continuously on each side with yellow ocher. A black dot on the common origin of the subcostal and cubital veins; beyond is a series of four black dots forming not a straight but a sinuous line, one of each being situated on the costa, on the cubital and internal veins, and on the internal edge.

A roundish, oval, small black discal mark. *No distinct extradiscal white band like that in C. occidentalis*, but a subapical black shade ending on the first cubital vein and edged within with dots of yellow ocher, succeeded behind by a black and yellow dot on the first, second, and third venules, and a large black patch edged with yellow within on the internal angle, the yellow spot being continuous with the yellow lining of the outer side of the median black band. The usual marginal row of coarse black dots.

Hind wings white, with a distinct discal mark; a dusky patch on the internal edge, and a distinct row of black spots. In ♀ the hind wings are somewhat dusky, the discal mark larger and diffuse, and the outer third of the wing dusky white, while the spots in the smoky fringe are black and diffuse.

Underside: Fore wings of male white, with three large equidistant costal black spots; from the third of these on the outer fourth of the costa a broad sinuous dusky shade crosses the wing, losing itself on the submedian fold. A submarginal dusky costal patch halfway between the line and the apex of the wing. Hind wings white, with a discal dot and one in the internal angle, and with black dots on the base of the white fringe. Fore wings of ♀ more dusky than the hind wings; no distinct sinuous line or black costal spots except those near the apex. Hind wings white, with a large diffuse black discal mark on each wing, and traversed by an extradiscal sinuous line of diffuse dark dots. Expanse of wings, ♂ 38–42 mm., ♀ 43 mm.; length of body, ♂ 13 mm., ♀ 13 mm. My specimens were so labeled by Riley, also by Edwards and Dyar, and the ♀ in the United States National Museum was so labeled by Mr. Lintner.

This species may be known by the irregular, hourglass-shaped median black band edged with ocher, by the inner band of four black dots, and by the absence of an extradiscal line.

The figure in Griffith's Cuvier well represents the female. The statement made by Harris in his description of "*C. borealis*," that the outer blackish band "is traversed and interrupted by an irregular, wavy, whitish line," shows that he had before him an example of *C. occidentalis*, while those individuals before him with dusky wings and indistinct bands are stated by Lintner to belong to *C. cinerea*.

The caterpillars occurred at Providence, September 18 to 24; one cocooned September 21.

The following account of the ontogeny of this species (identified from Professor French's description) has been drawn up in part from alcoholic specimens and in part from greatly enlarged and most carefully executed drawings by Mr. J. Bridgham. The different stages occurred at Providence on the wild cherry in September. Hellins states that the eggs of *C. vinula* are 1.6 to almost 2 mm. in diameter, and that the larva at its first molt is not more than 7 mm. long. Possibly the first stage was not observed by Mr. Bridgham, and the following description should apply to the second. Compare also Dyar's detailed description:

Egg.—"Less than hemispherical—obtusely conoidal, the base flat; minutely shagreened, color black; a little lustrous, but not shiny. Laid singly on either surface of the leaf." (Dyar.)

Cocoon.—Oval elliptical flattened, but central area well rounded; the edges broad and thin; spun of light drab silk; attached to side of breeding box or to bark of tree, and thus easily mistaken for an excrescence on the tree; being a case of protective mimicry.

Larva: Stage II.—Length in all, 15 mm. September 4. Head only as wide as the body behind the middle. The filamental anal legs, or stemapods,[1] as we may designate them, are now more than slightly half as long as the body. The horn-like tubercles on the prothoracic segment are slightly longer than in the second stage. The head and body are dark reddish brown above, the filamental anal legs with two broad, pale, greenish rings. All the other abdominal legs are green; the green patch extends from the underside of the first abdominal segment back over the third to eighth pair of spiracles, and underneath to the end of the body.

Stage II.—Length of body, 14 mm.; of stemapods, 7–8 mm., and of flagella, 3 mm. September 11. The head is rough and warty, the small warts bearing fine hairs. On the front toward the vertex are four papilliform, piliferous warts of the same size and shape as those on the prothoracic projections, and concolorous with the dark brown head. These spines are represented in the other species (*C. occidentalis*) from the willow only by very minute warts, bearing long, tapering bristles. The prothoracic segment is very wide and large, the well-defined cervical shield very broad, and ending on each side in a large, stout tuberculated horn, bearing about twelve piliferous, papilliform tubercles, there being a rude whorl of spines in the middle of the horn, the others growing out at the end. There are four coarse piliferous warts on the hinder edge of the cervical shield.

Along the body are scattered coarse piliferous warts, the dorsal four being arranged in a trapezoid. The stemapods are coarsely spined (more so than in *C. occidentalis*).

A peculiarity of the genus is the pair of very long papilliform infraanal tubercles, situated under the suranal plate, and ending in two long, stiff, sharp bristles.[2] The suranal plate is long and narrow, well rounded, and the surface is provided with high papilliform, piliferous warts.

In this species the head and the prothoracic horns above and beneath are reddish brown, the latter in *C. occidentalis* being yellowish beneath, the two species by this mark being easily separated.

The body is now more green on the sides, the green hue encroaching on the back and nearly meeting on the third thoracic segment. Only the fourth abdominal segment is wholly dark seen from above, and the green approximates high up on the sides of the sixth and seventh segments.

Stage III.—September 17. Length of body, 19 mm. and of stemapods, 12 mm. The body is now much thicker than before. The head is now smooth, with no traces of piliferous warts or of hairs representing them. The head is now larger in proportion to the body and paler red,

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[1] The term "tails" or caudal filaments is too vague for these highly modified anal legs; hence we propose the term *stemapoda* or stemapods for those of Cerura and Heterocampa. The derivation is Gr. στημα, filament; πους, ποδος, leg or foot. Mr. J. Hellins, referring to these organs in Buckler's Larvæ of the British Butterflies and Moths (Roy Soc., ii, 138), remarks "but now through Dr. T. A. Chapman's good teaching I regard them as dorsal appendages, somewhat after the fashion of the anal spines of the larvæ of the Satyridæ." This, I am satisfied, is an error. After repeated comparisons of the filamental anal legs of Cerura with those of *Heterocampa marthesia*, and comparing these with the greatly elongated anal legs of young *H. unicolor* as figured by Popenoe, and taking into account the structure and homologies of the suranal and preanal flaps, one can scarcely doubt that those of Cerura are modified anal legs.

It should be also remarked that this was the view of Latreille (Gen. Crust., et Insect., 1809, p. 219), who defines the genus thus: *Eruca pedibus analibus in caudam furcatam transformatis.*

[2] The use of these I find explained by Mr. Hellins in his description of the larva of *C. bifida* in Buckler's Larvæ of British Butterflies and Moths, ii, p. 142, as follows: "At the tip of the anal flap are two sharp points, and another pair underneath, which are used to throw the pellets of frass to a distance." Similar dungforks are very generally present in geometrid larvæ, the infraanal papilliform tubercles being well developed, though we have not seen them in use. (See also Dyar.)

spotted with still paler patches. The prothoracic segment is still large and broad, but the lateral projections are much shorter, and now the tubercles of the preceding stages are represented by sunken pits, from the bottom of which arise small hairs.[1] The hairs on the body are minute, only being visible with a lens. The suranal plate is smooth, the papilliform tubercles much thicker and shorter in proportion than before, and the bristles arising from them slenderer and more flexible. The spinules on the stemapods are much slenderer and smaller than before, but it is to be noticed that by this time they are larger on the underside, i. e., that side now almost constantly held up and thus more exposed to external stimuli, than those on the upperside of the filaments.

The colors of the body are nearly the same as in Stage II, but the brown is tinged with lilac and reddish, with greenish patches on the upper side of the second to fifth abdominal segments.

Stage IV.—September 16. Length of body, 26 mm.; of stemapods 15–16 mm. The larva is still much paler in hue than before, with more decided lilac blotches on the back. The thoracic dorsal hump is now very marked, while the lateral projections of the prothoracic segment have nearly disappeared. The front edge of this segment is vermilion red.

Full-fed larva.—Length, 45 mm., exclusive of the tails, which are about 15–20 mm. The head is pale reddish or mahogany-brown; about one third as wide as the body at the third thoracic segment. The prothoracic segment is very broad above, square in front on the sides, and not ending in a distinct tubercle, but simply a low projection. The body is pale greenish yellow (the colors somewhat faded in my three specimens, as they are about to transform). A dorsal median reddish brown band beginning at each angle of the prothoracic segment and narrowing on the second and third thoracic segments; it begins to widen on the first abdominal segment, becoming widest on the fourth, and extending down on each side to near the base of the abdominal legs, and contracting and becoming narrowest on the end of the seventh abdominal segment, and widening a little on the ninth. The anal plate is triangular, rounded at the end; the "tails" are brown, with three paler rings on the outer half. The thoracic legs are deep red; the abdominal ones pale, with brown plantae.

It differs from *C. multiscripta* in that the dorsal reddish patch in the middle of the body does not descend so far down on the side; otherwise it is like it in general shape and appearance. (Dr. Dyar tells me that the dorsal patch is very differently colored in *C. multiscripta*; it is a white patch, whereas *borealis* has a brown one.)

When at rest the head is retracted and sunken between the lateral fleshy conical projections of the prothoracic segment, which are temporarily improvised or pushed out by the larva when at rest. The thoracic legs are held close to the body and directed forward, the tail extended out behind, with the tips slightly curved up, the flagella being retracted. But when irritated or teased, and probably when visited or stung, by an ichneumon, the tails are jerked up and the flagella protruded, the head, with the thoracic segment, also being jerked up. The colors at this time are precisely those of a cherry leaf partly turned yellow and partly brown.

The caterpillar described below occurred in August and September at Brunswick, Me., on the aspen. It apparently differs from those of *C. occidentalis* and *cinerea* in the longer spines on the prothoracic segment in the young larva, and in the smooth slight rounded projections which replace them in the full-grown caterpillar.

Larva before last molt.—Length to base of caudal appendages, 11 mm. Head large, full, rounded, dark lilac-brown, speckled with yellow, slightly wider than the body except the front part of the prothoracic segment; the latter very broad, over twice as broad as long, the front edge laterally produced, and at each angle bearing a large, long, spiny tubercle three-fourths as long as the segment itself, the tubercle bearing about twelve setiferous spines; across the posterior edge of the segment is a row of four setiferous spines. On the back of the other segments are four short tubercles arranged in a short trapezium, and on each side of the segments are two smaller sharp tubercles. The dorsal tubercles on the mesothoracic segment are larger than those behind; those on the metathoracic segment smaller than those on any other segment. The body tapers gradually to the end; the supraanal plate longer than broad, rounded, bearing two long, large,

[1] Dr. Dyar writes me that he has never observed any species of Cerura to lose the tubercles on the cervical horns till the last stage.

setiferous fleshy tubercles, which lie between the bases of the spiny anal legs or filaments, which are about one-half or two-thirds as long as the body, and yellow, with two broad brown rings, and brown at the tip. Body greenish yellow, marked as usual with lilac-brown, this tint mimicking the dead, withered brown of the edge of poplar leaves of late summer; it is a dark lilac-brown with reddish brown and lilac brown patches, and in this way the caterpillar mimics the dead stained portion of the leaf on which it feeds and thus escapes observation. From head to end of mesothoracic segment a brown patch, succeeded by a pointed brown band which extends to the base of caudal appendages, but contracted on the eighth abdominal segment, the dorsal tubercles of which are yellow.

Larva after last molt.—Length, except caudal appendages, 17 mm. Differs from foregoing stage in the prothoracic spiny horns being replaced by smooth, shining tubercles with faint traces of the spines of the former stage; the sides of the thoracic segments more distinctly spotted, with faint traces of broken yellow lines in the middle of the body.

Cocoon.—"Like those of the other species of Cerura, but rather flatter for its size. Length, 38 mm.; width, 11 mm.; height above the surface of the wood, 6 mm." (Dyar.)

Pupa.—"Cylindrical, flattened a little on the ventral side, the ends rounded, not tapering; cases prominent, those covering the antennæ large; a slight depression behind thorax dorsally; no cremaster; color, red brown; cases finely wrinkled; dull; body smooth, slightly shiny. Length, 17 mm.; width, 5 mm." (Dyar.)

Habits.—The caudal appendages are soft and extensible on their outer third, forming the "flagellum," and are quickly jerked up when the creature is disturbed; they are evidently delicate repellant organs.

The close resemblance in the lilac-brown patches of this caterpillar and others of the genus to the sere and brown edges of certain of the leaves is remarkable, and plainly enough serves to protect the caterpillar from observation. I have observed the same in other Notodontians, especially *Schizura unicornis* and allied forms.

Food plant.—Species of wild cherry (Cerasus). In Edwards's Bibliographical Catalogue of the described Transformations of North American Lepidoptera, page 70, the word "Salix," should be replaced by "Cerasus," in line 13 from the bottom of the page.

Geographical distribution.—Maine (Packard); Franconia, N. H. (Mrs. Slosson); Massachusetts (Harris). Lintner gives the following localities for *C. borealis* (emend.): "New York, Pennsylvania, Virginia, Washington, D. C., Georgia, Missouri, August 26, at light (Riley)." Plattsburg, N. Y. (Hudson); Illinois (Dyar); Ormond, Fla., darker than the one from Franconia, N. H. (Mrs. Slosson); New York, Wisconsin, Carbondale and Champaign, Ill. (French); Chicago, Ill. (Westcott).

Cerura occidentalis Lintner.

(Pl. VI, fig. 15.)

Cerura borealis (in part, and *cinerea*) Harris, Rep. Ins. Mass., p. 306, 1841; Treatise Ins. Inj. Veg., 3d edit., p. 423, 1862.

Cerura occidentalis Lintner, Ent. Contr., iv, p. 82, June, 1878.
Grote, New Check List N. Amer. Moths, p. 20, 1882.
Smith, List Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 588, 1892.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 189, June, 1894; Journ. N. Y. Ent. Soc., ii, p. 114, Sept., 1894.

Larva.

French, Can. Ent., xiii, p. 111, 1881.

Packard, Fifth Rep. U. S. Ent. Comm., p. 565, 1890 (description copied from French) (Pl. XI, fig. 7, from a colored drawing by Dr. Lintner. This is more probably *cinerea* or *borealis*.)
Proc. Bost. Soc. Nat. Hist., xxiv, p. 554, 1890 (Stages II, III).

Moth.—One ♂, and others examined. Very distinct from *C. borealis* and *scolopendrina*. Head and collar dusky white; a black band crosses the thorax between the fore wings, behind which are yellow scales; black over the scutum. Fore wings ashy white, outer edge and base sordid white; *extrabasilar line of five close, large black dots*, the line interrupted as if a dot on the subcubital fold had dropped out. *The black median band unusually broad and straight on each side*, with a distinct, firm, black edge on each side, especially within, and the band is thickly dusted with white scales. A heavy outer parallel line close to the band, slightly sinuous, beginning on the inner edge and ending on the first cubital venule. A distinct scalloped white extradiscal line, edged with black on each side, and an inner faint dusky line between it and the discal spot, the latter being elongated and distinct. The usual subapical triangular patch extends backward farther than usual, being continuous with the outer of the extradiscal lines. Marginal black dots distinct.

Hind wings white, a large diffuse discal dot, marginal black dots distinct; a small dark patch on internal angle. Underside of fore wings dusky, the outer edge of the wings a little whiter; the white extradiscal line appears through. Hind wings white, with a large diffuse discal oval mark and distinct dots.

Expanse of wings, ♂ 30 mm.; length of body, ♂ 14 mm.

This fine species is known by the broad black band, dusted with white, and distinctly edged with black within and without; by the extrabasilar line of five large crowded dots, and by the distinct white scalloped broad extradiscal line. Lintner says that in respect to the extrabasilar row of five dots it does not differ from *aquilonaris*, but thus far I have not seen an example of the latter with more than four dots, the row not being so crowded.

Larva, Stage II.—Length of body, 11 mm.; of stemapods, 8 mm. It differs from the foregoing species of the same stage in wanting the frontal tubercles of the head, which is paler, and in the longer and slenderer prothoracic horns, the latter having smaller spines; it is also yellow beneath. The spines on the stemapods are finer. There is more yellow on the sides of the body, the yellow extending along the sides of the stemapods.

Stage III.—Length of body, 15 mm.; of stemapods, 4 mm. It differs from the third stage of *Cerura borealis* in the longer cervical shield and the shorter horns, so that the shield is more normal in shape, being as usual in many caterpillars. The piliferous warts over the body are a little larger, while the dorsal reddish saddle-like spots are more definitely lined with deep red.

Larva.—Length when fully grown, 1.25 to the fork of the tail. Body slightly enlarged in front and somewhat compressed. In about the middle of the prothoracic segment is a prominent projection on each side, the body sloping from these down to the rather small head; there is but little sloping from the back to segment 9; from this there is a rapid sloping to the anal segment, this ending in the two usual caudal filaments; when withdrawn these are a little more than a quarter of an inch long, but may be extended to three-quarters. Clear bright green, sides spotted with clear purple brown, the spots round the stigmata and at the base of the thoracic and abdominal legs the largest. The back is marked with lilac, varying in shade, and arranged as follows: From the two small contiguous tubercles on the back of joint 2 to the head is a somewhat diamond-shaped space, the broadest part at the subdorsal tubercles on the prothoracic segment. From the tubercles on this segment to those on the next the lilac is bordered by bright brownish purple with a white line; outside of this, in the middle of this diamond, is a little green shading. From the tubercles on the second joint from the head to the end of the body is another particolored space, lighter than the anterior one. This gradually expands so as to include the stigmata on segment 7, then decreases in width to the anterior part of the anal segment, expanding a little in the middle of this, but contracting again at its posterior part. The lilac of this is like the first, considerably suffused with green on the back, and is bordered with brownish purple and white, though the colors are a little lighter posteriorly. These two dorsal patches are not continuous, but are separated on the second segment by a distinct though small patch of green. The posterior projections are mostly brownish purple, though with somewhat greenish annulations, and when extended a ring of white near the extremity. Head dark lilac. Previous to the last molt the tubercles on the prothoracic segment ("joint 1") were covered with little spines. (French, Can. Ent., xiii, 144.)

Food plant.—Willow.

Habits.—The caterpillars of this moth were found feeding on willows (*Salix nigra*) by Prof. G. H. French, at Carbondale, Ill., from September 9 to October 5. The moths began to appear the following season from April 30 to June 3. In Maine it occurred on the willow throughout August.

Geographical distribution.—Orono and Mount Desert, Me. (Mrs. Fernald); Brunswick, Me. (Packard); Massachusetts (Harris); Franconia, N. H., common (Mrs. Slosson); eastern New York (Lintner, Edwards, Dyar); Plattsburg, N. Y. (G. H. Hudson); Canada, Maine, New York, Pennsylvania, Wisconsin, Illinois, Texas (French); Pennsylvania, Wisconsin, and Montreal, Canada (Lintner); thus far not known to occur beyond the limits of the Appalachian subprovince.

Cerura scolopendrina Boisduval.

(Pl. VI, figs. 13, 14.)

Phalæna furcula Abbot and Smith, Lep. Ins. Georgia, 1797.
Dicranura scolopendrina Boisd., Lep. de la Cal., p. 86, 1869.
Cerura aquilonaris Lint., Ent. Contr., iv, p. 85, June, 1878.
Harpyia albicoma Streck., Proc. Acad. Nat. Sci. Phil. for 1884, p. 284, Jan., 1885.
Cerura bicuspis Butler, Ann. Mag. Nat. Hist., viii, p. 31, Oct. 7, 1881.
Smith, List. Lep. Bor. Amer., p. 31, 1891.
Cerura scolopendrina Dyar, Can. Ent., xxiii, p. 186, Sept., 1891.
Cerura aquilonaris Grote, New Check List N. Amer. Moths, p. 20, 1882.
Cerura modesta Hudson, Can. Ent., xxiii, p. 197, Sept., 1891.
Cerura scolopendrina Kirby, Cat. Lep. Het., i, p. 588, 1892.
Cerura aquilonaris Kirby, Syn. Cat. Lep. Het., i, p. 588, 1892.
Cerura scolopendrina Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 189, 1894; Journ. N. Y. Ent. Soc., ii, p. 111, 1894.

Larva.

Thaxter, Can. Ent., xxiii, p. 34, Feb., 1891. (Food plant only mentioned.)
Dyar, Proc. Bost. Soc. Nat. Hist., xxvi, p. 159, 1894. (Entire life history probably of this species, the moth not being bred.)

Moth.—Nine ♂, three ♀. Body as in *C. borealis*, but the end of the abdomen is white, with longer hairs. Fore wings with the median dark band moderately broad, *usually straight on the inside, and irregular, scalloped, on the outside*, and interruptedly edged with ocher-yellow; extrabasilar line with four black dots forming a straight line, straighter than in *C. borealis*. Discal mark small, *three extradiscal faint dark scalloped lines*, and within these a short scalloped line parallel to the outer edge of the band, beginning on the internal edge and ending on the cubital vein. Subapical black shade distinct, more so than in *C. borealis; the black and yellow spot on the internal angle absent or small.* Wings white with black intervenular spots, smaller than usual. Hind wings white, with a distinct discal spot, *but with no dusky patch on the internal angle.*

Underside of fore wings dusky except at the base and on the outer edge. Hind wings with a diffuse discal mark and a dusky diffuse extradiscal shade. End of the abdomen white, and with very long, loose, wooly hairs.

Expanse of wings, ♂ 40 mm., ♀ 42 mm.; length of body, ♂ 18 mm., ♀ 15 mm.

The normal forms of this species are characterized by the usually narrow median band, the three extradiscal scalloped lines, and the small black and yellow spot on the internal angle of the fore wings.

Var. *modesta* Hudson (Pl. VI, fig. 14) a ♂ specimen collected by Mrs. Slosson at Franconia, N. H., had the following characters: The antennæ white, with long dark branches. Head in front and above white, on the sides and beneath black; palpi black, prothorax or collar cream-white; the thorax behind is deep black, with scattered brown scales. Abdomen above smoky brown, white on the sides, at the end, and beneath.

Fore wings cream-white, becoming slightly buff, brownish on the outer margin. A black dot at the base of the subcostal vein, and extrabasilar line of three dots, one on costa, and a second on the cubital, and a third on the internal vein, the three forming a straight line. On the inner third, just before the middle of the wing, is a broad steel-blue black, very conspicuous, band, which is either slightly contracted in the middle or very much so, being hourglass-shaped, spreading out equally on the costa and on the inner edge of the wing, being narrowest on the cubital vein. At the origin of the third (hinder) cubital branch is a dark dot from which a faint line goes to the inner edge parallel with the outer side of the black band. A small black discal dot. From a dot on the costa, a faint narrow line, curved inwardly around to the first cubital branch, curves inward between the first and second cubital branches, outward below the third cubital venule, ending in a black dot at the internal angle. A large, conspicuous, oblique, steel-blue black costal patch extending inward and downward to the first cubital venule; a row of intervenular marginal black dots.

Hind wings white, with a discal dot, and a dark spot on the inner angle. Fringe white, with black dots. Beneath white, the dark patches and band showing through; the discal dot is distinct, especially on the hind wings, and there is a curved extradiscal narrow dusky line. Tarsi black, ringed with white.

In a type specimen from Plattsburg named by Mr. G. H. Hudson (in United States National Museum), another from Providence, R. I., which is more rubbed, the median band is much broader, scarcely contracted in the middle.

In a series of six ♂ ♂ from Colorado in the museum of Brown University, presented by Mr. H. L. Clark, one closely approaches *C. cinerea* in its white color and in having the black thorax nearly overgrown with white hairs, while the median band on the fore wings is nearly obsolete, being represented only by a triangular costal dark spot and a small round spot near the inner edge of the wing; in another specimen the band is very much contracted, only represented by a narrow line on the cubital vein. On comparing such specimens it is seen that *C. cinerea* may have originated from this species, and that it is a more recent form than *scolopendrina*.

Larva.—Although the species is so widely diffused, its larva has not been detected except by Mr. Thaxter in Maine, who says that it feeds on Populus, but gives no description of it.

I copy, however, Dr. Dyar's description of the egg and different larval stages of what he thinks is this species.

The larva of *Cerura scolopendrina* has not been described, but I believe that I have observed it. No moths were bred from the larvæ here described; but several considerations render it probable that they are *C. scolopendrina*, so that I venture to present my notes under the name.

(1) *C. scolopendrina* is common throughout California and was taken by me in the Yosemite Valley.

(2) These larvæ have not been described before, and could only be *C. paradoxa*[1] of the known Californian forms.

(3) I am informed by Dr. Thaxter, who has bred it, that the larva of *C. aquilonaris* (=*scolopendrina*) is much like that of *C. cinerea*, and those here described recall *cinerea* in the undulating outline of the dorsal patch.

(4) Dr. Behr writes in answer to an inquiry: "[In the larva of] *Cerura scolopendrina* the dorsal band . . . is three times widened, or I would call it twice constricted, but the degree of the constriction is rather variable, so that sometimes, although rarely, the band is almost interrupted."

Egg.—Slightly more than hemispherical, the base flattened, smooth, sublustrous black, under a lens appearing minutely punctured. Diameter, 1 mm. Under a half-inch objective it is seen to be covered with flat, irregularly hexagonal and elongated reticulations which become very small at the micropyle. Between them the surface seems smooth with a few extremely minute punctures.

First larval stage.—Head round, slightly shining, dark red-brown, almost black; clypeus and mouth parts paler, ocelli black; a few short hairs; width, 0.5 mm. Body smooth, of even width; a pair of spinose subdorsal processes on joint 2; the anal feet modified into spinose stemapods, 3 mm. long; cervical shield small, very dark. Color of body blackish red-brown, feet and venter whitish; two greenish dorsal patches, one on joints 3–5, the other on joints 8–10; elliptical, diffuse at their ends; a third patch appears later, on joint 12. On the body are a number of minute setæ. Tails twice annulated with yellowish and tipped with white. Extensile threads black, whitish at the base. The larvæ eat only the parenchyma of the leaf during this stage.

Second stage.—Head rounded, slightly narrowing to the vertex, its sutures deep; color, even red-brown, with a few minute yellow dots; width, 0.8 mm. Joint 2 is swollen, its subdorsal processes conical, thick, spinose; low, rounded, small, setiferous tubercles on the body, apparently normal in arrangement; anal plate and stemapods spinose. Body rusty brown with two elliptical, diffuse, dorsal patches of yellowish green, the anterior one on joints 2–6, the posterior on joints 8–10; subventral region and all the feet pale whitish. Tails red-brown at basal half, then blackish, with two sordid white annulations. Length, 3.8 mm. As the stage advances the anterior patch becomes larger, joins the subventral coloration, and is obscurely divided by a brown dorsal line, while the whole dorsal region, except joint 11, becomes pale.

Third stage.—Head higher than wide, roundly rectangular, flattened in front; reddish brown, the upper two-thirds thickly covered with little round yellowish spots, but leaving a narrow line of the ground color on each side of the central suture above the clypeus; antennæ white; width, 1.15 mm. Body enlarged at joint 2, bearing a pair of heavily spined subdorsal processes; tails minutely spined. The normal piliferous dots on the body consist of

[1] There is good reason to believe that *C. paradoxa* is only a very pale form of *C. cinerea*, the larva of which is well known.

conical tubercles, each with a short spine, tubercles one and two on joints 6 and 7 larger than the others. Cervical shield colored like the head; horns red-brown, their tubercles paler; body green, a broad red-brown dorsal band, very narrow and nearly obsolete on joints 3 and 4, widening into an elliptical patch on joints 5–11 and inclosing on joints 7 (posteriorly), 8, 9, and 10 (anteriorly) a patch of the ground color, faintly bisected by a brown dorsal line. On joints 12 and 13 the band is faint, only tinging these segments. Tails red-brown, twice annulated with green; length, 4.5 mm. Five days after the molt, the following description was made: Body highest at joint 3 posteriorly; a red-brown dorsal band begins widely on joint 2, covering the horns, narrows to a line on joint 4, rapidly widens and reaches the spiracle on joint 8; then narrows to a line on joint 12 and, widening again, covers the anal plate. It is edged with yellow and contains, on joints 6–9, an ocherous yellow patch which is broken by a narrow, brown dorsal line and the brown tubercles. The sides of the body are clear green, dotted with yellow. The anterior annulation of the tails is yellowish, the posterior one yellow. Venter, especially posteriorly, whitish. Joint 2 edged with yellow at the sides anteriorly.

Fourth stage.—Head partly retracted beneath joint 2, shaped as before and colored much the same, but yellow on the sides posteriorly; mouth parts whitish; a few piliferous tubercles; width, 1.9 mm. Prothoracic horns thick, pointing forward, covered with piliferous tubercles. The tubercles on the body are short, but bear stiff black setæ. They are concolorous with the markings except tubercles one and two on joints 6, 7, 10, and 11, which are larger than the rest and blackish. Tails covered with spines which arise from enlarged bases. Body marked as in the last part of the previous stage except that the paler patch on joints 6–9 is more brownish, and the anal plate is tinged with yellowish. Tails 5 mm. long, the extensile threads black, but white at base and middle.

Two days after the molt the markings had more the appearance of the last stage, the central patch (that part of the band on joints 4–11) being slightly indented along its edges in each segmental incisure.

Fifth stage.—Head partly retracted below joint 2, rounded, higher than wide; clypeus small, depressed; red-brown, the upper two-thirds, except the clypeus, covered with little, round, yellowish dots, but leaving an obscure line of the ground color on each side of the median suture; yellow at the sides posteriorly; mouth parts pale, jaws brown, antennæ yellowish; width, 3 mm. Cervical shield large, horns short, rounded, smooth, without tubercles but sparsely punctured. Piliferous dots absent, the setæ short and fine. Tails spinose, turned up at the end. Body pale yellow, thickly sprinkled with little whitish and brownish dots, not very distinct; spiracles pale brown; a subventral row of brown spots corresponding to legs on the posterior apodal segments, and a medio-ventral line posteriorly. Dorsal band ferruginous brown, consisting of three connected patches; the first triangular, covering the horns, marked like the head on joint 2 and narrowing to a line at the elevation at joint 3 posteriorly; the second widens rapidly, reaching below the spiracle on joint 8, and narrows to a line on joint 11 posteriorly, being incised on its edges in the segmental sutures, shaded with blackish brown around its borders, and containing a darker dorsal and oblique subdorsal line, beside brown dots representing the tubercles; the third, on joint 12 posteriorly and joint 13, elliptical, covering the anal plate, but largely replaced by whitish. All the patches are bordered by a continuous yellow line. Tails brown, green below at base and twice annulated with yellowish green; length, 6 mm.

As the stage advances a purplish tint suffuses the dorsal patches, the second one becomes darker, obscuring its markings, but three pale orange patches appear in it on each side, behind the former oblique subdorsal lines, distinct or confluent and becoming pinkish yellow. There is a narrow, reddish edging inside the now obscure yellow border.

Cocoon.—Made, as usual in the genus, of pieces of bark and wood spun together over the hollow in the wood from which they were bitten out by the larva. The cocoon is not so thick as that of *Cerura multiscripta*, and it can be indented by the finger. It fits the pupa closely.

Pupa.—Cylindrical, slightly flattened ventrally, the ends rounded; no cremaster. Color shining blackish brown, the cases darker, almost black, wrinkled, and less shining than the abdomen. Length, 14 mm.; width, 4.5 mm.

Food plant.—Willow (Salix). Larvæ from Yo Semite, Cal.

If the larvæ here described are not different from those of *Cerura bicuspis* Borkh. (which I can not determine at present), then the name *scolopendrina* must be referred to the synonymy; for all the characters of the European species are exhibited in a series of specimens before me which were collected in California, Oregon, and Colorado. I am satisfied that *C. albicoma* Strecker is only a varietal form, the transverse band of the fore wings tending to be narrower.

Food plant.—Populus (Thaxter).

Habits.—The moth (var. *modesta*) occurred at Plattsburg, N. Y., and at Franconia, appearing very early in the season, one being taken by Mr. Hudson at light May 15, May 9 to June 20, while "*occidentalis*" has not been taken before May 11, and *cinerea* and *borealis* not before the 28th. At Taos, N. Mex., the normal form was captured by Lieutenant Carpenter July 14. It is to be noticed that the normal *aquilonaris* is paler, whiter, with less heavy black marks than *modesta*, and is most common in the West in the arid region, as well as at Washington, on Puget Sound, while *modesta* is, so far as known, confined to New England, and the darker forms of it to the cool and damp region of the White Mountains.

Geographical distribution.—Its range is very extensive, passing from the northern limits of the Hudsonian fauna, if Franconia, N. H., be regarded as an outlier of that assemblage, and extending throughout the Campestrian subprovince westward to the Pacific Coast, through California, Oregon, and Washington, and southward into New Mexico.

Var. *modesta*, at Franconia, N. H. (Mrs. Slosson); Plattsburg, N. Y. (Hudson, United States National Museum); Providence, R. I. (Clark); Kittery, Me. (Thaxter); Saratoga Springs, N. Y. (McKnight).

The normal *aquilonaris*, at Montreal, Canada (Lintner); Canada, Maine, New York, Colorado (French); Colorado (Hulst); Denver, Colo., April 30, at light (Gillette); Olympia, Wash. (T. Kincaid); Miles City, Mont. (Wiley ex Dyar); Taos, N. Mex. (Lieutenant Carpenter, Wheeler's expedition); Mendocino County, Cal. (Walsingham ex Butler); "Oregon and California" (Dyar); normal form *scolopendrina*, Oakland, Cal., Yosemite, Cal., Portland, Oreg., April 24; Nanaimo, British Columbia, Manitou, Colo., May 3; Miles City, Mont. (Dyar); var. *albicoma*, Denver, Colo., April 29 (Dyar); Colorado (Palm); Calgary, Alberta (F. H. Wolley Dod).

Cerura cinerea Walker.

(Pl. VI, figs. 16–20; Pl. VII, fig. 30.)

Cerura cinerea Walk., Cat. Lep. Het. Brit. Mus., xxxii, p. 407, 1865.
Grote, New Check List N. Amer. Moths, p. 20, 1882.
Cerura paradoxa Behr, Bull. Cal. Acad. Sci., p. 64, 1885.
Cerura cinereoides Dyar, Can. Ent., xxii, p. 253, Dec., 1890.
Druce, Biologia Centr. Amer. Het., i, p. 241, 1887.
Smith, List Lep. Bor. Amer., p. 31, 1891.
Kirby, Syn. Cat. Lep. Het., i, p. 588, 1892.
Cerura meridionalis Dyar, Psyche, vi, p. 291, July, 1892.
Heterocampa nivea Neum., Can. Ent., xxiii, p. 124, June, 1891.
Cerura cinerea var. *placida* Dyar, Psyche, vi, p. 291, 1892.
Cerura nivea Palm, Journ. N. Y. Ent. Soc., i, p. 20, March, 1893, Pl. I, fig. 8.
Cerura cinerea Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 190, 1894; Journ. N. Y. Ent. Soc., ii, p. 114, 1894.

Larva.

(Pl. XXXVI, figs. 4, 4*a*; XXXVII.)

Edwards and Elliot, Papilio, iii, p. 130, Dec., 1883.
Packard, Proc. Bost. Soc. Nat. Hist., xxiv, p. 555 (Stages II, V (last), and pupa), 1890.
Dyar, Psyche, p. 80, 82, May, 1891. (Egg and all the larval stages, with cocoon and pupa described in detail.)

Moth—Two ♂, one ♀, and several others examined. The wings of the ♀ wider and more triangular than in *C. scolopendrina*. Head and body uniformly ash gray to whitish gray. Thorax pale gray, but with yellowish and steel-blue scales concealed by the long gray hairs. Palpi and head smoky black.

Fore wings with the markings very indistinct; the usual dot at base of wing; extrabasal line of four dots, the line being much curved outward. Traces of a median band shaped as in *C. scolopendrina* var. *modesta*, though the species seems nearer allied to *C. scolopendrina*. *No extradiscal line, but traces of an imperfect one of dots instead*, and the discal dot either absent or only a small blackish dot. The usual subapical dark shade is nearly obsolete and of the same shade with the dusky outer edge. The marginal dots distinct.

Hind wings uniformly white, with a small discal dot; the marginal dots present, but none on the internal angle. Underside of fore wings uniformly dusky; a large distinct, but diffuse discal spot, and an extradiscal diffuse wide dark shade. Hind wings a little whiter. Expanse of wings, ♂ 40 mm., ♀ 43 mm.; length of body, ♂ 16 mm., ♀ 18 mm.

The Colorado examples are, so far as we have seen, somewhat larger than the Eastern ones, the ♂ expanding 40 mm. and the ♀ 43 mm.

Besides being perhaps a little smaller, the ♂ from New York (from Mr. Hulst) is darker and the markings are more distinct than in the Colorado examples.

I suspect that this species has been derived from *C. scolopendrina*, which seems nearest to it in markings, its geographical range being also nearly coextensive with that widely diffused species. In two ♀ Colorado specimens faint traces of the costal portion of the dark median and subapical bands are to be seen.

From an examination of *C. paradoxa* Behr, in Mr. Dyar's collection, I feel quite sure that it is a very pale white variety of *C. cinerea*; and a more extreme form seems *C. nivea*, in which the markings are obsolete, including the marginal dots on both pairs of wings; as this is from southern Utah, it is much bleached and rather larger than usual; it is another case of the law in the geographical distribution of the moths, that the species become both bleached and larger in the arid region of the Southwest.

Egg.—Slightly more than hemispherical, the base flat, color dead black; diameter, 1.2 mm. Of the Californian form, "color dull, brownish black, smooth. Diameter, about 1 mm. Duration of this stage, eight days."

Larva.—Messrs. H. Edwards and S. L. Elliot (Papilio, iii. 130) have well described the larva of this species, which lives on the willow. I have been able to compare some very well-preserved alcoholic specimens of the mature and young caterpillars (kindly loaned by Professor Riley) with similar stages of the two foregoing species.

Larva, Stage I.—Var. *cinereoides.* "Head dark red-brown. On joint 2 are two brown processes, minutely spined. Joint 13 has two "tails" 3 mm. long, brown, twice broadly annulated with pale yellow and minutely spined. The body is brown, with three dorsal pale yellow patches; on joints 2 to 6, 8 to 10, and 12, respectively, the posterior one faint. Venter and legs pale whitish. Length of larva, exclusive of the tails, 4 mm. It spins a slight web on the surface of the leaf to which it clings (p. 82).

Stage II.—"Length, without the filamental legs, 12 mm.; of the latter, 7 mm. It is at once distinguished from the larvæ of *C. occidentalis* and *C. borealis* of the same size by the larger bristles, the warts bearing them being scarcely larger, but the bristles themselves being two or three times as large. The head is as usual in the genus, as are the two lateral prothoracic "horns" and the cervical shield from which they arise. The "horns" are as in *C. occidentalis*, being spined in the same manner, and pale yellowish beneath. A large reddish triangular dorsal patch extends backward from the horns, the apex resting on the second thoracic segment. The back is discolored from the third thoracic segment to the end of the supraanal plate, not so decidedly reddish as in my specimens of the two other species previously described.

Stage III.—"Head subquadrate, rounded, flat in front, dead brownish black, the lower part paler and mottled centrally in front with a paler color. Antennæ white, labrum and ocelli brown; width of head, 1.3 mm. Cervical horns thick, heavily spinose, brownish black; several rows of minute piliferous tubercles on the body; tails spinose, dark red-brown, twice broadly annulated with yellowish and tipped with the same color. Body green, a purple-brown subdorsal line passing down the sides to spiracles on joints 7 and 8, the subdorsal spaces filled in with purple-brown on joints 2, 3, 6–9, 11 and 13, though not completely on joints 8 and 9, but with a trace of a dorsal line on the other joints. Venter whitish." (Dyar.)

Stage IV.—"Head higher than wide, rounded, a little flattened in front; a minute tubercle before the apex of each lobe; purplish black, finely mottled with yellow, green at the sides posteriorly; antennæ white, ocelli black; width 2.2 mm. Cervical horns thick, covered by piliferous tubercles with about six rows of similar tubercles on each side of the body, only the upper two distinct. Color yellowish green. A triangular dorsal patch on joints 2 and 3, covering the cervical horns, purplish black, mottled with little yellow spots; a larger patch on joints 4–9, elliptical, retracted at the segmental incisures, reaching the spiracle on joint 8, replaced centrally irregularly by yellow and broadly connected with a small patch on joints 10 and 11, widening on joint 11 and joining a small patch on joint 13, replaced by greenish on the anal plate. Tails purplish brown, twice annulated with yellow." (Dyar.)

Mature larva.—Length, without the "tails," 38 mm.; of the filamental legs, 15 mm. The head is small, being one-half as wide as the body, reddish, but darker on the sides.

The prothoracic horns in this stage are reduced to smooth projecting tubercles of the usual size, which are blackish above and pale below. Body pale green. From the horns a lilac-red, nearly equilaterally triangular spot edged with yellow, extends backward, its apex resting on the hinder edge of the second thoracic segment. An oval lilac-red spot edged with yellow on the hind edge of the third thoracic segment separated by the suture from a similar spot on the first abdominal segment, but which is three or four times as large. A transversely subelliptical similar spot on the second abdominal segment twice as large as the one in front, succeeded by a much wider one on abdominal segments 3 and 4; that on the fifth segment is of the same size as that on the second. On the sixth abdominal segment is a transversely oblong spot. (These spots were all connected in Edwards's and Elliot's specimens.) Along the back of segments 7 to 10 is an elongated dumb-bell-shaped spot, the contraction in the middle of the spot occurring on the back of the eighth segment; the spot terminates on the end of the suranal plate, which is squarely docked at the end.

The stemapods, or anal filamental legs, are reddish at the base above and beneath, with two pale rings beyond the middle, the flagellum being reddish lilac. There is a lilac-red spot at the base of the thoracic and abdominal legs, one near the origin of each leg, and one on the sides of abdominal segments 7–9; besides these, reddish, lilac dots are elsewhere scattered over the sides of the body. The paranal lobes and the excrementiferous bristles are well developed.

The larva of this species differs from that of *C. borealis* and *occidentalis* in the less connected and narrower dorsal lilac-red patches, and in the end of the suranal plate being squarer, that of *C. occidentalis* being somewhat rounded behind. It is more nearly allied to *C. occidentalis* than to *C. borealis.*

Cocoon.—"Formed on a piece of wood, first of gummy silk, which is strengthened by many little pieces of wood bitten off from inside. When finished it is elliptical, quite hard, and of the color of the wood or bark on which it is made. Length, about 30 mm.; width, 13 mm." (Dyar.)

Pupa.—"Cylindrical, tapering slightly at both extremities, somewhat flattened. Color, pale brown, venter yellowish, and a dark dorsal line. Wing and leg-cases greenish. Abdomen very minutely punctured. Wing-cases creased. Length, 18 mm.; width, 6 mm." (Dyar.) The foregoing description refers to the Californian form *cinereoides.* Dyar states that the cocoon of the Eastern *cinerea* is "constructed on bark of gummy silk and bits of bark and wood, like that of the other species of Cerura." (P. 81.)

Habits.—Its general appearance and habits are, so far as known, the same as in *C. occidentalis* and *borealis.* Dyar states that "the eggs are laid singly; the larva hatches by eating a hole in the side, but does not devour the rest of the shell." Dyar, speaking of the Californian form, states that "the duration of the first larval stages was from three to six days, the last two seven days. The pupa state lasts through the winter."

The larva represented on Pl. XXXVI, figs. 4, 4*a*, occurred on the poplar at Brunswick, Me., August 30.

Riley (MS.) states that the eggs are laid in June, the moths appearing in April, May, June, July, and August, while the larva is found in June and in September.

Food plant.—Different species of willow and poplar.

Geographical distribution.—This species apparently has the widest geographical range, with consequent greater variability, of any of our species, probably extending farther south, into Mexico and Guatemala, than *C. scolopendrina*, and thus ranging through the entire North American region, including the cold temperate subregion and warm temperate subregion, and the humid and arid provinces of the latter, as will be seen by the following localities: Boston, Mass. (Harris); Brunswick, Me. (Packard); New York (Edwards, Elliot, Dyar); New Jersey (Palm); Plattsburg, N. Y. (Hudson); Canada, New York, Maryland, Ohio (vars. *cinereoides, paradoxa, meridionalis*), California (French); Utah, dark form (Westcott); Florida (Mrs. Slosson); Franconia, N. H., "a little darker than the Florida ones" (Mrs. Slosson); Colorado (Bruce); Fort Collins, Colo., June 21 (Baker); Denver, July 14 (Gillette); Manhattan, Kans., June 10–17, of normal, not very pale, color (Popenoe); New York, Iowa, Nebraska, Missouri, Washington, D. C. (United States National Museum), Jalapa, Mexico, San Geronimo, Guatemala. Mr. Druce remarks: "The specimens I somewhat doubtfully refer to this species are very much stained. So far as I am able to see, they appear to be almost identical in the markings of the primaries with Walker's type." (P. 241.)

Dyar's var. *cinereoides* was collected at Los Angeles, Cal., and also at Miles City, Mont.

The pale form, *paradoxa* Behr, is from among the mountains of Nevada County, Cal. *C. nivea*, whiter than any other form and without the marginal black spots, was collected at El Paso, Tex., on the Rio Grande River, and Mr. Palm's example (collected June, 1890) is from the Virgin River, southern Utah, in a hot, dry region, and its white color is evidently the result of the action of bright sunlight, heat, and dryness.

Cerura scitiscripta Walker.

(Pl. VI, figs. 21-23; Pl. VII, fig. 31; XLIX, fig. 3.)

Cerura scitiscripta Walker, Cat. Lep. Brit. Mus., xxxii, p. 408, 1865.
Cerura multiscripta Riley, Trans. St. Louis Acad. Sci., iii, p. 241, 1875 (figure in text reproduced on Pl. XLIX, fig. 3).
Cerura candida Lintn., Ent. Contr., iv, p. 87 (30th Rep. N. Y. State Mus., p. 199), "1877," June, 1878.
Cerura scitiscripta Grote, New Check List N. Amer. Moths, p. 20, 1882.
Cerura multiscripta Grote, New Check List N. Amer. Moths, p. 20, 1882.
Cerura scitiscripta Smith, List Lep. Bor. Amer., p. 31, 1891.
Cerura multiscripta Smith, List Lep. Bor. Amer., p. 31, 1891.
Cerura scitiscripta Kirby, Syn. Cat. Lep. Het., i, p. 588, 1892.
Cerura multiscripta Kirby, Syn. Cat. Lep. Het., i, p. 588, 1892.
Cerura scitiscripta Dyar, Can. Ent., xxiii, p. 87, April, 1891.
Neum. and Dyar, Trans. Amer. Ent. Soc., xxi, p. 189, 1894. Journ. N. Y. Ent. Soc., ii, p. 114, 1894.

Larva.

(Pl. XXXVI, figs. 5, 5*a*, 6, 7. C. multiscripta.)

Tepper, Bull. Brooklyn Ent. Soc., i, p. 4, May, 1878.
Dyar, Psyche, v, p. 393, Oct., 1890. (Egg and larva in all stages.)
Riley, Trans. St. Louis Acad. Sci., iii, p. 241, 1875. (Egg described; larva confounded with that of *borealis*.)

While *multiscripta* is generally regarded as distinct from *scitiscripta*, I think that if Professor Riley had had examples of *scitiscripta* before him he would have hesitated about describing the melanotic specimens, as I believe them to be, under a different name.

C. candida only appears to differ from *scitiscripta* in the thorax being white and in having no dots on the hind wings (two ♂ collected in Florida by Mrs. Slosson).

Moth.—Five ♂. Head white above; sides, below, and breast black. Thorax: collar white, edged with black behind, and two rows of spots more or less connected (in var. *candida*, according to Lintner, the thorax is entirely white).

Fore wings without the usual broad median black band; snow-white, crossed by four scalloped, more or less perfect, lines within, and by four scalloped lines without the ring-like discal mark. The outer mark or submarginal line heavier on the costal and inner edge. Second and third lines forming a more or less perfect series of ringlets and sometimes (*multiscripta*) filled in with scattered fine black scales, giving the band thus formed a dusky hue. Fringe white, with more or less intravenular dots.

Hind wings varying from white to uniformly dusky or smoky, with distinct heavy black dots (one from Florida is without any dots, this being var. *candida* Lintner). Underside snow-white, with heavy black costal spots, the outer one forming a submarginal line extending to the median vein, both wings dark smoky with the darker diffuse lines on each wing, and a diffuse discal mark.

Expanse of wings, ♂ 28-35 mm.; length of body, ♂ 13-19 mm. I add Riley's description of his *C. multiscripta*.

"Color white, with brown-black and black markings. Primaries white, slightly silvery, crossed with eight irregularly undulate and angulate narrow black lines, as follows: 1, basal, obsolete on costal and inner borders and preceded by a black spot close to thorax; 2, reaching to both borders, but broken; 3, 4, and 5, proximate, and irregularly undulating almost straight across the basal fourth of wing, 3 and 4 thickened and confluent toward costa and generally forming a circular spot between subcostal and cubital veins; 6, 7, and 8, obliquing more toward apex, lunulate and more widely separated between veins 2, 3, and 4, more approximate and retreating toward base between veins 1 and 2 and 4 and 6, and generally so close along vein 2 as to coalesce; broader, more intense, irregular marks occupy the spaces toward apex and anal angle, left by the retreating of line 8, thus leaving a regularly defined terminal space. Veins more or less dusted with black and conspicuously marked in terminal space. A distinct row of terminal spots between the veins. The median space between lines 5 and 6 is about as wide as the terminal, and has a small discal ring and a costal spot. Fringes white. Under surface fuliginous, with the borders white, the costal and terminal marks mostly repeated, and with two duskier shades across subterminal space. Secondaries fuliginous, with terminal black spots between the veins; lunule and two more or less distinct transverse bands dusky; fringes white; under surface paler, with the dusky bands more strongly relieved. Head beneath, front femora and tibiæ inside, two spots on middle and hind tibiæ, tarsi, pectinations of antennæ, a mark (obsolete in one specimen) between eyes and bases of wings, across the shoulders, around the tegulæ, and at base of thorax, a spot on each tegula and two in middle of thorax, and a transverse band on anterior edge of each joint superiorly, brown-black.

"Alar expanse, 1.25–1.50 inches. Length of body, 0.60–0.75 inch.

"Described from three ♀, one bred by myself, one by Miss M. E. Murtfeldt, of Kirkwood, Mo., and one by J. R. Muhleman, of Woodburn, Ill.—all from willow-feeding larvæ. In each case the larvæ were supposed to belong to *borealis*, and no critical descriptions were taken. The variation is not great; in one specimen the wings are noticeably shorter and more rounded than in that chosen for my figure, and the marks on primaries are less clearly defined; the bands on secondaries are also scarcely indicated, or only by faint spots on the veins, while the costal marks on primaries inferiorly coalesce so as to form but three broad marks.

"The eggs of Cerura are hemispherical, i. e., very flat on the attached side; and while the larvæ of *multiscripta* and *borealis* resemble each other, their eggs are easily distinguished, those of the former being pale yellowish green and those of the latter jet black.

"The species approaches nearer to the European *bicuspis* than to the North American *borealis*. I am unacquainted with the *scitiscripta* Walker of Grote and Robinson's "List," but as Mr. Grote has seen *multiscripta* and pronounced it new, I have no hesitancy in describing it."

Of these two specimens, one is like the *candida* of Lintner's description in the hind legs being entirely white above and beneath, with no marginal black dots. In the other examples the dots are minute, though distinct, showing that they are on the verge of extinction.

Multiscripta also varies in our examples from New York (Doll); the hind wings are white above and beneath, and another is intermediate between the foregoing example and those with dark wings. The thorax also varies in the amount of black markings, and the two hinder lines are wanting.

The following notes on the preparatory stages of *Cerura multiscripta* Riley, by Dr. Dyar, are copied from Psyche, vi.

Egg.—Slightly more than hemispherical, the base flat, dead sordid white, covered with many short, dark-brown hairs irregularly laid on and distributed also on the parts of the leaf adjoining. Diameter, 1.5 mm. Laid in groups of five or less on the under surface of a leaf. These eggs had hatched when found, the larva having emerged from a hole in the side, leaving the rest of the shell intact.

First stage.—Head subquadrate, depressed at the vertex, black and shining. Width, 0.6 mm. Body furnished with minute tubercles, a spined process at each side of the cervical shield and two tail-like appendages which take the place of the anal feet. Color black throughout, a little paler ventrally.

Second stage.—Head rounded, minutely punctured, with a tubercle below the vertex of each lobe. Color purplish black, a little paler about the sutures of the clypeus (triangular plate). A few short hairs. Width, 0.9 mm. The body has several rows of minute piliferous tubercles, two large, thick, heavily spinose cervical horns on joint 2; tails long, sharply spinose, shiny black, the extensile threads purple black, whitish at base. Body velvety purple black, the venter greenish. Length of body, 4 mm.; of tails, 4 mm.

Third stage.—Head with two tubercles before the apex of each lobe, one in the center of and one each side of the clypeus. Color, dull black, clypeus and mouth reddish, ocelli black, antennæ pale. Width, 1.3 mm. Cervical horns thick, heavily spinose, the spines blunt and each tipped with a hair. About six rows of elongated, piliferous tubercles on each side, alternating anteriorly and posteriorly on each segment. Tails long, heavily spinose, black, the extensile threads brown, white at base. Body and legs greenish yellow, a black dorsal band covering the cervical horns, narrowing to joint 4, where the dorsum is angularly elevated, widening to near the spiracles on joints 8 and 9, then continuing evenly over the subdorsal space to the last segment. Spiracles narrowly black ringed. Length of tails, 5 mm.

Fourth stage.—Head dead purple-black, greenish at the sides posteriorly, the upper half sprinkled with little yellowish dots, but leaving a line of the ground color each side of the central suture.

Clypeus and mouth paler and shiny, antennæ whitish, ocelli black. Width, 2.1 mm. Body as before, considerably elevated dorsally at joint 4, with a rounded pinkish dorsal process. Cervical shield large, purplish black; the horns rather thick and short, heavily tuberculated. Body yellow-green; the dorsal stripe black as before, but a little purplish; spiracles white, with a fine black border, the posterior ones more or less surrounded by black.

Tails heavily spinose, black; length, 7 mm. The piliferous tubercles of the body are very small, those on the lateral region white, besides many small lateral white spots. A narrow, yellowish, stigmatal line. Two erect, spiny, black hairs beyond the anus.

As the stage advances, the spines on joint 2 become partly white, the dorsal band partly striated and indistinctly bordered anteriorly with white; the stigmatal line just below the spiracles is white, and there is a general approach to the next stage.

Fifth stage.—Head rounded, rather flat in front, shagreened. Color black, green at the sides posteriorly, a large band in front as wide as the space between the eyes at base, but narrowing to the vertex, sordid white, mottled a little with the ground color. Labrum whitish; maxillæ black; antennæ white. Width of head, 3.7 mm. Cervical shield large, angulated at the corners, without any horns or spines. Beneath it the head can be partly retracted. Body angularly elevated at joint 4, with a dorsal, fleshy process. Tail 9 mm. long, whitish above and green below at the base, the rest purple with black spines. Extensile threads yellowish at base, then red, fading to yellowish again toward the ends. Body green, a broad white dorsal band edged with white, confusedly striated on a purple ground which soon becomes green, a little purple on joints 2–4, decidedly so on the anterior corners of the cervical shield (where it shades into pinkish in the fold of skin behind the head), on the hump on joint 4, and on joint 8 subdorsally in the angle of the band. It begins broadly on joint 2, covering the cervical shield, narrows to the process on joint 4, widens to just above the spiracles on joint 8, and gradually narrows to joint 13, where the anal plate is greenish. A distinct white substigmatal line, edged below with brown and narrowly above with black, absent on joint 2 and turned up at its anterior end. Many small lateral white flecks. Spiracles black, white centrally. Thoracic feet twice lined with black longitudinally; abdominal, once transversely, the claspers tipped with black. Length, 25 mm., exclusive of the tails. The erect spines beyond the anus whitish. When the larva has finished eating, all the white of the dorsal band except its borders fades out, leaving the back green and the cervical shield pale blue.

Cocoon.—Formed on wood, of gummy silk, strengthened by many little pieces of bark and wood bitten off from the inside, thus forming a hollow. It is elliptical, just large enough to contain the larva, and becomes very hard, closely resembling a lump or excrescence on the bark.

Pupa.—Cylindrical, tapering a little toward both ends, the last two abdominal segments rounded and appressed, the others capable of motion; no cremaster. Eyes prominent; a narrow carinated ridge runs along the head from between the eyes to the back of the place of origin of the antennæ. Cases creased and very minutely punctured, not shiny; eyes and body sublustrous, the latter minutely granulated at the anterior half of each abdominal segment; spiracles distinct. Color dark reddish brown, with a blackish shade over the dorsum. Length, 18 mm.; greatest width, 6.5 mm. Pupation occurs in about two weeks after the completion of the cocoon, and the insects remain in this stage throughout the winter.

Egg.—The eggs are said by Professor Riley to be hemispherical and pale yellowish green, while those of *C. borealis* differ in being jet-black. On the other hand Dr. Dyar tells me that the eggs of all our Cerura are black, except those of *multiscripta* which are covered by the hairs from the body of the moth.

Habits.—Mr. F. Tepper found the larva of this fine moth on the willow July 30; a male imago emerged August 30 and a female September 30 (Bull. Brooklyn Ent. Soc., i, 4). No description of the larva was published. The life history has been fully described by Mr. Dyar in Psyche (v, p. 393), which we have copied. It remains to be seen whether the larva of the white form, *scitiscripta*, differs from what we should call the melanotic form, *multiscripta*.

Food plants.—Different species of willow and poplar, also wild cherry. The figures on pl. — were drawn from a specimen found on the wild cherry September 10, at Providence, R. I. Mrs. Slosson has raised it from the pomegranate in Florida.

Geographical distribution.—Its range extends throughout the Appalachian and Austroriparian subprovinces, passing into the eastern limits of the Campestrian (Kansas). It is to be observed that the pale whiter form, *scitiscripta*, inhabits the Austroriparian subprovince (Florida, Georgia to Kansas), while the darker form, with heavier black lines and spots, has thus far only occurred in the Northern States. It has not yet been reported from any of the New England States; eastern New York (Dyar, Doll, Elliot); Illinois and eastern Missouri (Riley, United States National Museum); Kansas (Lintner ex Strecker); Manhattan, Kans., August 10 (Popenoe); Jacksonville, Fla. (Mrs. Slosson); "Georgia" (Dyar); New York, Missouri, Texas (*multiscripta*, Riley's notes, United States National Museum); *multiscripta*, New York, Carbondale, Ill.; var. *scitiscripta*, Illinois, Georgia; *candida*, New York, Kansas (French); *multiscripta*, New York, New Jersey (Palm).

Riley mentions a "new species" of Cerura from Owens Valley. (Merrian's North Amer. Fauna, No. 7; The Death Valley Exp., Pt. II, May 31, 1893, p. 245.)

RECAPITULATION OF THE MORE STRIKING FEATURES IN THE ONTOGENY OF CERURA.

Congenital characters.

(1) The larva hatches with fully developed stemapoda, indicating that the genus has descended with little modification from a form like Macrurocampa.

(2) The prothoracic horns are longer, better developed than in the mature worm, showing that in this respect also the genus has originated from the Heterocampinæ.

Acquired characters.

(3) The head is smaller in proportion to the body than usual, owing to the great width of the prothoracic segment.

(4) The body is all brown above in the first stage, beginning to turn green in the second, and in the third becoming nearly as in the last stage. Thus the colors are more diversified, with more green in the fourth and fifth stages, rendering the now more exposed larva more adapted for protection by the resemblance of its markings to the yellow and red spots on the green leaves of its food plant, which appear early in autumn.

(5) The dorsal hump on the third thoracic segment does not seem to appear until the last stage. (Dr. Dyar, however, tells me that it appears in *C. multiscripta* in stage III.)

(6) The filamental legs retain their shape from the first to the last stage, but if anything are a little shorter in the last. On the other hand, the spinules in the third stage become larger on the underside than before, the filaments being held curved up more than before, so that the defensive spines on the underside, in response to external stimuli, have developed more rapidly than those on the upper side.

(7) Novel structures are the very long and well-developed supraanal plate and the pair of coproliferous spines (or dungforks) arising from the paranal lobes, and available for tossing away the pellets of excrement. These seem to be peculiar to the genus in this family.

APPENDIX A.

Some of the following notes and additions were kindly sent me by Dr. Dyar as this memoir was being printed. They fill up gaps in our knowledge of the life histories of the species.

EGG AND STAGE II OF ICHTHYURA ALBOSIGMA (see p. 139).

Egg.—Laid two to seven together on the upper side of the leaf. Hemispherical, the base flat. Diameter, 0.9 mm. Shells dead white. Larva hatches by a hole in the top.

Stage II.—Head black, mouth a little paler. Width, .8 mm. Body yellow, purple-brown on the sides, except the large yellow subventral warts on segments 2–4, 6, 9–12; the color extends across the back on segments 2, 5, 7, 8, 12, and 13 posteriorly, not completely replacing the yellow on segments 7 and 8. An indistinct triplicate dorsal line, purple-brown; venter dull brownish. Segments 5 and 12 a little enlarged dorsally. Hairs white, few. Cervical shield nearly linear, black. Length of larva, 8 mm. (Dyar.)

EGG AND LARVAL STAGES OF NADATA GIBBOSA (see p. 143).

Egg.—(Jefferson, N. H.) Three laid together near edge on underside of leaf. Spheroidal; base flat, opaque white; diameter, 1.1 mm., 0.7 mm. high. Reticulation linear but rather high and with harder base, rather small and regularly hexagonal; the pores at the angles distinct, bead-like in the empty shell. The cells between reticulations form shallow hollows as in *behrensii*. (Dyar.)

Larval stages.—A larva bred at Jefferson, N. H., had five stages, with width of head as follows: I, about 0.7 mm.; II, 1.2 mm.; III, 2 mm.; IV, about 3 mm.; V, 4.6 mm., thus apparently omitting the normal stage III instead of II, as the Yosemite ones did. (Dyar.)

EGG AND LARVAL STAGES OF NERICE BIDENTATA (see p. 171).

Egg.—Rather more than hemispherical, with a flat base; not shining; whitish yellow. Diameter, 1 mm.; height, 0.7 mm. Reticulations small, linear, rather elongate, irregularly hexagonal; much smaller toward the micropyle, where there is an almost smooth area surrounding a slight prominence, or all smooth. (Dyar.)

Stage I.—On hatching the larva runs to the tip of a tooth on the side of a leaf or end of the midrib and sits with the anterior part of its body projecting beyond the edge. It eats the upper portion of the leaf, leaving the lower epidermis. Head shining, blackish, notched a little at the vertex, paler below, mouth vinous; width, 0.5 mm. Body whitish with a green tint, feet and tubercles black; cervical shield blackish. A dorsal spot on segments 6 and 12, and subventral ones on segments 4, 6, and 10, brownish red. Later a slight prominence appears dorsally on segments 6 and 12 corresponding to the tubercles i of each side and being the first indication of the future high humps. Setæ normal, i–v, vi absent, three on the distinct leg plate.

Stage II.—Eating the whole leaf and resting on a perch formed of the midrib from which the substance of the leaf has been eaten away by the larva. Head higher than prothorax, slightly bilobed, shining luteous with brown side stripe to vertex; width, 0.8 mm. Body cylindrical, shining green, a little dorsal red-brown dot on segment 5; a considerable bilobed process on segment 6, the anterior lobe longest, red-brown; a single low, broad hump, on segment 12, yellowish on the sides bearing tubercles i toward apex. Legs all red-brown with subventral spots, more reddish on segments 2 to 5 and 11, all used by the larva. Setæ short and dark, normal, i–vi, with vii and viii, on the legless segments as usual. On segment 6, tubercle i is borne on the base of the horn.

Stage III.—Head flattened in front, depressed at vertex; yellowish green, a black line from vertex of each lobe to side of mouth; width, 1.3 mm. Dorsal processes visible on segments 5, 6, 7, and 12, highest on 6, but all slight, brown tipped. None on the other segments. Faint, oblique, lateral, yellowish lines. Legs red-brown, with a faint yellowish substigmatal shading. Body not very opaque, tracheal line evident. As the stage advances lumps appear slightly on all the intervening segments and the larva more nearly resembles the last stage.

Stage IV.—Head higher than wide, narrowing to vertex, flattened in front; green, the clypeus shining, a black line as before; width, 2.1 mm. Dorsal processes as in the mature larva, but much slighter; present on segments 5 to 12 and a slight one on 13, consisting of two small tubercles. The processes are all small, except on segments 6 and 12. Markings as before, but more distinct and approaching the mature larva. All the mature characters are now assumed, but are less developed than in the next, which is the last stage (Stage V). (Dyar MS.)

Stage V.—The following description was drawn up October 5, from the three specimens figured on Pl. XXIII. They were kindly sent me by Miss Mary Murtfeldt, from Kirkwood, Mo.

Length, 32–33 mm. Body much compressed. Head moderately large, rather narrow and high, slightly bilobed above, not so wide as the body; pale green, with four broad white bands in front and on the side, the two median ones approaching each other over the apex of the clypeus, and then separating. Behind, a white band on each side passes down underneath the back of the head, making six white bands in all. On each side of the front is a narrow, blackish line, edging each lateral frontal line.

The three thoracic segments of nearly the same size and width, much wrinkled, but unarmed, and with three white longitudinal bands on each side, the lower one narrow, irregular, and edging the lateral conspicuous infrastigmatal purplish line.

Abdominal segments 1 to 8 with a high recurved, soft, fleshy, distinctly retractile, conical tubercle, the apex of which is bilobed and curved over backward so as to touch the apex of a second much smaller conical tubercle, the first one being a little smaller than the others, and the last one a little slenderer than the others. On the tip ot each tubercle is a reddish brown median line, best marked on the second and third tubercles, the other being simply tipped with the same hue. The sides of the tubercles and of the segments bearing them is glaucous-white, and from the anterior part of the base of each tubercle a green line passes obliquely backward and downward to the suture behind. There are eight of these lateral oblique lines; the eighth is a little higher than the seventh, is piliferous, bearing a short hair on each side. Ninth abdominal segment not tuberculated, but with a pair of small dorsal tubercles. Suranal plate narrow, quite smooth, and with four longitudinal white bands. Low down on the sides of abdominal segments 7 to 9 is a broken infrastigmatal purplish line which extends along the underside of the rather slender anal legs. Spiracles yellow, with a dark, narrow edge. Distal ends of the four pairs of middle abdominal legs purplish, with two parallel black lines above the planta. Thoracic legs pale green, with a narrow dark red line on the outside.

There is not much variation in the three individuals, except that the purplish lateral line in one is represented on the abdominal segments by isolated spots. The tubercles are unusually extensile and flexible in this caterpillar, and their resemblance to the serrate edge of the elm leaves, together with the leaf-green ground color and greenish white markings, and purplish brown spots like those on the elm leaves, is most remarkable.

Habits.—The larva eats away the leaf from the midrib, leaving the latter as a "perch," on which it rests just like Lophodonta. When large the larva rests on the base of the leaf or stem. (Dyar.)

FULLY GROWN LARVA OF HYPARPAX AURORA (see p. 186).

Last stage (*V*).—Like Stage IV at first. Later and gradually the colors change. Head rounded, higher than wide, not reaching above segment 2 nor retracted within it; width, 3 mm. Ground color white with a yellow tint, reticulated with mottled bands of purple-brown, a broad one running from antennæ to top of each lobe. Body pointed dorsally. On segments 5 and 12 the tubercles i red, large, conspicuous, elsewhere very small, though i on segments 6–8 are white and rather distinct. All other tubercles inconspicuous, setæ dark, moderately long. Venter and legs purple-brown, dotted with white; sides whitish green, finely dotted with white and brown and shading into a brighter green on segments 2–4 (representing the usual patch of Schizura and Janassa). On segments 2–3 a dorsal purple-brown band, white dotted and bordered with yellow; on segment 5 a white subdorsal band marked with fine irregular purple-brown lines, beginning at tubercle i, loops up to i on 12 and runs to anal foot. The dorsal space thus inclosed is bright yellowish leaf-green, dotted with white, with a narrow white dorsal line indicated. Tubercle i on segment 6 is marked by a little white patch, and there is a triangular enlargement of the subdorsal line on segment 8. Anal feet pale outwardly, not used, slender, gently divergent. Mature larva corresponds in structure of the humps to *Schizura badia*, and like it is largely green, being more green than Janassa and with lower humps. The larva in Stage I is scarcely distinguishable from *Schizura ipomoeæ*. (Dyar.)

EGG OF XYLINODES LIGNICOLOR (see p. 190).

"From two to ten laid together on underside of leaf. Rather more than hemispherical, flat below. Smooth, slightly shining, whitish green. Diameter, 1.1 mm.; height, 0.7 mm. Under Zeiss aa objective (60 diameters) covered with small, slightly raised hexagonal reticulations, which become gradually smaller toward the micropyle, finally becoming minute and flattened. Micropyle not depressed. The reticulations are slightly elongate on the sides but become round below and pass to the underside, where they are somewhat irregular, forming a triradiate area of much elongated meshes, the center of which is not always at the center of the egg. Approximate diameter of a reticulation of upper surface = 0.05 m. (50 μ.)." (Dyar.)

LARVAL HISTORY OF HETEROCAMPA PULVEREA (see p. 219).

I received too late for description in the body of this work the eggs and freshly hatched larva of this species, kindly sent by Miss Ida M. Eliot, from Nonquitt, Mass. It was received and described August 29. It feeds on the oak.

Egg.—Of the usual hemispherical form, shell white; surface seen under a lens to be finely granulated; under a one-half inch objective surface reticulated with distinct, regular hexagonal areas, which become narrow and small toward the apex of the egg; the surface of each area is roughened. Diameter, about 1.3 mm.

Larva, Stage I.—Length, 4 mm. Head large, much wider than the body, well rounded: surface smooth, unarmed, honey-yellow. Body tapering to the end, pale greenish yellow; abdominal segments 1, 3, 6, and 8 banded with pink-red; on the side of segment 1 a distinct, oblique, pink, lateral stripe extending forward and ending at the base of the third pair of thoracic legs; the third abdominal segment pink above and on the sides, while only the upper side of segments 6 and 8 are pink. There are nine pairs of dorsal horns. Those on the prothoracic segment forming a pair of very large antlers, with four large tines, two extending forward, one shorter laterally, and the fourth extending backward. The other eight pairs on the abdominal segments are much as in *H. guttivitta* in general shape and size, though differing in relative size. Those of the pair on the second abdominal segment are slightly longer than those on the first. The fourth to seventh pairs of the same size and length; eighth pair slightly longer; ninth pair about a quarter shorter than the eighth pair; all are piliferous, and become black-brown.

This larva is nearest to that of *H. guttivitta* in Stage I; it differs in the following respects: *The lowest tine of the prothoracic antlers is a little more than twice as long as in guttivitta*, all the four tines being nearly equal in length. All the chitinous plates from which the abdominal horns arise are entire except that on the eighth segment, and they are honey-yellow in color. The abdominal horns are nearly as in *guttivitta* (Fig. 83, III, *b*, *c*, *d*), but the second abdominal pair are smaller than those in segment 1 and only very slightly smaller than those behind; those on the third abdominal segment are of the same size as the three following pairs; those on the eighth segment are of the same size as those on segment 1. The suranal plate is rounded and greenish, not black. The tines of the próthoracic antlers are spinulose, especially the one projecting backward. The thoracic legs are blackish; the abdominal ones pale greenish yellowish. Miss Eliot writes me that when first hatched the spines are pinkish, but that they change color in a few hours to brown.

Stage II.—Length, 6 mm. Now of the same shape as in *H. obliqua* (Pl. XXX, figs. 2, 2*a*), the prothoracic dorsal spines of the same shape, ending in two unequal sharp spines. In my alcoholic specimens the markings are as in *H. obliqua* of the same stage, but the dorsal lines are reddish, not greenish. The head is now banded and spotted, there being two longitudinal reddish bands on each side of the clypeal region. From the prothoracic dorsal spines two parallel blackish lines extend to the hind edge of the prothoracic segment. The body is mottled with red on the sides

Stage III.—Length, 14-15 mm. Head with two parallel blackish lines. The prothoracic spines large but blunt, bearing a hair, with two lateral teeth. Body with a reddish dorsal band forked in front, extending anteriorly to the inside of each tubercle and behind on the third thoracic segment, dividing to unite again on the second abdominal segment, and sending an oblique line down on the side of the first abdominal segment to the base of the third pair of thoracic legs. The dorsal line divides again on the fifth abdominal segment, inclosing a long triangle extending back to the ninth segment. An oblique reddish line on the seventh abdominal segment. On the suranal plate are two parallel dorsal dark lines.

Stage IV.—Length, 26 mm. Markings as in Stage III, but much more distinct, and now the two dorsal prothoracic spines are slightly shorter, thicker, and more rounded at the end, without the two lateral teeth, being of the same shape as in the full-fed larva. Head reddish, nearly as in the last stage. Thoracic legs reddish.

Stage V (and last).—Length, 35 mm. Head (in alcoholic specimen) deep reddish on the sides. Prothoracic spines rounded, reddish, tipped with blackish. Body leaf green, the lines faintly marked; the two dorsal reddish lines dividing on the third thoracic segment, uniting again on the fourth abdominal segment, and inclosing a lanceolate oval dorsal spot, the dorsal line again dividing on the fifth abdominal segment, and in my specimen nearly obsolete behind. A lateral oblique reddish band on the first abdominal segment beginning just behind the spiracle and extending to the base of the third pair of legs. A lateral reddish band on third and sixth abdominal segments, suranal plate broadly edged with reddish. Anal legs reddish above and on the sides. Thoracic and abdominal legs reddish.

A NOTE ON THE LARVA OF DATANA FLORIDANA Graef.

"Having examined some specimens of the larva of *Datana floridana* in the collection of the Museum of Comparative Zoology at Cambridge, I am able to confirm the description by Mr. Koebele (Bull. Brooklyn Ent. Soc., iv, 21), and to add that the lateral lines are slightly broader than the intervening black spaces, or as broad: not confluent at the extremities. The large, normal hairs are white, and arise singly from minute tubercles. The fine short (secondary) hairs are black, very inconspicuous without a lens, and not differing from the corresponding structures in *D. major* and *D. palmii*. The species is closely allied to *D. palmii*, and may prove, on further investigation, to be not specifically distinct." (Psyche, vi, p. 573.)

A NOTE ON DATANA CALIFORNICA Riley.

This form, labeled by the late C. V. Riley as *Datana californica*, I find, on examination of the types of the moths and two blown larvæ in the National Museum, to be only a slightly marked variety of *Datana ministra*. The specimens are all from Santa Clara County, Cal.

The moths, ♂ and ♀, six in all, only differ from Eastern *D. ministra* in being a little paler; the lines and other markings are the same, as well as the scallops of the wings. They are of large size, a female expanding 52 mm.; length of a fore wing, 25 mm.; that of an Eastern ♀, 22 mm.

The two larvæ were of large size, 58 mm. in length, blown specimens. They differ slightly from several blown specimens of Eastern *ministra*. The head is black and the prothoracic shield gamboge-yellow, as in normal *D. ministra*, and the stripes along the body are yellow, and as in normal *ministra*, but very slightly narrower. Beneath, the body is decidedly darker, and the base of the legs is darker, deep reddish where those of the Eastern *ministra* are usually gamboge-yellow. Also the latero-ventral yellow line is much narrower and more nearly obsolete. However, a blown specimen of an Eastern *ministra* approaches the California larvæ in having deep red legs. On the whole, while there are slight differences in the California form, I am yet somewhat in doubt whether to call it a well-marked climatic variety. Dr. Dyar, on seeing the specimen, coincides with me.

NOTE ON THE VESTIGES OF MANDIBLES IN THE PUPA.

Regarding the nature of the pieces which I have designated as paraclypeal, Dr. Chapman, to whom I submitted proofs, writes me as follows: "The paraclypeal pieces have always passed with me as mandibles, but there is room for doubt. Where there is a distinct articulation all around I think it is so, but in other cases it may be the corner of the head case of the larva, just as prolegs and other larval marks often present." I am inclined to adopt this view. On comparing the paraclypeal pieces in figs. 12, 23, 24, 26, 27, 28, 29, 30, 31, 37, 41, 45 with the swollen bases of the large functional mandibles of *Micropteryx purpuriella* (fig. 5) they seem to agree with them in position.

ADDITIONS TO MAPS II TO X.

The following additions of numbers representing localities mentioned in the preceding pages may be made on the maps:

Map II.—Insert 1 (var. *quinquelinea*) on east shore of Puget Sound. Insert 2*b* at El Paso, Tex. Remove 3 from Brunswick, Me.

Map III.—Insert 2 in eastern New York; 4 in northeastern Pennsylvania; 5 at Savannah, Ga.; 7 in southwestern Arkansas, and 12 near Boston, Mass.

Map. IV.—Insert 1 near Boston, Mass.; 5 at Savannah, Ga.; Jacksonville and Indian River, Florida.

Map V.—Insert 2, 3, and 8 in eastern New York; 5 at Orono, Me.; 5*a*, eastern Kansas and Chicago, Ill.; 6 at Brunswick, Me., and in Alaska; 4, 6, and 7 in Virginia; 7 in North Carolina, Ohio, Texas, Missouri, Chicago (Ill.), Wisconsin, Kingston (Canada), and Mississippi; 1 in Alabama; 4 in Colorado, and San Antonio and Dallas, Tex.

Map VI.—Insert 1 and 2 in western Massachusetts; 3 and 4 in eastern New York; 6 and 8 in southwestern Arkansas.

Map VII.—Insert 1 and 5 at Plattsburg, N. Y.; 6 at Amherst (Mass.), Washington (D. C.), southwestern Arkansas, and Fort Collins, Colo.

Map VIII.—Insert 2 at Plattsburg, N. Y.; 3 in New York and southwestern Arkansas; 5 in eastern Pennsylvania and near Philadelphia; 6 in western Washington, and 7 in British Columbia.

Map IX.—Insert 1 at Plattsburg, N. Y.; 2 at Jalapa (Mexico) and in Guatemala; 1 and 7 at Boston; 3 at Orono (Me.), Racine (Wis.), and Fort Collins, Colo.; 4 at Jalapa, Mexico; 5, 9, and 11 in southwestern Arkansas; 6 at Jacksonville, Fla.; 7 at Savannah, Ga.; 8 at Dallas, Tex.; 13 opposite Micco, Indian River, Florida.

Map X.—Insert 7 at Franconia, N. H.; 2, 4, and 5*a* at St. Louis, Mo.; 3 at Calgary, Alberta, and Saratoga Springs, N. Y.; 1 at Miles City (Mont.) and Los Angeles (Cal.), also at Jalapa (Mexico) and in Guatemala; 5*a* at Springfield, Ill.

DESIDERATA.

The following gaps or desiderata occur in our knowledge of the larvæ or life history of the North American Notodontidæ, and attention is drawn to them here in order that collectors and students may aid us in filling them up. It is particularly requested that the desired eggs and larvæ may be sent to the author in order that colored drawings may be made of them for future publication.

Three genera are still unknown either in the egg, larval, or pupal stage; these are *Ellida*, *Euhyparpax*, and *Nystalea*.

Eggs and larva in all stages of—
- *Gluphisia wrightii.*
- *rupta.*
- *albofascia.*
- *formosa.*
- *lintneri.*
- *Apatelodes angelica.*
- *Datana californica.*
- *floridana.*
- *modesta.*

Eggs and early larval stages of—
- *Ichthyura apicalis.*
- *inornata.*
- *strigosa.*
- *brucei.*
- *Lophodonta basitriens.*

Eggs and larva in all stages of—
- *Drymonia georgica.*
- *Lophopteryx elegans.*
- *camelina.*

Eggs and Stages I and II of *Notodonta stragula.*

Eggs and all the larval stages of—
- *Notodonta simplaria.*
- *Ellida caniplaga.*
- *Dasylophia thyatiroides.*

Eggs and larva of the two forms of *Symmerista albifrons.*

Eggs and larva of *Symmerista packardii.*

Eggs of *Hyparpax aurora.*

Eggs and all the larval stages of—
- *Hyparpax perophoroides.*
- *Hyparpax venus.*
- *Euhyparpax rosea.*
- *Schizura apicalis.*
- *perangulata.*

Eggs and Stages I, II, and III of—
- *Seirodonta bilineata.*
- *Heterocampa manteo.*
- *astarte.*

Eggs and all the larval stages of—
- *Heterocampa chapmani.*
- *plumosa.*
- *hydromeli.*
- *belfragei.*
- *subrotata.*
- *Cerura occidentalis.*
- *scolopendrina.*
- *Nystalea indiana.*

The pupa of each or any of these is desired, either alive or in alcohol, or the cast shells.

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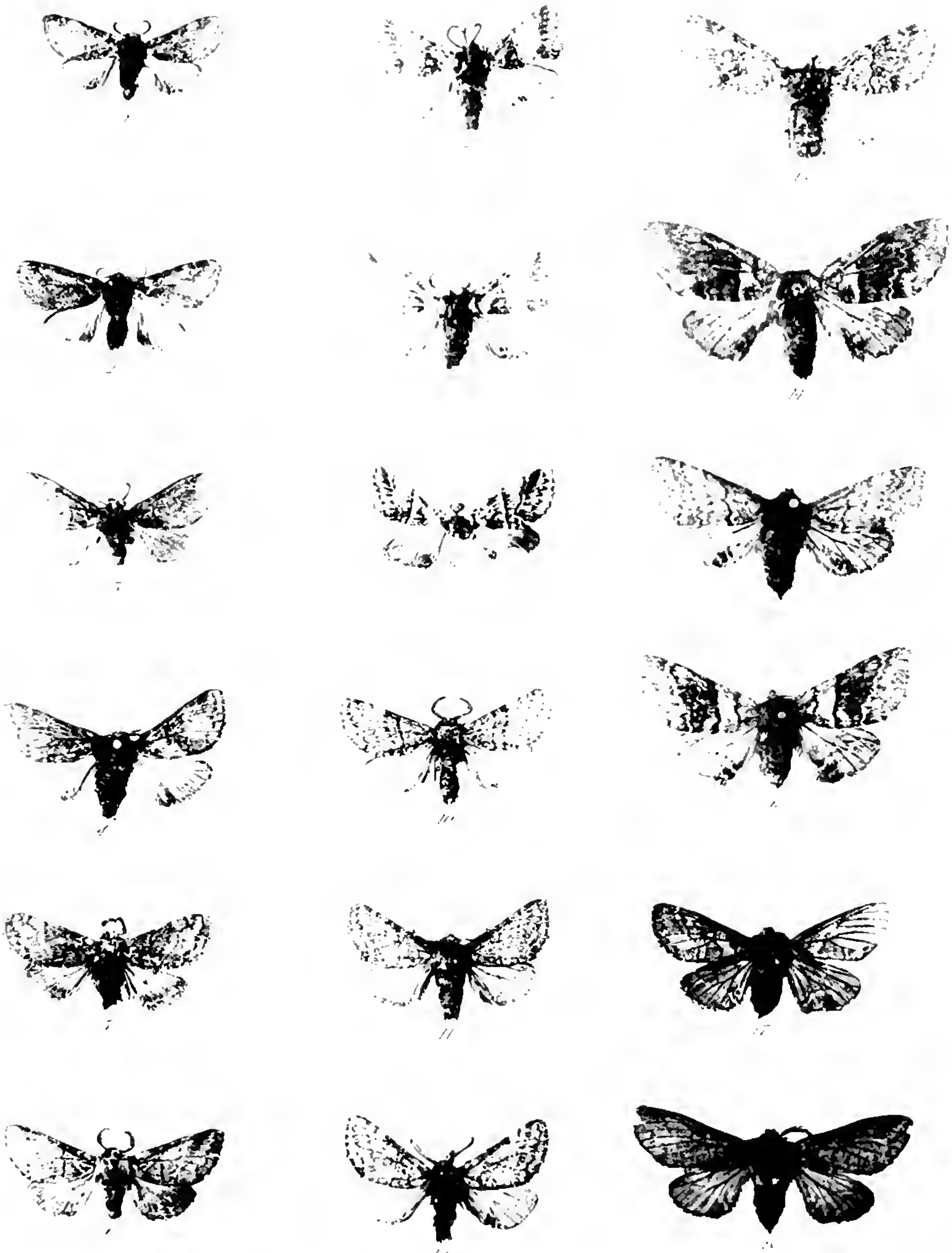
EXPLANATION OF THE PLATES.

Plate I.

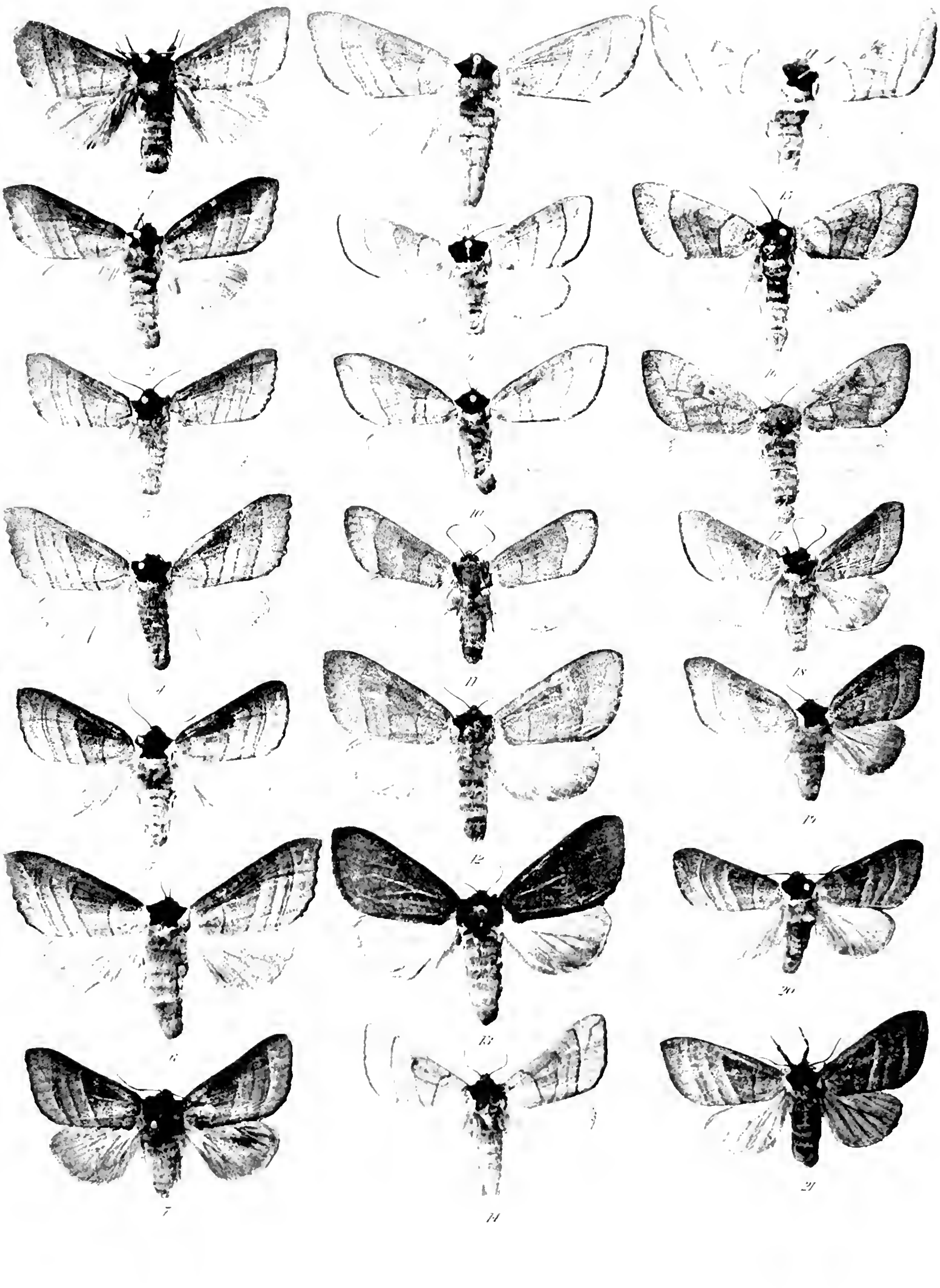
Figs. 1, 2, 3. *Gluphisia septentrionis* Walk. ♂.
Fig. 4. *Gluphisia septentrionis* var. *quinquelinea*.
Figs. 5, 6. *Gluphisia ridenda* Edw. ♂.
Figs. 7, 8. *Gluphisia albofascia* Edw. ♂.
Fig. 9. *Gluphisia rupta* Edw. ♂.
Figs. 10–12. *Gluphisia formosa* Edw. ♂.
Fig. 13. *Gluphisia wrightii* Edw. ♀.
Figs. 14–16. *Gluphisia severa* Edw. ♀.
Fig. 17. *Gluphisia severa* (*avimacula* Hudson). ♀.
Fig. 18. *Gluphisia lintneri* (Grote). ♂.



North American Species of Gluphisia

Plate II.

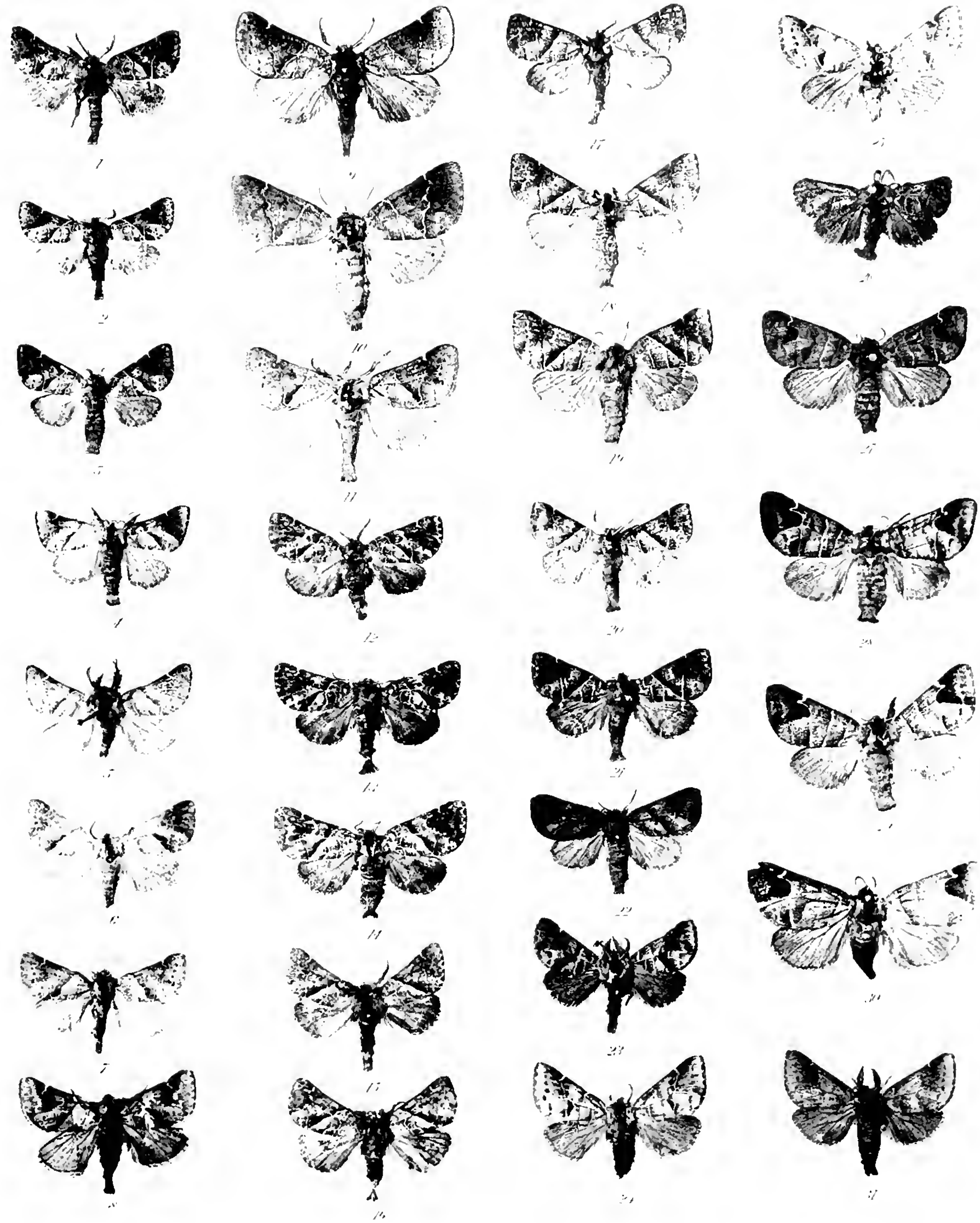
Figs. 1, 2. *Datana angusii* Grote and Rob. ♂, ♀.
Figs. 3, 4. *Datana ministra* Drury. ♂, ♀.
Figs. 5, 6. *Datana drexelii* Edw. ♂, ♀.
Figs. 7, 8. *Datana major* Grote and Rob. ♂, ♀.
Figs. 9, 10. *Datana palmii* Beut. ♂, ♀.
Figs. 11, 12. *Datana floridana* Graef. ♂, ♀,
Fig. 13. *Datana modesta* Beut. ♀.
Figs. 14, 15. *Datana perspicua* Grote and Rob. ♂, ♀.
Figs. 16, 17. *Datana robusta* Strecker. ♂, ♀.
Figs. 18, 19. *Datana contracta* Walk.
Figs. 20, 21. *Datana integerrima* Grote and Rob. ♂, ♀.



North American Species of Datana (D. Californica excepted)

PLATE III.

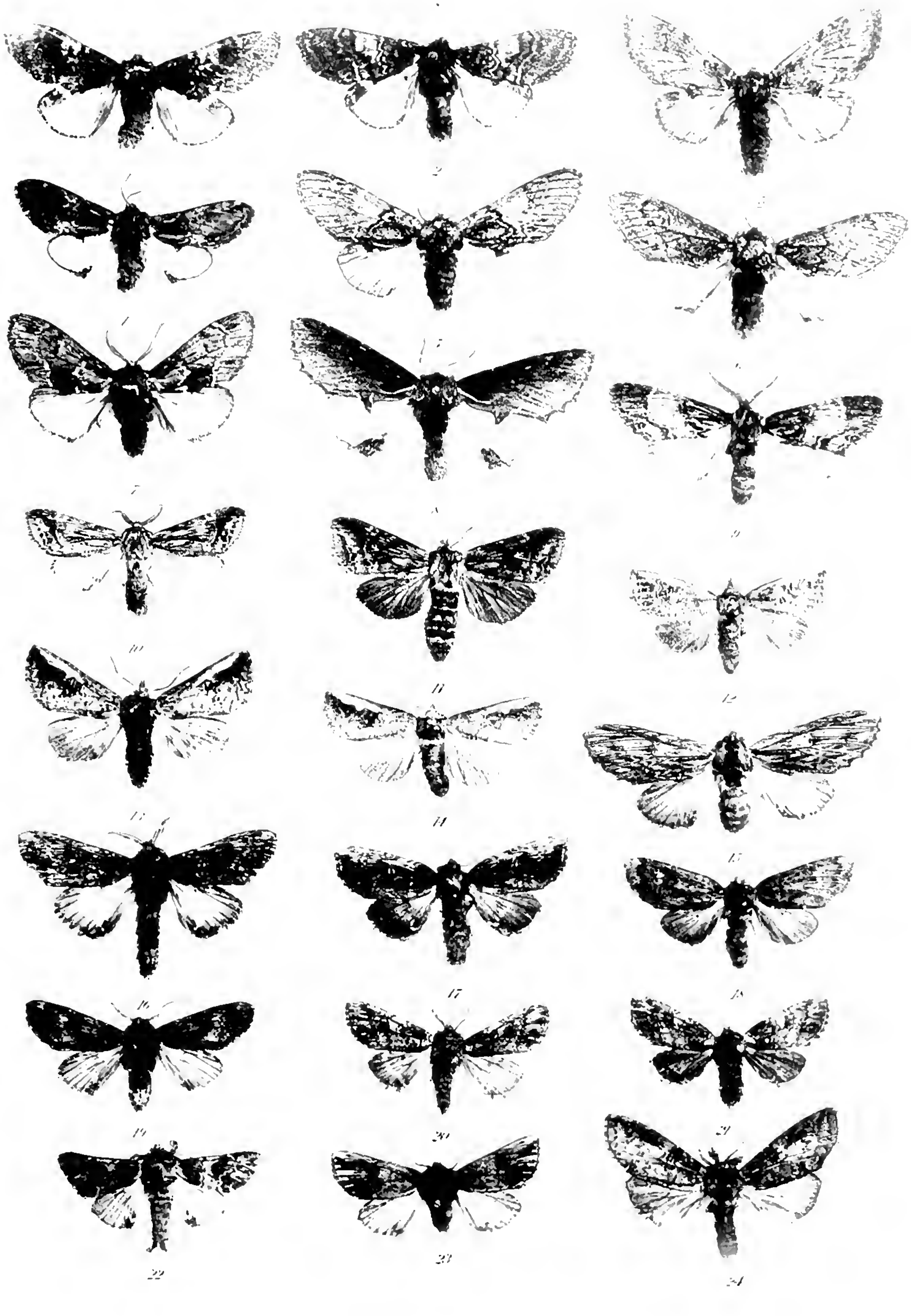
FIGS. 1–3. *Ichthyura apicalis* Walk. (*van*). ♂, ♂, ♀.
FIGS. 4–7. *Ichthyura apicalis* var. *incarcerata* Boisd. (*ornata* Edw.) ♀, ♂, ♀, ♂.
FIG. 8. *Ichthyura apicalis* var. *bifiria* Edw. ♂.
FIGS. 9–11. *Ichthyura inornata* Neum. ♂, ♀, ♂.
FIGS. 12–14. *Ichthyura strigosa* Grote. ♂, ♂, ♀.
FIGS. 15, 16. *Ichthyura strigosa* var. *luculenta* Edw.
FIGS. 17–19. *Ichthyura inclusa* Hübn. ♂, ♀, ♀.
FIGS. 20, 21. *Ichthyura inclusa* var. *inversa* Pack. ♂, ♂.
FIG. 22. *Ichthyura inclusa* var. *jocosa* Edw. ♀.
FIGS. 23–25. *Ichthyura brucei* Edw. ♂, ♀, ♀.
FIG. 26. *Ichthyura brucei* var. *multnoma* Dyar. ♂.
FIGS. 27, 28. *Ichthyura albosigma* Fitch. ♀, ♀.
FIGS. 29, 30. *Ichthyura albosigma* var. *specifica* Dyar. ♀, ♂.
FIG. 31. *Ichthyura apicalis* var. *incarcerata*, subvar. *alethe* Dyar. ♀.



North American Species of Ichthyura with their varieties

Plate IV.

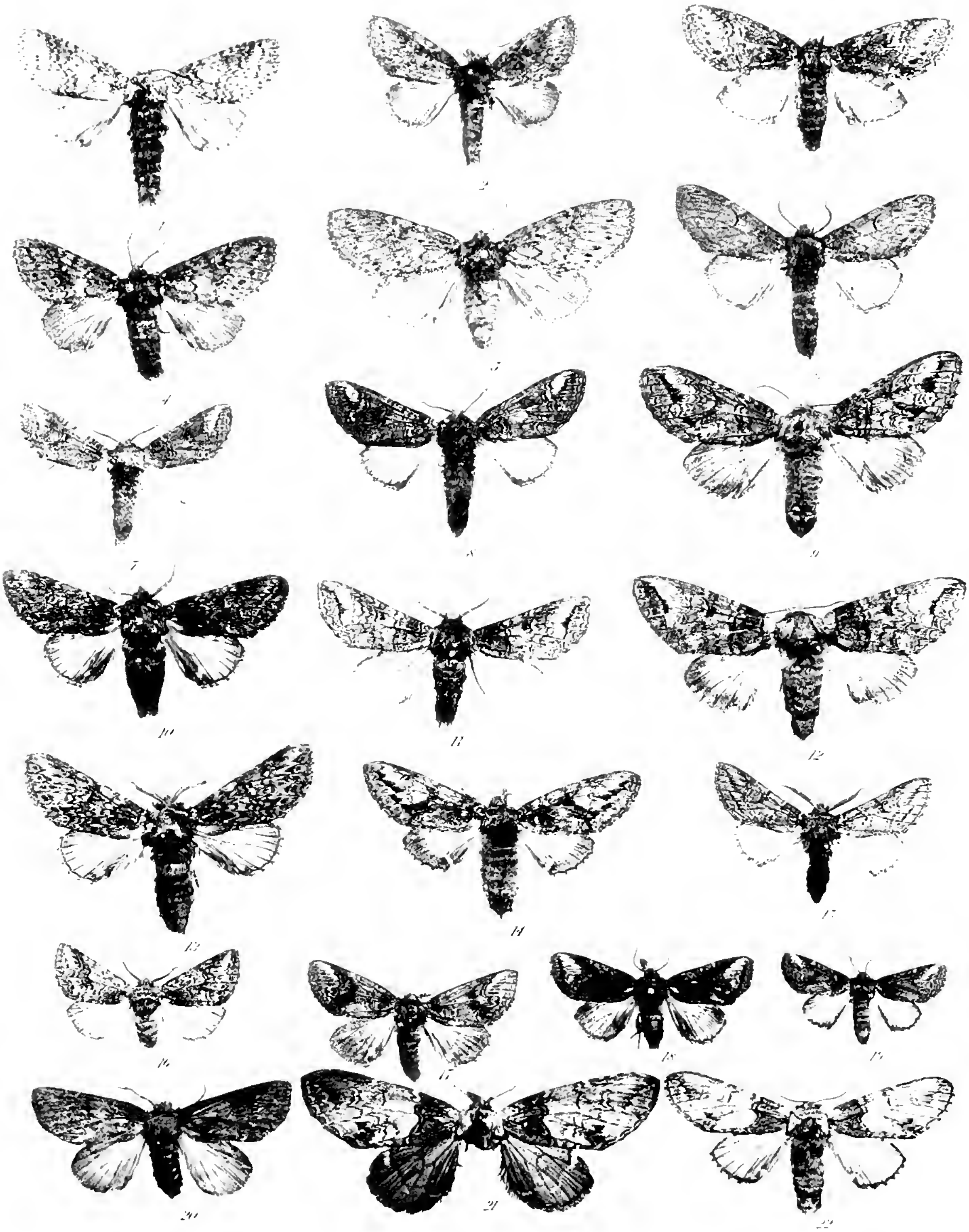
Fig. 1. *Lophodonta ferruginea* Pack. ♂.
Fig. 2. *Lophodonta ferruginea* Pack. ♂.
Fig. 3. *Lophodonta angulosa* Abbot and Sm. ♂.
Fig. 4. *Notodonta stragula* Grote and Rob. ♂.
Fig. 5. *Lophodonta basitriens* (Walk.). ♂.
Fig. 6. *Notodonta simplaria* Graef. ♂.
Fig. 7. *Drymonia georgica* Herr.-Sch. ♂.
Fig. 8. *Lophopteryx elegans* Streck. ♂.
Fig. 9. *Dasylophia interna* Pack. ♂.
Fig. 10. *Dasylophia anguina* Abbot and Smith, var. *punta gorda* Slosson. ♂.
Fig. 11. *Dasylophia anguina* Abbot and Smith. ♀. Normal.
Fig. 12. *Symmerista packardii* (Morr.). ♀.
Fig. 13. *Symmerista albifrons* Abbot and Smith (*albicosta* Hubn.). ♂.
Fig. 14. *Symmerista albifrons* var. from Florida (*albifrons* A. and S.). ♂.
Fig. 15. *Xylinodes lignicolor* (Walk.). ♀.
Fig. 16. *Schizura ipomea* Doubleday. ♂.
Fig. 17. *Schizura ipomea* var. *cinereofrons* Pack. ♀
Fig. 18. *Schizura leptinoides* Grote and Rob. ♀.
Fig. 19. *Schizura leptinoides* Grote and Rob. ♂.
Fig. 20. *Schizura unicornis* Abbot and Sm. ♂.
Fig. 21. *Schizura unicornis* Abbot and Sm. ♀.
Fig. 22. *Schizura apicalis* Grote and Rob. ♂.
Fig. 23. *Schizura badia* Pack. ♂.
Fig. 24. *Ellida caniplaga* (Walk.). ♂.



Notodontinæ and Heterocampinæ

Plate V.

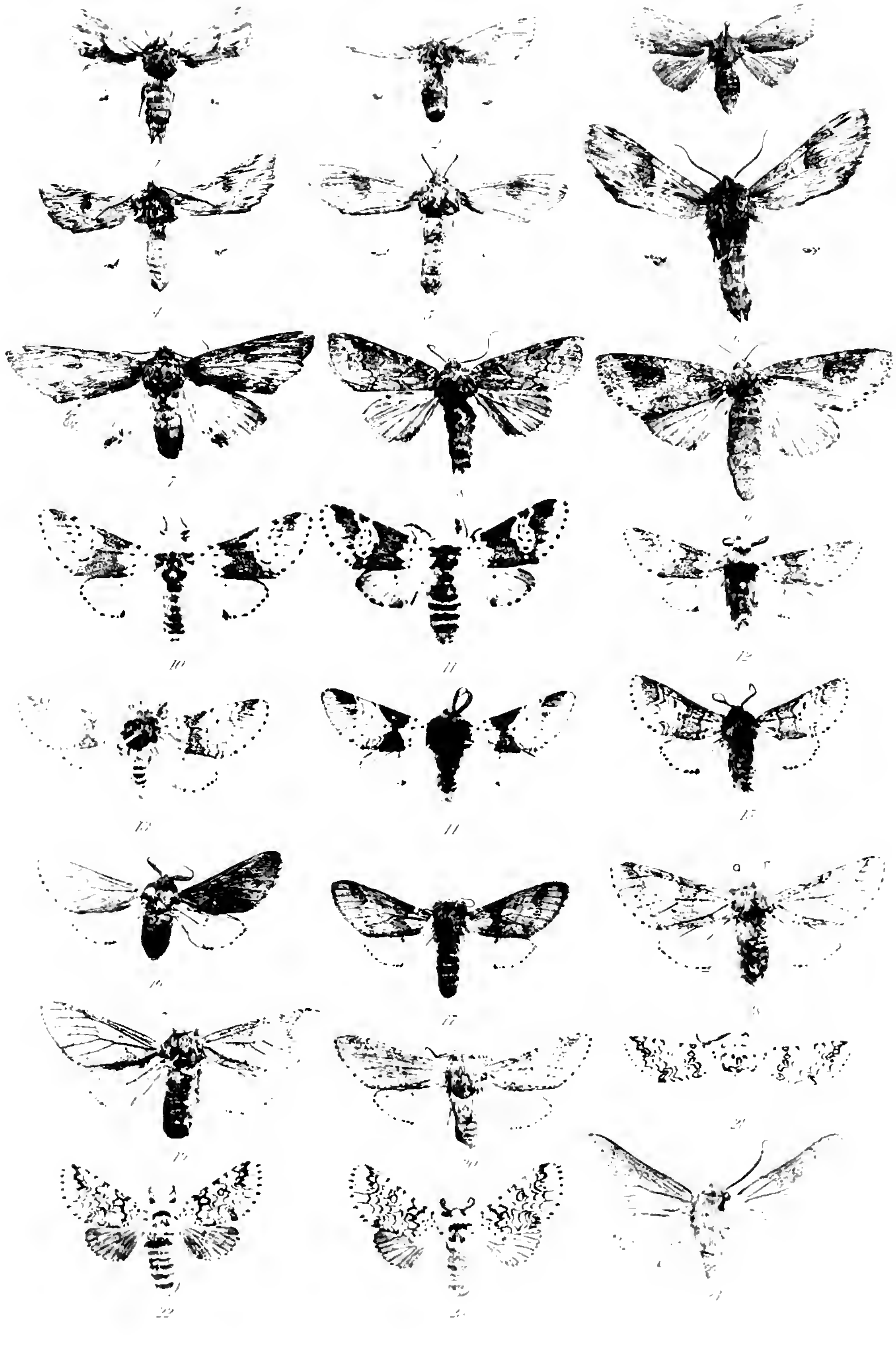
Fig. 1. *Heterocampa manteo* (Doubleday). ♂.
Figs. 2, 3. *Heterocampa guttivitta* (Walk.). ♂, ♀.
Figs. 4, 5. *Heterocampa biundata* Walk. ♂, ♀.
Fig. 6. *Heterocampa lunata* Edws. ♂. Edwards's type.
Fig. 7. *Heterocampa obliqua* var. *pecolivata* Pack. ♂ (type).
Figs. 8, 9. *Heterocampa obliqua* Pack. ♂, ♀.
Fig. 10. *Heterocampa pulverea* Grote and Rob. ♂.
Figs. 11, 12. *Heterocampa astarte* Doubld. ♂, ♀.
Figs. 13, 14. *Heterocampa pulverea* Grote and Rob. ♂, ♀.
Fig. 15. *Heterocampa belfragei* (Grote). ♂.
Fig. 16. *Heterocampa hydromeli* Harvey. ♀.
Figs. 17, 18. *Heterocampa subrotata* Harvey. ♂, ♀.
Fig. 19. *Heterocampa subrotata* (*celtiphaga* Harvey). ♂.
Fig. 20. *Heterocampa unicolor* Pack. ♂.
Figs. 21, 22. *Macrurocampa marthesia* (Cramer). ♀, ♂.



Heterocampa and Macrurocampa

Plate VI.

Figs. 1, 2, 3. *Schizura concinna* Abbot and Sm. ♂, ♂ (from Idaho), ♀.
Fig. 4. *Schizura perangulata* Edws. ♂. Edwards's type.
Fig. 5. *Schizura perangulata* Edws. ♂. Utah. U. S. Nat. Mus.
Fig. 6. *Schizura perangulata* Edws. ♂. Colorado. Coll. Neumoegen.
Fig. 7. *Schizura eximia* Edws. ♂.
Fig. 8. *Seirodonta bilineata* (Pack.).
Fig. 9. *Heterocampa manteo* (Doubld.) var. U. S. Nat. Mus.
Figs. 10–12. *Cerura borealis* Boisd. ♂, ♂, ♂.
Fig. 13. *Cerura scolopendrina* Boisd. ♂. California. Coll. Dyar.
Fig. 14. *Cerura scolopendrina* var. *modesta* Hudson. ♂.
Fig. 15. *Cerura occidentalis* Lintner. ♂.
Fig. 16. *Cerura cinerea* Walk. ♂.
Fig. 17. *Cerura cinerea* var. *cinereoides* Dyar. ♀.
Fig. 18. *Cerura cinerea* var. *nivea*. ♀. Colorado.
Fig. 19. *Cerura cinerea* var. *nivea*. Dyar's type of *meridionalis*. ♀.
Fig. 20. *Cerura cinerea* type of Behr's *paradoxa*. Coll. Dyar. ♂.
Fig. 21. *Cerura scitiscripta* Walk. ♂. Florida.
Figs. 22, 23. *Cerura scitiscripta* var. *multiscripta* Riley. ♂, ♂.
Fig. 24. *Euhyparpax rosea* Beutenmüller. ♂. Type in Amer. Mus. Nat. Hist.



Heterocampinæ and Cerurinæ

Plate VII.

Fig. 1. *Glaphisia septentrionis* Walker. ♂. H. Knight del. from Walker's type in British Museum.
Fig. 2. *Ichthyura apicalis* Walker. ♂. Normal form. Bridgham del.
Fig. 3. *Ichthyura apicalis* var. *astoria* Edws. ♂. Nebraska. Bridgham del.
Fig. 4. *Ichthyura apicalis* Walk. ♂. H. Knight del. from Walker's type in British Museum.
Fig. 5. *Ichthyura inclusa* Hübn. ♂. Normal Eastern form. Bridgham del.
Fig. 6. *Ichthyura strigosa* Grote. ♂. Bridgham del.
Fig. 7. *Ichthyura brucei* Edws. ♂. Franconia, N. H. Bridgham del.
Fig. 8. *Ichthyura albosigma* Fitch. ♂. Bridgham del
Fig. 9. *Ichthyura inclusa* var. *inversa* Pack. Bridgham del.
Fig. 10. *Apatelodes torrefacta* Abbot and Sm. ♂. Bridgham del.
Fig. 11. *Pheosia dimidiata* H.-Sch. ♂. Bridgham del.
Fig. 12. *Notodonta stragula* Grote and Rob. ♂. Bridgham del.
Fig. 13. *Lophodonta basitriens* Walk. ♂. H. Knight del. from Walker's type in British Museum.
Fig. 14. *Lophopteryx elegans* (Strecker). ♂. Bridgham del.
Fig. 15. *Nerice bidentata* Walk. ♂. Bridgham del.
Fig. 16. *Dasylophia anguina*. ♂. H. Knight del. from Walker's type of "*Edema cana*" in British Museum.
Fig. 17. *Ellida caniplaga* (Walk). ♂. Bridgham del.
Fig. 18. *Hyparpax venus* Neum. ♂. Bridgham del. from example in Neumoegen's coll.
Fig. 19. *Schizura ipomeæ* Doubleday. ♂. var. *cinereofrons* Pack. Bridgham del.
Fig. 20. *Schizura eximia* Grote and Rob. ♂. Bridgham del. from Grote's type in Mrs. Bridgham's coll.
Fig. 21. *Heterocampa manteo* Doubled. ♂. Bridgham del.
Fig. 22. *Heterocampa guttivitta* Walk. ♂. H. Knight del. from Walker's type of "*Scirodonta albiplaga*" in British Museum.
Fig. 23. *Heterocampa belfragei* (Grote). ♂. Bridgham del. from example in Neumoegen's coll.
Fig. 24. *Heterocampa plumosa* Edws. ♂. Bridgham del. from example in U. S. Nat. Mus. (does not show the basal scalloped lines).
Fig. 25. *Heterocampa pulverea* Grote and Rob. ♂. H. Knight del. from Walker's type of "*H. umbrata*" in British Museum.
Fig. 26. *Heterocampa biundata* Walk. ♂. H. Knight del. from Walker's type in British Museum.
Fig. 27. *Heterocampa astarte* Doubled. ♂. Bridgham del.
Fig. 28. *Macrurocampa marthesia* (Cramer). ♀. Bridgham del. from Grote and Rob.'s type labeled "*H. elongata*" in Mrs. Bridgham's coll.
Fig. 29 *Heterocampa pulverea* Grote and Rob. ♀. Bridgham del. from type labeled by Mr. Grote in Mrs. Bridgham's coll.
Fig. 30. *Cerura cinerea* Walk. ♂. H. Knight del. from Walker's type in British Museum.
Fig. 31. *Cerura scitiscripta* Walk. ♂. H. Knight del. from Walker's type in British Museum.

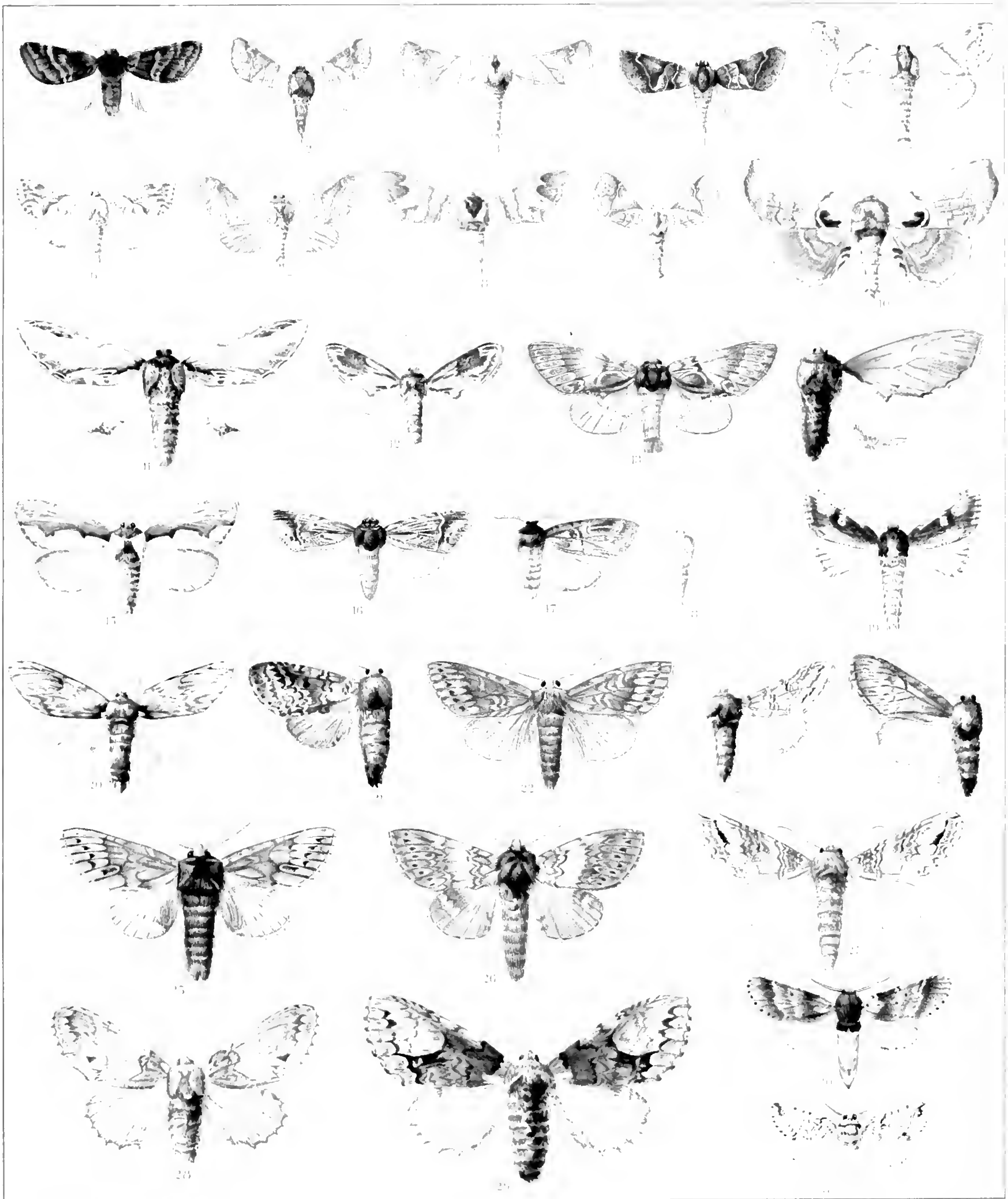


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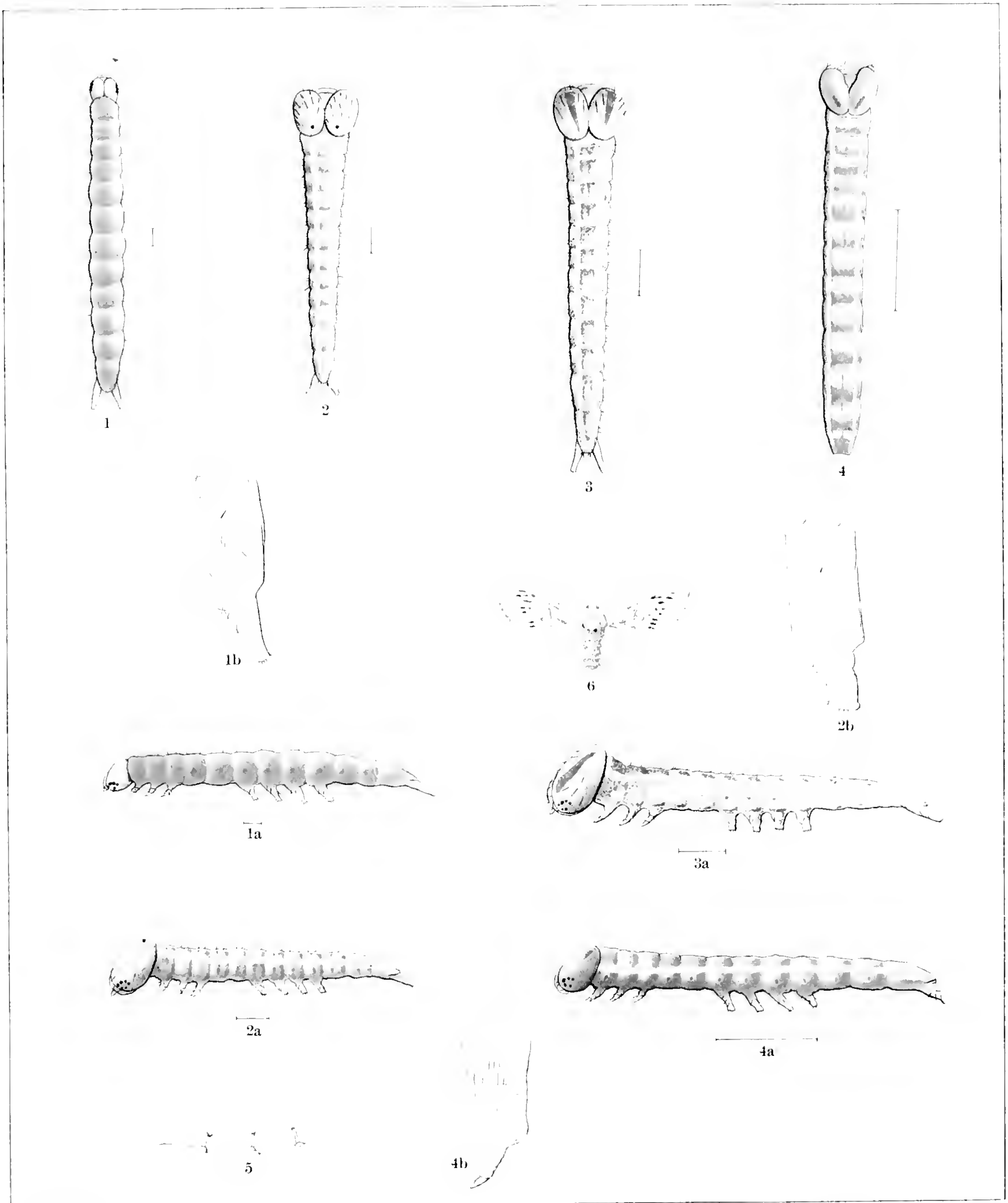
Plate VIII.

The larval stages of Glaphisia septentrionis Walk.

Fig. 1. Larva, Stage I, dorsal view; *1a*, side view; *1b*, side view of the third abdominal segment.
Fig. 2. Larva, Stage II, dorsal view; *2a*, side view; *2b*, side view of the third abdominal segment.
Fig. 3. Larva, Stage III, dorsal view; *3a*, side view.
Fig. 4. Larva, Stage IV, dorsal view; *4a*, side view; *4b*, side view of second thoracic segment.
Fig. 5. Three of the glandular hairs of the freshly hatched larva.
Fig. 6. *Glaphisia ridenda* Edwards. ♂. Natural size.

All the figures drawn by J. Bridgham.



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Gluphisia septentrionalis.

PLATE IX.

Larval stages of Apatelodes torrefacta.

FIG. 1. Egg, seen from above; *1a*, seen from the side; *1b*, markings of the surface; egg natural size between 1 and *1a*.

FIG. 2. Larva, Stage I, dorsal view; *2a*, side view; *2b*, third abdominal segment without the hairs, dorsal view; *2c*, the same, side view; *2d*, prothoracic segment; *2e*, end of the body with anal leg, all magnified.

NOTE.—The line by the side of the body indicates in all the plates the natural length of the larva.

FIG. 3. Larva, Stage II, dorsal view; *3a*, side view; *3b*, head seen in front; *3c*, third abdominal segment, side view.

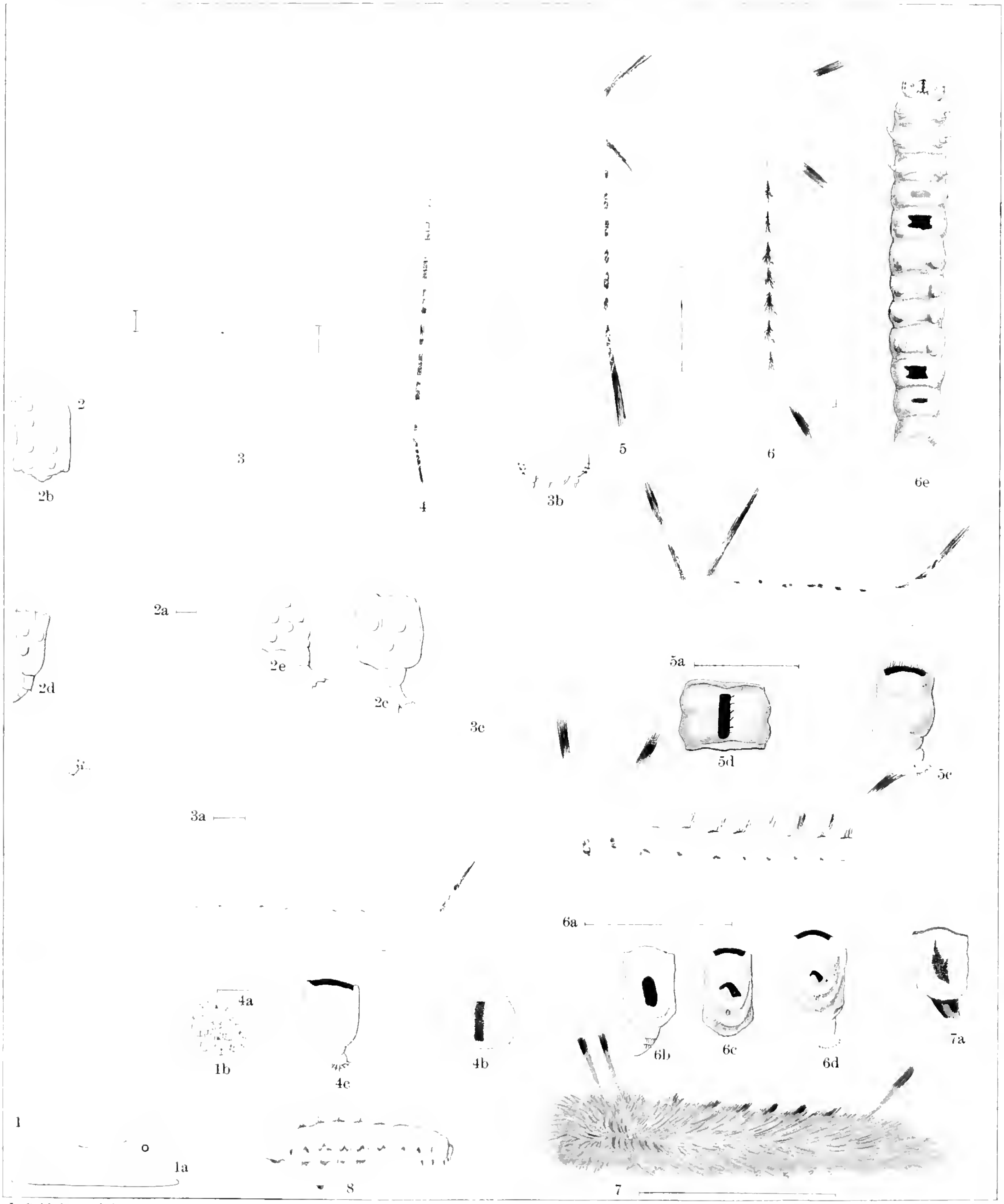
FIG. 4. Larva, Stage III, dorsal view; *4a*, side view; *4b*, third abdominal segment, dorsal view; *4c*, side view of the same.

FIG. 5. Larva, Stage IV, dorsal view; *5a*, side view; *5b*, third abdominal segment; *5c*, side view of the same.

FIG. 6. Larva, Stage V, dorsal view; *6a*, side view; *6b*, second thoracic segment, side view; *6c*, second abdominal segment, side view; *6d*, sixth abdominal segment, side view; *6e*, larva at this stage, ventral view.

FIG. 7. Larva, Stage VI (and last), *7a*, third abdominal segment, side view. Figs. 1-7 drawn by J. Bridgham.

FIG. 8. Fully fed larva, natural size, Georgia. Leconte del.



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Egg and Larval Stages of Apateiodes torrefacta.

PLATE X.

Larva of Datana ministra, D. angusii, etc.

FIG. 1. *Datana ministra*, last stage. Miss Emily L. Morton del.

FIGS. 1*a*, 1*b*. *Datana ministra*, last stage. Riley direxit; from Department of Agriculture.

FIG. 1*c*. *Datana ministra*, last stage. Riley direxit; from Department of Agriculture.

FIG. 1*d*. *Datana ministra*, Stage IV. Bumpus del. From 5th Rep. U. S. Ent. Comm.

FIG. 1*e*. *Datana ministra*. Georgia; on oak. Leconte del.

FIG. 2. *Datana angusii*, last stage. Miss Morton del.

FIG. 3. Datana, on walnut, not identified. 3*a*, side view; 3*b*, natural size; 3*c*, third abdominal segment. Bridgham del.

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Larva of Datana ministra, D. Angusii, etc.

Plate XI.

Larva of Datana drexelii, etc.

Fig. 1. *Datana ministra*, from Olympia, Wash.; 1*a*, prothoracic segment, side view; 1*b*, second abdominal segment; 1*c*, third abdominal segment.

Fig. 2. *Datana drexelii*, a small belated caterpillar; 2*a*, side view, natural size.

Fig. 2*b*. *Datana drexelii*, head and prothoracic segment.

Fig. 2*c*. *Datana drexelii*, third abdominal segment, side view.

Fig. 3. *Datana drexelii*, from a blown specimen from Mr. H. Edwards. J. Bridgham del.

J. Bridgham, del.

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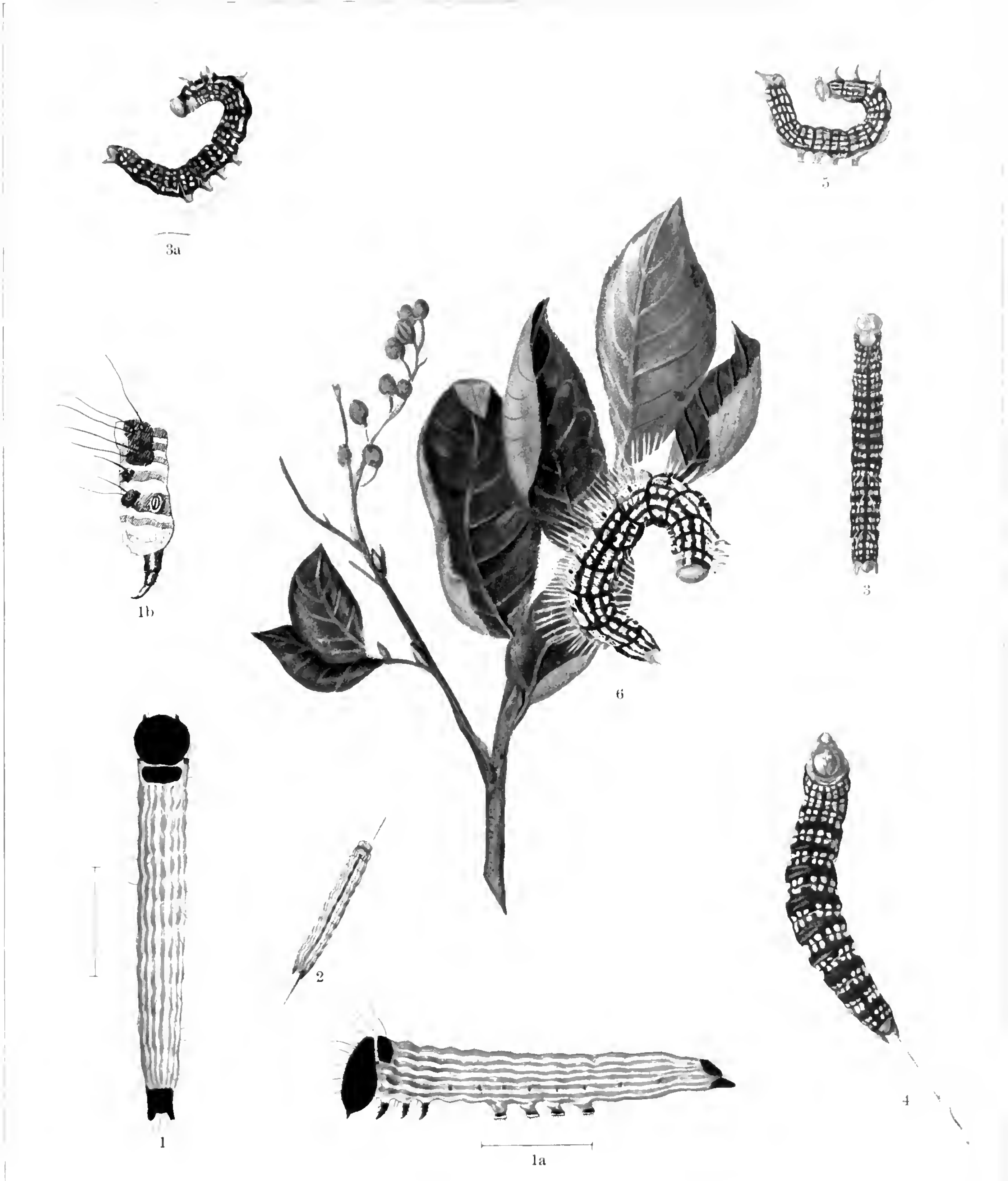
Larva of Datana Drexelii, etc.

Plate XII.

Larva of Datana major.

Fig. 1. *Datana major*, 1*a*, side view; 1*b*, prothoracic segment, side view. Bridgham del.
Fig. 2. *Datana major*, Stage IV?; Riley direxit. Department of Agriculture, No. 899 P.
Fig. 3. *Datana major*, Stage IV?; 3*a*, side view; Riley direxit, Department of Agriculture, No. 899 P.
Fig. 4. *Datana major*, last stage; Riley direxit, Department of Agriculture, No. 899 P.
Fig. 5. *Datana major*, Georgia, Leconte del.
Fig. 6. *Datana major*. Miss Morton del.



J. Bridgham, Miss Morton, Le Conte, etc., del.

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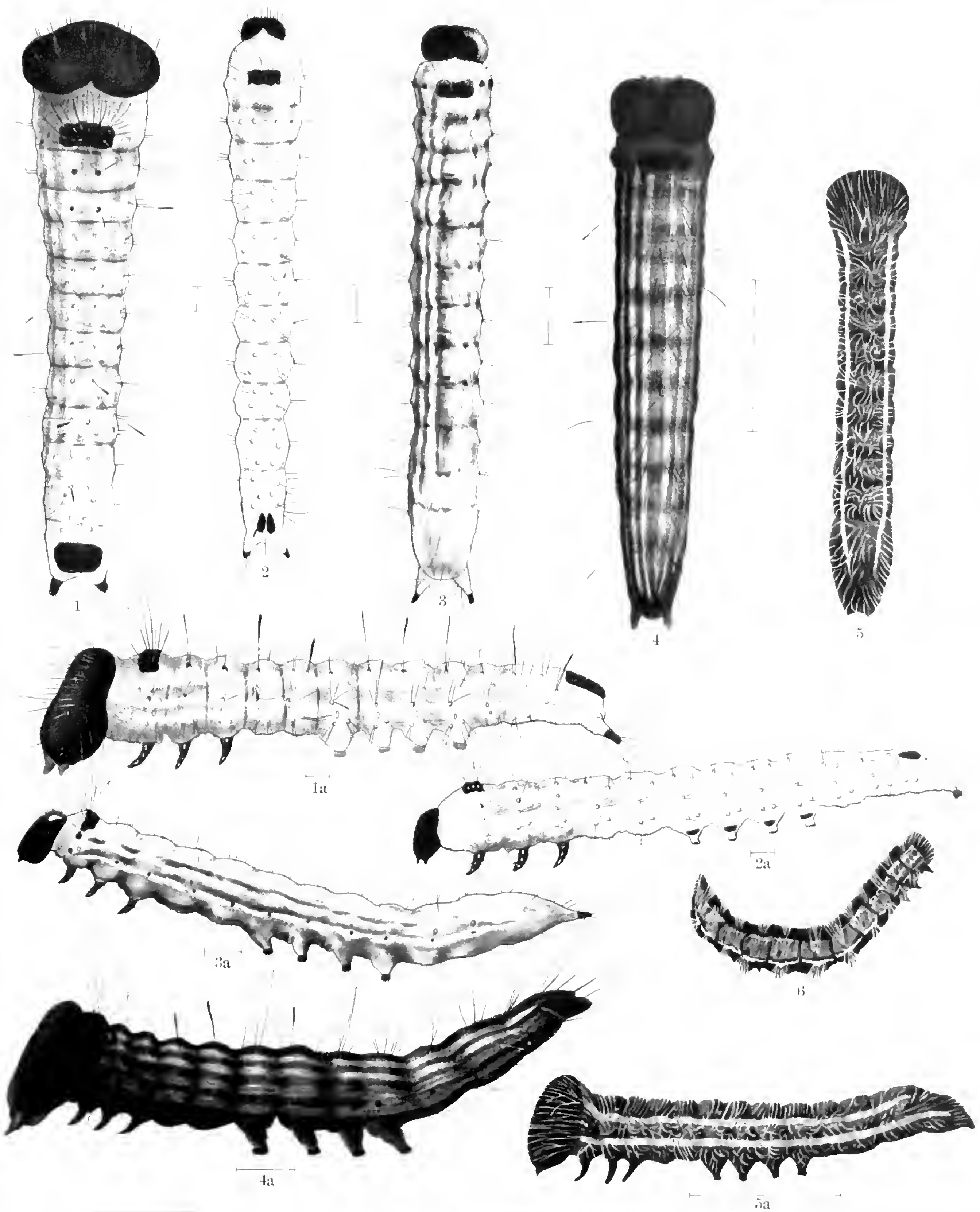
Larval Stages of Datana major.

Plate XIII.

Larval stages of Datana integerrima.

Fig. 1. *Datana integerrima*, Stage I; 1*a*, side view.
Fig. 2. *Datana integerrima*, end of Stage I; 2*a*, side view.
Fig. 3. *Datana integerrima*, Stage II; 3*a*, side view.
Fig. 4. *Datana integerrima*, Stage III; 4*a*, side view.
Fig. 5. *Datana integerrima*, Stage IV; 5*a*, side view. Bridgham del.
Fig. 6. *Datana integerrima*, last stage, natural size. Miss Morton del.



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Larval Stages of Datana integerrima.

Plate XIV.

Larva of Datana floridana, D. palmii, D. perspicua, and D. contracta.

Fig. 1. *Datana floridana*, last stage; Riley direxit, United States Department of Agriculture, No. 3271.

Fig. 2. *Datana palmii*, Stage IV; *2a*, head and two succeeding segments; *2b*, third abdominal and *2c*, end of the body enlarged. Bridgham del.

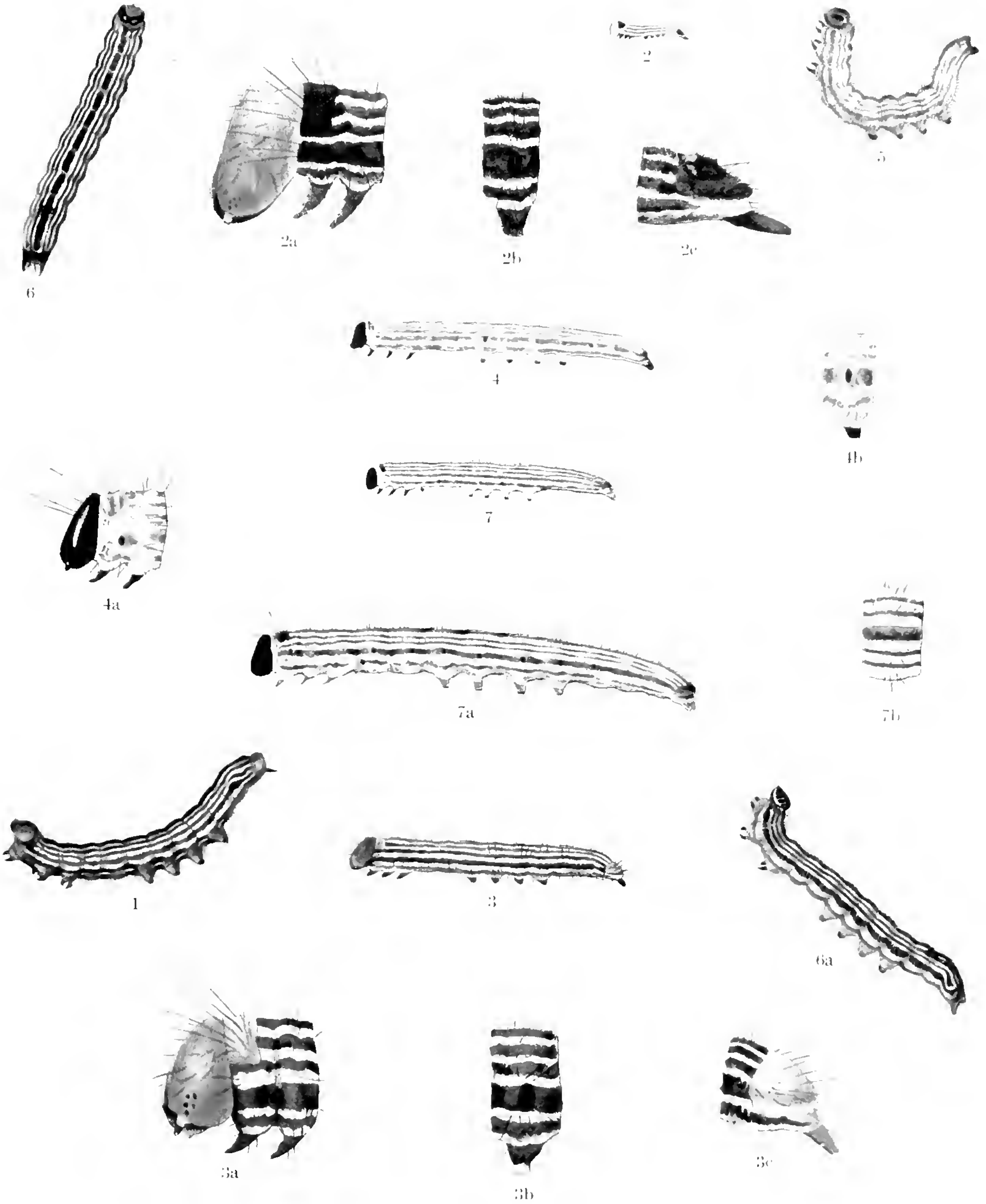
Fig. 3. *Datana palmii*, Stage V; and last; *3a*, *3b*, *3c*, same parts figured as in *2a*, *2b*, *2c*. Bridgham del.

Fig. 4. *Datana perspicua*, Stage IV; *4a*, head and two following segments; *4b*, third abdominal. Bridgham del., from blown specimen.

Fig. 5. *Datana perspicua*, last stage; Riley direxit, United States Department of Agriculture, No. 283 L.

Fig. 6, *6a*. *Datana perspicua*, last stage; Riley direxit, United States Department of Agriculture, No. 671½.

Fig. 7. *Datana contracta*, Stage IV; *7a*, enlarged, *7b*, third abdominal segment. Bridgham del., from a blown specimen.



J. Bridgham. Riley, del

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Larva of Datana Floridana, 1; D. Palmii, 2; D. perspicua, 5, 6. D. contracta, 7.

Plate XV.

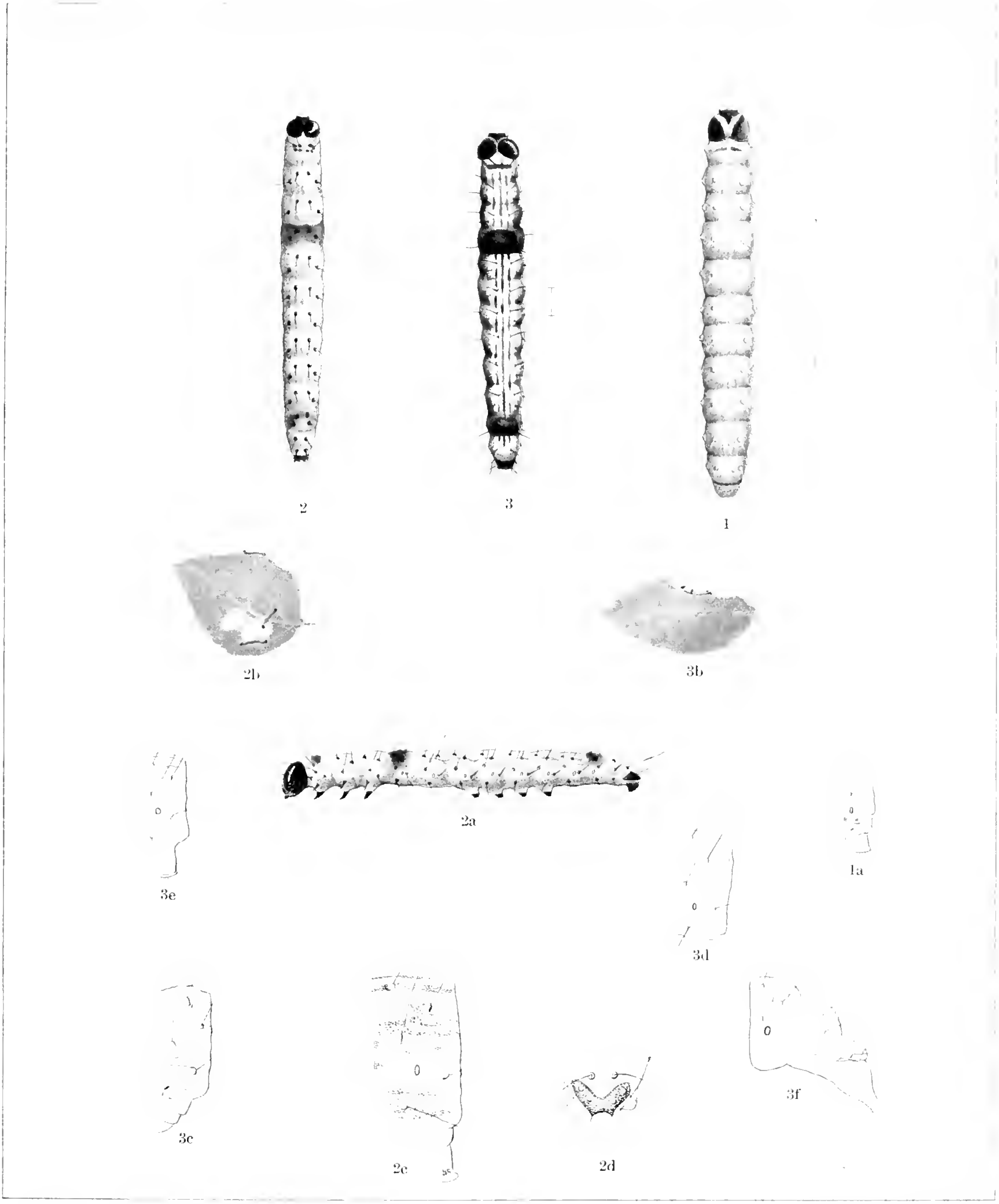
Larval stages of Ichthyura apicalis and var. astoria.

Fig. 1. *Ichthyura apicalis* (van), last stage; 1*a*, third abdominal segment, side view.

Fig. 2. *Ichthyura apicalis*, var. *astoria*, Stage I; 2*a*, side view; 2*b*, natural size; 2*c*, third abdominal segment, side view; 2*d*, end of body, dorsal view.

Fig. 3. The same, Stage II; 3*a*, side view; 3*b*, larva natural size; 3*c*, second thoracic segment; 3*d*, second abdominal; 3*e*, third abdominal segment; 3*f*, end of body with anal leg. J. Bridgham del.

PLATE XV.



J. Bridgham, del.

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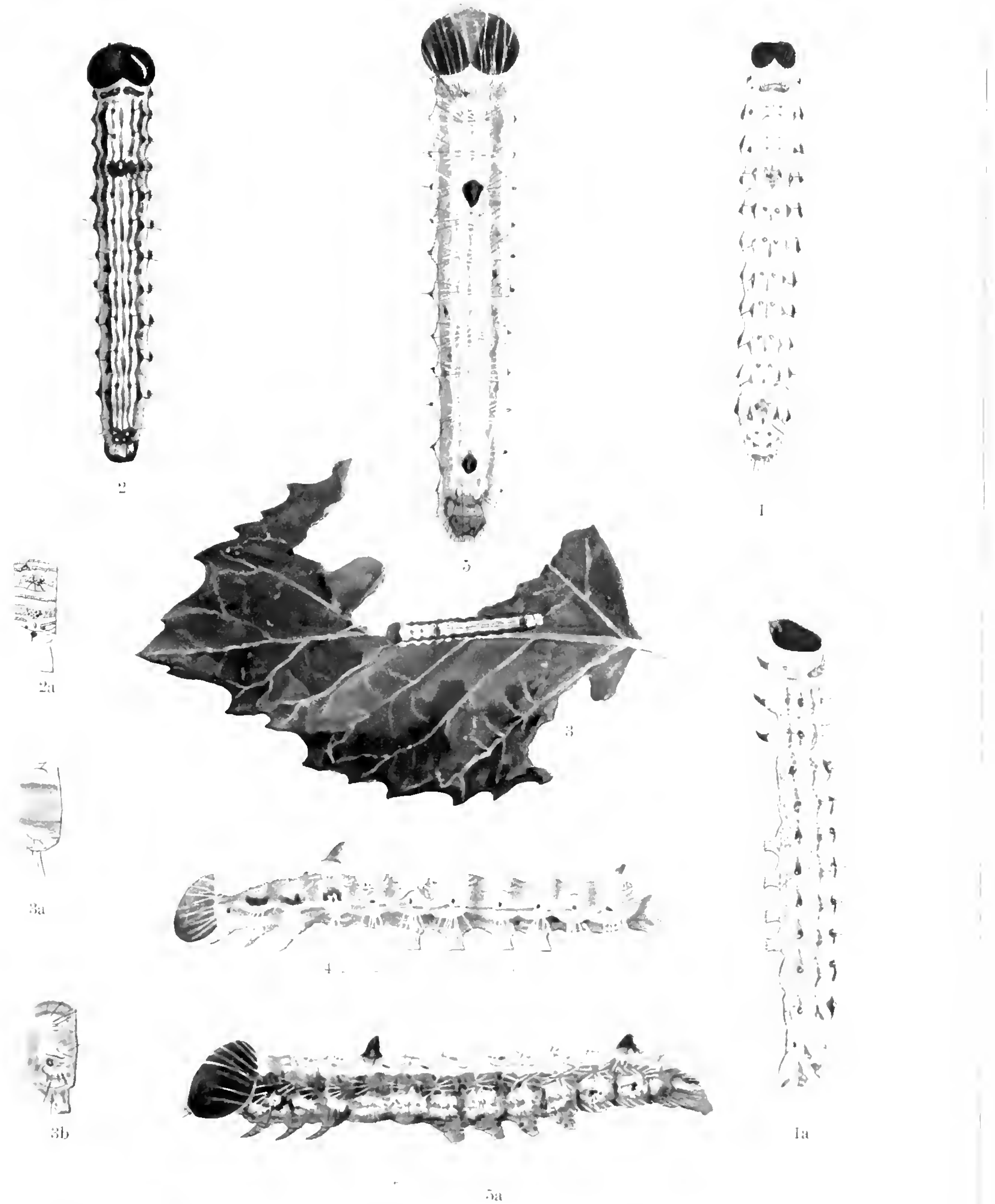
Larval Stages of Ichthyura apicalis (1) and var. Astoriæ (2, 3)

Plate XVI.

Larval stages of Ichthyura inclusa and albosigma.

Fig. 1. *Ichthyura inclusa*, Stage I; 1*a*, side view.
Fig. 2. *Ichthyura inclusa*, Stage II; 2*a*, side view of third abdominal segment.
Fig. 3. *Ichthyura albosigma*, Stage III?; 3*a*, third abdominal segment, dorsal view; 3*b*, the same, side view.
Fig. 4. *I. albosigma*, Stage IV.
Fig. 5. *I. albosigma*, Stage V (and last); 5*a*, side view.



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Larval Stages of Ichthyura inclusa (1, 2, 2a.) and albosigma (3–5, 5a.)

Plate XVII.

Life history of Nadata gibbosa.

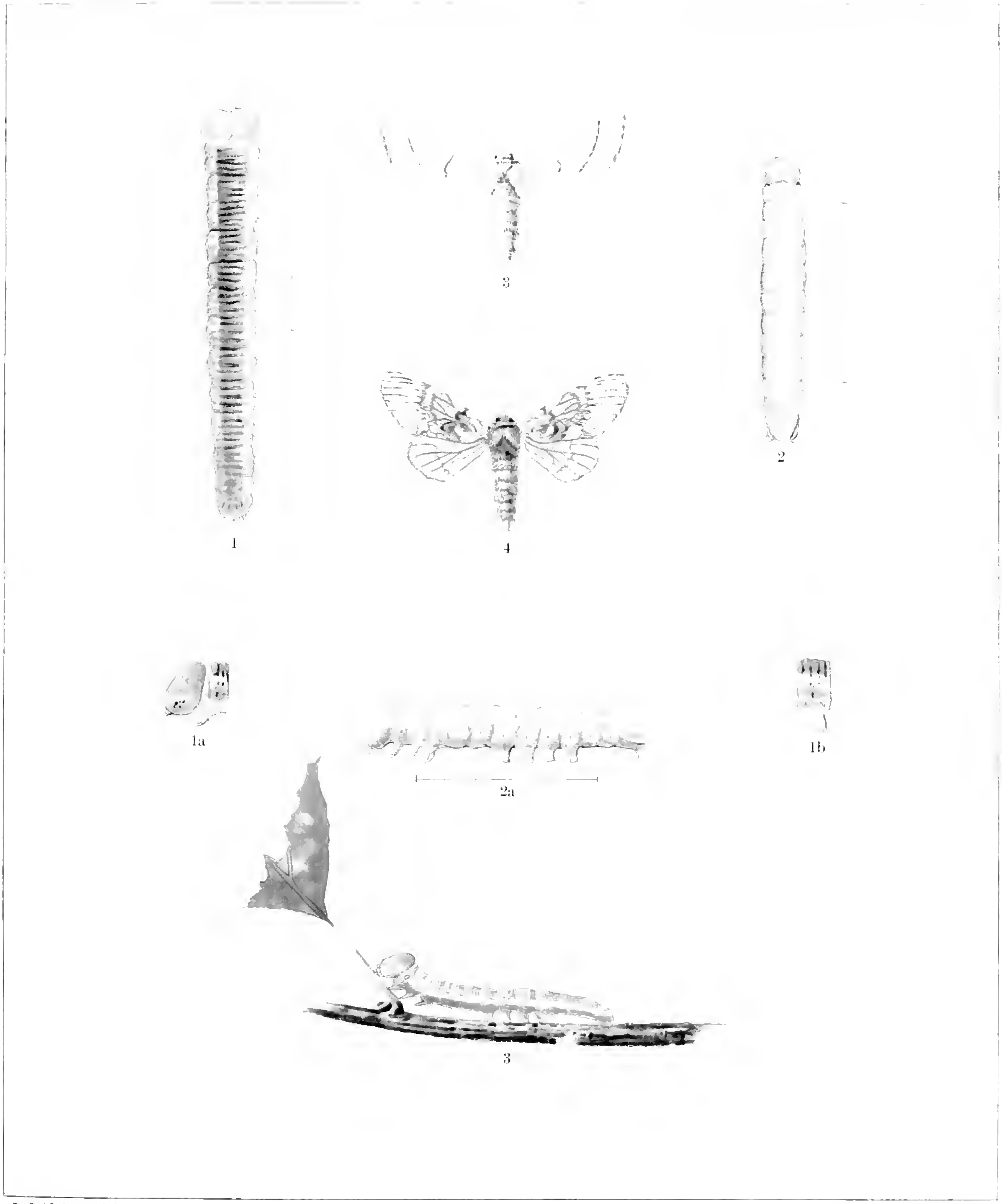
Fig. 1. *Nadata gibbosa*, Stage 1; 1*a*, head and prothoracic segment, side view; 1*b*, third abdominal segment, side view.

Fig. 2. *Nadata gibbosa*, last stage; 2*a*, side view.

Fig. 3. *Nadata gibbosa*, moth ♂.

Fig. 4. *Lophodonta basitricus*. Bridgham del.

Fig. 5. *Lophodonta angulosa*, last stage.



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Larval Stages of Nadata gibbosa.

PLATE XVIII.

Larval stages of Lophodonta ferruginea.

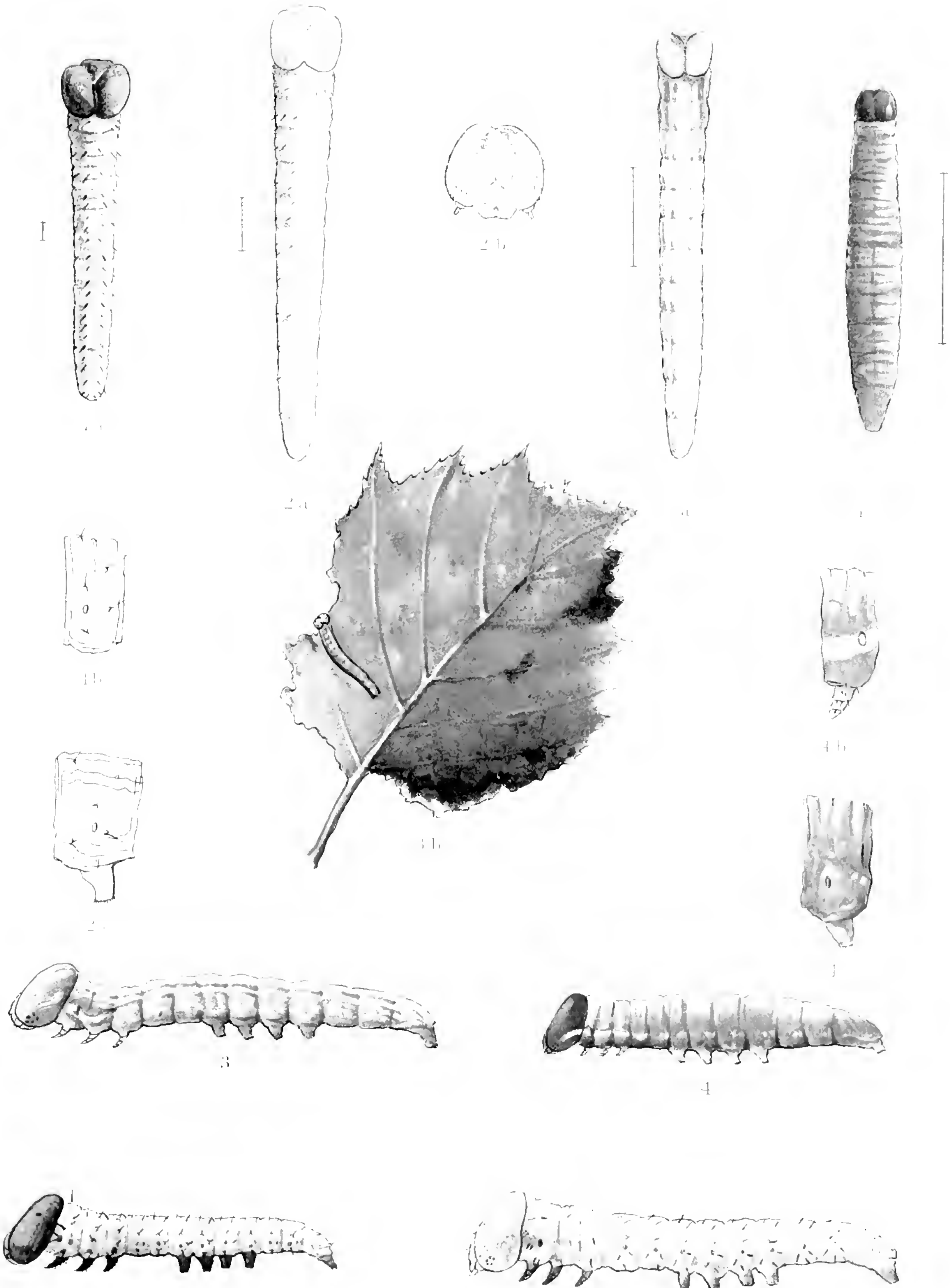
FIG. 1. Stage I: *1a*, dorsal view, enlarged; *1b*, side view of first abdominal segment, enlarged.

FIG. 2. Stage III; *2a*, dorsal view, enlarged; *2b*, front view of head; *2c*, second abdominal segment.

FIG. 3. Stage IV; *3a*, dorsal view, enlarged; *3b*, natural size. Providence, July 30.

FIG. 4. Stage V and last; *4a*, dorsal view; *4b*, prothoracic segment, side view; *4c*, second abdominal segment, side view. Food plant, white birch. Providence, Sept. 11. Bridgham del.

Plate XVIII



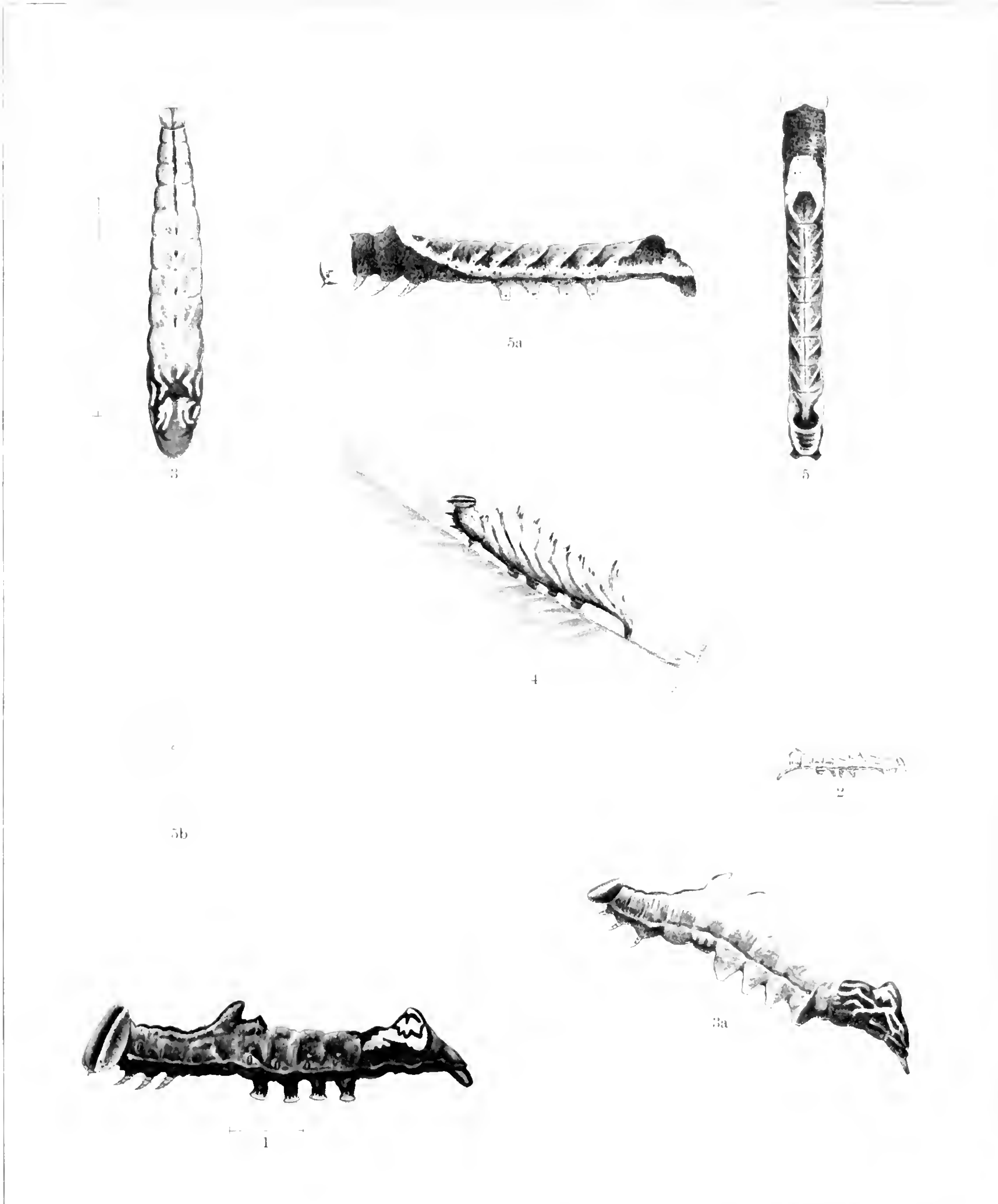
LARVAL STAGES OF LOPHODONTA FERRUGINEA

Bridgham, del

PLATE XIX.

Larva of Notodonta stragula, Nerice bidentata, etc.

FIG. 1. *Notodonta stragula,* Stage IV ? Bridgham, del.
FIG. 2. *Notodonta stragula,* stage before the last, IV. Wilder del.
FIG. 3. *Notodonta stragula,* last (V) stage; 3*a*, side view.
FIG. 4. *Nerice bidentata,* last stage. Miss Caroline G. Soule del.
FIG. 5. *Pseudothyatira cymatophoroides* Grote; Maine; 5*a*, side view; 5*b*, third abdominal segment. Bridgham del.



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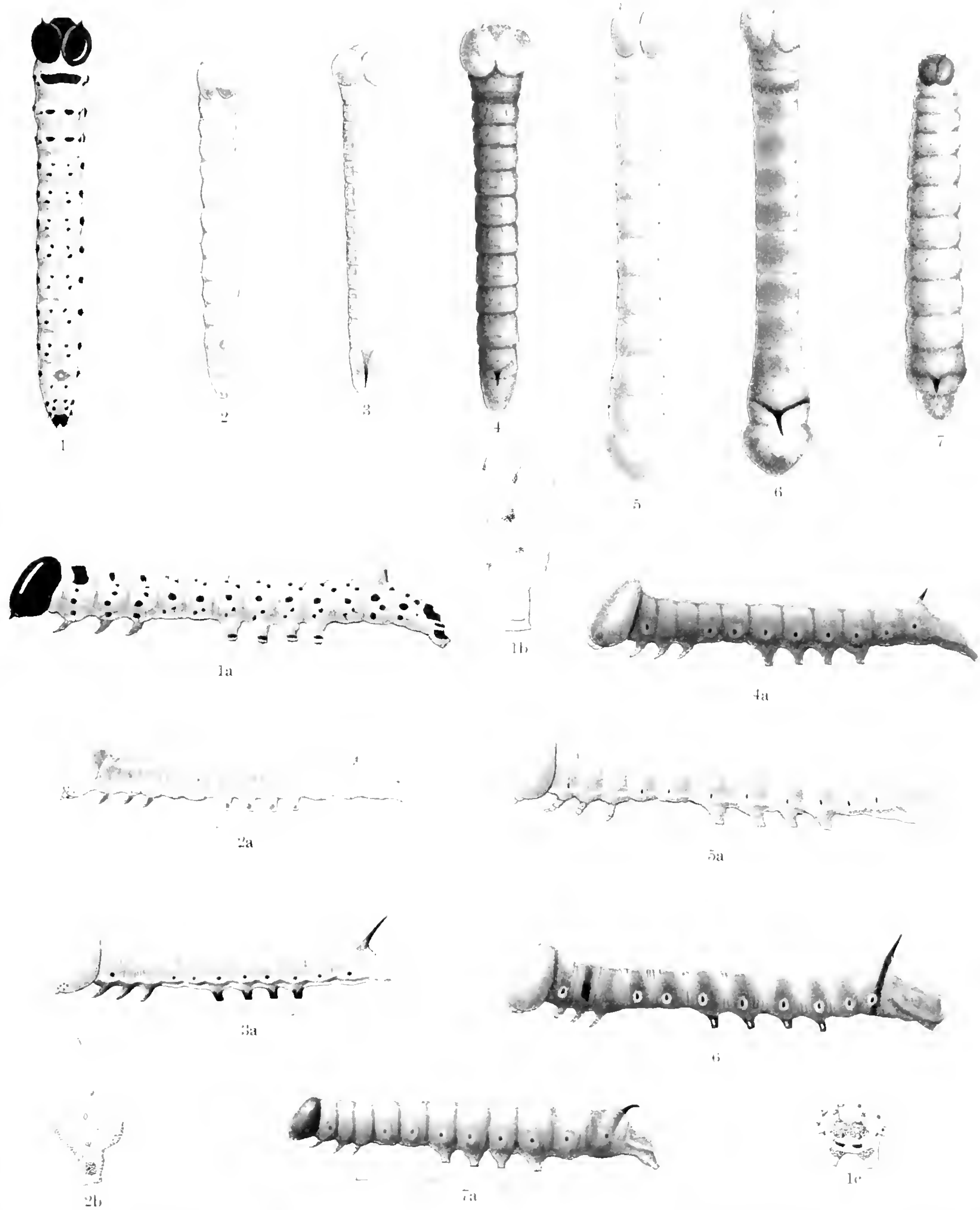
Larvae of Notodonta stragula, 1–3; Nerice bidentata, 4.

Plate XX.

Life history of Pheosia dimidiata.

Fig. 1. *Pheosia dimidiata*. Stage I: 1*a*, side view.
Fig. 2. *Pheosia dimidiata*, Stage II: 2*a*, side view.
Fig. 3. *Pheosia dimidiata*, Stage III: 3*a*, side view.
Fig. 4. *Pheosia dimidiata*, Stage IV: 4*a*, side view.
Fig. 5. *Pheosia dimidiata*, Stage V: 5*a*, side view.
Fig. 6 *Pheosia dimidiata*, Stage V; 6*a*, side view.
Fig. 7. *Pheosia dimidiata*, Stage V: about to pupate. Bridgham del.



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Larval Stages of Pheosia dimidiata.

Plate XXI.

Life history of Dasylophia anguina.

Fig. 1. *Dasylophia anguina*, Stage I: 1*a*, side view; 1*b*, first and second thoracic segments, side view; 1*c*, the freshly hatched larvæ, natural size.

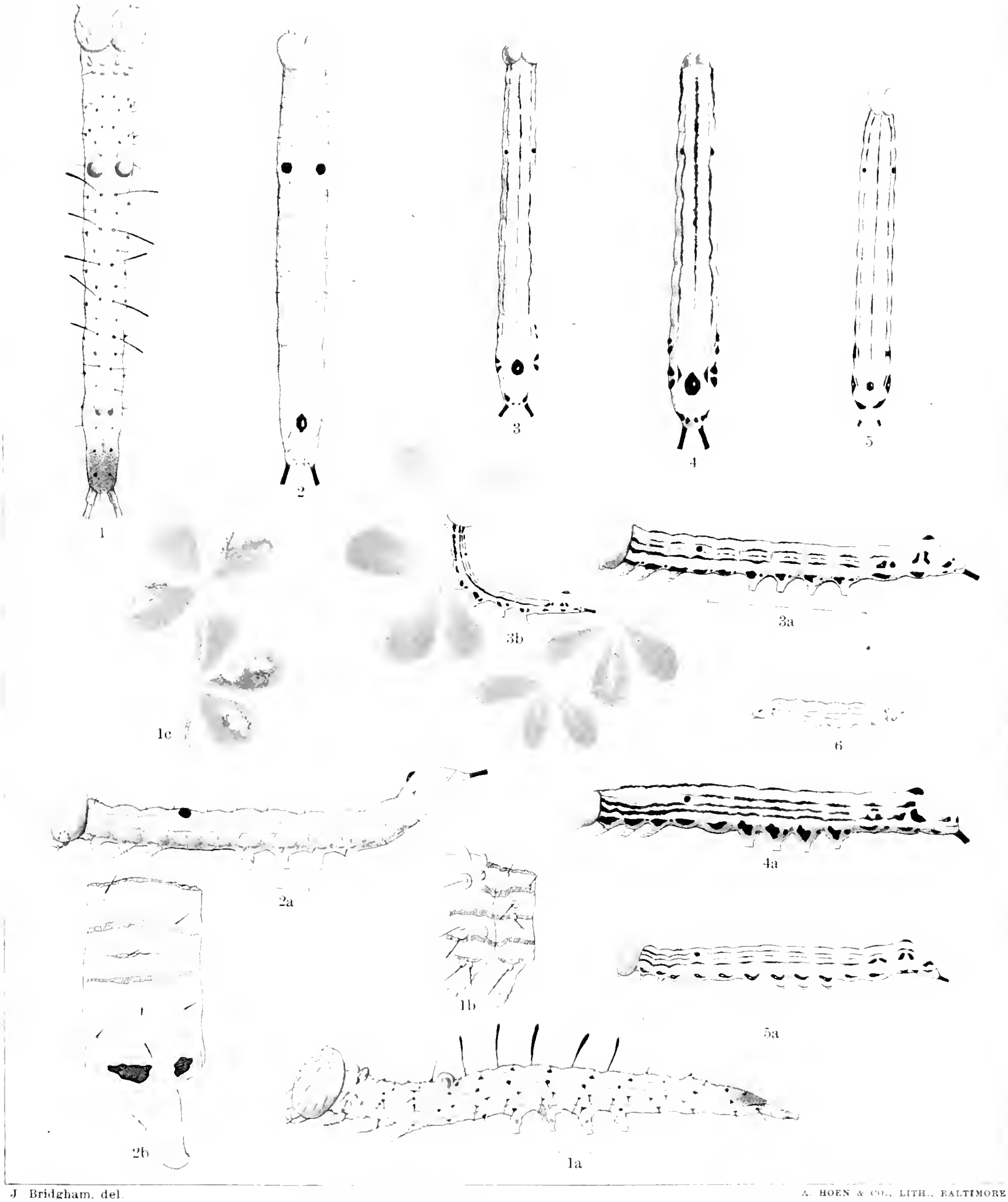
Fig. 2. *Dasylophia anguina*, Stage II; 2*a*, side view; 2*b*, third abdominal segment, side view, enlarged.

Fig. 3. *Dasylophia anguina*, Stage IV; 3*a*, side view; 3*b*, the same, natural size.

Fig. 4. *Dasylophia anguina*, last stage; 4*a*, side view.

Fig. 5. *Dasylophia anguina*, last stage; 5*a*, side view; another example. Bridgham del.

Fig. 6. *Dasylophia anguina*, last stage; natural size. Georgia. Leconte del.



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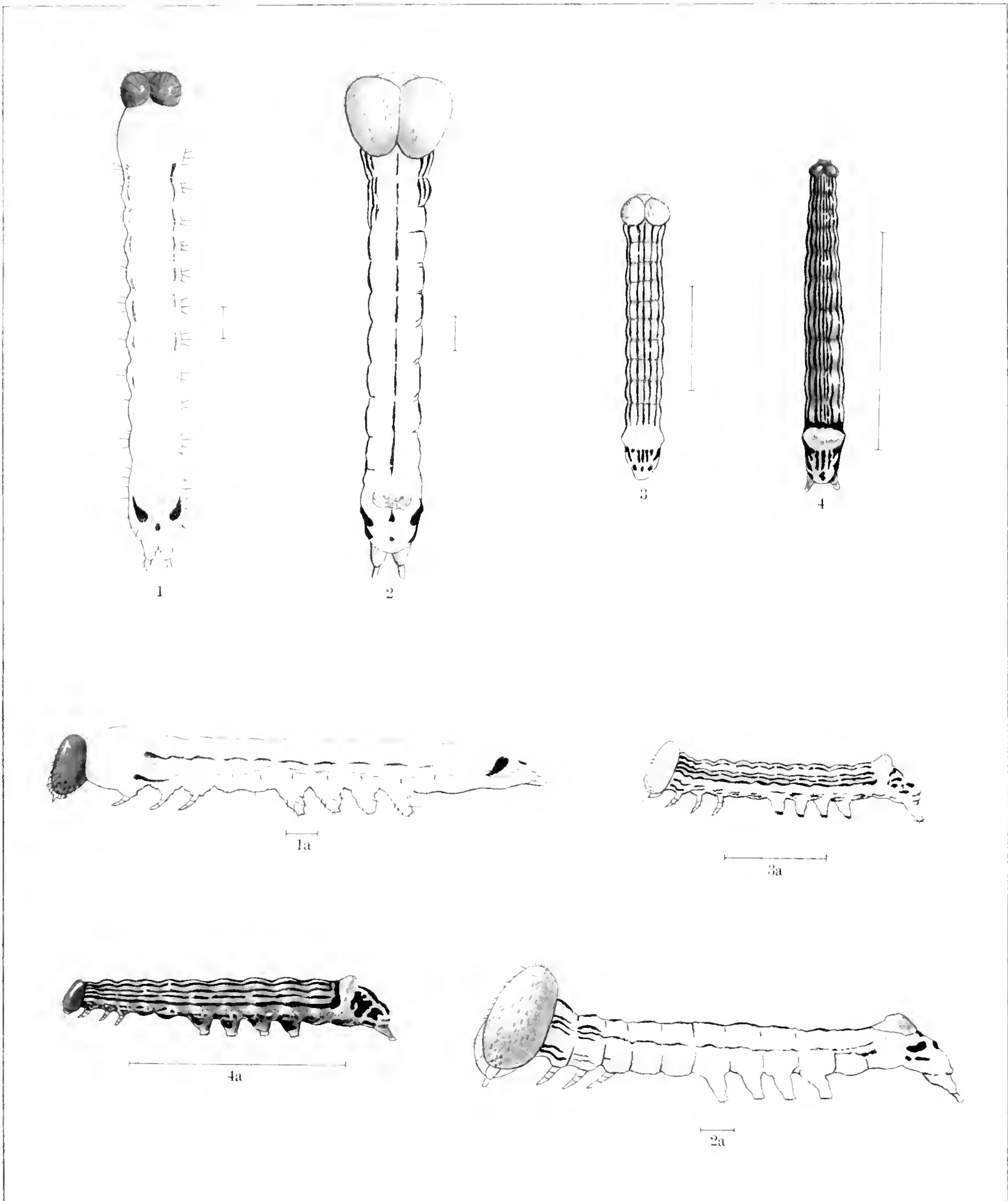
Larval Stages of Dasylophia anguina.

Plate XXII.

Larval stages of Symmerista albifrons.

Fig. 1. *Symmerista albifrons*, Stage I; 1*a*, side view.
Fig. 2. *Symmerista albifrons*, Stage II; 2*a*, side view.
Fig. 3. *Symmerista albifrons*, Stage III; 3*a*, side view.
Fig. 4. *Symmerista albifrons*, Stage V (and last); 4*a*, side view.



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Larval Stages of Symmerista albifrons.

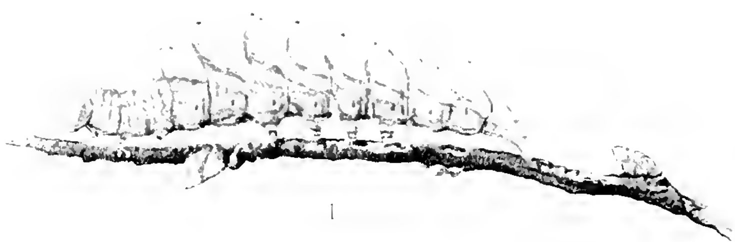
Plate XXIII.

Larva of Nerice bidentata.

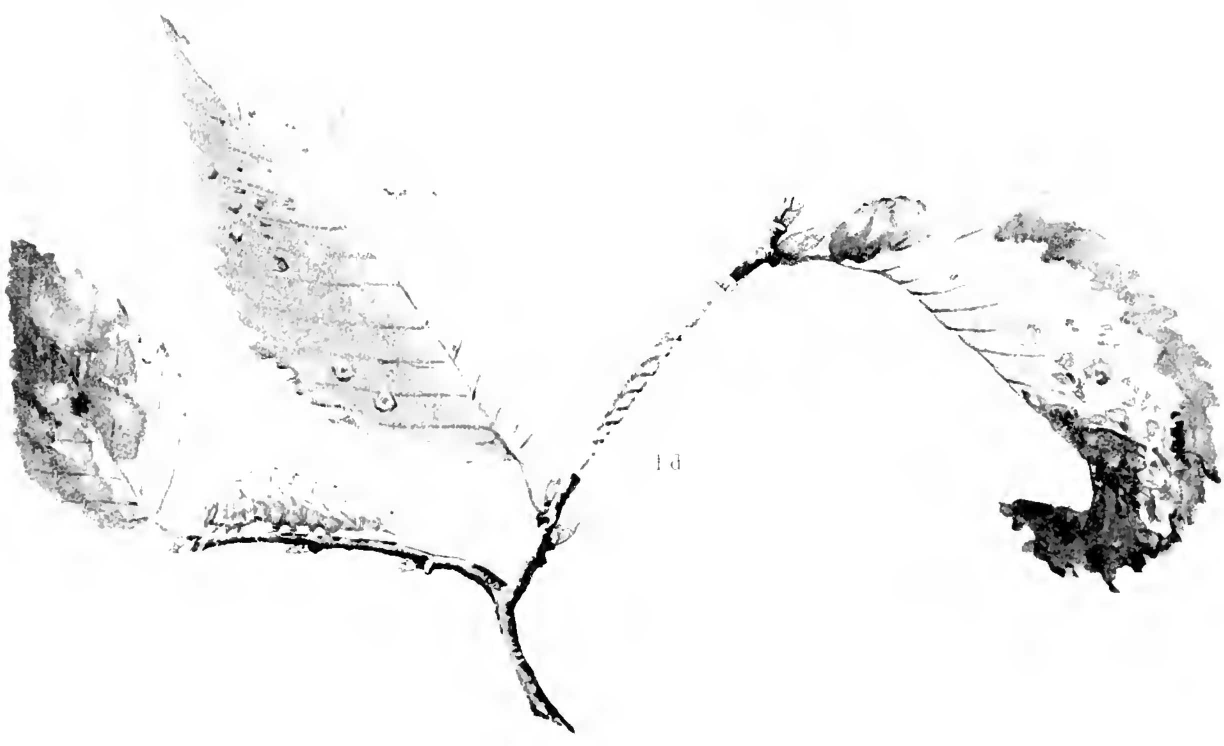
Fig. 1. Last stage, enlarged twice; 1*a*, head; 1*b*, second abdominal segment, dorsal view; 1*c*, the same, side view; 1*d*, two larvæ, natural size; Oct. 6. Bridgham del.

1 a

1 b



1



1 d

NERICE BIDENTATA

J. Bridgham, del.

Plate XXIV.

Life history of Hyparpax aurora.

Fig. 1. *Hyparpax aurora*, Stage I, dorsal view; 1*a*, side view; 1*b*, dorsal piliferous tubercle.

Fig. 2. *Hyparpax aurora*, end of Stage I; 2*a*, side view; 2*b*, freshly hatched larvæ, natural size.

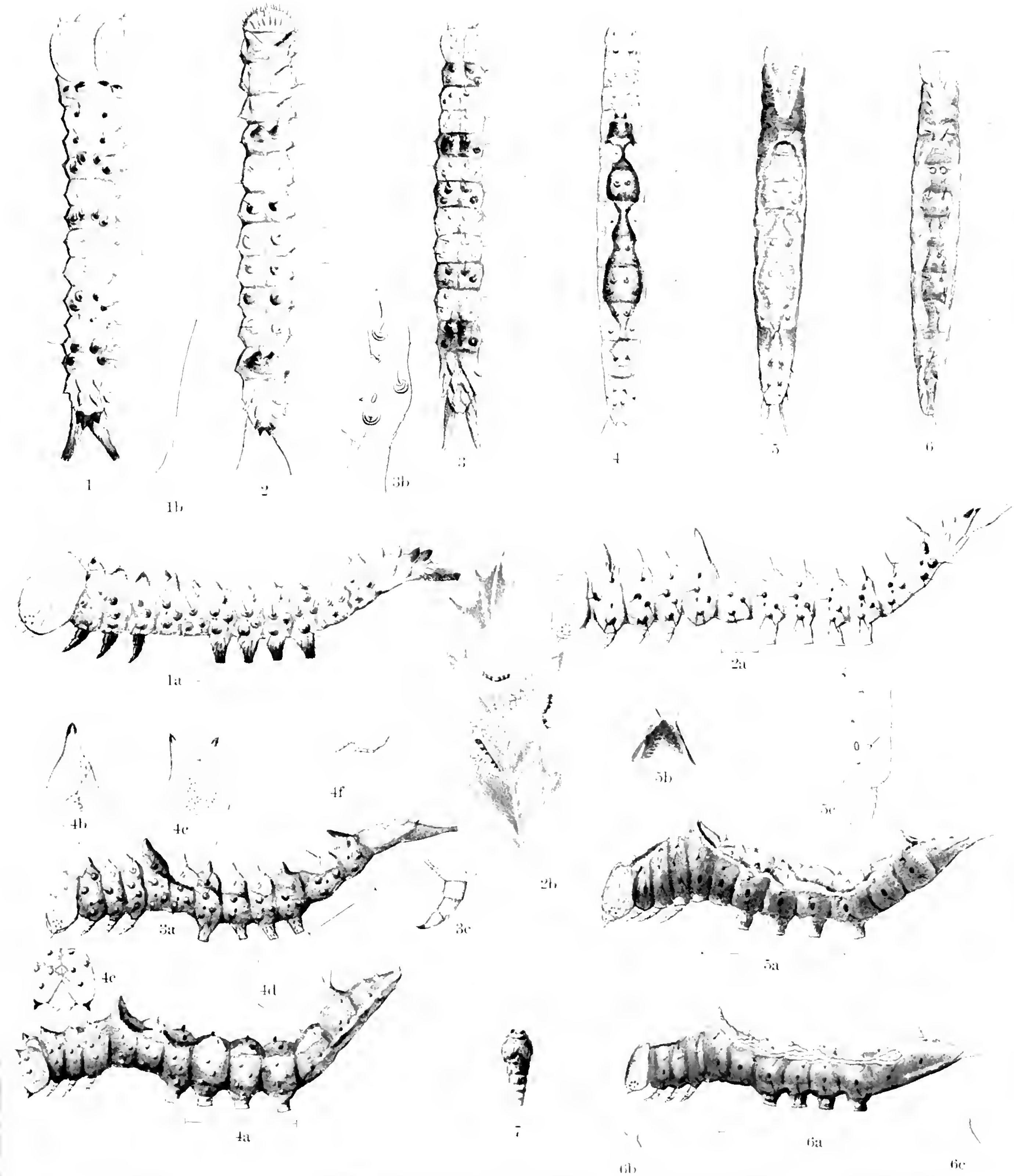
Fig. 3. *Hyparpax aurora*, Stage II; 3*a*, side view; 3*b*, third abdominal segment, side view; 3*c*, a thoracic leg.

Fig. 4. *Hyparpax aurora*, Stage III; 4*a*, side view; 4*b*, dorsal tubercle; 4*c*, front view of the same; 4*d*, subdorsal tubercle; 4*e*, face; 4*f*, natural size.

Fig. 5. *Hyparpax aurora*, Stage IV; 5*a*, side view; 5*b*, dorsal tubercle of eighth abdominal segment; 5*c*, third abdominal segment, side view.

Fig. 6. *Hyparpax aurora*, last stage; 6*a*, side view; 6*b*, dorsal tubercle of first abdominal; 6*c*, of eighth abdominal segment.

Fig. 7. *Hyparpax aurora*, male; natural size. Bridgham del.



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Early stages of Hyparpax Aurora.

Plate XXV.

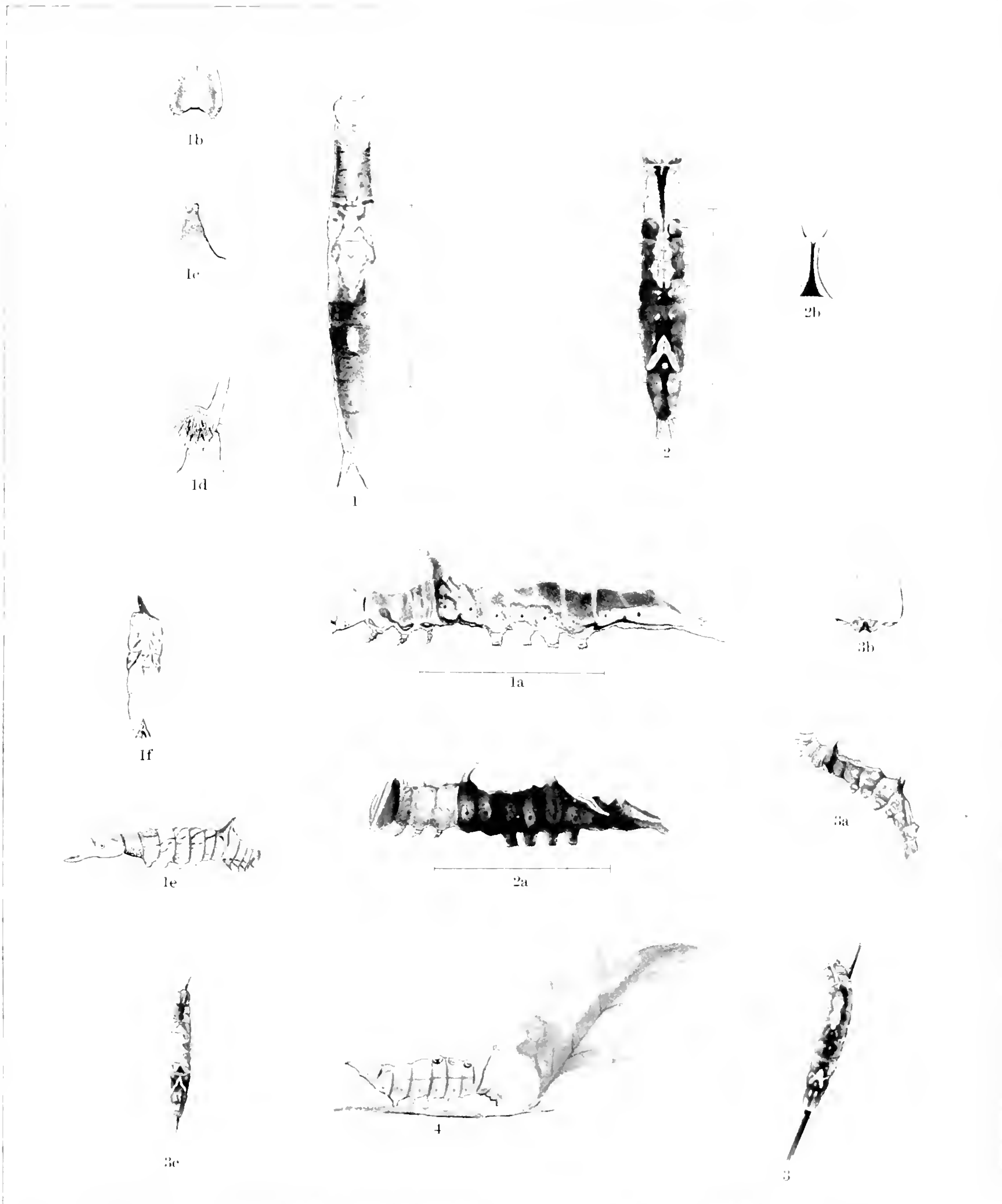
Fig. 1. *Xylinodes lignicolor*, last stage; 1*a*, side view; 1*b*, face; 1*c*, rear view of dorsal tubercle of first abdominal segment; 1*d*, dorsal view of end of the body. Bridgham del.

Fig. 1*e*. *Xylinodes lignicolor*, Georgia, Leconte del.; 1*f*, dorsal view of abdominal segments 1 to 6 of the same.

Fig. 2. *Schizura ipomeæ*, full-grown larva; 2*a*, side view; 2*b*, dorsal tubercle of first abdominal segment.

Fig. 3. *Schizura ipomeæ*; 3*a*, side view, natural size; 3*b*, face; 3*c*, the same at an earlier stage. Riley direxit, Department of Agriculture, No. 120 L.

Fig. 4. *Schizura unicornis*, Georgia. Leconte del.



J. Bridgham and del., etc.

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(1,) Larva of Xylinodes lignicolor, (2, 3,) Schizura ipomeæ, etc.

Plate XXVI.

Fig. 1. *Schizura leptinoides*, Stage I; 1*a*, side view; 1*b*, third abdominal segment; 1*c*, a dorsal piliferous tubercle.

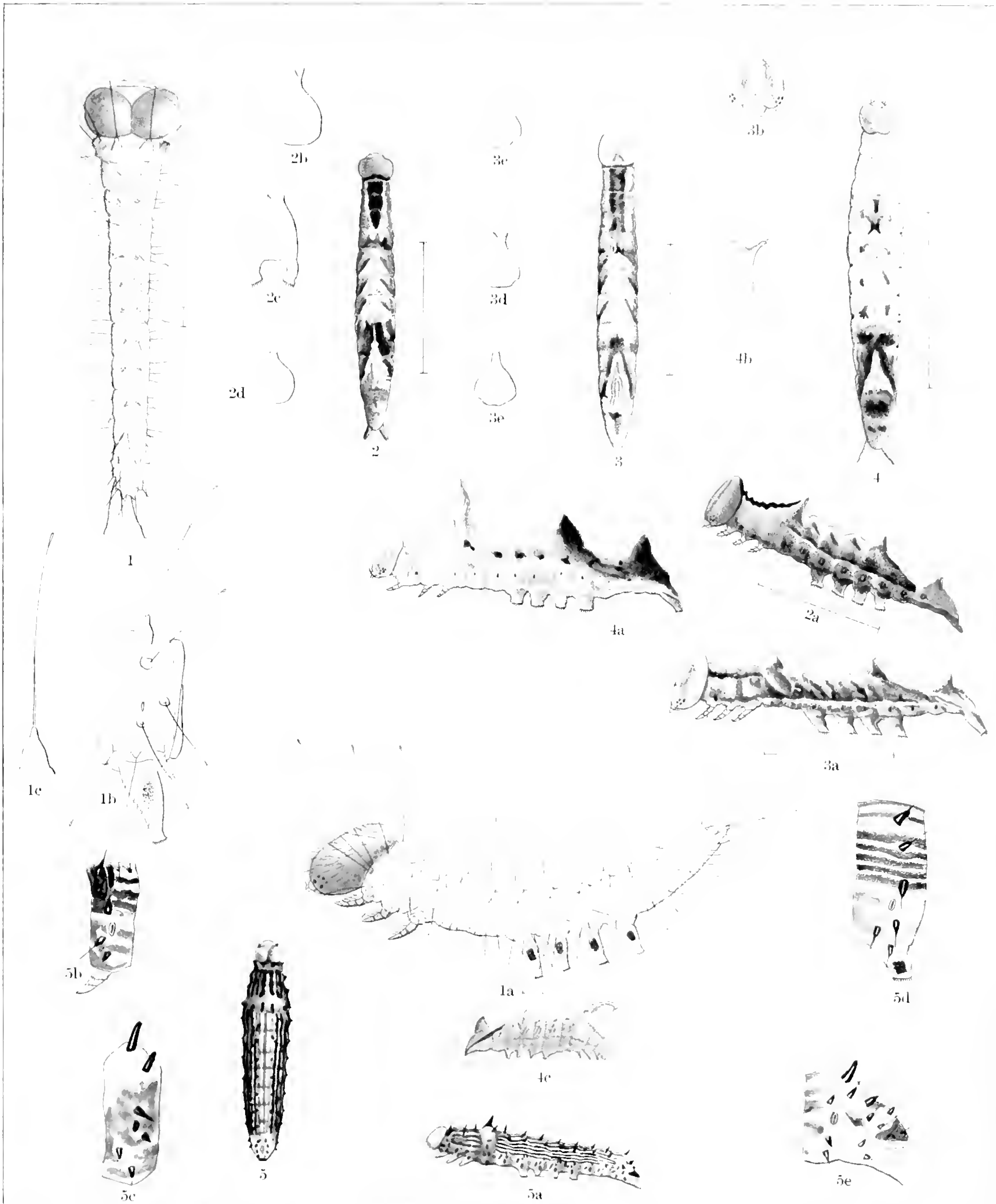
Fig. 2. *Schizura leptinoides*, Stage IV?; 2*a*, side view; 2*b*, section of first abdominal; 2*c*, of fifth; 2*d*, of eighth abdominal segment.

Fig. 3. The same, different individual; 3*a*, side view; 3*b*, face; 3*c* to 3*e*, sections of first, fifth, and eighth abdominal segments.

Fig. 4. *Schizura eximia*, full-grown larva; 4*a*, side view; 4*b*, dorsal tubercle on first abdominal segment. Bridgham del.

Fig. 4*c*. *Schizura eximia*, mature larva, Georgia. Leconte del.

Fig. 5. *Schizura concinna*, mature larva; 5*a*, side view; 5*b*, prothoracic segment, side view; 5*c*, first abdominal segment, side view; 5*d*, third abdominal segment, side view; 5*e*, end of the body. Bridgham del.



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Larval Stages of Schizura leptinoides, 1-3, S. eximia, 4 and S. concinna 5.

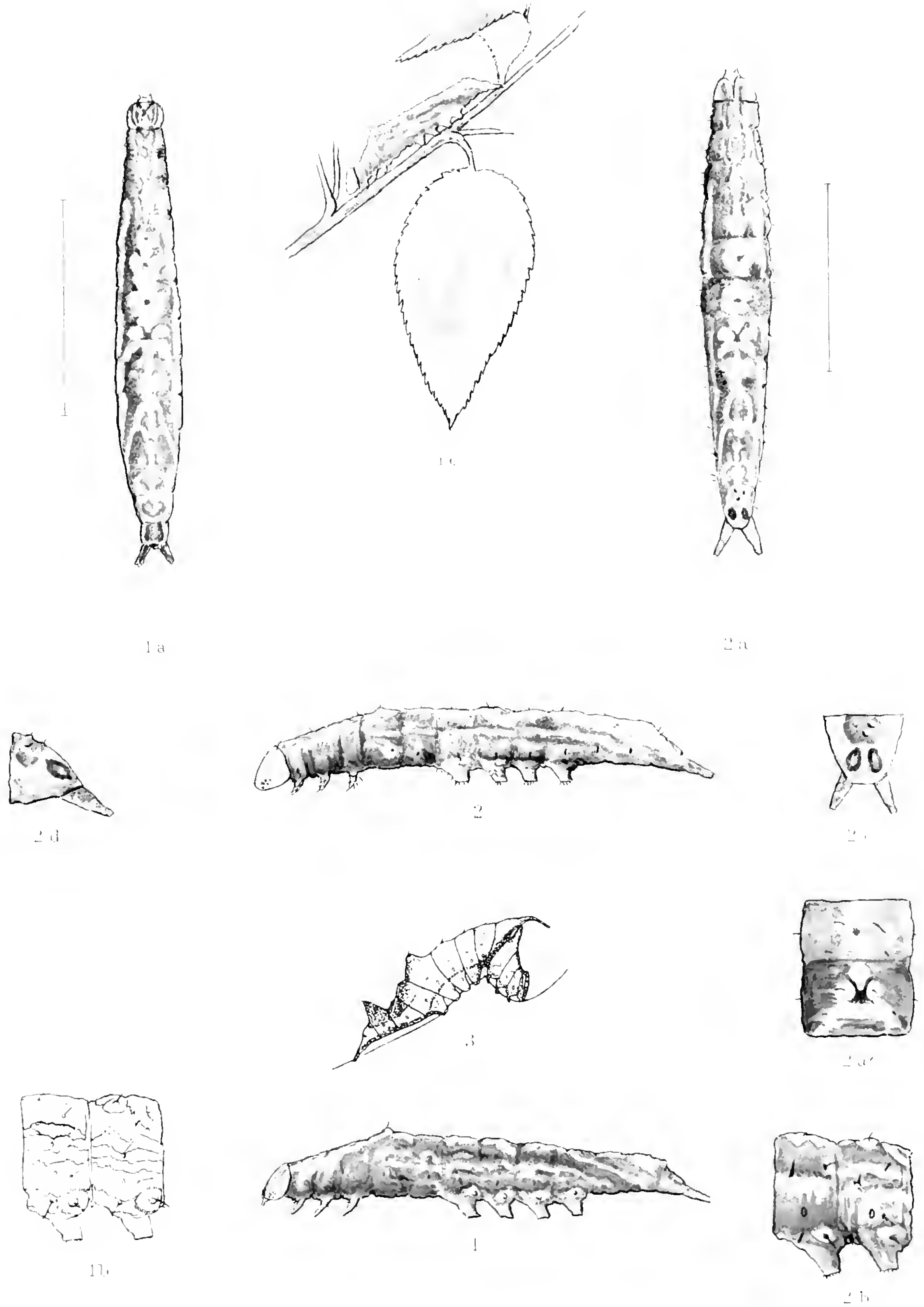
PLATE XXVII.

Last stages of Schizura badia.

FIG. 1. *Schizura badia*, last stage ? 1*a*, dorsal view, enlarged ; 1*b*, second and third abdominal segments, enlarged ; 1*c*, larva, natural size. Drawn July 6.

FIG. 2. A larva drawn July 8. 2*a*, dorsal view ; 2a , second and third abdomimal segments ; 2*b*, the same side view ; 2*c*, suranal plate and anal legs, dorsal view ; 2*d*, the same, side view. Bridgham del.

FIG. 3. *Schizura eximia*, natural size and attitude, while feeding. Copied from Dyar



LARVAL STAGES OF SCHIZURA BADIA

Bridgham del

Plate XXVIII.

Fig. 1. *Schizura unicornis*, Stage I; 1*a*, side view; 1*b*, third segment, side view, enlarged.

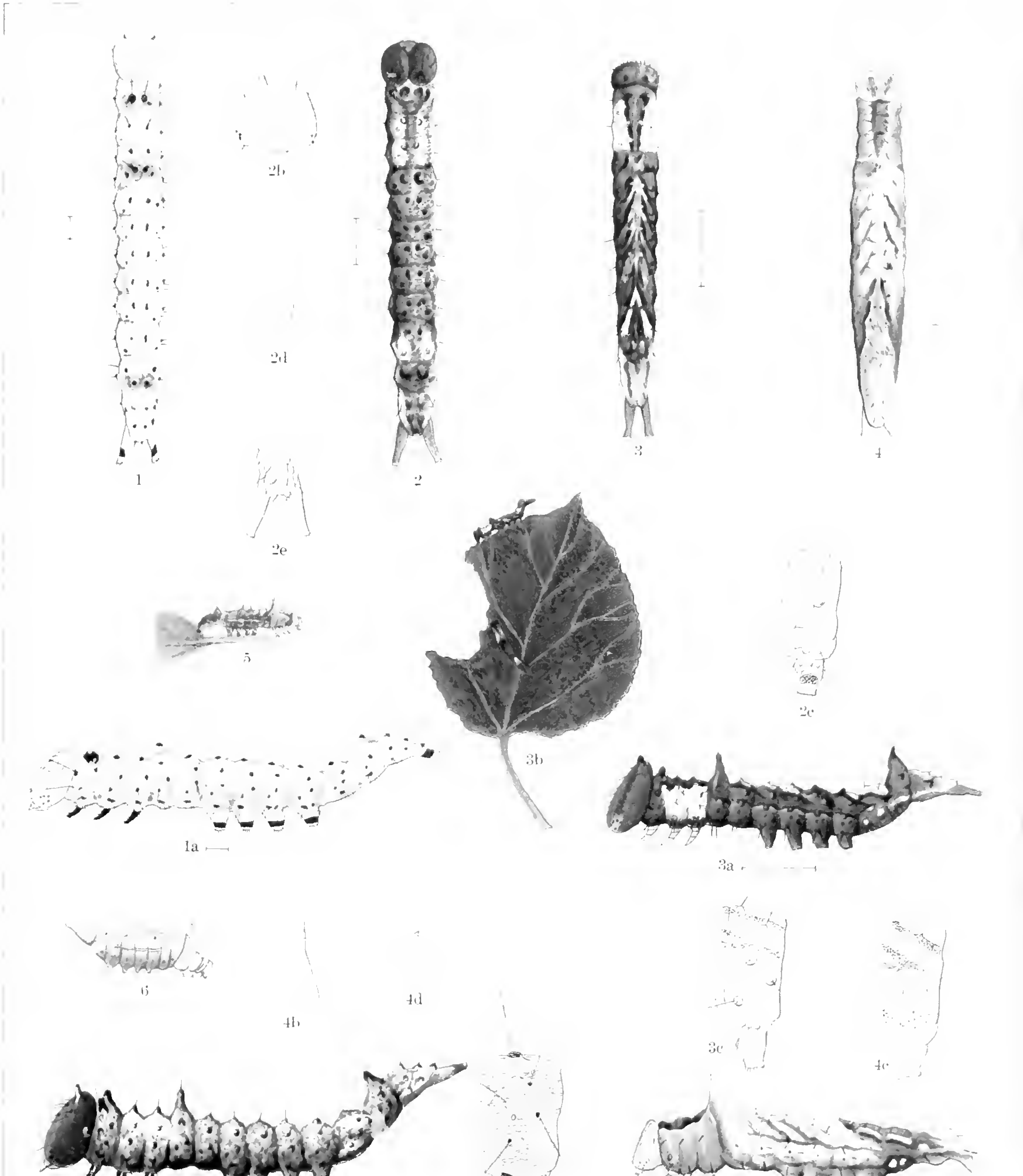
Fig. 2. *Schizura unicornis*, Stage II; 2*a*, side view; 2*b*, face; 2*c*, third abdominal segment, side view; 2*d*, tubercle of first abdominal segment, front view; 2*e*, dorsal view of end of body.

Fig. 3. *Schizura unicornis*, Stage III; 3*a*, side view; 3*b*, larva natural size; 3*c*, third abdominal segment, side view.

Fig. 4. *Schizura unicornis*, Stage IV; 4*a*, side view; 4*b*, dorsal tubercle first abdominal segment; 4*c*, third abdominal segment, side view; 4*d*, dorsal tubercle, third abdominal segment. Bridgham del.

Fig. 5. *Schizura unicornis*, natural size. Wilder del. From 5th Report U. S. Entomological Commission.)

Fig. 6. *Schizura unicornis*, Georgia. Leconte del.



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Larval Stages of Schizura unicornis.

Plate XXIX.

Fig. 1. *Scirodonta bilineata*, next to the last stage?; 1*a*, side view.

Fig. 2. *Heterocampa manteo*, Stage II?; 2*a*, side view; 2*b*, face.

Fig. 3. *Heterocampa manteo*, fully grown; 3*a*, side view, drawn from a blown larva, No. 359, United States National Museum.

Fig. 4. *Heterocampa manteo*, 4*a*, side view, drawn from a blown larva, No. 350, on linden, in United States National Museum.

Fig. 5. *Heterocampa manteo*, 5*a*, side view, drawn from a blown larva, No. 180, on birch, Virginia, September 14, 1884, United States National Museum.

Fig. 6. *Heterocampa manteo*, young, Riley direxit, No. 2752, United States Department of Agriculture.

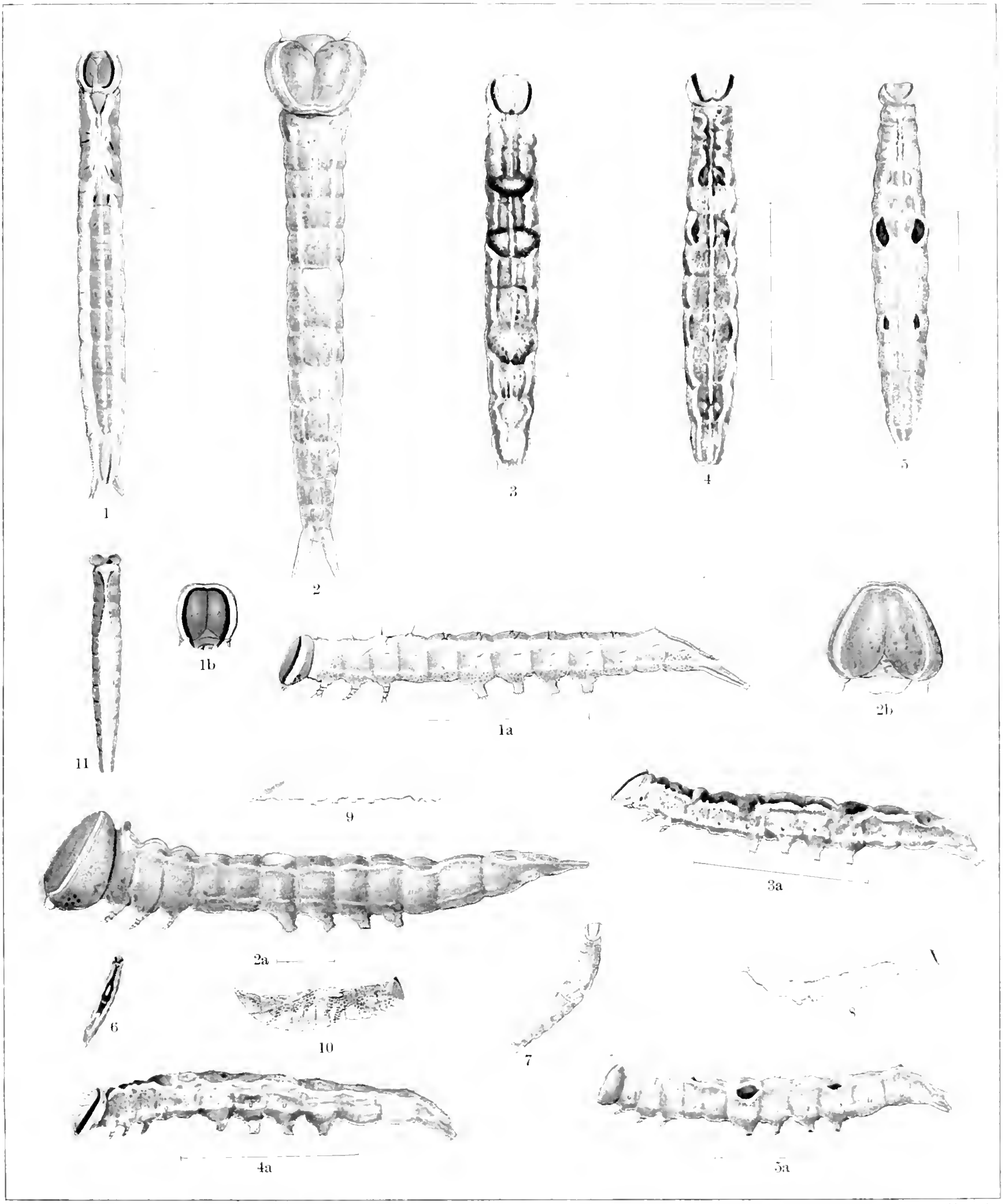
Fig. 7. *Heterocampa manteo*, mature stage of No. 6, Riley direxit, No. 2752, United States Department of Agriculture. Bridgham del.

Fig. 8. *Heterocampa manteo*, Georgia. Leconte.

Fig. 9. *Heterocampa*, undetermined, Georgia. Leconte.

Fig. 10. *Heterocampa*, undetermined, Georgia. Leconte.

Fig. 11. *Heterocampa obliqua* var. *perolivata*, from a blown larva, No. 2804, Maryland, in United States National Museum.



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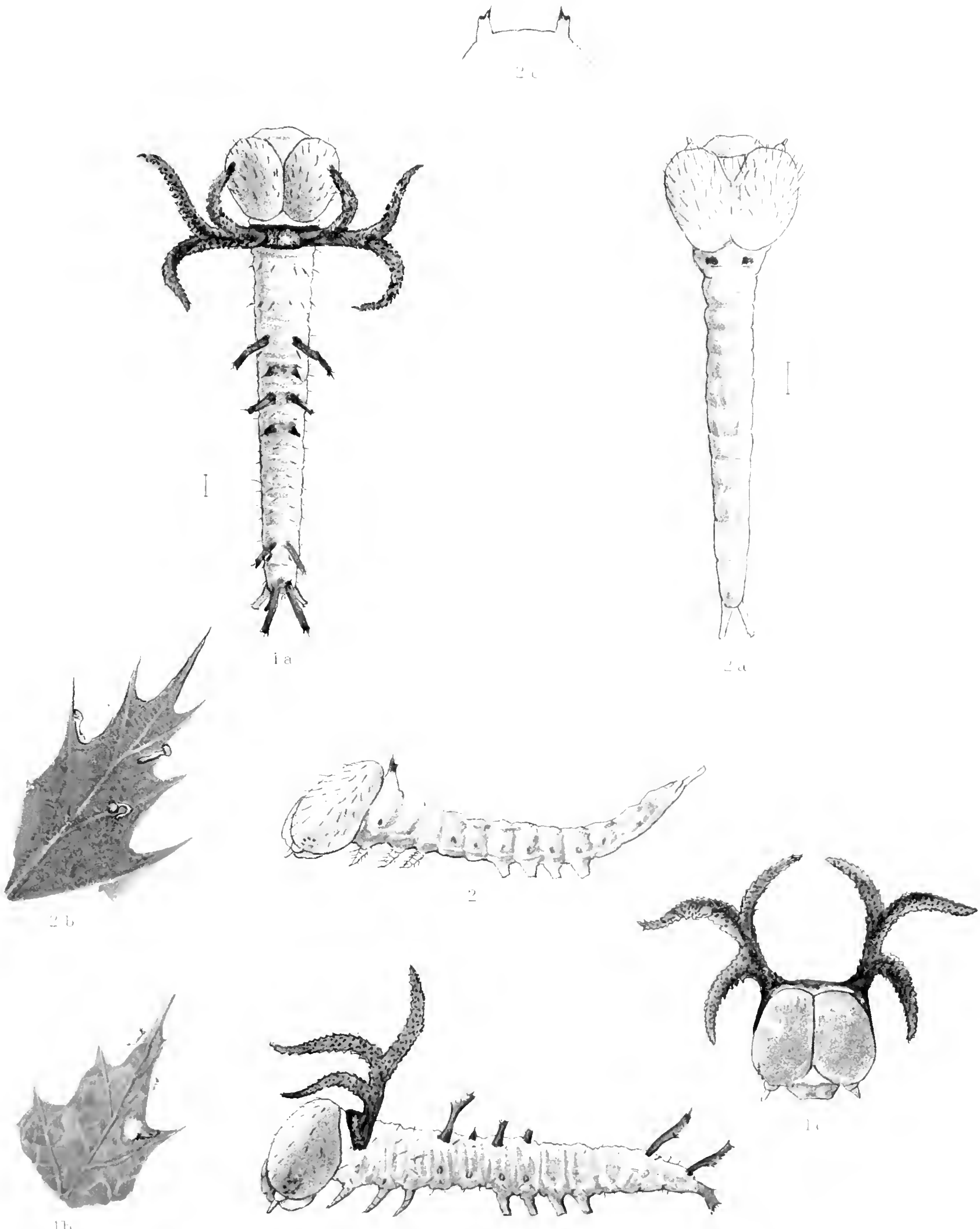
Larval Stages of Seirodonta bilineata 1; Heterocampa Manteo 2, etc.

PLATE XXX.

Larval stages of Heterocampa obliqua.

FIG. 1. Stage I, freshly hatched; 1*a*, dorsal view, enlarged; 1*b*, larva of natural size; 1*c*, front view, much enlarged, of head and prothoracic antlers.

FIG. 2. Stage II, enlarged; 2*a*, the same, dorsal view; 2*b*, the same, natural size; 2*c* front view of prothoracic tubercles. Bridgham del.



LARVAL STAGES OF HETEROCAMPA OBLIQUA

J. Bridgham, del

Plate XXXI.

Larval stages of Heterocampa guttivitta.

Fig. 1. *H. guttivitta*, Stage I; 1*a*, side view; 1*a*', prothoracic antlers; 1*b*, 1*b*', antlers on first abdominal segment; 1*c*, 1*c*', antlers on second to seventh abdominal segments; 1*d*, 1*d*', antlers on eighth abdominal segment.

Fig. 2. *H. guttivitta*, Stage II; 2*a*, side view.

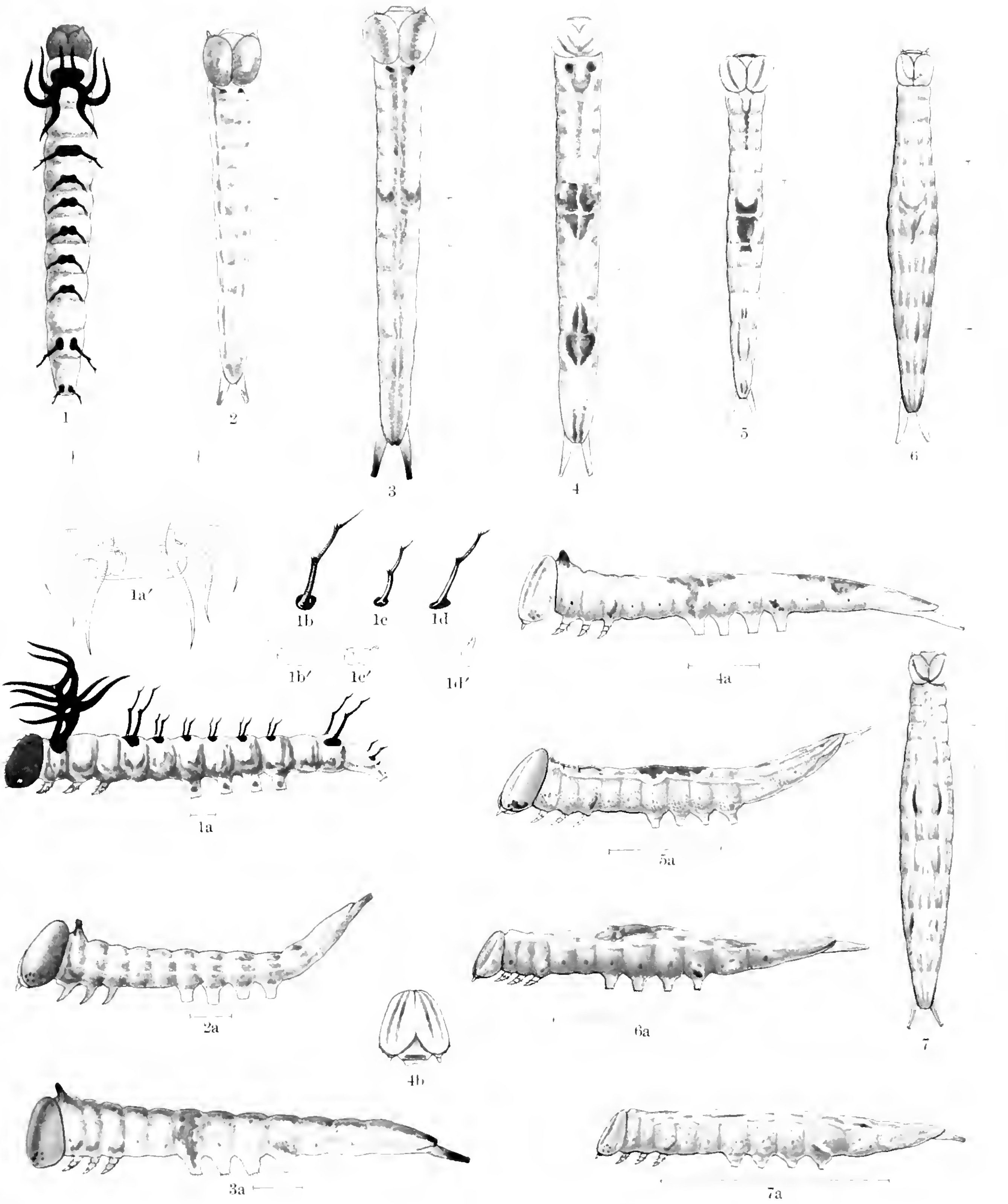
Fig. 3. *H. guttivitta*, end of Stage II, 3*a*, side view.

Fig. 4, 4*a*. *H. guttivitta*, Stage III.

Fig. 5, 5*a*. *H. guttivitta*, Stage IV.

Fig. 6, 6*a*. *H. guttivitta*, end of Stage IV.

Fig. 7, 7*a*. *H. guttivitta*, Stage V. Bridgham del.



J. Bridgham, del.

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Larval History of Heterocampa guttivitta.

Plate XXXII.

Larval stages of Heterocampa biundata.

Fig. 1. 1*a*, *H. biundata*: 1*b*, natural size; 1*c*, third abdominal segment, side view; 1*d*, end of body, side view.
Fig. 2, 2*a*. *H. biundata*, Stage III; 2*b*, face.
Fig. 3, 3*a*. *H. biundata*, Stage IV; 3*b*, face.
Fig. 4. *H. biundata*, natural size. Bridgham del.

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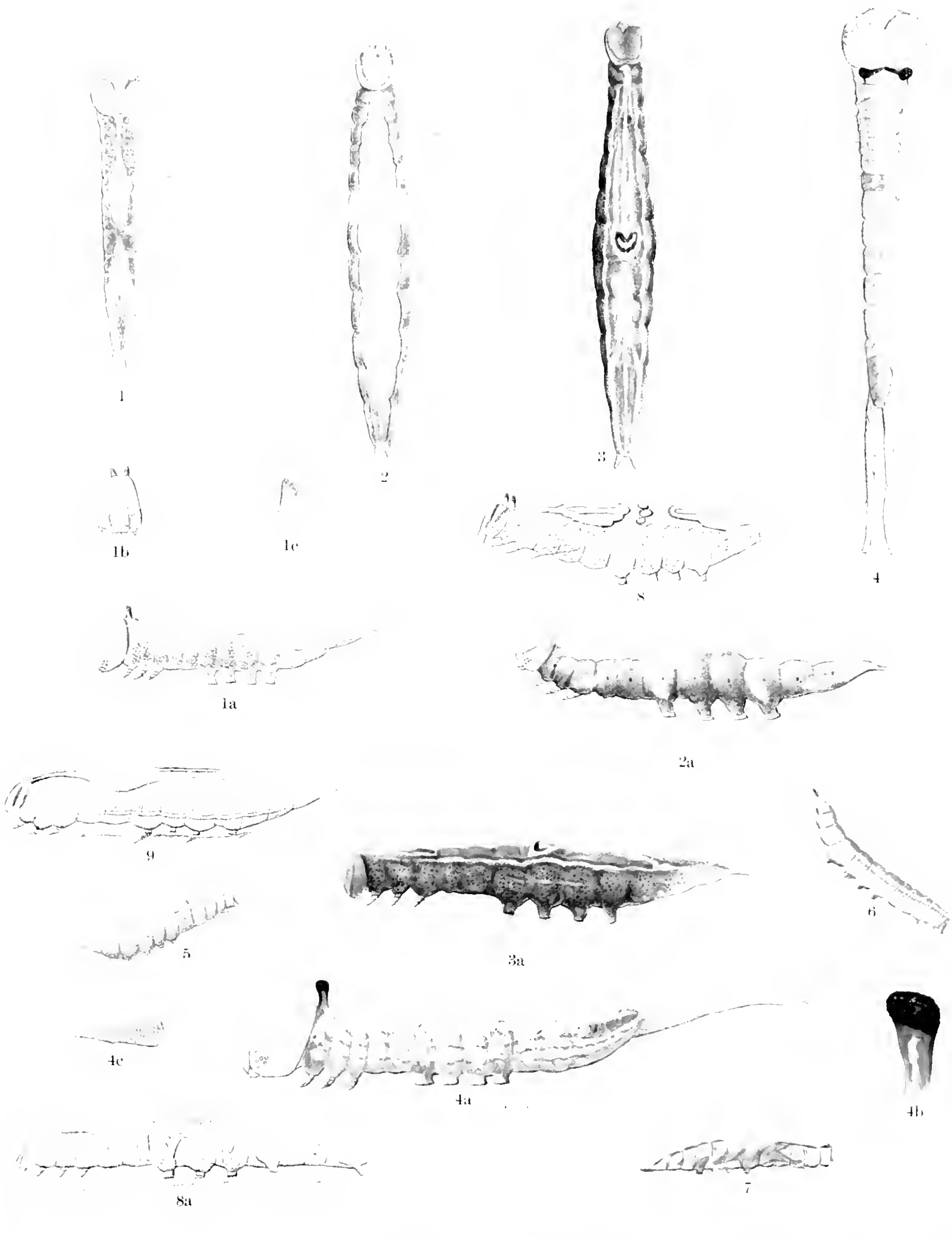
Larval Stages of Heterocampa biundata.

Plate XXXIII.

Fig. 1, 1*a*. *Heterocampa guttivitta*, Stage III; 1*b*, face; 1*c*, prothoracic tubercle.
Fig. 2, 2*a*. *Heterocampa guttivitta*, fully grown larva, July 21, on scrub oak (the moth reared).
Fig. 3, 3*a*. *Heterocampa guttivitta*, Stage IV, of fig. 2.
Fig. 4, 4*a*. *Heterocampa unicolor*: Stage I, 4*b*, 4*c*, dorsal tubercle of prothoracic segment. Bridgham del.
Fig. 5. *Heterocampa* on oak, Georgia. Leconte del.
Fig. 6. *Heterocampa*, Georgia. Leconte del.
Fig. 7. *Heterocampa* on oak, Georgia. Leconte del.
Fig. 8, 8*a*. *Heterocampa umbrata* (*athereo*, *pulverea*), copied from Doubleday's figures in the Entomologist.
Fig. 9. *Heterocampa astarte*, copied from Doubleday's figure in the Entomologist.



Bridgham & Doubleday, del.

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Larval Stages of Heterocampa guttivitta, H. unicolor 4, H. Astarte, etc.

Plate XXXIV.

Life history of Macrurocampa marthesia.

Fig. 1, 1*a*. *M. marthesia*, Stage I; 1*b*, end of stemapod; 1*c*, prothoracic tubercle.
Fig. 2, 2*a*. *M. marthesia*, Stage II; 2*b*, end and 2*c*, base of stemapod; 2*d*, prothoracic tubercle.
Fig. 3, 3*a*. *M. marthesia*, Stage III, and 3*a*, 3*b* natural size; 3*b*, side view of third abdominal segment.
Fig. 4, 4*a*. *M. marthesia*, Stage IV; 4*b*, head, 4*c*, face; 4*d*, 4*e*, prothoracic tubercles; 4*f*, stemapod or "tail;" 4*g*, third segment, side view. Bridgham del.
Fig. 5. *M. marthesia*, fully grown larva, Georgia, on oak. Leconte del.

J. Bridgham, del.

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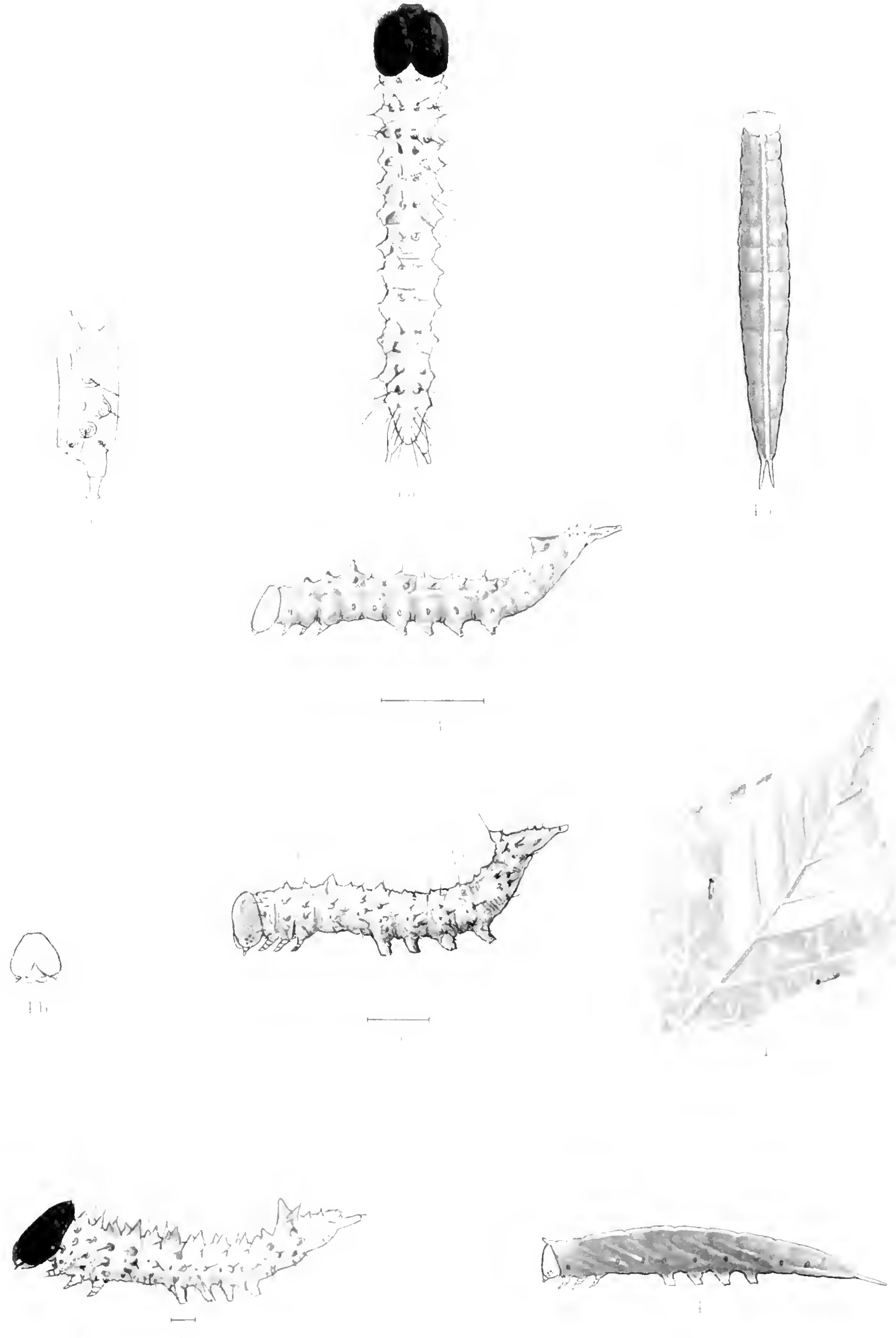
Larval Stages of Macrurocampa Marthesia.

Plate XXXV.

Fig. 1. *Scirodonta bilineata?* Stage I, June 25; 1*b*, natural size; 1*c*, second abdominal segment.
Fig. 2. *Scirodonta bilineata?* Stage II, June 29.
Fig. 3. *Scirodonta bilineata?* Stage III, July 3.
Fig. 4. *Macrurocampa marthesia*, Last stage, natural size; 4*a*, dorsal view; 4*b*, front view of head. Brigham del.

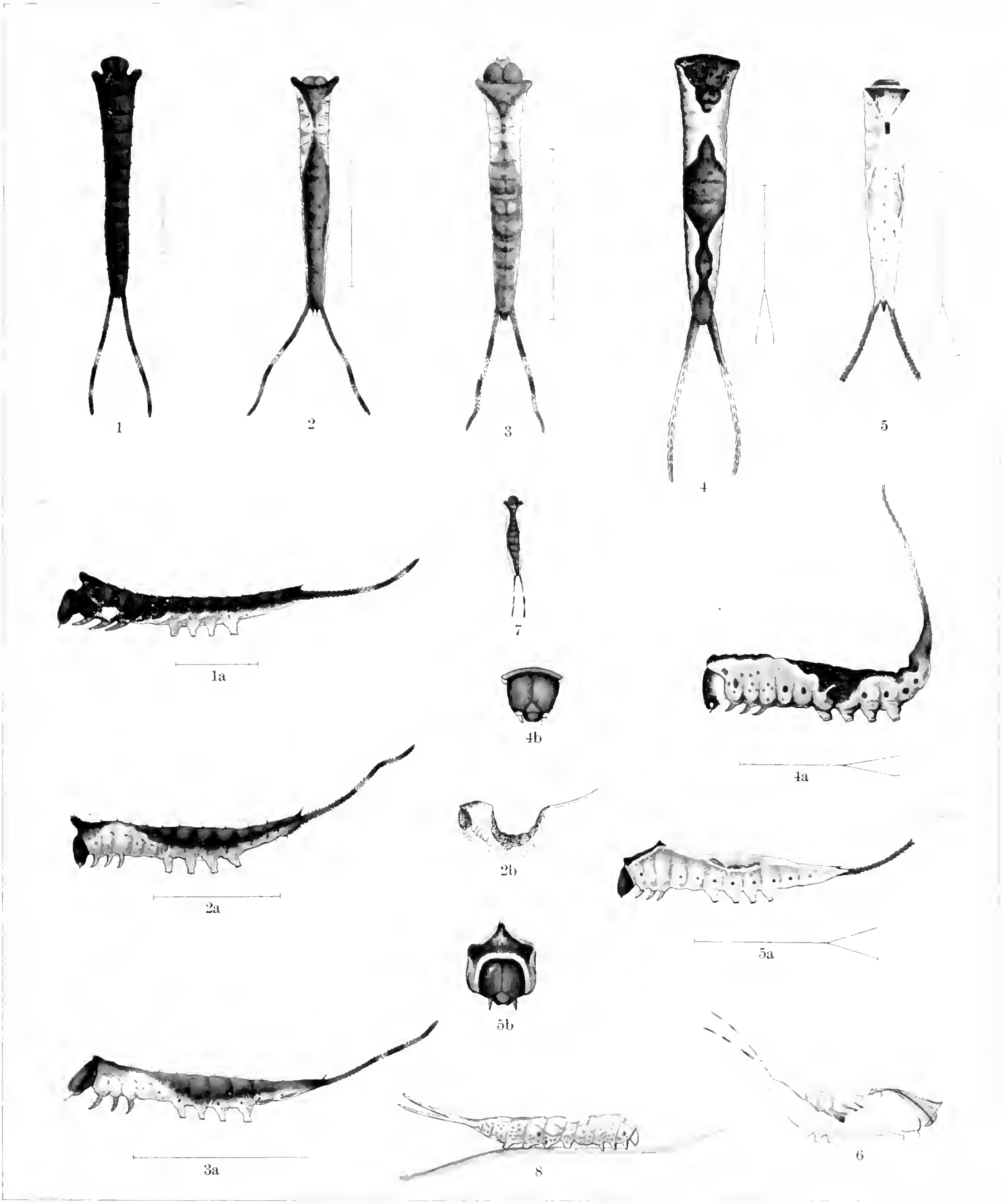


LARVAL STAGES OF SEIRODONTA BILINEATA, MACRUROCAMPA MARTHESIA

[illegible] del.

PLATE XXXVI.

FIG. 1, 1*a*. *Cerura borealis*, Stage I.
FIG. 2, 2*a*. *Cerura borealis*, Stage II; 2*b*, natural size and attitude.
FIG. 3, 3*a*. *Cerura borealis*.
FIG. 4, 4*a*. *Cerura cinerea*; 4*b*, face.
FIG. 5, 5*a*. *Cerura multiscripta*; 5*b*, face. Bridgham del.
FIG. 6. *Cerura borealis*, larva on poplar, Georgia. Leconte del.
FIG 7. *Cerura borealis*, larva on willow, Maine. Wilder del.
FIG. 8. *Cerura occidentalis*. Lintner del. (Dr. Dyar thinks this is *cinerea*.)



Bridgham Le Conte and Lintner, del.

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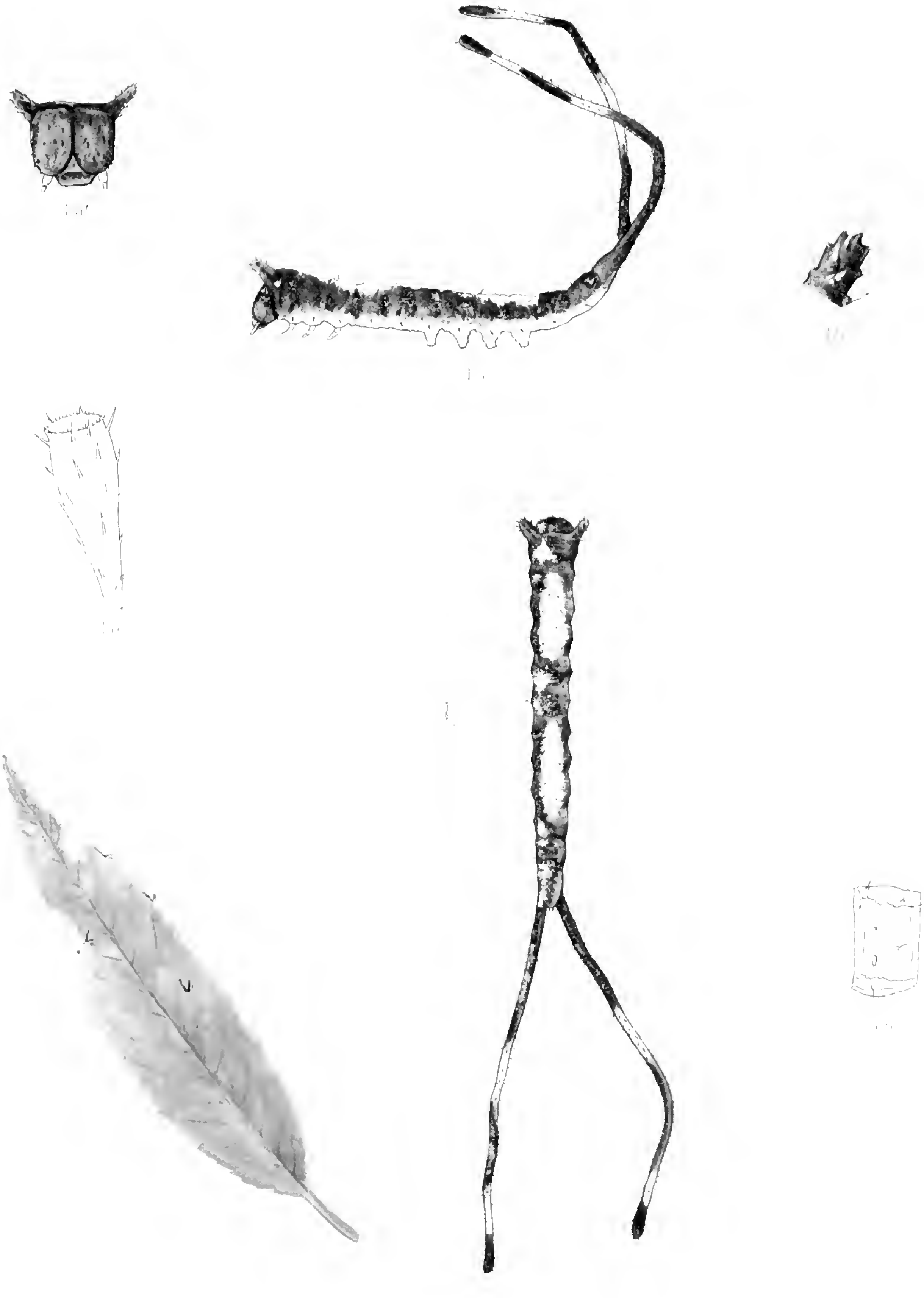
Larvæ of Cerura borealis 1-3; cinerea 4; multiscripta 5, etc.

PLATE XXXVII.

FIG. 1. *Cerura cinerea*, freshly hatched larva, Stage I; 1*a*, the same dorsal view, much enlarged; 1*a*, front view of head; 1*b*, dorsal prothoracic tubercle, enlarged; 1*c*. larvæ, natural size; 1*d*, second abdominal segment, enlarged; 1*e*, end of one of the "tails."



LARVA OF CERURA CINEREA

PLATE XXXVIII.

Venation of Gluphisia and of Apatelodes.

FIG. 1. *Gluphisia septentrionis*, fore wing; 1*a*, hind wing.
FIG. 2. *Gluphisia ridenda*.
FIG. 3. *Gluphisia lintneri*; 3*a*. hind wing.
FIG. 4. *Gluphisia severa*, var. *slossoniae*.
FIG. 5. *Apatelodes torrefacta*, fore wing; 5*a*, portion of the wing showing the origin of the subcostal branches; 5*b* hind wing; 5*c*, hind leg. Author del. with the camera.

PLATE XXXIX.

Venation of Datana.

FIG. 1. *Datana ministra*, part of fore wing.
FIG. 2. *Datana angusii*, part of fore wing.
FIG. 3. *Datana drexelii*, part of fore wing.
FIG. 4. *Datana floridana*, part of fore wing.
FIG. 5. *Datana perspicua*, part of fore wing (the first subcostal arises far within the origin of the second cubital venule).
FIG. 6. *Datana integerrima*, part of fore wing.
FIG. 7. *Datana contracta*, fore and hind wings. Author del.

Plate XL.

Venation of Ichthyura and Datana major.

Fig. 1. *Ichthyura ornata*, from Olympia, Wash.; part of fore wing.
Figs. 2, 2a. *Ichthyura inclusa*.
Fig. 3. *Ichthyura brucei*, from Franconia, N. H.
Fig. 4. *Ichthyura albosigma*.
Fig. 5. *Datana major*.

Packard del.

Plate XLI.

Venation of Nadata, Lophodonta, Drymonia, and Notodonta.

Fig. 1. *Nadata gibbosa.*
Fig. 2. *Lophodonta angulosa.*
Fig. 3. *Lophodonta ferruginea.*
Fig. 4. *Lophodonta basitriens.*
Fig. 5. *Drymonia georgica.*
Fig. 6. *Notodonta simplaria.*

Plate XLII.

Venation of Notodonta, Lophopteryx, Pheosia, Ellida, and Dasylophia.

Fig. 1. *Notodonta stragula.*
Fig. 2. *Lophopteryx elegans*; 2*a*, fore leg; 2*b*, tibia of the same denuded, to show the spur.
Fig. 3. *Pheosia rimosa.*
Fig. 4. *Ellida gelida.*
Figs. 5, 5*a*. *Dasylophia anguina.*
Fig. 6. *Dasylophia thyatiroides* (*interna*).

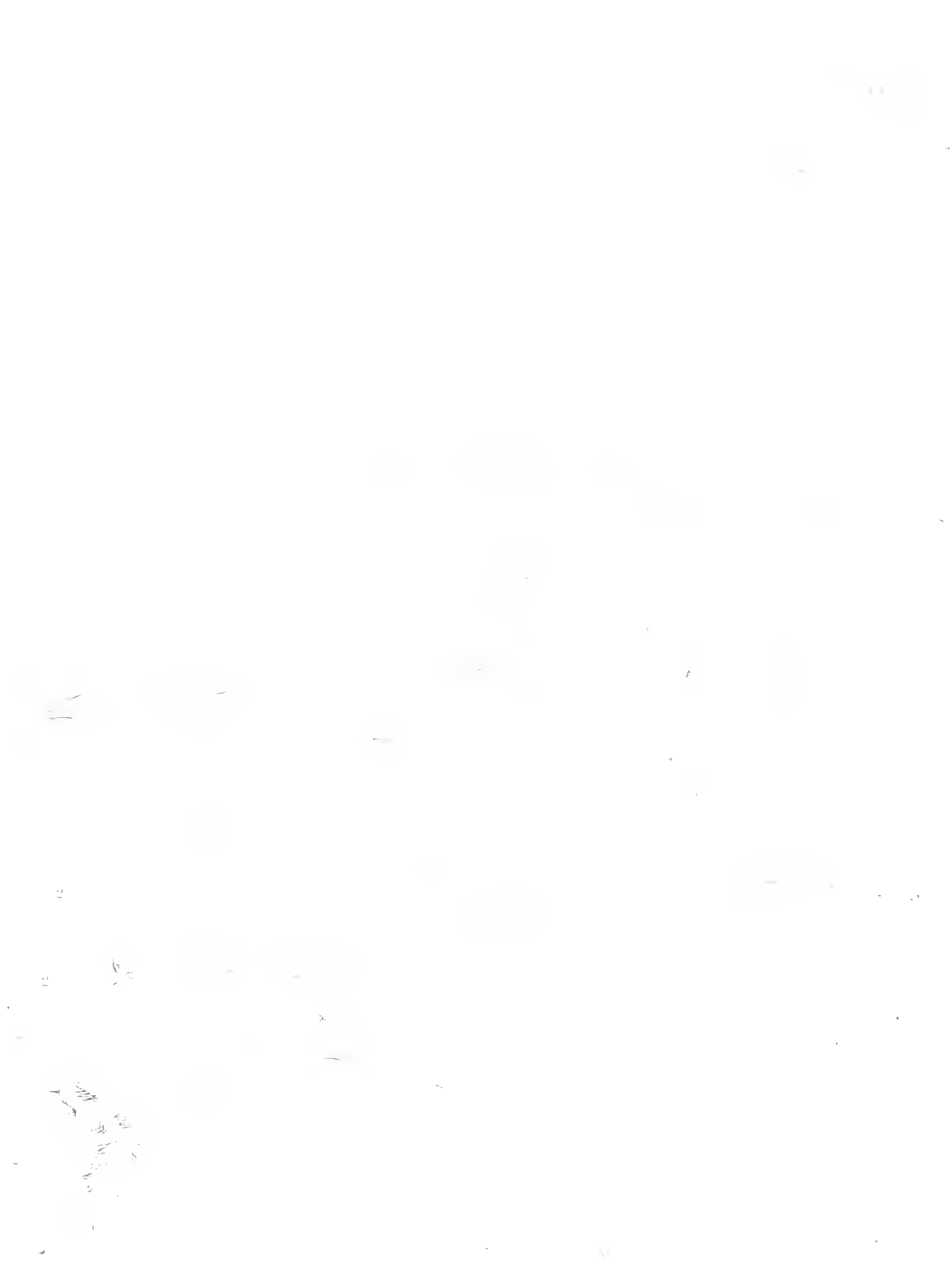


Plate XLIII.

Venation of Nerice, Symmerista, Hyparpax, and Xylinodes.

Fig. 1. *Nerice bidentata;* 1a, hind wing.
Fig. 2. *Symmerista albifrons;* 2a, hind wing.
Fig. 3. *Hyparpax aurora;* 3a, hind wing.
Fig. 4. *Xylinodes lignicolor;* 4a, hind wing.

Plate XLIV.

Venation of Schizura.

Fig. 1. *Schizura ipomea*, part of fore wing; 1*a*, part of hind wing.
Fig. 2. *Schizura leptinoides*.
Fig. 3. *Schizura unicornis*, 3*a*, hind wing.
Fig. 4. *Schizura concinna*, fore wing; 4*a*, hind wing.
Fig. 5. *Schizura eximia*, part of fore wing.

Plate XLV.

Venation of Seirodonta and Heterocampa.

Fig. 1. *Seirodonta bilineata:* 1*a*, hind wing; 1*b*, subcostal cell enlarged.

Fig. 2. *Heterocampa manteo*, fore wing; 2*a*, hind wing, normal; 2*b*, fore wing with cell absent and no subcostal venule (Vein II_3 wanting); hind wing also with different arrangement of the discal veins.

Fig. 3. *Heterocampa biundata.* Specimen compared with Walker's type. 3*a*, the same, hind wing.

Fig. 4. *Heterocampa guttivitta;* 4*a*, part of a wing showing the vestiges of the fourth subcostal venule (Vein II_4).

Packard, del.

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Venation of Seirodonta and Heterocampa.

PLATE XLVI.

Venation of Heterocampa.

FIG. 1. *Heterocampa guttivitta*: 1*b*, costal region enlarged. From Franconia.
FIG. 2. *Heterocampa lunata*, fore wing.
FIG. 3. *Heterocampa obliqua*.
FIG. 4. *Heterocampa astarte*: 4*a*, costal region enlarged.
FIG. 5. *Heterocampa subrotata* (superba); 5*a*, portion enlarged; 5*b*, hind wing.

Packard, del.

Venation of [illegible]

Plate XLVII.

Venation of Heterocampa, Macrurocampa, and Cerura.

Fig. 1. *Heterocampa pulverea*, fore wing; 1*a*, portion of fore wing.

Fig. 2. *Heterocampa hydromeli*; 2*a*, costal region of fore wing enlarged; 2*b*, sketch from another specimen; 2*c*, hind wing.

Fig. 3. *Heterocampa unicolor*, fore wing; 3*a*, hind wing.

Fig. 4. *Macrurocampa marthesia*; 4*a*, hind wing.

Fig. 5. *Cerura scolopendrina*, portion of fore wing.

Fig. 6. *Cerura scitiscripta*, from Florida; 6*b*, hind wing. Author del.

Plate XLVIII.

Front views of head and figures of palpi of Notodontians.

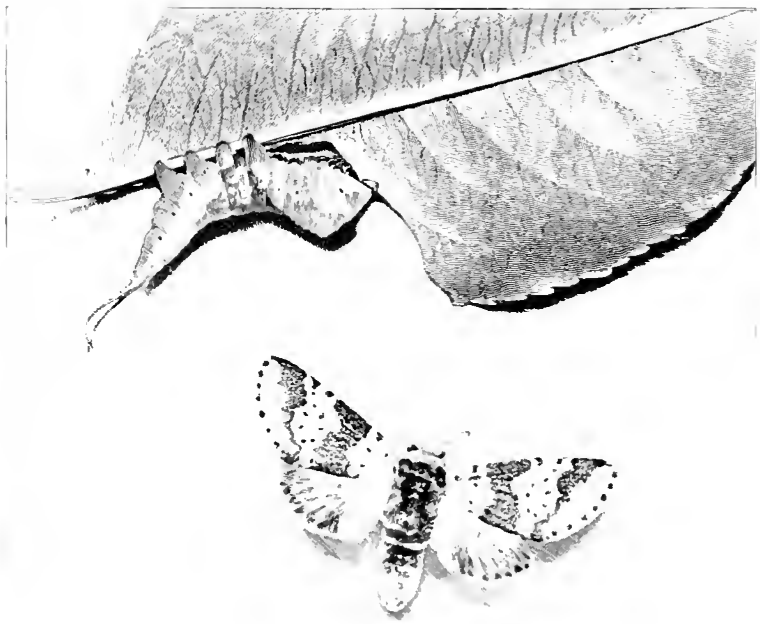
Fig. 1. Head of *Gluphisia septentrionis*, denuded, front view.
Fig. 2. Head of *Apatelodes torrefacta*, denuded, front view.
Fig. 3. Palpus of *Apatelodes torrefacta*.
Fig. 4. Head of *Ichthyura inclusa*, denuded, front view.
Fig. 4*a*. Head of *Notodonta stragula*, denuded, front view.
Fig. 5. Head of *Schizura ipomeæ*.
Fig. 6. Head of *Heterocampa guttivitta*.
Fig. 7. Head of *Datana ministra*.
Fig. 8. Palpus of *Ichthyura inclusa*.
Fig. 9. Palpus of *Datana ministra*.
Fig. 10. Palpus of *Scirodonta bilineata*.
Fig. 11. Palpus of *Heterocampa manteo*.
Fig. 12. Palpus of *Heterocampa guttivitta*.
Fig. 13. Palpus of *Macrurocampa marthesia*.
Fig. 14. Head of *Cerura scolopendrina*.
Fig. 14*a*. Palpus of *Cerura scolopendrina*, outside.
Fig. 15. Palpus of *Cerura scolopendrina*, inside.
Fig. 16. Palpus of *Nadata gibbosa*.
Fig. 17. Palpus of *Dasylophia anguina*.
Fig. 18. Palpus of *Schizura unicornis*.

PLATE XLIX.

FIG. 1. *Apatelodes angelica* and larva. From a photograph by Dr. R. Thaxter, loaned by Dr. C. V. Riley.
FIG. 2. *Cerura borealis* and larva. From a photograph by Dr. R. Thaxter, loaned by Dr. C. V. Riley.
FIG. 3. *Cerura multiscripta*. After Riley.

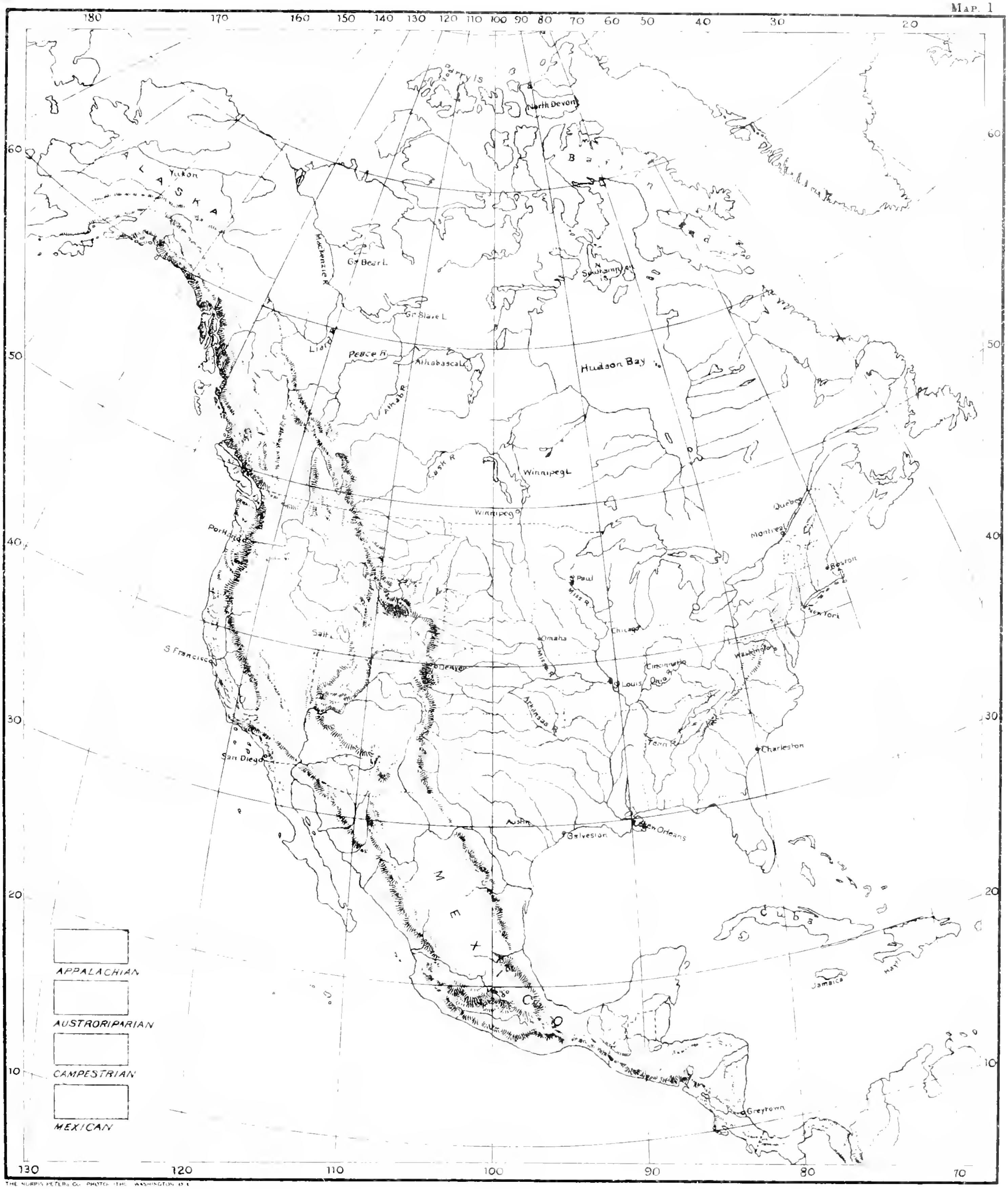
1

3

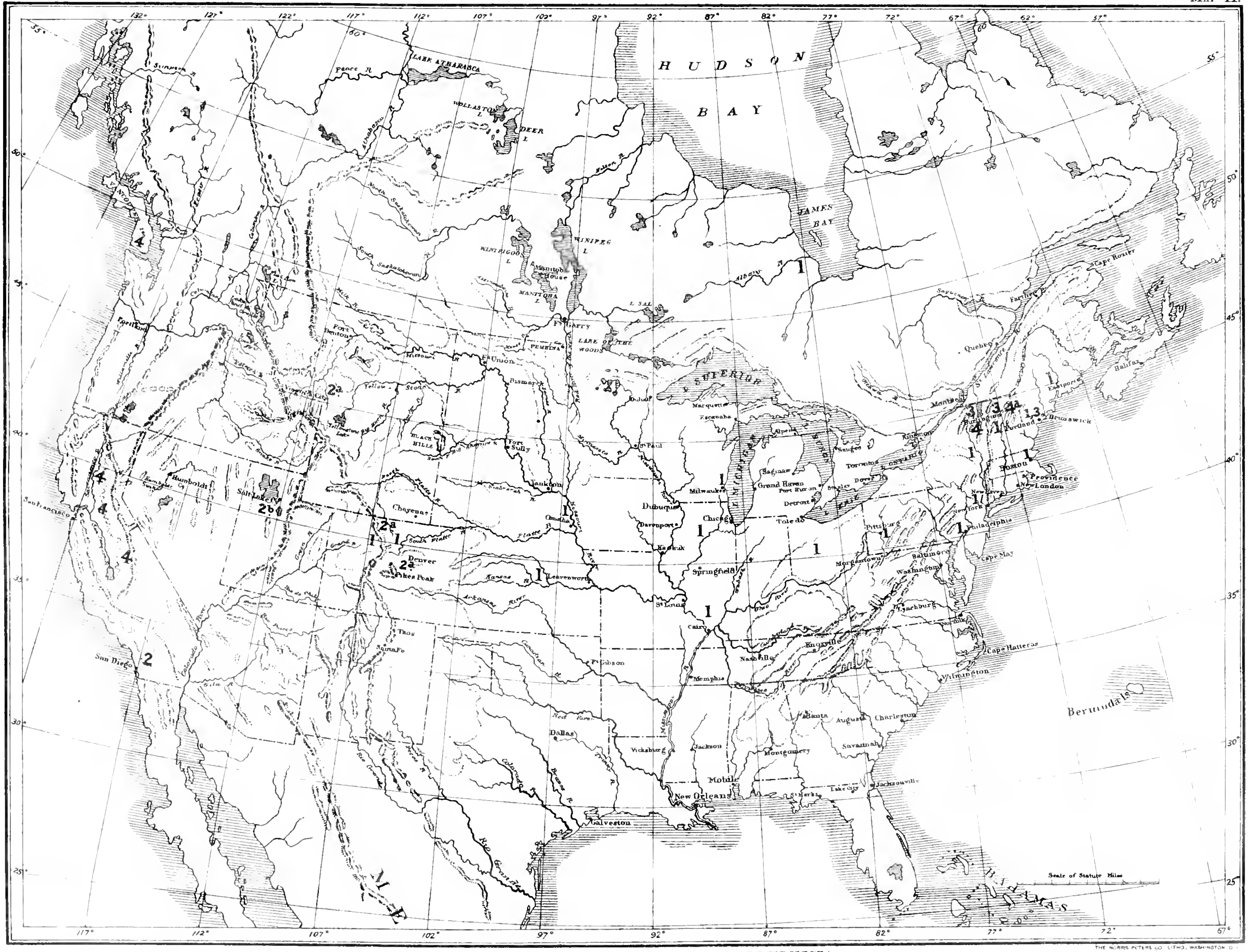


2

1, APATELODES ANGELICA AND LARVA; 2, CERURA BOREALIS AND LARVA; 3, CERURA MULTISCRIPTA

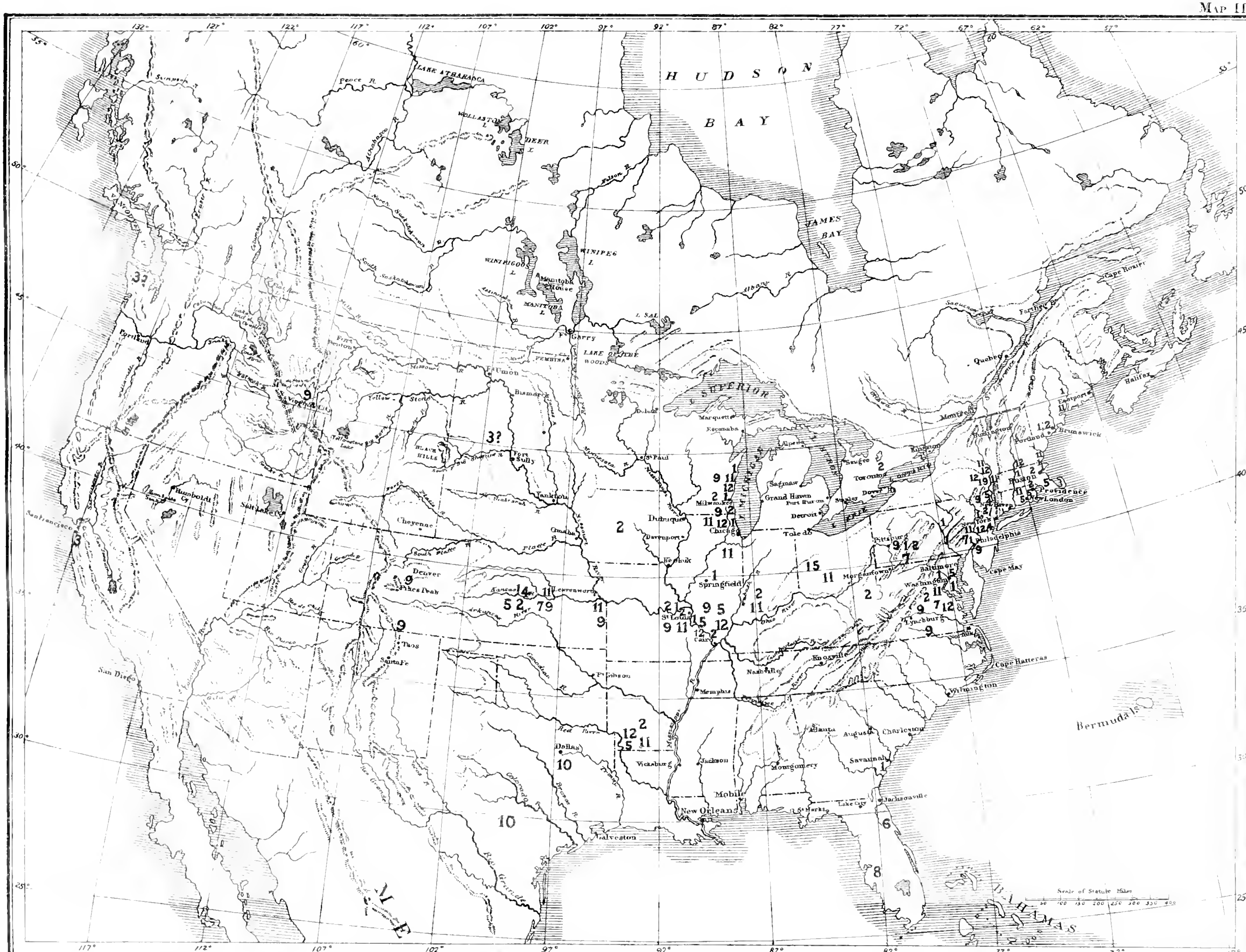


ZOOLOGICAL SUBPROVINCES. (After J. A. Allen, with a few changes)



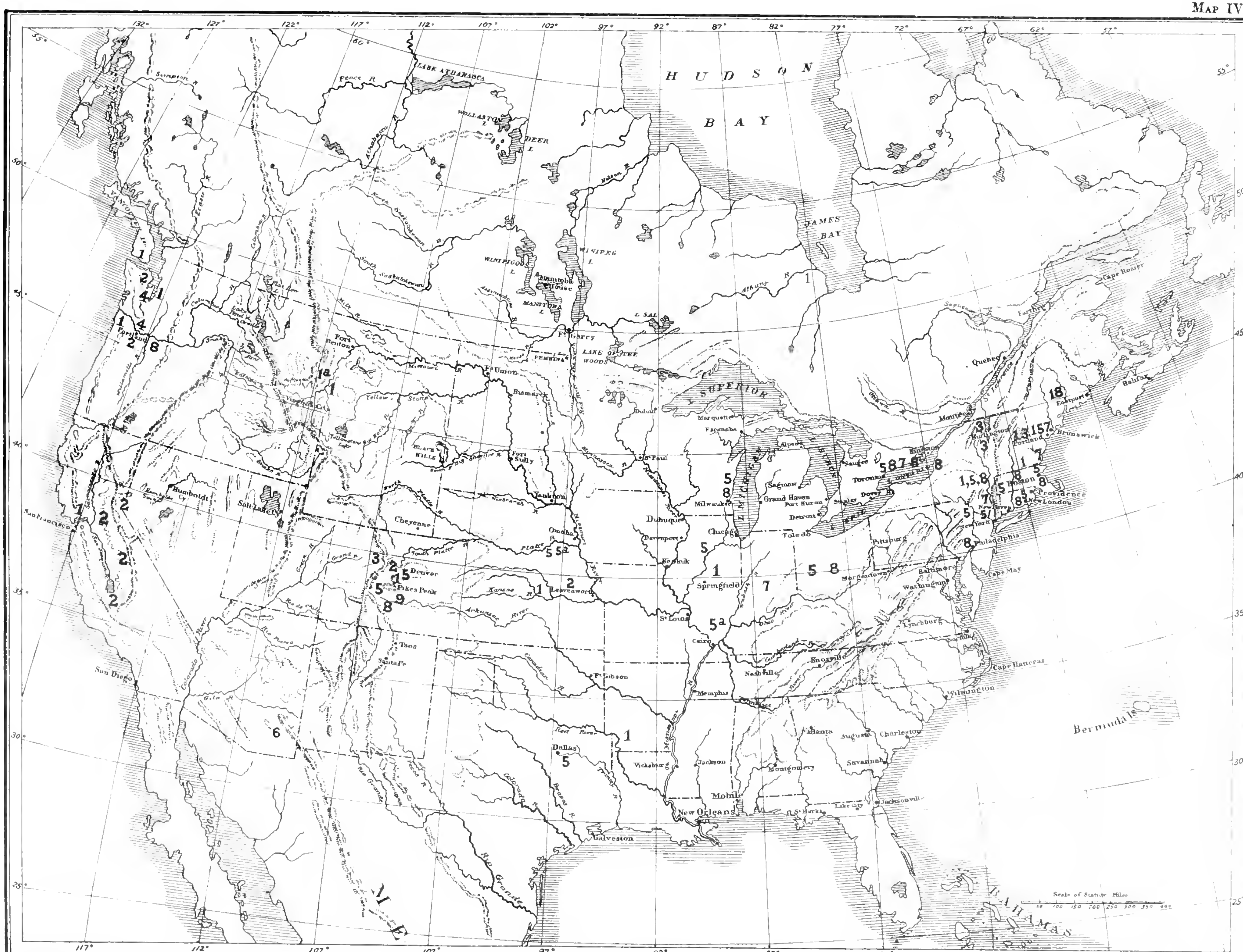
DISTRIBUTION OF THE SPECIES OF GLUPHISIA.

1. G. septentrionis; 2. G. wrightii; 2ª. G. rupta and G. ridenda; 2ᵇ. G. formosa and albofascia; 3. G. lintneri; 4. G. severa; 4ª. var. slossoniæ.



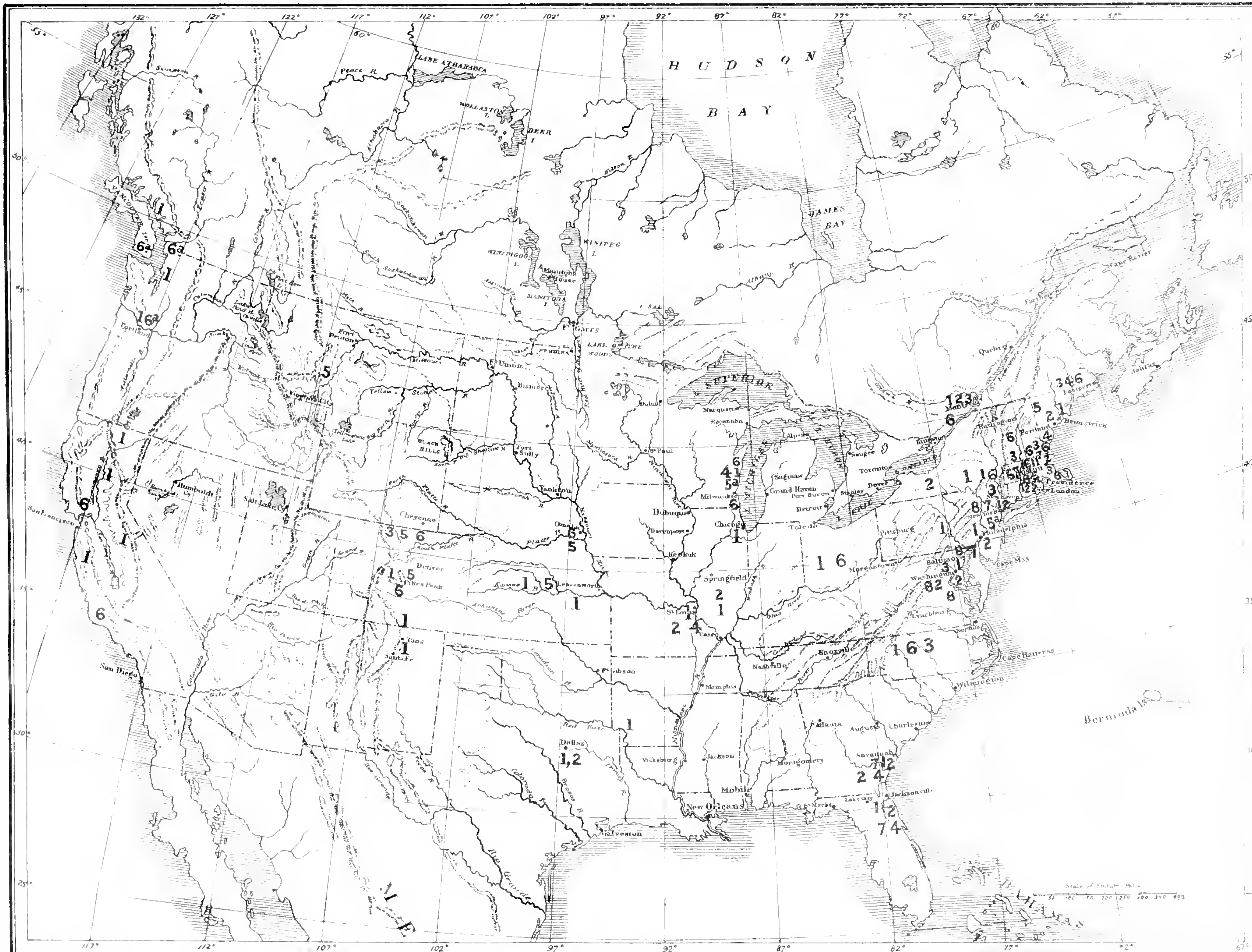
DISTRIBUTION OF THE SPECIES OF DATANA.

1. D ministra; 2. D. angusii; 3. D. californica; 4. D. drexelii; 5. D. major; 6. D. floridana; 7. D. palmii; 8. D. modesta; 9. D. perspicua: 10. D. robusta; 11. D. integerrima; 12. D. contracta.



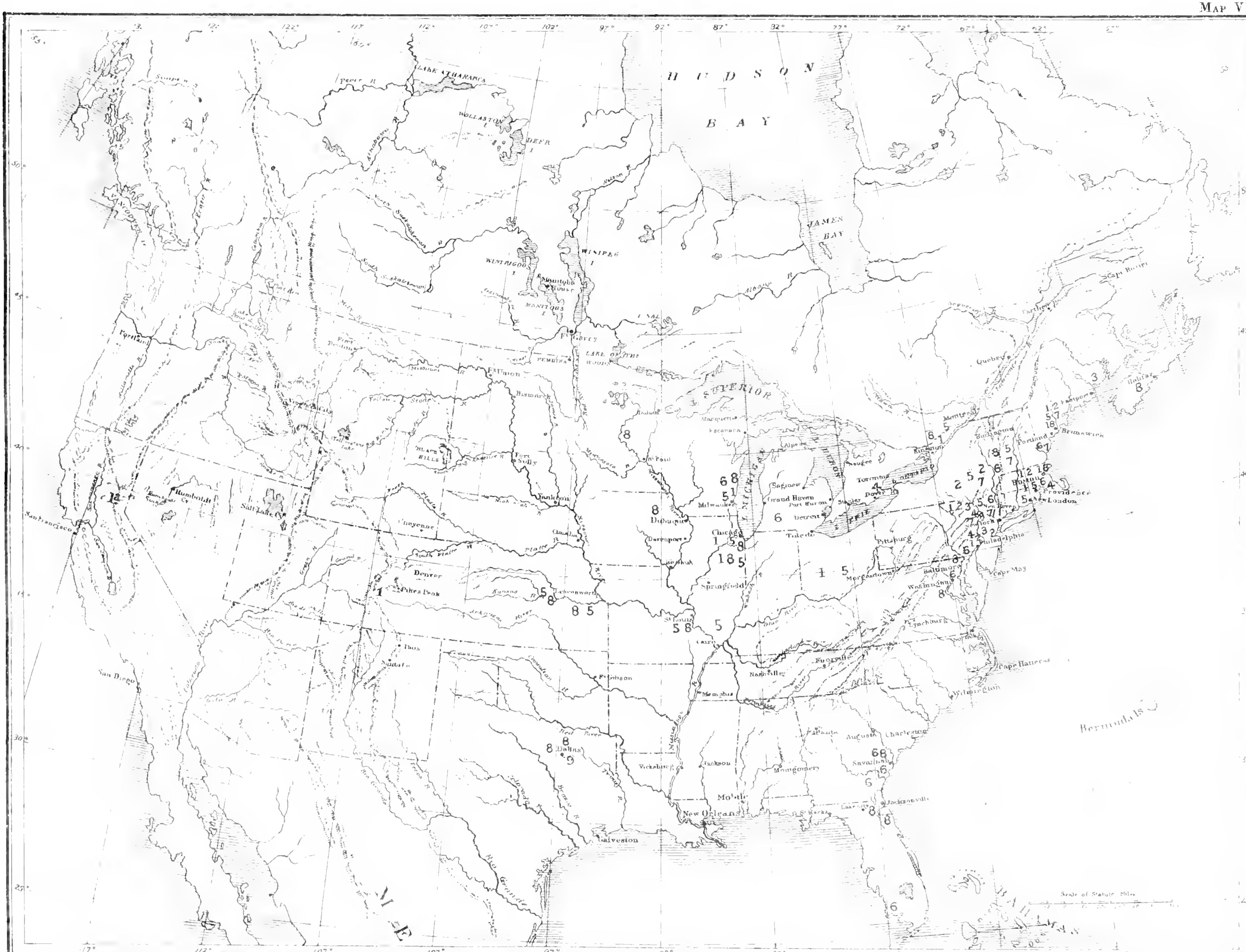
DISTRIBUTION OF THE SPECIES OF ICHTHYURA.

1. I. apicalis (vau); 1[a]. pale western form (astoriæ); 2. var. ornata; 3. brucei; 4. var. multnoma; 5. inclusa; 5[a]. var. palla; 6. inornata; 7. strigosa; 8. albosigma; 9. pale form specifica.



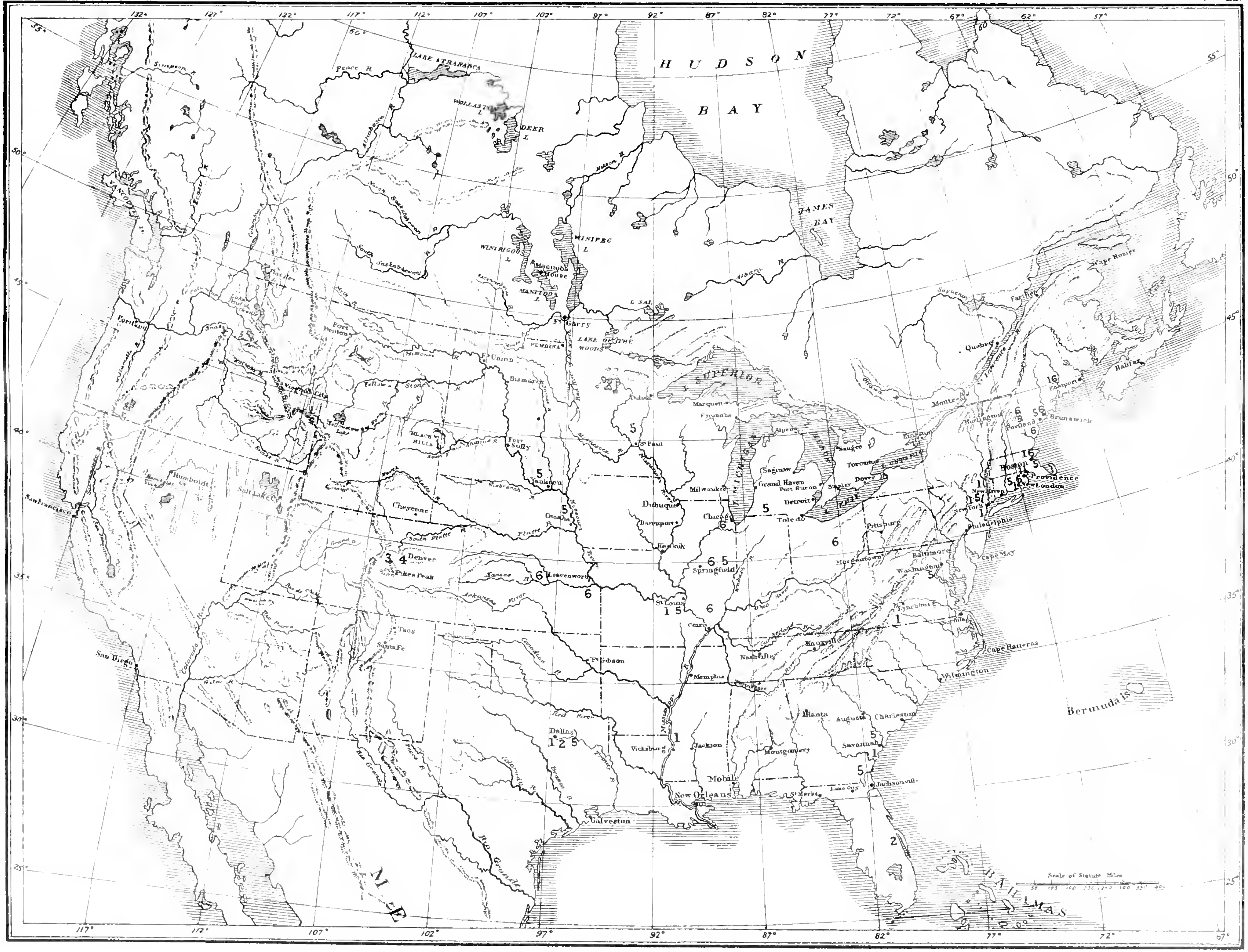
DISTRIBUTION OF NADATA, LOPHODONTA, LOPHOPTERYX, PHEOSIA, AND APATELODES.

1. Nadata gibbosa; 2. Lophodonta angulosa; 3. L. ferruginea; 4. L. georgica; 5. Lophopteryx elegans; 5a. L. camelina; 6. Pheosia dimidiata. 6a. dark var. portlandia; 7. Apatelodes torrefacta. 8. A. angelica.



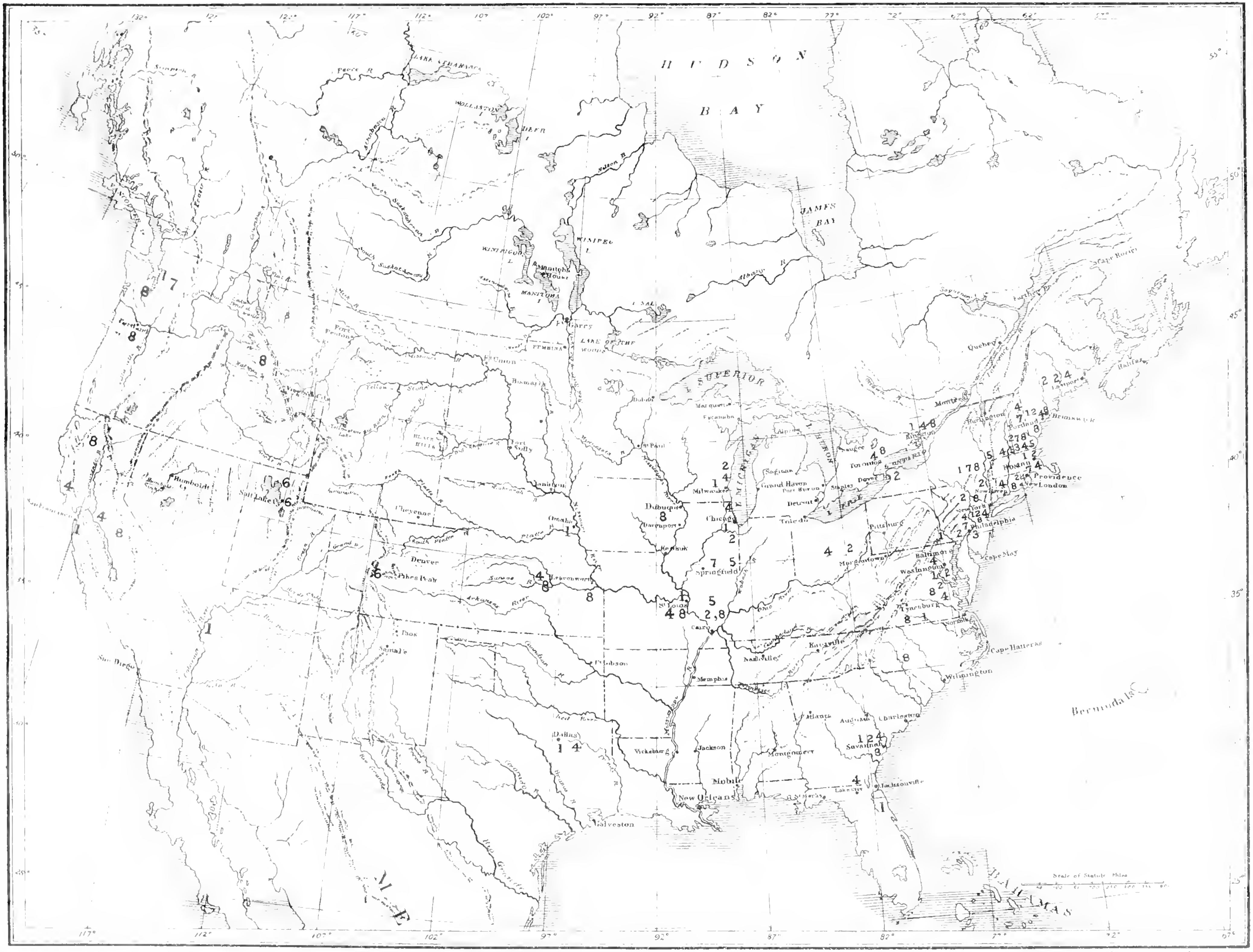
DISTRIBUTION OF NOTODONTA, ELLIDA, NERICE, DASYLOPHIA, AND SYMMERISTA.

1. N. stragula; 1ª. dark form; 2. N. basitriens. 3. N. simplaria; 4. E. caniplaga; 5. N. bidentata; 6. D. anguina; 7. D. thyatiroides 8. S. albifrons; 9. S. packardii.



DISTRIBUTION OF HYPARPAX, EUHYPARPAX, XYLINODES, AND SEIRODONTA.

1. H. aurora; 2. H. perophoroides; 3. H. venus; 4. E. rosea; 5. X. lignicolor; 6. S. bilineata.



DISTRIBUTION OF THE SPECIES OF SCHIZURA.

1. S. ipomeæ; 2. S. leptinoides; 3. S. apicalis; 4. S. unicornis; 5. S. badia; 6. S. perangulata; 7. S. eximia; 8. S. concinna.

DISTRIBUTION OF THE SPECIES OF HETEROCAMPA AND MACRUROCAMPA.

1. H. manteo; 2. H. biundata; 3. H. guttivitta; 4. H. lunata; 5. H. obliqua; 6. H. astarte; 7. H. umbrata; 8. H. belfragei; 9. H. subrotata; 10. H. hydromeli; 11. H. unicolor; 12. H. chapmanni; 13. M. marthesia.

Map X

DISTRIBUTION OF THE SPECIES OF CERURA.

1. C. borealis. 2. C. occidentalis. 3. C. scolopendrina. 3[a]. var. modesta; 4. C. cinerea. 4[a]. pale form; 4[b]. var. nivea.
5. C. scitiscripta. 5[a]. var. multiscripta

NATIONAL ACADEMY OF SCIENCES.

VOL. VII.

SECOND MEMOIR.

ON REACTION-TIMES AND THE VELOCITY OF THE NERVOUS IMPULSE.

ON REACTION-TIMES AND THE VELOCITY OF THE NERVOUS IMPULSE.[1]

BY J. McKEEN CATTELL, PH. D., AND CHARLES S. DOLLEY, M. D.

The object of this research is to determine the conditions which affect the length of the reaction-time on dermal stimuli, and to study the application of the reaction time to the measurement of the velocity of the nervous impulse in motor and sensory nerves and in motor and sensory tracts of the spinal cord.

Since von Helmholtz first measured the velocity of the nervous impulse in 1850 much work has been directed to the subject, but the results are not accordant. The experiments on the nerve-muscle preparation of the frog are the most easily carried out, and these are usually regarded as valid for the motor and sensory nerves of man. It does not, however, follow that the effects of electrical stimulation on the excised and dying nerve of the frog are the same as the effects of cerebral discharge in the living animal, nor that these effects (could they be determined) would hold for man.

Determinations made by electrically stimulating the living nerve of the lower mammals and of man are of more value for human physiology than those on the excised nerve of a frog. They are, however, less accordant. We are ignorant of the relations between electrical stimulation and nervous discharge, and do not know what happens in the motor nerve and muscle when the skin is stimulated by electricity. It seems evident that the velocity of the normal nervous impulse can not be determined in this way, owing to the great variation in results, which must be due to the method of stimulation and not to the velocity of the normal impulse. Thus von Helmholtz obtained times twice as long in winter as in summer, and supposes this to be due to differences in the conductivity of the nerve. This is not, however, the case, as we find that the reaction-time, in which the time of transition along the nerves is a large factor, is the same in winter as in summer. It is further evident that such experiments apply only to the motor nerve. The time of transmission may be the same as in the sensory nerve, but to assume this would be arbitrary.

So long as we can not record the progress of the nervous impulse along the nerve nor the instant at which it reaches or leaves the brain, the rate of transmission of the normal sensory or motor impulse can only be determined indirectly. In the case of motor nerves it is necessary to make movements with muscles at varying distances from the brain following as quickly as possible on the same stimulus. In the case of sensory nerves the stimulation must be given at varying distances from the brain, and the arrival must be followed by a movement or directly judged by consciousness.

In these experiments the results are obtained by measuring the time of a complex process—the reaction. The reaction-time is the interval elapsing before a predetermined movement follows on a predetermined stimulus. During this interval a series of physiological processes takes place. (1) The stimulus is converted into a nervous impulse; (2) the nervous impulse travels along the sensory nerve and, it may be, the spinal cord to the brain; (3) through sensory tracts of the brain to a sensory center; (4) changes occur in this center; (5) these changes are followed by

[1] Presented by Prof. G. F. Barker before the meeting of the National Academy of Sciences, Albany, 1893.

a discharge from a motor center; (6) the motor impulse travels along motor tracts in the brain; (7) along the motor nerve and, it may be, spinal cord, and, finally, (8) the muscle is innervated. The process is probably an acquired cerebral reflex, not accompanied by consciousness. The stimulus is indeed perceived, but probably not before the motor impulse has been discharged. The stimulus causes two sorts of cerebral changes, the discharge of the motor impulse, and changes in the cortex, which are accompanied by consciousness. But, contrary to the views of most physiologists, we think the movement does not follow on changes in consciousness, but is simultaneous with or actually prior to them. What volition is concerned in the process precedes the reaction and consists in preparing the motor impulse, which is reflexly discharged.[1]

The conditions on which the duration of the reaction depends are partly such as relate to the subject reacting and partly such as relate to the stimulus. Some subjects react more quickly than others, and this difference in time must represent real differences in the nervous system. The personal difference in reacting has not yet been adequately investigated.[2] Observations which we have made indicate that the reaction-time is shorter for women than for men, and for Americans than for Germans. The reaction-time is said to be longer in childhood and in old age. We have, however, found a normally short reaction in a child of 3 and an unusually short and regular reaction in a man of 65. We have found the reaction-time to be lengthened in certain diseases of the nervous system, and the test (especially in unilateral diseases in which the reacting hand or foot and the point of application may be varied) might prove useful in diagnosis, more especially in indicating progression or recovery. We have found the times of mental processes such as perception, volition, memory, association, etc., to vary more in different individuals than the times of the simple reaction, and these may prove useful not only in diagnosis of disease, but in scientific pedagogy and in directing the ordinary conduct of life. Our experiments on personal differences are not completed, and will not be treated in this paper.

In the same individual the duration of the reaction time and of mental processes differs at different times. Owing, however, to the reflex nature of the reaction its length is not greatly affected by the condition of the observer, the time of day, the number of reactions already made, nor the amount of practice. These factors, and especially the effects of attention, we shall consider in view of our own results. It may here be stated that in our experiments the mean variation of a reaction from the series to which it belongs was usually less than 0.01 second, and the mean variation of series made on different days was also usually less than 0.01 second.

The length of the reaction-time is clearly influenced by the nature of the stimulus and the point of its application. The reaction-time is about 0.025 second longer for light than for sound and touch. This may be due to the greater time required for converting the physical motion into a nervous impulse in the retina, where a chemical process is supposed to take place. It may also be due to the cerebral reflex being less perfect, reflex and automatic movements being made more readily in answer to sounds and touches than to lights. We have found the reaction on touch shorter than on electric stimulation. The reaction-time becomes shorter as the intensity of the stimulus is increased, though the difference is not great except in the case of very weak stimuli. The area of the stimulus probably only affects the length of reaction in so far as it alters the intensity. The quality of stimuli of the same intensity (e. g., different colors or noises) does not appreciably affect the length of the reaction.

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[1] It is not necessary to repeat in this place references to the somewhat extended literature on reaction-time and the velocity of the nervous impulse; cf. for these Hermann, in his Handbuch der Physiologie, Vol. II, and Exner, in the same work, Vol. III, Leipzig, 1879; Wundt, Grundzüge der physiologischen Psychologie, 4th edition, Leipzig, 1893; Cattell, Philosophische Studien, Vol. III, and Mind, Vol. XI, 1886; Dumreicher, Zur Messung der Reactionszeit, Dissertation, Strassburg, 1889; Jastrow, The Time Relations of Mental Phenomena, New York, 1890, and the Catalogue of the Surgeon-General's Library.

[2] It is, indeed, the case that the whole question of reaction-time has had its origin in the personal equation of the astronomer. But the problems, though often confused, are quite distinct. The astronomer watches the star as it crosses the field of his telescope and records as nearly as he can the instant at which it passes the central thread. In such a case a reaction may perhaps be said to take place, but the personal equation of the astronomer depends not on the duration of the reaction but on the time at which the process is initiated, and may be as great as one second. It seems likely that the astronomer could greatly reduce his personal equation by adopting the methods of the psychologist. If the star passed behind a screen and emerged as it passed the meridian, the observer could not have a negative personal equation, and the probable error of a single observation might be reduced to 0.01 second.

The point of application of the stimulus on the body affects the length of the reaction, and this is the problem which we have more especially attempted to study. If the cerebral reflex and motor processes remain the same, the difference in the time of reaction may be used to measure the velocity of the sensory impulse in the nerve and spinal cord. The chief difficulty we have met is not the variable error in the cerebral reflex, but the fact that the same physical stimulus applied at different parts of the body produces physiological effects varying in intensity and cerebral reflexes varying in facility.

The length of the reaction is also affected by the muscles used, and by using organs at varying distances from the brain (e. g., hand or foot) the velocity of the motor impulse may be studied. The duration of the reaction is the same for the right and left hands, but is shorter when the stimulus is applied to the reacting hand than when applied to the other. In this case, the cerebral reflex is shorter, because it is natural to draw away the hand from a stimulus which may be hurtful (e. g., a hot surface). The reaction is shorter and more regular when the hand releases a key than when it presses a key—this doubtless because the innervation can not be prepared so thoroughly in advance in the latter case, lest it be discharged prematurely. This is a point which has not been duly regarded by experimenters and has increased the irregularity of some investigations.

The factors which we have been considering chiefly concern the nature of the cerebral reflex. We, ourselves, believe that the time of transmission of the impulse in the nerve must be far more constant than might be supposed from the discordant results of former investigations. We shall show that the mean variation (and probable error) of a reaction-time may be as small as one-thirtieth of the time, and this small variation is doubtless due to changes in the nature of the cerebral processes rather than to alteration in the rate of transmission in the motor and sensory nerves.

In conclusion, it may be noted that the experiments here described were begun (in 1889) in the psychological laboratory of the University of Pennsylvania and completed (in 1893) at Columbia College. The observations were made and the records taken by C. and D. (the writers), and J. (Mrs. J. McKeen Cattell). The larger part of the new apparatus was secured through an appropriation from the Bache fund of the National Academy of Sciences and is preserved by the Academy.

Part I.—Apparatus and Methods.

In order to measure a reaction-time at least three instruments are required—one to give the stimulus and record the instant at which it is given, one to record the instant at which a movement is made, and one to measure the intervening time. For measuring time we used the Hipp modification of the Wheatstone electric chronoscope and a new instrument, which we may call a gravity chronometer.[1]

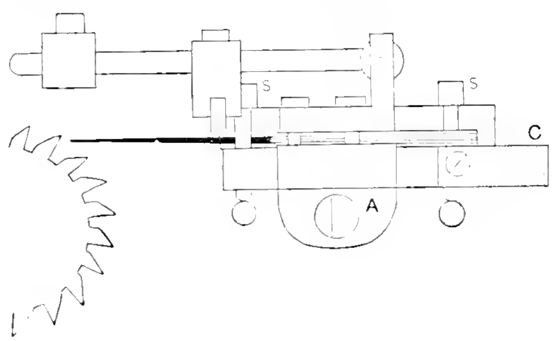

Fig. 1.

The electric chronoscope has been described in various places. It is much more convenient than any chronographic method in which a tuning fork writes on a moving surface, and when properly regulated it is fully as accurate. The chronoscope is a clockwork moved by a weight and regulated by a vibrating rod. The rod vibrates (say) five hundred times in a second, and at each vibration the tooth of a wheel is allowed to pass, as in the escapement of a clock. The details of the clockwork and method of regulation are not essential, and can be improved. The rod and wheel are shown in fig. 1. The rod is adjusted by the screws *s s*, the carriage of the rod moving on the axle *A*. When the rod vibrates, however, the screws *s s* become loosened and the rod retreats from the wheel. We have corrected this fault to a large extent by placing a

[1] The electric chronoscope is made by Peyer & Favarger, Neuchatel. The gravity chronometer was made by D. G. Brown, Camden, N. J., who also made alterations for us in the electric chronoscope.

clamp, *C*, on the carriage. In the chronoscope the clockwork is started by pulling a string, and unless the string be pulled with a given force and to a given extent the clockwork is apt not to start properly. We have replaced the string with a bar attached to a telegraphic key, and when the key is tapped the clockwork is properly started. We have replaced the glass bell supplied by the makers with a wooden house. This keeps out dust, deadens the noise, and need not be removed on winding. Lastly, we have rewound the electro-magnets with coarser wire, which greatly reduces the latent time of magnetization and demagnetization. The chronoscope runs one minute only, and must consequently be stopped after each experiment. A clockwork running a longer time, say one hour, would be much more convenient, and could be regulated more exactly. It would also be convenient if the hands could be sprung back to zero as in an ordinary stop watch.

The value of the chronoscope consists in the application of an electro-magnet. The hands recording the time are not in connection with the clockwork, and do not move when it is set in motion; but when an electric current is sent through the coil of the electro-magnet the armature is attracted, a system of levers throws the hands into connection with the clockwork, and they are set in motion. Then when the current is broken a spring draws back the armature and the hands stand still.[1] The distance the hands have moved is read from the two disks, time being recorded to one-thousandth of a second, and the hands returning to their original position every ten seconds.

It is evident that short times can thus be measured with great convenience. It is easy to close or break an electric current when events occur, and the time is found by subtracting the position of the hands before their motion began from that after it ended. This method of measuring the time of an event is, however, subject to a considerable error, which was first corrected by one of us. If the strength of the current in relation to that of the spring be too great the recorded times are too long and conversely. This may be conveniently illustrated by a diagram (fig. 2).

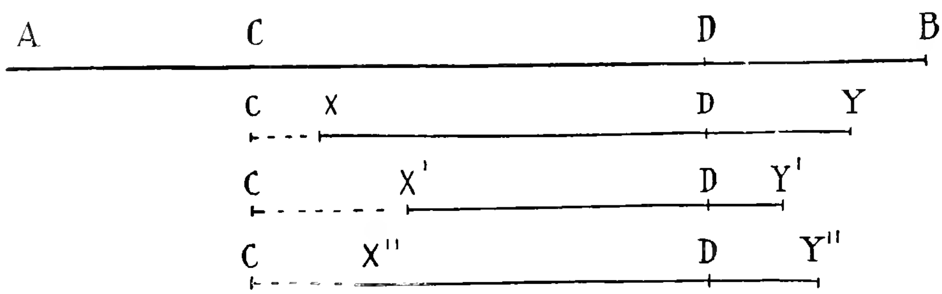

FIG. 2.

Let the time be represented by the line *A B*, and the interval the current is closed (which is the duration of the process) by the line *C D*. After the current is closed there is a latent period before the armature is attracted and the hands are started, and after the current is broken there is a second latent period before the magnetization disappears sufficiently for the spring to draw away the armature. Supposing the tension of the spring to remain constant, when a strong current is used the magnetization occurs quickly, say in the time *C X*, and the demagnetization slowly and the time recorded by the hands *X Y* is longer than the real time of the event *C D*. On the other hand, when a weak current is used the magnetism requires a comparatively long time, say *C X'*, whereas the demagnetization occurs more quickly, say in *D Y'*, and the recorded time is shorter than the real time. This is not a mere matter of theory. With the chronoscope used by us, the real time being 100σ (one-tenth second, $\sigma = 0.001$ second), the recorded time may have an error greater than 50σ. The discordant results obtained by different observers and the large variation in the time of reaction is probably in many cases due to neglect of this factor. With a variable battery (such as Grenet, which is or was formerly supplied by the makers of the

[1] A second electro-magnet makes it possible to reverse this process and measure the time a current has been broken.

chronoscope) the recorded times would scarcely ever be correct, and would become much shortened in the course of an hour's work.[1]

For each degree of tension of the spring there is one strength of current with which the time of magnetization and demagnetization will be equal. $C X''$ being in this case the same as $D Y''$, and the recorded time $X'' Y''$ is equal to the real time $C D$. This strength of current may be found empirically by letting the chronoscope measure a known interval and adjusting the current until it gives the correct time. The times given by the chronoscope will then be constant so long as the current remains constant.

In order to secure such a standard time (and for other chronometric purposes) we have constructed an instrument which is, to a certain extent, the inversion of the principle of the Atwood gravity machine. This is a falling screen, which is shown in outline in the accompanying figure (fig. 3). On a heavy triangular base, *B B*, a perpendicular iron column 2 m. in height is fastened. This column may be made exactly perpendicular by means of the heavy set screws *S S* in the base. On this iron column two brass bars, 3 cm. square, are bolted 5 cm. apart and exactly parallel (having been planed in position). On the inside of these brass bars or columns are triangular grooves, in which a screen, *S S*, runs up and down. The screen is 30 cm. long, 5 cm. wide, and 2 cm. thick, and weighs 2 kg. On each side of the screen two wheels are inserted, which barely touch the grooves and allow the screen to run up and down almost without friction. This screen is held at the top of the columns by the electro-magnet *M M*, or may be held at any height by means of a second adjustible magnet not shown in the figure. When the current supplying the electro-magnet is broken the screen falls, and at the rate required by the laws of gravity, excepting in so far as it may be retarded by resistance of the air and friction. Owing to the shape and weight of the screen the resistance of the air is slight, and as the column is exactly perpendicular the wheels of the screen scarcely touch the grooves, and what slight friction there would be is nearly obviated by the revolution of the wheels. We did not, however, depend on the theoretical time of fall, but measured the time with a tuning fork, as described below. The force with which the screen strikes the base is broken by rubber cushions on the bottom and sides. The cushions on the sides are especially useful. The screen is slightly cut away, as shown in the figure, and is gradually stopped by the projecting rubber bars on both sides; these obviate most of the jar and prevent the screen from rebounding. The screen is lifted by means of the pulley shown in the cut. The cord *a a* is pulled by the handle *b* and lifts a carriage behind the screen, which in turn lifts the screen. The carriage moves in separate grooves back of the screen and falls into its place when the screen touches the electro-magnet.

On the front of the brass columns are also grooves in which pins are inserted which can be placed in any position. By means of these pins electrical contacts *C C* can be securely adjusted to the columns at any height. The electrical contacts were made especially for us. They consist of wheels (*W W*, fig. 4) which turn on points. The circumference of each wheel is half platinum (*P P*), the rest being rubber or being cut away. From the wheel a pin (not visible in the figure) projects, and this is struck by the screen when it falls, causing the wheel to turn. A platinum contact presses gently on the wheel, and as the wheel revolves the contact is brought against the platinum circumference, thus closing one circuit and simultaneously breaking a second circuit. A current is thus closed or broken (or two circuits may be simultaneously closed or broken, or one circuit closed at the instant another is broken) at a given point in the fall of the screen. We especially recommend this contact for closing a circuit; a circuit may be readily broken, but in order to close a circuit a mercury contact is nearly always used, which involves various inconveniences and sources of error. By means of this wheel-contact a current can be closed at a given instant and remains closed, or the circuit could be closed for any given fraction of a hundredth of a second, which might be useful for many experiments. The rubbing keeps the contacts clean.

[1] In the Hipp chronoscope the latent time of magnetization is much larger than necessary. The electro-magnet has a very high resistance and self-induction, and the levers carried by the armature are needlessly complicated and heavy. We have, as stated, greatly reduced the latent time by rewinding the magnets with coarser wire. We are sure that a chronoscope could be constructed in every way better than that by Hipp, and it is only the expense which has prevented us from making one.

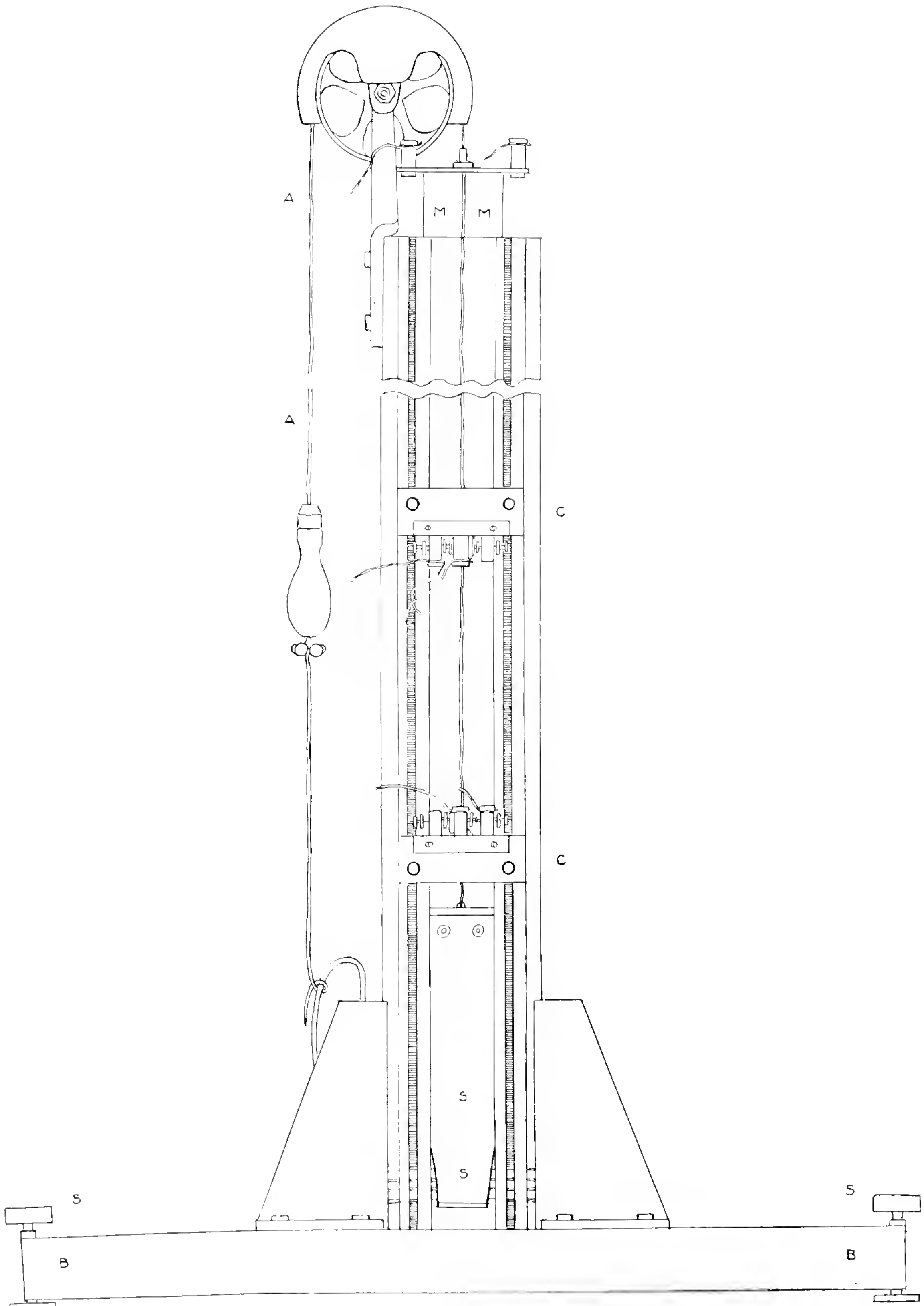

Fig. 3.

The current in these wheels does not pass through the points of the axis (which might cause variation in the resistance), but through a platinum spring, *S*, which touches the side of the wheel.

The falling screen and contacts described make a chronoscope useful for many psychological, physiological, and perhaps physical purposes. We have used the instrument chiefly to simultaneously close and break currents, and to give a standard interval of 100 σ (one-tenth second) for the regulation of the chronoscope. In two other directions, however, experiments have been begun with the instrument. Electric shocks are produced separated by (say) 10 σ. These shocks are applied to the nerve at varying distances from the brain, the earlier shock having farther to travel. When the shocks are felt simultaneously we have measured the time it takes to travel the distance between the two contacts. This method involves several psychological difficulties, but we hope to secure results supplementary to those given in this paper. In the second place the instrument has been used to uncover any object and register the instant at which this occurs. Thus a printed word may be covered by the screen and the screen be allowed to fall. The instant the word becomes visible a current is closed and the time recorded. Thus the time required to see the word, for the association of ideas, etc., may be measured. The special experiments now in progress consist of uncovering two

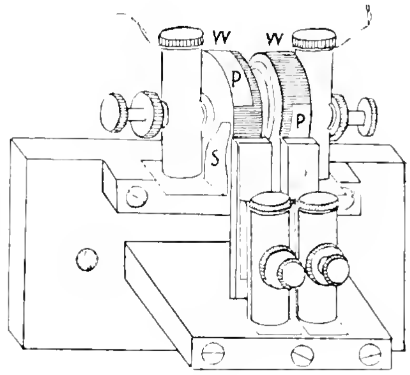

FIG. 4.

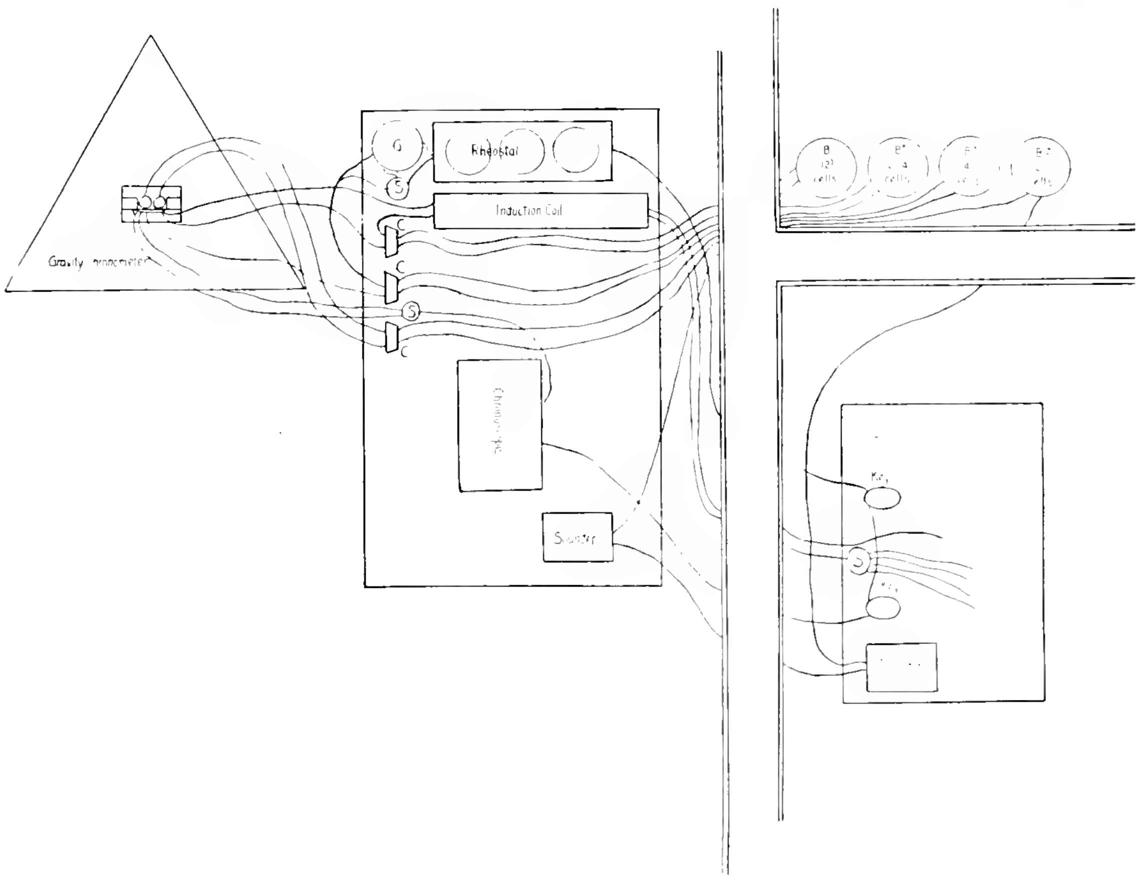

FIG. 5.

surfaces nearly alike in intensity and measuring the time required to perceive which is the brighter. The time becomes longer as the difference is taken less, and one mental quantity is thus determined as the function of another.

We may here confine ourselves to describing the method used to give a standard interval of time. A key which closes a contact was placed so that it was struck by the falling screen, and the contact closed at a given point, say when the screen had fallen 44.1 mm., or three-tenths second. A contact which broke the same circuit was placed so that it would be broken when the screen had fallen 78.4 mm., or four-tenths second. The circuit was consequently closed one-tenth second. The distances were calculated theoretically and controlled by means of a recording tuning fork.

When the chronoscope was being regulated and when the experiments were being made, the apparatus was arranged as shown in the figure. The current which controlled the chronoscope was from twenty-four large gravity cells in pairs, which were placed in a separate room. After the electro magnet had been rewound with coarser wire fewer cells sufficed. The wires were led from a battery, B', to a commutator, C, and thence the current passes through a rheostat, R, and could, when required, be sent by a switch, S, through a galvanometer, G. From the rheostat the current was led to a room in another part of the building in which the subject was placed. In this room the current passed through one or two sensitive telegraphic keys. From these keys the current was conducted to the chronoscope and thence to the contacts of the gravity chronometer and back to the commutator and battery.

When the chronoscope was being regulated the circuit was closed, excepting the upper circuit of the gravity chronoscope. The electric chronoscope was set in motion and the screen allowed to fall by breaking the separate current (from four gravity cells) B'', which supplied the electro-magnet. When the screen fell to the contact (C on fig. 3) it closed the circuit, and the hands of the electric chronoscope were set in motion. After the screen had fallen 100 σ farther it struck the lower contact (C' on fig. 3) and broke the circuit, and the hands were stopped. The time recorded by the hands would not usually be 100 σ, but a time perhaps 10 σ or even 50 σ longer or shorter. The strength of the current (or the tension of the spring in the chronoscope) was then adjusted until the chronoscope gave the correct time. The current from the battery being very constant, the variation from day to day was small, usually not more than 2 σ, but it might be considerable if a change in temperature occurred. Under the conditions present a change in time of 1 σ was caused by a change in resistance of about 5 ohms. The time was adjusted so that the chronoscope had a constant error of less than 1 σ. The average variable error of the chronoscope as controlled by the falling screen was usually less than 1 σ. Thus, in one trial (June 18, 1892) the average variable errors in seven series each containing ten measurements were 0.96, 0.8, 0.42, 0.4, 0.61, 0.64, and 0.56 σ. Occasionally, however (about once in ten trials), the time was about 7 σ too short. We were unable to discover the origin of this error, but it was probably due to an irregularity in the teeth of the wheel which caught up the hands of the chronoscope. This error would make all times given in this paper about 1 σ too short, and would increase the mean error of the series. As we are, however, concerned with a difference in times, the result would not be affected except by increasing the probable error to the amount shown in the tables.

The errors of the chronoscope are thus small. The variable error is practically eliminated in a series of one hundred experiments. The constant error of adjustment would not affect a difference in time when the processes were measured alternately and on the same day. The constant error in the rate at which the chronoscope runs would also be practically eliminated when a difference is taken. As a matter of fact, this error is very small. In a series of seven determinations it was one two-thousandth of the time. There is a theoretical error in the fact that the chronoscope is regulated for 100 σ, and in measuring longer times the current would magnetize the magnet more and the times given would be too long. The magnetism would, however, be nearly complete within 100 σ, and the times actually measured were always in the neighborhood of 100 σ. We had proposed measuring this error, if appreciable, but in the meanwhile this has been attempted in Germany[1] with entirely negative results. A very serious inconvenience in the chronoscope, as supplied by the makers, is found in the fact that the bar regulating the rate sometimes allows two vibrations between each tooth of the escapement, and the times recorded are only half of the true times. This error we have, however, nearly corrected, as described above; in any case it does not cause other than inconvenience, as the false rate is betrayed by the tone of the instrument.

[1] Külpe und Kirschmann, Philos. Stud., vii, 1892.

As shown in fig. 5, the subject was placed in a quiet room, where the sounds of the apparatus could not be heard. In the case of experiments with touch, this was not done, as no disturbance in the length or variation of the reaction could be noticed when the subject was in the same room, and this was more convenient. When the subject was in a separate room signals were made by Morse sounders, as shown in fig. 5.

In measuring reactions the circuit was closed, excepting in the instrument giving the stimulus. The instruments used for various kinds of stimuli will be described below. In all cases, the circuit was closed (either directly or by means of a secondary circuit) when the stimulus was given. The circuit was then broken by the subject lifting the hand (or foot) which held a telegraphic key closed. The difference in readings of the chronoscope would then give the time of the reaction.

In making a reaction the subject placed two fingers of his hand on the telegraphic key and awaited the stimulus, of whose intensity, point of application, etc., he was aware. The recorder gave an auditory signal about two seconds in advance of the stimulus. The recorder obtained this time by watching a seconds pendulum which swung before him. This interval allowed the subject to prepare for the stimulus, but was not so exactly constant that he was likely to react prematurely before its occurrence. When the stimulus occurred the subject lifted his hand as quickly as possible. He did not, however, use great efforts to be quick, as we have found that this makes the reactions more irregular without appreciably shortening the time. As stated above, the reaction is apparently reflex, the movement following the stimulus automatically. Greater attention can only place the centers in a state of more unstable equilibrium, and this is done before, not after, the occurrence of the stimulus. Owing to the reflex character of the reaction, its time is not greatly altered by the condition of the observer, the time of day, the number of reactions already made, or the amount of practice. These factors we shall consider in describing our results.

Usually ten reactions of the same sort were made in succession, the interval between the separate reactions being about twenty seconds. The kind of reaction was then altered, the series to be immediately compared being made alternately, and the order being reversed on different days. In some cases (which are noted in the tables) ten reactions were made in succession at intervals of about two seconds, and only the resultant time of the ten reactions recorded. This can in many cases be recommended as an improvement in method, as in a given time about five times as many reactions can be measured and calculated as when they are recorded singly.

We have in all cases made ten series of each sort of reactions, and this result of one hundred reactions is given in the tables. Our tables are consequently more condensed than is usual in this kind of work (the times of each separate reaction being often published), but all necessary information is given by the mean variation (or average variable error) of the separate experiments and of the separate series. The mean variation of a single measurement from the average of ten measurements made under the same conditions was (approximately) 8 σ for J and C and 12 σ for D. To find the probable error of each series by the method of mean squares would involve a needless amount of calculation. When, as in this case, sufficient measurements have been made, we may regard the probable error of a single measurement as proportional to the variable error of a single measurement (0.845:1), and the probable error of the average of one hundred measurements would be about one tenth of this—that is, about .68 σ for J and C and 1.01 σ for D. In cases where we are concerned with the difference in the times of two series the probable error would be increased by $\sqrt{2}$.

It is worthy of note, however, that in measuring reactions, and in many other kinds of measurements and statistics, the ordinary assumptions of the theory of probabilities do not hold. Thus, in the case of reactions, there is a certain minimum reaction whose negative departure from the average is not considerable, whereas the positive lengthening of the reaction may be much greater. The median reaction is consequently smaller than the average reaction. We hope on some future occasion to consider these relations in view of our experimental results.

The methods of adjusting observations developed in the physical sciences have not always been followed in psychological and physiological measurements. Thus in the case of reactions the more irregular times have usually been omitted, and in some cases this has been carried so far as to invalidate the results. We have omitted no times whatever which measured reactions. We thus always have ten reactions in a series and ten series in a set. We did, indeed, consider, in addition to the ordinary criteria which have been proposed for rejecting observations with large residuals, two methods adjusted to the present work. One of these was for the subject, after he had made a reaction, to judge whether or not it was normal, and to assign its weight. We found, however, that directing the attention to the reaction interfered with its reflex character, and that it was difficult to assign a weight. We did not, therefore, continue this plan. We also applied a method for rejecting the more discordant observations. In each series we made thirteen reactions, and rejected the time which departed most from the mean, then the time which departed most from the mean of the remaining twelve reactions, and finally the third most discordant time. We thus had the mean of the ten most accordant reactions, which would represent a compromise between the median and the mean. We did not, however, continue this method, owing to the considerable calculation involved and to the fact that the corrected mean departed very little from the mean of all the observations. It is evident, however, that a result would be reached more quickly if some objective method were adopted which would exclude observations which are not normal, and we hope at some future time to consider the result of applying various criteria to our actual experiments. In this paper and others previously published we have made over twenty-five thousand separate measurements of the times of physiological and mental processess, and have consequently ample material for studying methods for adjusting errors of observation.

PART II.—REACTIONS ON ELECTRICAL STIMULI.

An electric shock can be applied conveniently to different parts of the body. We used a Du Bois-Reymond induction coil (cf. fig. 5) and the shock following breaking of the primary circuit. By means of a double key (fig. 4) on the gravity chronometer (which was at first closed by the falling screen and later by hand) the primary circuit was broken and the current controlling the chronoscope simultaneously closed. We had supposed, from theoretical considerations, that the induced current might occur at a not inconsiderable interval after the breaking of the primary circuit, and that this would explain the fact that the times were longer for electrical stimuli than for touches. By the kindness of Dr. Scripture we tested this on a chronograph, but could discover no appreciable interval between the breaking of the primary circuit and the spark from the induced current.

Various electrodes were used to apply the shock to the skin. We used electrodes 5 cm. apart and electrodes (platinum surfaces 10 mm. in diameter) which could be adjusted on opposite sides of the limb. The method we found best was to apply one electrode (usually 10 mm. in diameter) to the skin at the point we wished to stimulate while the other was conducted to a pail of saturated salt water in which the left foot and leg were placed. Electrodes were applied to several parts of the body, and the current could be switched to any electrode (fig. 5). The stimulus was given ten times in succession at the same point and then switched to another point immediately and without shifting the electrodes. The shock was usually given on the left-hand side of the body, the reaction being made with the right hand or foot.

The sensory effects of electrical stimulation of the skin have not been properly investigated. While works on physiology and psychology (e. g. Hermann, Foster, Wundt) discuss in detail the effects of electrical stimulation on the organs of sight, hearing, taste, and smell, they are curiously silent as to the sensory effects of electrically stimulating the skin. These effects are varied and interesting, and deserve a more careful investigation than we were able to make. In the case of a galvanic current from twenty-eight gravity cells in pairs the sensory effects on *C* were as follows: When the current passed through the body to the foot in saline solution no sensation was felt in the foot. When the *positive* pole was applied to the dry skin of the arm no sensation occurred on making, breaking, or with continuous current. When the skin was moistened with saline solution a slight prickling was felt on closing, not perceptible afterwards nor on breaking. When the *negative* pole was applied to the moistened skin of the arm there was a slight sensation on closing, then after a brief latent period a sensation as of piercing and boring followed, which became very painful. The stimulation caused tetanus of the muscle and left blisters on the skin. When the *positive* pole of the same current was applied to the dry skin of the outside of the upper lip there was on closing a slight prickling sensation, a slight flash of light, and a slight metallic taste. When the lip was moistened these were all stronger, the prickling and taste continued while the current was closed, and there was a flash of light on breaking. When the *negative* pole was applied to the dry lip there was a very slight shock and flash of light and no perceptible taste, but sensations of piercing quickly followed, which were unendurably painful. When the electrodes were taken 5 mm. apart and applied on the arm or lip, there was a slight shock on closing, followed by prickling sensations, not very painful and without tetanus. The pain was at the negative pole. We wish especially to call attention to the fact that the current from the negative pole was more intense and from the positive pole more diffused (extending with considerable energy from the lip to the visual apparatus), which indicates that the current passes through the body from negative to positive pole, confirming certain physical observations.

We are not here further concerned with the galvanic current, having used a momentary induced current in our experiments. The breaking of the primary circuit causes a steeper wave and greater physiological shock than the making. Unless we are mistaken in the direction of the winding of the coils (we had proposed determining the direction of the induced current directly, but failed to do so), the breaking shock was strongest from the positive pole, and we used this pole to give the stimulus, the negative pole being conducted to the foot, where little or no sensation occurred. When, however, the shock was weak there was but little difference between the poles, and the negative pole might even give the stronger shock.[1]

The intensity and nature of the sensation varies according to the size of the electrode and the part of the body stimulated. The sensation is more piercing from a pointed or small electrode or when applied close to the nerve; it is more massive (as from a blow) when applied by a larger electrode or when there is muscle intervening. The sensation of a shock from eight cells on the upper arm might be equal to that from twenty-eight cells on the wrist. The shock from the same current also varied with the pressure of the electrode and especially with the moisture of the skin. Further, as the experiments proceeded, the part of the skin to which the shock was applied became continually more sensitive. These were the most perplexing factors in our experiments, as the difference in the time of the reaction might be due to differences in the cerebral reflex rather than to the distance traveled by the impulse. We tried to eliminate these complications by adjusting the intensity and area and by choosing points on the skin where the sensations were alike, and shall subjoin the results of our experiments. It was, however, this difficulty which led us to substitute a touch or blow for an electric shock, and we believe our experiments on touch are the more satisfactory, as we could measure the force of the blow, whereas we could not measure the physiological effect of an electric shock.

In our first experiments we chose four points on the skin for the application of the stimulus. These were permanently fixed by pricking the skin and introducing nitrate of silver. Two of the points were on the arm over the median nerve and two on the leg over the posterior tibial nerve. The points on the arm *B* and *D* are shown in the cut; they were 30 cm. apart, and the length of

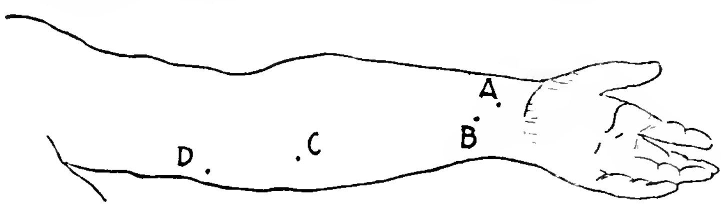

FIG. 6.

the intervening nerve would be nearly the same. The corresponding points on the leg *M* and *N* were 50 cm. apart. The same objective current did not call up the same sensation on the several points. The shock was more massive and stronger at the upper points, and was followed by contractions of the muscles. It was rather stronger on the arm than on the leg. Five hundred reactions with the hand to stimulation of each of these points and five hundred reactions with

[1] We are not in this place especially concerned with the muscular contraction directly following on electrical stimulation of the skin. Motor points have been mapped out on the skin, the stimulation of which is followed by the contraction of special muscles. These are considered in work on the application of electricity to medicine. We have made some observations on this matter, especially on the effects of successive stimuli, but they are not sufficiently systematic for publication.

the right foot to *A* and *M* were made by two observers, D and C. The reactions were made in series of ten, the order of the series being altered each day. The results of the sets of one hundred reactions, together with the mean variations of the ten series which made up the set, are given in the first part of the accompanying table. In the second part of the table are given the differences obtained by comparing the times for the several points of application of the stimulus and the two movements. Following the table are some further explanations, which to a certain extent apply to all the tables.

TABLE 1.—*Reaction-times on electrical stimulation on four points of the body. Movement with hand and with foot. D and C observers. 6,360 reactions.*

	Movement with hand.								With foot			
	Upper arm.		Lower arm		Upper leg		Lower leg.		Lower arm.		Lower leg	
D	131.3	*13.7*	132	*10.9*	140.8	*13.2*	143.1	*12.1*	157.3	*11.2*	170.1	*16.3*
	166	*9*	189	*11.2*	197	*14.1*	215.7	*21.2*	226.2	*12.5*	248.1	*18.3*
	153.4	*5.2*	167.8	*7.1*	179.3	*7.6*	201.3	*10.1*	208.5	*4.9*	221.6	*10.4*
	148.4	*5.6*	160.3	*5.9*	176.8	*5*	197.6	*5.8*	206.3	*6.6*	230.3	*5.6*
	149.1	*4.9*	170	*4.6*	179.3	*3.8*	196	*6.8*	209.2	*4.7*	232	*7*
Av. . .	**149.6**	*7.7*	**163.8**	*7.9*	**174.6**	*8.8*	**190.7**	*11.2*	**201.5**	*12.6*	**220.4**	*11.*
C	110.4	*5.8*	115.5	*8.5*	127.5	*6.2*	125.6	*8.2*	161.4	*7.5*	166.2	*8.1*
	108.7	*2.1*	116.4	*1.9*	139.7	*3.2*	150.4	*4.7*	162.9	*3.9*	163.6	*12.2*
	109.6	*1.5*	115.8	*4.8*	139.2	*5.1*	149.6	*5.4*	173.7	*8.4*	212.9	*8.2*
	120	*2.5*	128.4	*5.2*	143.2	*4.6*	154.5	*6.5*	190.3	*7*	215	*9.8*
	116.7	*3.2*	120.1	*1.7*	148.7	*3.5*	156.6	*8.2*	179.7	*4.2*	203.8	*5.3*
Av. . . .	**113.1**	*3.1*	**119.2**	*5*	**139.7**	*4.7*	**147.3**	*6.6*	**173.6**	*6.6*	**192.3**	*8.7*

		I.	II	III.	IV.	V.	Av.	Av. Av.
D	Lower arm less upper arm	0.7	23	14.4	11.9	20.9	**14.2**	**15.1**
	Lower leg less upper leg	2.3	18.7	22	20.8	16.7	**16.1**	
	Upper leg less upper arm	9.5	31	25.9	28.4	30.2	**25**	**23.6**
	Lower leg less lower arm	11.1	26.7	33.5	37.3	26	**26.9**	
	Lower leg (foot) less lower arm (foot)	12.8	21.9	13.1	24	22.8	**18.9**	
	Lower arm (foot) less lower leg	25.3	37.2	40.7	46	39.2	**37.7**	**33.7**
	Lower leg (foot) less lower leg.	27	32.4	20.3	32.7	36	**29.7**	
C	Lower arm less upper arm . . .	5.1	7.7	6.2	8.4	3.4	**6.1**	**6.9**
	Lower leg less upper leg.	—1.9	10.7	10.4	11.3	7.9	**7.7**	
	Upper leg less upper arm	17.1	31	29.6	23.2	32	**26.6**	**24.5**
	Lower leg less lower arm	10.1	34	33.8	26.1	36.5	**28.1**	
	Lower leg (foot) less lower arm (foot)	4.8	.7	39.2	24.7	24.1	**18.7**	
	Lower arm (foot) less lower arm.	45.9	46.5	57.9	61.9	59.6	**54.4**	**49.7**
	Lower leg (foot) less lower leg.	40.6	13.2	63.3	60.5	47.2	**45**	

The first set of 1,560 experiments was made in the winter of 1890. The experiments were then interrupted, owing to change of residence, until the summer of 1892.

In the first set 13 reactions were made in a series, and each time in the table is the average of 130 reactions. In the remaining sets and in the following table each time is the average of 100 reactions. In the first set on C and in all the sets on D the reactions were measured singly. In the last four sets on C, 10 reactions were made in succession, and only the resultant time recorded. In several cases, owing to inadvertence or the occurrence of times which could not be reaction-times, there was one reaction too few in a series. Premature reactions scarcely ever occurred, not once in 100 reactions. In the first set the electrodes were 5 mm. apart. In the remaining sets the electrodes were on opposite sides of the limb for D. In the case of C, one pole was conducted through salt water to the left foot.

The time is given in thousandths of a second. After the time of reaction the mean variation of the separate series from the average time of the 10 series is given in *italics*. This multiplied by 0.845 and divided by $\sqrt{10}$ would give approximately the probable error of the average of 100 experiments.

This table contains the result of more reactions than have been published in the many researches hitherto made on the subject. The probable error of a single experiment is also much smaller. When the probable error of each measurement is five times as great as in these experiments, as has often been the case, it is evidently necessary to make twenty-five times as many measurements in order to secure a result equally valid. We consequently believe that these experiments supersede those hitherto made.

We find that the reaction-time for an electric stimulus applied to the upper arm was 149.6 σ for D and 113.1 σ for C, about one-seventh and one ninth second, respectively. The cause of this personal difference remains obscure. It must either be due to differences in the nature of the process or to differences in the sensitiveness of the parts of the nervous system concerned. The maximum and minimum times in the sets differed by 34.7 σ for D, and by 11.5 σ for C. The differences are not due to the variable error, but to real differences in the condition of the nervous system. These are obscure, but the longer times in the case of D were obtained at a time when the nervous system was in a less efficient condition.

When the stimulus was applied on the lower arm or on the leg the reaction-time was longer. The excess of time when it was applied on the lower arm was 14.2 σ for D and 6.1 σ for C. The maximum and minimum times differed by 22.3 σ for D and 5 σ for C. These considerable differences are not due to the variable error, but to real differences in the process. The lower point was 30 cm. farther from the brain than the upper point, and if we can assume the difference in time to be due to the difference in the length of the nerve traveled, we shall have a velocity of the impulse in the median nerve of 21.1 meters per second for D and 49.5 meters per second for C. The velocities in the sensory fibers of the posterior tibial nerve would be for D 31.1 meters per second and for C 64.9 meters per second. These times would come within the limits of those obtained by others, but we are not prepared to accept them as valid. The differences in the times of reaction are undoubtedly correct, and with a very small probable error. The variable error of reactions has been eliminated, and the times give the reaction-times on objectively equal stimuli applied to the four points. But in the first place it does not seem likely that the velocity of the nervous impulse in the plain nerve should differ so greatly in the two observers. We can understand that the entire complex process of reaction might be 25 per cent longer in one case, as this may be due to less complete coordination in the brain centers, but there seems to be no reason why the velocity in the plain nerve should be 140 per cent slower. This would require us to conclude that the central reflex was actually shorter in the case of D. In the second place the probable error in the case of the velocity of the impulse is far greater than it should be from the variations in the reactions.

We are consequently compelled to conclude that the differences in the reaction-times are due to differences in the cerebral processes, and not merely to the length of the nerve traveled. The times for the points nearer the brain may be shorter because the physiological effects of the shock were greater (as was in fact the case) or because the fibers from the upper points lead to a more rapid transference in the brain. The difference in the two observers and in the same observer at different times are not due to variation in the velocity of the nervous impulse, but to differences in the nature of the cerebral reflex. For example, C's reaction-time being shorter and more regular than D's, we may conclude that it is more automatic and less influenced by changing conditions. The greater intensity and massiveness of the shock on the upper points would consequently shorten the reaction-time less for C than for D, and the results in the table are thus explained. This would also explain the larger variation in the sets in the case of D. This variation may be partly attributed to differences in the relative effect of the shock on the two points at different times, and may be partly due to cerebral changes. These considerations led to further experiments by which they were fully confirmed.

When the shock was applied to the leg in one case and to the arm in the other the impulse in the former case had in addition to travel through the spinal cord from the lumbar to the brachial plexus and the times are considerably longer. The difference in reaction-time with the hand when the shock was applied to the upper leg and upper arm, respectively, was for D 25 σ for C 26.6 σ. When the shock was applied to the lower leg and arm, respectively, the differences were for D 26.9 σ, and for C 28.1 σ. These times agree very well, better, perhaps, than the probable error would warrant; but in this case the probable error is a comparatively small part of the whole time, and the difference is undoubtedly due to the different point of application. It remains an open question whether the cerebral reflex might not be shorter when the stimulus is applied to the arm, in which case the times would not measure the velocity in the sensory tracts of the spinal cord. Indeed, this seems to be proved by the fifth line in the table, which gives the difference in time when the movement was made with the foot and the stimulus applied to the lower leg and lower arm, respectively. In this case the difference in time (with a rather large probable error for C) was for D 18.9 σ, for C 18.7 σ. The excess of distance in the spinal cord was the same as before, but the times are about 8 σ shorter. We are enabled, consequently, to draw the interesting conclusion that when the stimulus is applied to the left arm the cerebral reflex is 8 σ shorter when the movement is made with the arm than when made with the leg and conversely. The sensory fibers from one part of the body are most closely connected with the motor fibers to the same part.

We conclude, with some confidence, that when a stimulus is applied so that the impulse must traverse the spinal cord and from the lumbar to the brachial plexus the time of reaction is about 26 σ longer when the movement is made with the hand and about 18 σ longer when the movement is made with the foot. The difference in the two cases is due to greater rapidity of the central reflex owing to closer connection in the brain between sensory and motor fibers from the same part of the body. If the whole excess of time in the case compared be due to transmission in the cord we should have a velocity of about 15 meters per second in the sensory tracts of the spinal cord. The velocity is at least not less than this.

There remains for consideration the difference in the time of reaction when the movement is made with the hand and foot, respectively. When the stimulus was applied to the lower arm the difference was for D 37.7 σ and for C 51.4 σ; when the stimulus was applied to the lower leg the difference was for D 29.7 σ and for C 45 σ. The difference was less (D 8 σ and C 9.4 σ) when the stimulus was applied to the leg, and by almost exactly the same amount as before. We have evidently measured the difference in time of the cerebral reflex when the motor impulse proceeds to the part of the body from which the sensory impulse arrives, and when it proceeds to a different part. The differences in the times when the reaction is made with hand and foot are partly due to the time required to traverse the motor tracts of the spinal cord, but they may also be due to differences in the cerebral processes. The cerebral reflex is undoubtedly less perfect for the foot than for the hand. The difference in the case of the two observers (16.3 σ greater for C) is almost certainly a difference in the cerebral process. C's reaction with the hand is very automatic; with the foot it is more nearly like D's. How much of the delay is due to traversing the motor tracts between the brachial and lumbar plexus can not be decided. If the whole time in the case of D were so consumed (ignoring the difference in the plain nerve) the velocity of transmission would be about 10 meters per second, and this is at least a minimum velocity. In so far as we can accept these results the velocity in the sensory tracts of the cord would be greater than in the motor tracts. This difference in velocity might be explained by the partial coordination of the movement in the cord. The difference, however, may be equally well attributed to the delay of coordination in the brain centers.

In view of the fact that the velocity in the sensory nerve had not been determined in a satisfactory manner, owing partly to the varying physiological effects of the shock on the points stimulated, we sought for a point on the lower arm for which the sensation should be as nearly as possible the same as on the point D of the upper arm. The best place we could find was a point 3 cm. below B and a little on the side of the line of the median nerve, as shown in fig. 6, the point being marked A. The stimulation of this point was followed by a strong contraction of the thumb and a massive sensation similar to that following the stimulation of the point D. We also chose a point, C (fig. 6), on the line of the median nerve, the stimulation of which was followed by a sensation similar in quality to that from the point B. This point was 20 cm. above B and 10 cm. below D. In Table II are given the reaction-times when the points A and B were alternately stimulated; also reactions in which the current was from electrodes 5 mm. apart, when on opposite sides of the limb, and when it passed through the body to the foot.

TABLE II.—*Reaction times on electrical stimulation. D and J observers. [illegible] reactions.*

C	Current through arm	On A	142.3	*4.9*	On B	143.2	*4*
	do	do	120.2	*5.2*	do	127.5	[illegible]
Av.			**131.3**	*5*		**135.4**	[illegible]
J	Current through arm	On A	119	[illegible]	On B	121	*1*
C	Electrodes 5 millimeters apart	do	120.7	*1.2*	do	125.7	[illegible]
	do	do	121.6	*4*	do	132.9	[illegible]
	do	do	117.7	*4*	do	130.3	[illegible]
Av.			**120**	[illegible]		**129.6**	[illegible]
J	Electrodes 5 millimeters apart	On A	137.8	[illegible]	On B	141.5	[illegible]
C	do	do	121.6	*5*	Through arm (at A)	120	[illegible]
	do	On B	122.4	[illegible]	Through arm (at B)	118.1	[illegible]
	do	On A	116.7	....	On D	117	....
C	do	do	122.7	[illegible]	On D (5 ohms resistance)	125	[illegible]

The total time of ten reactions was measured, excepting in the first, second, third, and eighth sets, in which the reactions were measured singly. In these sets the mean variation of the single reactions from the series to which they belong was for J, 9.7 σ; C, 8.7 σ.

The experiments do not discover any marked difference in the time of reaction when the shock was applied to the skin by electrodes 5 mm. apart, when the electrodes were on opposite sides of the limb, and when the current was conducted through the body to the foot. In the two sets in which the differences were directly compared the times were 1.6 σ and 1.3 σ shorter when the current passed through the limb than when it was applied simply to the skin. The sensation is more *intense* when the shock is applied through electrodes close together, and more *massive* when they are farther apart. This is a psychological distinction of some importance. One sensation would be greater than another either because it is more intense, the same nervous elements being more actively stimulated, or more massive, more nervous elements being stimulated. When the points A and B were stimulated—A being slightly the more distant from the brain—the reaction-time on A was the shorter, the differences being, for C, 0.9, 7.3, 5, 11.3, 12.6, 0.8, and −1.9 σ; for J, 2 and 3.7 σ; on the average, 4.6 σ. The shorter time for the point D is due to the greater massiveness of the shock or the different nerve supply and cerebral connections. It is, consequently, evident that the reaction-time from the same physical stimulus applied to different points on the skin does not of necessity measure the velocity of the impulse in the plain nerve. When the shock was applied on A and D, at which points the quality of the shock was nearly the same, the times were nearly alike—116.7 σ and 117 σ—and when 5 ohms resistance was placed in the current giving the shock on D (in order to make the intensities the same) the times were A 122.7 σ, and D 125 σ.

The experiments given in Table II were preliminary to a more thorough investigation of the variation in the reaction-time according to the point to which the stimulus was applied and its intensity. We took the four points in the arm marked (in fig. 7) A, B, C, and D, and made a large number of reactions on each of these points, the physical stimulus being always the same. As already stated, the sensation was not the same either in intensity or quality. The quality of sensation was much alike for A and D, massive as from a blow, and for C and B more piercing. This difference is accounted for by the intervening muscle in the case of A and D and the muscular contractions which followed stimulation of these points. The intensity of sensation was not, however, alike for A and D and for B and C, respectively. A further and unexpected complication occurred, the relative intensities not being the same for the two observers who took part in the experiments. In the case of C the order of intensity was D, A, C, B, the differences between D and A and between C and B being large. A and C were nearly alike in intensity, but the difference in quality made it difficult to compare the intensities. The shock from eight cells in pairs on D was nearly the same as from twenty-eight cells on A; that from fourteen cells on A or C was nearly the same as from twenty-eight cells on B. In the case of J the order of intensity was A, D, B, C, but the differences were not large and seemed to vary from time to time. The results of these experiments are given on Table III.

TABLE III.—*Electric stimulation; points A, B, C, and D. J and C observers. 2,400 reactions.*

	A.		B.		C.		D.		Av.	
J	115.7	[illegible]	123.5	[illegible]	131	[illegible]	123.8	[illegible]	**128.5**	[illegible]
	124.3	[illegible]	122.8	[illegible]	137.3	[illegible]	128.5	[illegible]	**128.2**	[illegible]
	124.8	[illegible]	127.1	[illegible]	137.8	[illegible]	132.2	6.1	**130.5**	[illegible]
Av	**121.6**	[illegible]	**124.5**	[illegible]	**135.4**	[illegible]	**128.2**	[illegible]	**127.4**	[illegible]
C	125.8	[illegible]	134.3	[illegible]	128.9	[illegible]	116.6	[illegible]	**125.9**	[illegible]
	127.2	[illegible]	138.5	[illegible]	131.6	[illegible]	123.3	[illegible]	**130.1**	[illegible]
	124.7	[illegible]	138.1	6.6	131.8	[illegible]	121.1	[illegible]	**128.9**	4.5
Av	**125.2**	[illegible]	**137**	5.6	**130.8**	[illegible]	**120.3**	[illegible]	**128.3**	4
Av., Av	**123.4**	4.6	**130.7**	5.9	**133.1**	[illegible]	**124.2**	[illegible]	**127.8**	5.1

The averages of all the times for the two observers were almost exactly the same—127.4 σ for J and 128.3 σ for C. The departures from the average for the different points consequently represent real differences in the nature of the process. These are for J on A $-$ 5.8 σ B, $-$ 2.9 σ; D + 0.8 σ and C + 8 σ; for C on D, $-$ 8 σ A $-$ 3.1 σ; C + 2.5 σ and B + 8.7 σ. The reaction-times are without exception inversely proportional to the intensity of the sensation. It is consequently impossible to draw any conclusion from the experiments concerning the velocity of the nervous impulse in the sensory nerve.

In order to accomplish this it would at all events be necessary to make the sensations subjectively alike in intensity, or to make a correction for intensity. In order to study the relation between reaction time and intensity we made reactions on the four points on the arm with three intensities of shock. The strongest was nearly the same as in the preceding experiments, but a little stronger so as to be somewhat painful for J. The weakest was barely perceptible for C on the point B. The same physical stimulus produced much greater physiological effects on J than on C. The middle intensity was intended to be midway between the strongest and weakest, but after the experiments had been made it was thought to have been too weak. In Table IV the results are given of one hundred reactions on each of the four points and with each of the three intensities.

TABLE IV.—*Electric stimulation; strong, medium, and weak shocks. Points A, B, C, and D. J and C observers. 2,400 reactions.*

		A.		B.		C.		D.		Av.	
J	Strong	108.8	5	111.2	4.1	116.9	[illegible]	108.6	5	**111.4**	4.9
	Medium	122.6	[illegible]	127.4	6.1	131.3	4.4	118.5	[illegible]	**124.4**	[illegible]
	Weak	126.8	8.1	130.9	9.1	143.5	[illegible]	126.1	5.6	**131.8**	[illegible]
Av		**119.4**	6	**122.5**	6.4	**130.6**	[illegible]	**117.7**	6	**122.5**	5.8
C	Strong	125.3	5	132	5.9	127.5	4	123	4.4	**126.4**	4.8
	Medium	141.4	11.6	171.2	8.6	149.2	6.8	145.8	6.6	**152.6**	8.4
	Weak	151.4	[illegible]	186.2	5.8	166.9	4.9	156.7	8.5	**165.3**	7.1
Av		**140.1**	8.6	**163.1**	6.8	**147.9**	[illegible]	**141.2**	6.5	**148.1**	6.8
Av. av		**129.9**	7.3	**142.8**	6.6	**139.2**	5.1	**129.1**	[illegible]	**135.3**	6.3

The table shows that the reaction-time was shorter when the shock was stronger. The decrease in time, when the intensity was increased from weak to medium, was for J 7.4 σ, for C 12.7 σ; from medium to strong, for J 13 σ and for C 26.2 σ. The difference in the case of the two observers is due to the fact that the subjective differences were greater for C, in whose case the weakest shock was barely perceptible on B. The difference in the time of reaction for C, when the shock was barely perceptible (on B) and when it was very strong (on D), was 65.2 σ. The average times were nearly the same on A and D, for J 1.7 σ shorter on D, for C 0.8 σ longer. The shock seemed stronger on D. We must consequently conclude that the time of transmission in the nerve from A to D is counterbalanced by a shorter central time in the case of A, and that this shorter central time is not due to difference in intensity, but to difference in the distribution of fibers in the brain. As in the case of impulses from the arm and leg, we may here conclude that impulses from near the left hand lead more readily to a movement of the right hand than do impulses from the upper arm. This fact is itself interesting, but makes the determination of the velocity in the plain nerve by this method difficult or impossible.

In addition to these experiments on intensity we made reactions, in which the area of stimulation was altered. The sensation from a larger area is more massive, from a smaller area more piercing. It is consequently possible to make sensations from different parts of the body qualitatively more equal by using a smaller electrode on a point where the sensation is more massive, owing to anatomical structure. The small electrode was 1 mm., the large electrode 10 mm. in diameter, the area being consequently one hundred times as great in the case of the larger area. The electrodes were applied on the points A and D.

TABLE V.—*Electric stimulation: large and small areas. J and C observers. 800 reactions.*

	Large.				Small			
	A.		D.		A.		D.	
J	117.6	*4.8*	120	*5.9*	114.3	*6.1*	123.6	*6.2*
C	121.3	*4.4*	121.4	*3*	130.8	*5.1*	123.4	*2.4*

For J the time was 0.1 σ shorter with the large area, for C 5.7 σ shorter. The difference in the case of the two observers is due to the fact that for J the small area on A was the strongest and most painful of the four shocks, whereas for C it was the weakest. Owing to the same fact, for J the time was 5.8 σ shorter on A, for C it was 3.5 σ longer.

It is evident that if the velocity of the impulse is to be measured by the difference in the reaction times, points on the skin should be chosen in which the sensations are as nearly as possible alike, and the intensity and area of the shocks should be adjusted to make the sensations, so far as possible, exactly alike. We did not proceed with such experiments, however, partly because it did not seem possible to allow for the difference in time of the cerebral reflex due to the place of stimulation and partly because we found that better results could be obtained from mechanical touches or blows. Before going on, however, to describe our experiments on touch, we shall notice some experiments, chiefly on electrical stimulation, which we made with a view to studying the effects of attention directed to the point stimulated and the effects of the nature of the movement.

Experiments have recently been published in Germany[1] which gave a much longer reaction time when the attention was directed to the stimulus than when it was directed to the movement, and Wundt holds that in the former case the time is longer because the stimulus must be perceived before the movement is made. This might prove a complication in our experiments, as when the shock was shifted from place to place the attention would be naturally directed to it, more especially as it was somewhat painful. We made, consequently, reactions in which the attention was directed alternately to the stimulus and the movement, and used sounds as well as electrical shocks. The sound was a tolerably loud noise made by the single click of a Morse sounder, a strong current being used.

TABLE VI.—*Motor and sensory reactions on electrical stimulation and sound. C, J, and D observers. 1,000 reactions.*

		Motor reactions.			Sensory reactions		
C	Electrical stimulation	142.7	*10.1*	*(4.6)*	142.8	*8.1*	*(4.6)*
J	.... do	119	*9.1*	*(3.8)*	121.5	*10.1*	*(3.4)*
D	.... do	281.4	*58.3*	*(17.1)*	201.6	*31.2*	*(11.5)*
C	Sound	105.9	*6.9*	*(3.9)*	105.4	*5.9*	*(3.[illegible])*
J	.... do	105.5	*12.2*	*(3.7)*	105	*7.7*	*(2.9)*

[1] By Lange, Münsterberg, Martius, Külpe, and Titchener.

It follows that the length and variability of the reaction-time is the same for J and C, whether the attention be directed to the stimulus or to the movement. In the case of D the time was considerably lengthened when the attention was directed to the movement, he being in the habit of directing his attention to the stimulus. The shorter and more regular reactions of J and C are due to the process being more completely reflex, and in this case, as we might expect, the direction of the attention does not alter the times. But it seems that when the reaction is not completely reflex it may be lengthened by an unusual direction of the attention. Thus D is used to attending to biological details, whereas the observers in Germany may have their mental processes more exclusively accompanied by motor impulses.[1]

We next give some experiments in which the nature of the movement was varied. In one set the stimulus was applied alternately to the left and right hands, the reaction being made with the right hand.[2] The electrodes were introduced into the knob of the key and the shock applied to the first and second fingers. In this case only one battery was used, the current being divided and passing partly through the induction coil and partly through the chronoscope. Owing to the high resistance in the chronoscope nearly all the current passed through the induction coil. When the current passing through the coil was broken the shock was given, and all the current was simultaneously sent to the electro-magnet of the chronoscope and the hands started. This method is convenient, as only one battery is required and the current is sent through the chronoscope at exactly the instant in which the primary circuit of the induction coil is broken. In one set the reactions were made at intervals of about twenty seconds, and measured singly: in the other set they were made in series of ten seconds, the reactions being made at intervals of two seconds, and only the resultant time of ten reactions measured.

TABLE VII.—*Electrical stimulus on left and on reacting hand. C and J observers. 800 reactions.*

		Shock on left hand			Shock on right (reacting) hand.		
C . . .	Readings singly	112.8	*6.5*	(3.5)	97	*5.3*	(2.7)
	Readings in tens	121.4	. . .	(2.1)	118.3	. .	(5.8)
J	Readings singly	128.9	*6.2*	(4.4)	106.6	*5.2*	(3.2)
	Readings in tens	118.5	. . .	[illegible]	98.5	. . .	(3.3)

The reaction-time was shorter (for J 21.1 σ, for C 9.4 σ) when the movement was made with the hand to which the shock was applied. This might be expected, as the movement is a natural reflex—a person will without reflection withdraw the hand when it touches a hot surface. The fact is of interest in connection with the results noticed above, which show that the cerebral reflex is in general quicker when the sensory fibers stimulated are from the same part of the body as that with which the movement is made. The table further shows that J made the reactions more quickly when ten were made in succession, whereas C made them more quickly when they were made singly. This would have a bearing on the relative times of the two observers in the other tables, but the experiments were not sufficient in number to determine the exact difference.

We give, lastly, reactions on sound in which the key was released by a movement made, respectively, with the finger, the wrist, the forearm, and the shoulder.

TABLE VIII.—*Reactions on sound; movement with finger, wrist, forearm, and shoulder. J and C observers. 800 reactions.*

	Finger.		Wrist.		Forearm.		Shoulder.	
J	121	*14.6* (5.7)	117.1	*11.9* (7)	130	*12.7* (6)	138.7	*15.4* (7.8)
C	114.4	*9.9* (4.5)	118.6	*9.3* (3.2)	117.2	*7.9* (1.8)	134.2	*10.5* (4.2)

The times show that the reactions were slower when the movement was made from the shoulder, although the muscles concerned are nearer the brain. In the case of J it was also slower with the forearm. The movement with the finger and wrist seems to require about the same time.

[1] Results similar to ours have been simultaneously obtained by Dessoir, Flournoy, and Baldwin.

[2] Cf. Exner, Dumreicher and Reigart.

This shows that when the reaction is made with the foot the delay may be partly due to a more difficult coordination in the higher centers. In earlier experiments made by one of us it was also found that a time about 30 σ longer was required to make a movement with the organs of speech than with the hand. The reaction time seems, however, to be the same for the right and left hands. Thus, for *C* the reaction-time on light was 146 σ with the right hand, and 147 σ with the left hand.

PART III.—REACTIONS ON TOUCH.

In the case of reaction experiments with dermal stimuli the electric shock has mostly been used, as it is easy to apply the shock to different parts of the body. We have, however, seen that the physiological effects of the shock vary greatly on different parts of the body, and even at the same point they can not be kept constant. The reaction-time following a touch or blow can be measured without difficulty beyond the inconvenience of applying the blow to different parts of the body. We have found that the same objective force of blow is followed by the same subjective sensation more nearly than in the case of electric stimulation. On different parts of the body the same blow, indeed, calls forth different sensations, the sensations being more intense when the part is harder, as over a bone. But the difference is not so great as in the case of the electric shock, and at the same point the same sensation can be given time after time and day after day. The probable error is consequently smaller than in the case of electric shock; indeed, the variable error in our experiments on touch is much smaller than in any reaction-time experiments hitherto published. We have, for example, measured ten successive reaction times, as follows: 102, 102, 100, 100, 100, 100, 100, 100, 101, 100 σ. We have in this series a mean variation or variable error of 0.7 σ, which of course includes the error of the apparatus, with which readings are only made to thousandths of a second. Such experiments certainly demonstrate great constancy in complex physiological processes, the variable error comparing favorably with that of many physical measurements.

We used three methods for applying the blow, the last of which was much the best. We shall, however, describe briefly our earlier experiments, as the methods might prove useful in clinical work when the greatest accuracy is not necessary. In our first experiments we tied telegraphic keys to the limb. These were adjusted so that a surface about 10 mm. across touched the spot. When the arm of the key was hit with a hammer the circuit was broken, and at the same time the knob was forced against the skin. In this case a contact was broken, not closed, and the chronoscope was started by means of a secondary circuit. The current could pass either through the contact of the key or the coils of the electro-magnet of the chronoscope. As the resistance in the chronoscope is great, the current would pass almost exclusively through the key, but when the contact at the key was broken the current would go to the chronoscope and start the hands. In this case a secondary current must also be used in regulating the chronoscope by means of the gravity chronometer.

The keys were applied on the lower and upper arm at the points *A* and *D*, and three intensities were used—a gentle pressure, a medium blow, and a hard blow. The gentle pressure was barely perceptible, as the surface was always in contact with the skin. The results of 2,400 reactions, ten being made in succession at intervals of two seconds, are given in Table IX.

TABLE IX.—*Pressure strong, medium, and weak. Points A and D. J and C observers. 2,400 reactions.*

		First set				Second set.				Av	
		A.		D.		A.		D.			
J	Strong	114.9	[illegible]	106.2	4.8	120.5	[illegible]	109.9	[illegible]	**112.9**	[illegible]
	Medium	121.2	[illegible]	116.3	[illegible]	121.7	[illegible]	119.8	4.1	**119.7**	[illegible]
	Weak	152.5	[illegible]	139.6	[illegible]	161.9	[illegible]	148.7	[illegible]	**150.7**	[illegible]
	Av	**129.5**	[illegible]	**120.7**	[illegible]	**134.7**	[illegible]	**126.1**	[illegible]	**127.8**	[illegible]
C	Strong	110.6	[illegible]	105.7	[illegible]	118.3	[illegible]	112.5	[illegible]	**111.8**	[illegible]
	Medium	109.9	[illegible]	114.9	[illegible]	117.8	[illegible]	116.6	[illegible]	**114.8**	[illegible]
	Weak	145.8	[illegible]	142.7	[illegible]	173.1	[illegible]	141.1	[illegible]	**145.7**	[illegible]
	Av	**122.1**	[illegible]	**121.1**	[illegible]	**129.7**	[illegible]	**123.1**	[illegible]	**124.1**	[illegible]
	Av., Av	**125.8**	[illegible]	**120.9**	[illegible]	**132.2**	[illegible]	**124.7**	[illegible]	**125.9**	[illegible]

It is evident that the reactions on the weakest pressures are long, the sensation being near the threshold. In this case the reaction is always long, as the brain centers can not be held in a state of unstable equilibrium, lest the motor impulses be [1 σ] prematurely discharged. The time was for J 6.8 σ, and for C 3 σ, shorter for a strong blow than for a medium blow. The strong blow was just less than painful, but the intensities could not be measured, nor were the blows exactly constant. The differences in time for D and A were fairly constant, being shorter for the point nearer the brain. In the two sets the differences were for J 8.8 σ and 8.6 σ, and for C 1 σ and 6.3 σ; but in view of our other experiments, and for reasons already given, we can not regard these differences as the time of transmission in the median nerve.

In order to keep the force of the blow constant and to avoid a continual pressure on the point of application we devised a second method, which can be recommended for anthropmetric and clinical work. We placed thin tin foil over the part of the limb to be stimulated, and this was connected with one wire of the circuit. Then we allowed a hammer to fall on the tin foil. The surface of the hammer which struck the foil was 10 mm. across, and was connected with the other wire of the circuit. Consequently when the hammer struck the foil the blow was given and the circuit closed. The hammer swung in points and fell from a height of 15 cm., the blow thus being constant. The arm was held in position by being placed in a wooden case, and the blow applied to the back or outside of the arm on points E and F, nearly opposite the points B and D. The back of the arm was used because it could be struck by the hammer when placed in an unstrained position.

TABLE X.—*Reaction-times on blows. J and C observers. 800 reactions.*

	E		F			E		F.	
J.....	120.1	*6.9*	126.5	*5.9*	C.....	104.9	*4*	121.3	*6.8*
	112.5	*4.5*	119.3	*4.7*		113.6	*4.8*	128	*4.9*
Av..	**116.3**	*5.7*	**122.9**	*5.3*	Av...	**109.2**	*4.4*	**121.6**	*5.8*

In these experiments the reaction-time was shorter (for J 6.6 σ, for C 15.4 σ) when the blow was applied nearer the wrist than when it was applied to the upper arm, exactly the opposite of what was found on the opposite side of the arm. The shorter reaction-time with the lower point was due to the fact that the blow was given over the bone, and was much stronger than when the same blow was given in the muscle of the upper arm.

In order to avoid the tin foil over the skin and the rebound (which would break the circuit) we devised a hammer which worked in a very satisfactory manner. In its final form the instrument is shown in fig. 7.

The hammer swings in points, and is held up by the electro-magnet *M*. This magnet can be placed at any height, and the velocity of the blow can thus be altered. In our experiments the hammer fell a perpendicular distance of 20 cm. The area of the surface giving the blow can also be altered, but in our experiments it was always circular, 10 mm. across, the edge being slightly rounded. The arm of the hammer (25 cm. in length from the points to the center of the area with which the blow was given) is a very light aluminium tube, and the weight is almost exclusively in the hammer at the point where the blow is given. The weight of the hammer can be adjusted by means of weights which are screwed on the tip. In our experiments the weights (the hammer being in its points) were 15, 30, and 60 grams, and the force of blow was proportional to these weights. Sixty grams falling 20 cm. gave a sensation which was just short of painful when the blow was on a part of the body in which the skin is close to the bone.[1]

The current was closed when the blow was given by means of the contact shown in the figure. A small platinum spring makes the contact at almost exactly the instant the blow is given, and the current remains closed until the larger spring is released.

With this hammer we gave stimuli on various parts of the body and measured the time of reaction. It was necessary to place the part of the body in a horizontal position, and this was

[1] With this instrument experiments are now in progress in the psychological laboratory of Columbia College which should yield interesting results. The accuracy of discrimination is measured with blows of varying force (Weber's law) and the correlation of velocity, mass and area determined (e. g., is the sensation the same when the velocity is 1 and the mass 2 as when the mass is 1 and the velocity 2).

done and the part supported by simple devices. Thus the arm was placed comfortably in a padded wooden box and the base of the hammer could be swung around so that the blows could be given successively on the lower and upper arm without moving the arm. The points used were the back of the lower and upper arm (*E* and *F*, opposite the points *B* and *D*, fig. 7), at a distance of 30 cm., the lower and upper parts of the thigh (*G* and *H*, the front of the leg, but anatomically corresponding to the back of the arm) at a distance of 25 cm., the back of the second joint of the left forefinger (*I*) and of the left great toe (*J*), the cheek (*K*) below the zygoma about 2 cm. from

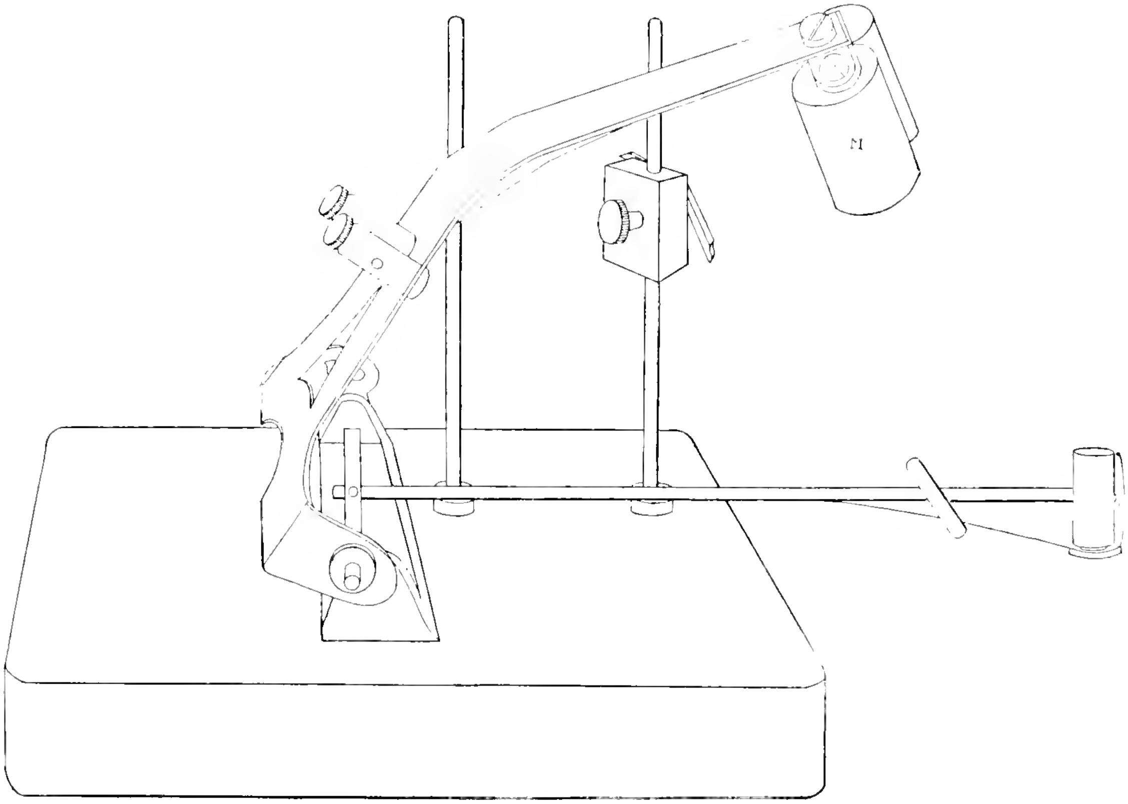

FIG. 7.

the base of the concha of the ear, and the back of the neck (*L*) over the second spinal process. Reactions were also made with the hand and foot, the stimulus being applied on the forefinger. The experiments were made in sets, *E* and *F*, *G* and *H*, *I* and *J*, *K* and *L*, and the movement with foot and hand, respectively, being made simultaneously. Experiments made simultaneously and under the same conditions can be best compared, but our times were found to vary but little from day to day. In these experiments the objective force of the blow was always the same (a weight of 30 grams falling 20 cm.). The reactions were measured singly, the variations of the separate times from the average time of the series and of the separate series from the average time of the set both being given.

TABLE XI.—*Reaction-times on blows on various parts of the body. D, C, and J observers. 2,000 reactions.*

		D			C			J		
E	Back of lower arm				115	[illegible]	(7.4)	113.3	[illegible]	(6.3)
F	Back of upper arm				115.8	8	(7.4)	114.7	9.8	(4.3)
G	Front of lower thigh	147.1	*11.6*	(4.6)	121.4	7.8	(4.3)			
H	Front of upper thigh	146.5	*11.1*	(5.2)	122.2	7.7	(3.7)			
I	Back of second joint of forefinger	1[illegible]7.3	*10.7*	(5.3)	105.5	6.6	(3.7)			
J	Back of second joint of big toe	160.7	*13.9*	[illegible]	120.8	7.3	(2.5)			
K	Cheek	130.2	*10.8*	(4.0)	103.1	[illegible]	(2.5)			
L	Back of neck	122.1	*9.7*	(7.4)	110.3	7.5	(3.1)			
I	Second joint of forefinger R with hand				106.1	5.7	[illegible]	110.6	7.2	[illegible]
I	Second joint of forefinger R with foot				168.9	*10.6*	(5.8)	147.3	*11*	(3.7)

The reaction-times were shorter than when the same points on the skin were electrically stimulated, and the mean variations of the separate reactions and of the series are less. An exact comparison can not be made, as the experiments on touch and electrical stimulation were not made simultaneously; but we may conclude that the reaction-time on touch is about 10 σ shorter than on electrical stimulation. The mean variations are smaller than any hitherto published, although we have omitted no measurements in calculating the averages. As in the case of electrical stimulation, the reaction-times of J and C are nearly the same, those of D being about 30 per cent longer.

In the case of C the shortest reactions followed stimulation of the forefinger or cheek. The two sets on the forefinger made at different times agree closely (105.5 σ and 106.1 σ). The times for the upper and lower arm and for the upper and lower thigh, respectively, are practically the same in all cases. The differences on the arm are: J 1.4 σ, and C 0.8 σ, the times being shorter on the lower point. On the thigh the time for the upper point was 0.6 σ shorter for D, and 0.8 σ longer for C. As in the case of electrical stimulation, we are unable to determine the velocity in the sensory nerve. The time of transmission is in this case exactly counterbalanced by a shorter cerebral reflex for the lower point. In the case of C the time is about 10 σ shorter when the forefinger is stimulated than when the arm is stimulated, and about 1 σ shorter for the toe than for the thigh. As before, we find that the cerebral reflex is shortened when the stimulus is applied on the opposite side of the body to a point corresponding to that with which the movement is made. For D the time was shorter when the blow was on the neck than when on the cheek, whereas it was the reverse for C; the differences are, however, small, and we may conclude that the reaction-times to stimulation of the back of the neck and cheek are about the same. The time was for J 26.7 σ, and for C 62.8 σ shorter when the movement was made with the hand than when it was made with the foot. This also corresponds with the results of electrical stimulation, C's reaction with the foot being more delayed than J's or D's. The difference in time is partly due to the time of transmission in the motor tracts of the spinal cord, but at least in the case of C it is probably chiefly due to delay in the coordination of the movement.

With the falling hammer we also made reactions in which the force of the blow was varied. In the experiments described above on electrical stimulation and on touch and in researches hitherto published[1] on the relation between the intensity of the stimulus and the length of the reaction-time, the intensity has not been measured. In this case we were able to measure exactly the force of the blow. The hammer always fell 20 cm., and the weight was 60, 30, or 15 grams. The blow from the heaviest weight was just less than painful; from the lightest it was still quite strong. The points E and F on the arm and G and H on the thigh were used. The sets, with 30 grams stimulus, are the same as those given in the preceding table.

TABLE XII.—*Reaction-times on blows of varying intensity. Lower and upper arm and lower and upper thigh. D, C, and J observers. 2,400 reactions.*

		E.	F.	G.	H.	Av.
D	Intensity 15	....	....	151.6 *12* (*7.1*)	146.4 *10.7* (*6.8*)	**148.9** *11.3* (*6.9*)
	Intensity 30	....	....	147.1 *11.6* (*4.6*)	146.5 *11.1* (*5.2*)	**146.9** *11.3* (*4.9*)
	Intensity 60	....	....	147.9 *11.8* (*7*)	149 *11.2* (*7.4*)	**148.4** *11.5* (*7.2*)
	Av	....	....	**148.9** *11.8* (*6.2*)	**147.3** *11* (*6.5*)	**148** *11.4* (*6.8*)
C	Intensity 15	115 *6.6* (*8.2*)	114.4 *7.5* (*17.2*)	122.2 *6.1* (*4.6*)	122.1 *6.8* (*3.8*)	**118.4** *6.6* (*5.9*)
	Intensity 30	115 *6.9* (*7.1*)	115.8 *8* (*5.4*)	121.4 *7.8* (*4.5*)	122.2 *7.5* (*3.7*)	**118.6** *7.6* (*5.2*)
	Intensity 60	110.8 *6.6* (*7.1*)	112.4 *6.6* (*6.2*)	121.3 *6.3* (*5.3*)	120.3 *6.3* (*4*)	**116.2** *6.5* ([illegible])
	Av	**113.6** *6.7* (*7.6*)	**114.2** *7.4* (*6.5*)	**121.6** *6.7* (*4.7*)	**121.5** *6.7* (*3.8*)	**117.7** *6.9* (*5.6*)
J	Intensity 15	119.3 *10.1* (*6.1*)	118.1 *11.7* (*5.1*)	....	....	**118.7** *10.9* (*5.6*)
	Intensity 30	113.3 *9.5* (*6.3*)	114.7 *9.8* (*4.3*)	....	....	**114** *9.6* (*5.3*)
	Intensity 60	111.8 *8.8* (*4.6*)	111.1 *9.6* (*5.9*)	....	....	**111.4** *9.2* (*4.2*)
	Av	**114.8** *9.5* (*5.7*)	**114.6** *10.4* (*4.4*)	....	....	**114.7** *9.9* (*5*)
	Av., av	**114.2** *8.1* (*6.6*)	**114.4** *9* (*5.5*)	**135.2** *9.2* (*5.1*)	**131.4** *8.8* (*5.1*)	**124.5** *8.8* (*5.6*)

[1] Excepting that on light by Berger and Cattell. Bryan also reported experiments at the meeting of the American Psychological Association (1892) in which the intensity of sounds was measured, and obtained results corresponding to those here given.

The reaction-time thus becomes shorter as the intensity of the stimulus is increased, but the difference in time is small so long as the stimuli are moderately strong. The difference is, indeed, so small that it is obscured by the error of observation, but in the final average of the two thousand four hundred reactions the time was decreased 1.3 when the intensity was increased from 15 to 30 grams, and decreased 1.7 when the intensity was increased from 30 to 60 grams. If, as Fechner's law assumes, the intensity of sensation increases as the logarithm of the stimulus, the reaction time would tend to decrease inversely as the intensity of sensation.

In the table we have a large number of experiments in which the points E and F, and G and H were stimulated by blows objectively alike. The differences with reference to the upper points are, on the arm for J, − 1.2, + 1.1, − 0.7 σ; for C, − 0.6, + 0.8, + 1.6 σ; on the leg for D, − 5.2, − 0.6, + 1.1 σ; for C, − 0.1, + 0.8, and − 1.0 σ. Considering the small unit of time in which the differences are given, the variations are strikingly small, and show how completely the variable error of reaction times may be eliminated. There is no doubt but that we have to a thousandth of a second the reaction-time under the conditions employed, and that the reaction-time is the same when the stimulus is applied to the upper and lower arm or the upper and lower thigh. Unless it is very short the time of transmission in the nerve is not counterbalanced by greater intensity of stimulus on the lower points, for doubling the stimulus shortens the reaction by only 1.5 σ, and the differences in sensation were not so great on the different points as on the same point when the stimulus was doubled. The time of transmission in the nerve seems to be counterbalanced by a shorter cerebral time when the stimulus is applied to a point farther from the brain, the sensory fibers from a point nearer the extremities discharging more quickly into the motor fibers to the extremities.

While we do not think that the velocity in the plain nerve can be measured by the difference in reaction-time, we believe that a general survey of our experiments indicate that the velocity is greater than that commonly accepted—30 meters per second. When the reaction is from hand to hand the whole time may be 100 σ, and the distance traveled in sensory and motor nerves must be in the neighborhood of 2 meters. It is not likely that two-thirds of the time is taken up in transmission and only one-third in the cerebral reflex. If so, the time from cheek to mouth would scarcely be longer than from hand to hand. Again, our experiments show that the cerebral reflex is almost certainly slower when the leg is stimulated than when the arm is stimulated, the movement being made with the hand, but the difference in time of the entire reaction is much too small to allow for a rate of 30 meters per second in the nerve. We do not think the difficulties in the way of determining the velocity in the nerve are obviated by electrically stimulating the motor nerve, as here the difference in time may depend on the point stimulated rather than on the rate of transmission. Indeed, our experiments show conclusively that the differences which von Helmholtz found—velocities twice as great in summer as in winter—are out of the question. And we do not in the least know the relation between movements due to electrical stimulation and such as are due to normal cerebral discharge. It would seem that the velocity of the nervous impulse in the plain nerve can not be measured until we are able to record its progress, as by electrical or chemical changes;* but more light may be thrown on the process by studying the variation of the cerebral processes with the part of the body stimulated.

In the table we have six cases on C in which the arm and leg, respectively, were stimulated, but the experiments were not made simultaneously. The times were always shorter for the arm 7.2, 6.4, 10.5, 7.8, 6.4, and 7.9—an average of 7.7 σ. We do not know why this time should be so much shorter than in the case of electrical stimulation. We have every reason to suppose that the cerebral reflex is slower when the leg is stimulated, and 7.7 σ should be the maximum time of transmission between the lumbar and brachial parts of the spinal cord. This would give a velocity of about 40 meters per second in the sensory tracts of the cord.

* We do not even know whether or not the velocity is uniform.

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THE BACTERIA OF RIVER WATERS.

THE BACTERIA OF RIVER WATERS.

By Dr. John S. Billings.

(Presenting a paper on the bacteria of the Schuylkill River by Dr. J. H. Wright.)

The bacteriology of river waters has been, for the last ten years, a subject of steadily increasing interest, and numerous observations have been made in Europe and in this country upon those streams which are used as sources of municipal water supply. These observations in the United States have, however, been, for the most part, made only on occasional samples and by imperfect methods, and there is no river in this country with regard to which we may be said to have an approximately complete knowledge of what might be called its natural bacteriological flora; that is, of the species, and relative proportions of each species, occurring at different seasons of the year, or as affected by rains, as distinguished from those derived from sewage or waste products of various kinds discharged into the stream.

Each river will probably be found to differ somewhat from other rivers as to its normal or usual bacteriological flora, and this flora also differs in different parts of the stream and at different times of the year; nevertheless, there are a few microorganisms of this class which are to be found in almost all such waters at all times. The ordinary river-water bacteria are not pathogenic, and little is known with regard to the circumstances which influence their growth and development in running streams, or as to the different effects which different species can produce. All that we can say is that these are probably influenced not only by rainfall, but also by the quantity and nature of the organic matters which the stream from time to time contains, by the presence of certain inorganic salts in minute quantities, by temperature, by more or less exposure to light, and by the greater or less aeration of the water, depending upon the depth and smoothness of flow of the stream. A fundamental difficulty in the way of scientific observations on these points is the want of accurate knowledge as to the characteristics of different species or varieties of the bacteria, and of means for distinguishing these without the expenditure of much time and labor. While the number of different species of bacteria which have been named is reckoned by hundreds, there are scarcely fifty which have been so described that an investigator can identify them by their descriptions.

We have, in fact, as yet no scientific classification of the bacteria, no agreement as to what kind or degree of difference should be considered as sufficient to determine that a particular form should be recognized as a distinct variety, or species, or genus. The mere morphology of the individual organism gives little aid in this respect, and bacteriologists are relying more and more upon differences in the shape, size, color, etc., of colonies or masses of the organisms growing on different media, on their effect on these media, their products, and on the effects which they or their products produce in different animals as means of distinguishing one from another.

Considered from the point of view of the general biologist, or from that of the botanist, many of the species admitted on these grounds as distinct by bacteriologists would not be accepted as species, hardly even as varieties, because the differences are differences in function rather than in structure; but for the present it seems best to accept the bacteriologist's point of view in order that different observers may know whether or not they are dealing with the same organisms, in experimenting upon the conditions of culture media, temperature, etc., which produce variations in the morphology or in the products. In obtaining "pure cultures"—that is, in obtaining from a sample of water containing several different kinds of organisms a series of cultures each of which contains but one kind—changes in the nutritive material, in the temperature, in exposure to light, etc., may produce quite different results, and hence descriptions based on the results obtained by the older and more simple methods are now found to be quite insufficient for purposes of identification, and there is a vast amount of work to be done over again.

In the hope of obtaining a useful contribution to this work, I suggested to Dr. J. H. Wright, on his appointment to a fellowship in connection with the Laboratory of Hygiene of the University of Pennsylvania, under my direction, that he should devote special attention to the chemistry and bacteriology of the water supply of the city of Philadelphia during his term of duty in the laboratory, and the result of this, covering a period of eight months in 1892–93, is herewith presented.

Dr. Wright found that the water supply of Philadelphia, from both the Delaware and Schuylkill, was impure, which was well known before; but it did not appear to be markedly impure as compared with the water supplies of some other large cities, and in his numerous tests he found no distinctly pathogenic organisms, such as the bacillus of typhoid, nor any which indicated excremental pollution, such as the bacterium coli. There is no doubt, however, that these organisms were present, at times at least, in the waters which he examined; but the method which he used of testing a drop or two from a sample would rarely detect these organisms if there were but three or four in half a pint of the fluid. In February and March of 1894 Dr. Olmstead, assistant in bacteriology in the Laboratory of Hygiene, at my request made a number of examinations of the Schuylkill water by taking 80 cc. in each sample, and after adding 20 cc. of sterilized alkaline sugar bouillon of four times the ordinary strength, placing the mixture immediately in a thermostat and keeping it at a temperature of 37° C. for twenty-four hours. This kills or prevents the growth of the ordinary water bacteria, and, as a rule, the bouillon thus treated was found to contain a luxuriant growth of but one organism—the bacterium coli—so far as could be determined. He also used the fermentation-tube method of Dr. Theobald Smith, with the same results. This colon bacillus is a constant inhabitant of the intestines of man and of domestic animals, where it ordinarily produces no ill effects, and probably aids somewhat in the digestive process by decomposing certain constituents of the food into more easily absorbable substances. Under certain circumstances, of which we know little, it passes from the intestinal tract into the organs and cavities of the body of the living animal, producing inflammation and suppuration, and, after the death of the animal, especially in warm climates, it may invade the tissues and organs, taking part in the complex process known as putrefaction. Either there are several closely allied species or else it varies considerably in the kind of growth it produces in different culture media, in its motility, in its effects as a ferment, and upon the casein of milk, etc. Whether it grows and flourishes to any considerable extent outside the animal body and its discharges is uncertain; but its presence in a water supply is usually considered to indicate fæcal contamination. It is evident, however, that it does not necessarily indicate human fæcal contamination, since it may come from manured lands and from the excreta of hogs, cows, etc., from which no stream in a cultivated country is free.

The morphology of the colon bacillus is in many respects similar to that of the typhoid bacillus; the individual rods are about the same shape and size, often varying considerably in length; both are aerobic, facultative anaerobic, and nonliquefying; the typhoid bacillus is motile; the colon bacillus is sometimes motile and sometimes not; neither is known to form spores. They grow at ordinary room temperatures, but flourish best at the temperature of the human body, 37° to 38° C. Attempts to find them by cultures inoculated with water at ordinary temperatures are usually unsuccessful, because many of the water bacteria which flourish at such temperatures liquefy the gelatin and make it impossible to identify the nonliquefying, slower-growing colonies of the typhoid and colon bacilli.

In this connection attention is invited to a valuable report upon the waters of the Mohawk, and Hudson rivers, contained in the thirteenth report of the State Board of Health of New York for 1892, and including a paper by Dr. Theobald Smith, entitled "A new method for determining quantitatively the pollution of water by fæcal bacteria," and also to Dr. Smith's paper on "The fermentation tube," in the Wilder Quarter Century Book, Ithaca, 1893.

There is no evidence that a few hundred or even a few thousand of the ordinary forms of the colon bacilli found in the excreta of healthy animals, or in river water, produce any special pathological effects when swallowed by men. Like the typhoid bacilli, they vary greatly in virulence—that is, in the power to produce disease—and this virulence appears to be much increased in certain diseases of the intestinal tract. Millions of them always exist in the lower part of the alimentary canal, and their importance in a water supply, from a sanitary point of view, depends not so much upon the risk of their producing disease by themselves as upon their associations with and relations to the bacillus of typhoid. It is possible that the typhoid bacillus is only a variety of the colon bacillus, which under certain circumstances may be transformed into it; but at present the majority of bacteriologists believe them to be distinct species. When the colon bacilli are found in a well water it usually indicates contamination of the well by washings from the surface; when found in a river water they may indicate either a recent rainfall bringing in the surface washing of the watershed, contamination by the droppings of animals, or pollution by sewage containing human excreta, which last is the specially dangerous form of pollution.

The number of bacteria in river water depends much upon the rainfall, and is usually lowest in summer when the rainfall is least; but this depends upon the character of the surface of the drainage area—that is, as to the proportion which is wooded, rocky, cultivated, etc. The duration of life, or the rapidity of multiplication of many species, appears to be small in flowing water, but in a sample collected in a bottle the multiplication is rapid for several days, and hence it is important to test the sample as soon as possible after it is collected. The differences in vitality between the bacteria in a flowing stream and in a closed vessel are probably due in part to the influence of light, and especially of direct sunlight, which has a powerful influence in killing bacteria.

Bacteria which will not grow at 37° or 38° C. will not grow in the human body; but occasionally some of these water bacteria, growing only at lower temperatures and which are not in themselves pathogenic, may become important in a municipal water supply by producing acids which will cause the water to attack lead service pipes to a dangerous extent.

Returning now to the report of Dr. Wright, I wish to call attention to its value as a contribution to the means of identification of different species or varieties of the bacteria found in river waters. This value depends in part upon the care with which the descriptions of the peculiarities of each supposed species have been given and in part upon the careful colored drawings of the appearances presented by the colonies of those forms which could not be identified from the descriptions of previous writers. Such drawings are often more useful than many pages of description, and it is extremely desirable that they should be made and published for all supposed new species. Photographs are desirable, but such colored drawings as Dr. Wright has made are needed also.

He describes two species of micrococci, two of cladothrix, and forty-five of bacilli, besides three varieties of the latter, making a total of fifty-two, nearly all coming from the Schuylkill water. It is quite certain that this water contained other forms which he did not detect. The great majority of them he could not identify with any of the bacteria previously described, and to these he has given specific names. Many of them are chromogenic under certain circumstances, and only three or four of them are pathogenic in animals.

It will be seen from his charts that the greatest number of bacteria were found in January in the Schuylkill water, and in November, January, and July in the Delaware water. There appears to be no relation between the number of bacteria and the number of cases of typhoid fever, or the amount of nitrates and of albuminoid ammonia, and but a slight relation between the proportion of cases of typhoid and the amount of free or of albuminoid ammonia.

REPORT ON THE RESULTS OF AN EXAMINATION OF THE WATER SUPPLY OF PHILADELPHIA.

By Dr. J. H. Wright, *Scott Fellow in Hygiene, University of Pennsylvania.*

The following is a report of a chemical and bacteriological study of the water supply of the city of Philadelphia, extending from October, 1892, to August, 1893. The investigation has been carried on in this laboratory under the direction of Dr. J. S. Billings and Dr. A. C. Abbott, whom the writer thanks for their active interest and many valuable suggestions.

The objects in view have been to determine the amounts and variation of those chemical constituents of the water which are of chief importance from a hygienic standpoint and the variation in the number of bacteria per cubic centimeter, together with the description and enumeration of their species.

The water supply of Philadelphia is derived from the Schuylkill and the Delaware rivers. The water of the Schuylkill, which constitutes the greater part of the supply, is obtained from two principal points on that river about 6 miles apart, and both within the city limits. The water taken at the upper one of these two points is distributed to that part of the city which includes the localities known as Germantown, Chestnut Hill, and Manayunk. This area is unequally divided into three distribution districts designated on the map of the water bureau as the "Roxboro" and the two "High Service" districts. (See Annual Report of the Bureau of Water for 1891.) The lower Schuylkill water supplies the central part of the city and all that portion lying between the two rivers, together with West Philadelphia. On the map above mentioned West Philadelphia constitutes the "Belmont" district, while the remainder of the area supplied from the same source is divided up into the distribution districts named "Direct Pumpage," "East Park," and "Fairmount." The water of the Delaware is distributed through the northeastern section of the city and also supplies a part of the central portion. This area forms what is called the "Frankfort" district. The pumping station is at Lardner's Point, within the city limits. In the results of analyses these names have been used to indicate the sources of the samples of water. The general scheme of the work has been as follows: After some isolated determinations had been made in October and November of the water of the laboratory (Belmont district), in the latter month, the systematic analysis of samples of water collected from taps in the various districts was begun. From January onward the analyses have been limited to samples from four districts, which were considered as representative of the different sources of the supply. These were the "Roxboro" district, representing the water of the upper Schuylkill, the "Fairmount," and the "Belmont" districts, representing the lower Schuylkill, and the "Frankfort" district, representing the water of the Delaware.

Two to four times each month four samples, one from each of these districts, have been analyzed simultaneously.

The analyses have consisted in the determination of the chlorine, oxygen consumed, free and albuminoid ammonia, nitrogen as nitrates, and the number of bacteria in 1 cubic centimeter. In the earlier part of the work the nitrogen as nitrites was also determined.

The water has usually been collected by an assistant. That which was intended for chemical analysis was brought to the laboratory in large bottles; that for bacterological determination in small, sterilized glass-stoppered bottles. The methods employed have been essentially the same in all the analyses reported, but in the course of the work the composition of the solution used and the manner of carrying out the different operations have varied in some cases, so that in the following descriptions some of the quantities named have not always been employed, nor have the details given been followed up in all determinations.

CHEMICAL METHODS.

In a number of cases the samples have been filtered through Swedish filter paper before analysis.

The chlorine has been determined by the method of Mohr, consisting in the use of a standard solution of silver nitrate with potassium chromate as indicator.

One hundred cubic centimeters of water is taken for each determination, to which three drops of a 10 per cent solution of potassium chromate are added. One-tenth of a cubic centimeter is deducted for the end reaction from the amount of silver solution used.

The solution of silver nitrate contains 4.7887 grams to 1,000 cc., and is standardized against a solution of sodium chloride containing 1.648 grams to 1,000 cc. One cubic centimeter of the silver solution is very nearly equivalent to 1 mg. of chlorine. The determinations have generally been made in duplicate or triplicate.

The oxygen consumed has been determined according to the principles of Kubel's method, consisting in the measurement of the amount of a solution of potassium permanganate reduced by a given volume of water in the presence of sulphuric acid at the boiling temperature.

The operation is conducted in a porcelain caserole of about 250 cc. capacity, supported by an iron ring over a Bunsen flame. One hundred cubic centimeters of the water, 5 cc. of a 25 per cent solution of pure sulphuric acid, and about 8 cc. of a solution of potassium permanganate (0.3945 grams to 1,000 cc.), standardized at the time of the analysis, against a solution of oxalic acid (0.7875 grams to 1,000 cc.), are placed in the caserole and boiled for approximately three minutes. At the expiration of this time the flame is removed and 10 cc. of the standard oxalic acid solution run in from a pipette.

Then more of the permanganate solution is added, until a faint red color is permanent. This solution is delivered from a Guy Lussac burette, by means of which the total amount used is read off and one-tenth of a cubic centimeter deducted for the end reaction.

The difference between this amount and the quantity of permanganate solution known to be reduced by the 10 cc. of oxalic acid solution represents the amount decolorized or reduced by the 100 cc. of water, and from this the oxygen consumed is calculated. The standardizing of the permanganate solution is effected in a manner similar to that above described for the determination, but about 100 cc. of distilled water is used in place of the sample. One cubic centimeter of this solution of permanganate contains approximately 0.01 mg. of available oxygen. The determinations have usually been made in duplicate, and about twenty-four hours after collection. For some time the determinations have been carried on together, three casseroles being employed. It is important in this operation that the sulphuric acid used should have little or no reducing effect on the permanganate. Such an acid seems to be unusual. That made by Baker & Adamson, of Easton, Pa., has been found satisfactory.

In the determination of the free and albuminoid ammonia the Wanklyn process has been used.

The distillations have been made from retorts of different capacities, and from round-bottomed flasks, all connected with Liebig's condensers.

The flasks are of 900 cc. capacity, with necks 11 cm. long, and the connections with the condensers are made by means of corks and bent glass tubes, the apparatus being essentially like that described by Drown. (Report Mass. Board of Health, 1890, pt. 1.)

With some exceptions, owing to accidents or other causes, the determinations have been made in duplicate throughout the systematic analyses. From November 14 to January 2 simultaneous distillations were made from each sample of water, one from a retort and the other from a flask, the latter being in connection with a condensing tube of block tin.

After this time four samples of water were analyzed at once, and eight simultaneous distillations were made from every set of four samples. For this purpose, up to the 7th of April four retorts and four flasks were employed, three of the flasks being connected with tin condensing tubes. Up to this date 500 cc. of water were taken from every determination, but beginning with the analyses of April 17 the use of the flasks was abandoned and small retorts of 200 to 500 cc. capacity substituted. In these 100 cc. of water were used for each determination, while 500 cc. continued to be the quantity taken for charging each of the larger retorts, the capacity of which has varied from about a liter to a liter and a half. This arrangement has been continued up to the close of the work.

In making the duplicate determinations a flask and a retort, or the 500 cc. and the 100 cc. methods, were used for each sample, so that comparisons might be made of the results obtained by both types of apparatus or by both methods. In the table of analyses the columns of ammonia determinations marked "tin tube" and "glass tube," respectively, contain the results given by the use of tin and glass condensing surfaces.

The tin tubes were used on the supposition that better condensation would be obtained and therefore higher results, but this does not seem to be supported by the figures. In the same columns, but farther down, the determinations by the 100 cc. method may be compared with those of the 500 cc. method. It will be seen that as a general thing the former method gives somewhat higher results.

The retorts and flasks are supported on iron rings and wire gauze. The apparatus is prepared for each determination by charging with distilled water and distilling off a quantity, the later portions of which are tested for ammonia, and if negative or if only a slight trace of color is produced by the "nessler" the residue is removed and the proper quantity of the sample turned in. For some time sodium carbonate was added to the water before beginning the distillation for free ammonia, but this has long been discontinued. The presence of this salt seems to favor explosive "bumping" and to retard ebullition. The distillation is usually made within twelve hours after the collection and carried out in the afternoon or evening. About the same time a series of standards is made up and these, together with the distillates, are nesslerized the next morning.

The rate of distillation has varied, as a constant rate could not very well be obtained when so many pieces of apparatus were working at once.

In 500 cc. determinations glass tubes 31 cm. long, which a volume of 50 cc. fills to within several centimeters of the top, are used for containing the standards and distillates, and in these, in volumes of about 50 cc., the readings are made. The standards consists of eighteen of these tubes, in which are placed, respectively, 0.1, 0.2, 0.3, 0.4, 0.5, 0.7, 0.9, 1, 1.3, 1.5, 1.8, 2, 2.3, 2.4, 2.5, 2.8, 3, 3.5, and 4 cc. of the standard ammonium chloride solution, of which 1 cc. contains 0.01 mg. of ammonia and sufficient distilled water to fill them to within some centimeters of the top.

The distilled water used for this purpose from January onward has been boiled. For the "free ammonia" 150 cc. are distilled. This is collected either in three portions of 50 cc. each or in a first portion of 100 cc. and a second portion of 50 cc. For the albuminoid ammonia 250 cc. are collected, the first 100 cc. in one portion and the remainder in three portions of 50 cc. each. The 50 cc. distillates are received in the long tubes above described. All the distillates and standards are nesslerized the next morning at one time, about 1 cc. of Nessler's reagent being used for each. The determination of the amount of ammonia in the 100 cc. portions is effected by transferring each into two of the long tubes after nesslerization and comparing these with the standards, as in the case of the 50 cc. distillates. This mode of collecting some of the distillates in 100 cc. portions was adopted not only because there were not enough of the long tubes, but also because the first 50 cc. of both kinds contain a large part of the ammonia, and as this quantity may be larger than that contained in the highest standard, it can be estimated with greater convenience if distributed through two volumes of 50 cc. A specimen determination of albuminoid ammonia is here given in detail to show the distribution of the ammonia through the distillates. The collection and reading has been carried out as above described.

(1) 100 cc. = { 0.0215 mg. NH_3 / 0.0215 mg. NH_3 }
(2) 50 cc. = 0.0035 mg. NH_3
(3) 50 cc. = 0.0025 mg. NH_3
(4) 50 cc. = 0.0040 mg. NH_3

The alkaline permanganate solution is thoroughly boiled when first prepared and made up to the proper volume.

About 40 cc. are used for each 500 cc. determination.

This quantity is steamed in a small flask on a hot iron plate during the collection of the free ammonia distillates and is turned into the apparatus from this. Eight of these flasks are used, all heated at once on the plate. In the case of the 100 cc. determinations about 50 cc. of the permanganate solution is divided into two nearly equal portions between two of these small flasks and steamed in the same manner. The portion contained in each of the flasks is afterwards divided, as equally as may be, between two of the small retorts by means of a pipette. The distillates in the 100 cc. method are collected in small test tubes in portions of about 10 cc., three portions for the "free ammonia" and five for the "albuminoid ammonia." These test tubes are about 11 mm. in internal diameter and about 14 cm. long. A volume of 10 cc. fills one of them to a height of about 10 cm.

The standards used in this method are made up in the same tubes with boiled distilled water, to about the same volume as the distillates, and contain, respectively, 0.05, 0.1, 0.15, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, and 1.4 cc. of the ammonium chloride solution used in the other method. In nesslerizing about 0.5 cc. of the reagent is used for each tube. No difficulty is experienced in reading to 0.0005 mg. of ammonia. Many of the details here adopted have been derived from the papers of Drown, above mentioned, and of Breneman. (Jour. Amer. Chem. Soc., VIII, No. 9, p. 221.)

The volumes of 50 and 10 cc. mentioned are not measured accurately, but are only approximate.

The nitrogen as nitrates has been determined by the method of Grandval and Lajoux (Comptes Rendus, July 6, 1885) as modified by Drown and Hazen (Rep. Mass. Board of Health, 1890, pt. 2, p. 711). Five cubic centimeters of the water is placed in a porcelain dish of about 35 cc. capacity, two or three drops of a 1 per cent solution of sodium carbonate added and evaporated to dryness on the top of a water bath. The steam should not be allowed to come in contact with the dish. The residue of the evaporation is treated with about 0.5 cc. of phenol sulphuric acid, made by digesting about 23 grams of pure crystalized phenol in 200 cc. of pure sulphuric acid for some hours. By appropriate manipulation of the dish the acid is worked well over the bottom and sides. After some time a few centimeters of distilled water are added and then a solution of caustic potash until the yellow color is well brought out. The strength of the caustic potash solution should be 10 per cent or more. It is important that too great an excess of this reagent be not added, for if this occurs crystals of potassium sulphate are thrown down, a result which is not desirable. A set of standards is made up for each analysis from 1, 2, 3, 4, 5, and 6 cc. of a solution of potassium nitrate, of which 1 cc. contains 0.001 mg. of nitrogen as nitrate. The first and last standards have often been omitted. These quantities are placed in small porcelain dishes, of the capacity above mentioned, and treated in the same manner as that described for the sample. In making up the standard solution 0.7215 gram of potassium nitrate is dissolved in 1,000 cc. of water, and this solution diluted 1:100.

The samples and standards are evaporated and treated together as above described, and then the contents of the dishes are transferred to the long tubes used in the ammonia determinations. More distilled water is added until they are all filled to about 2 or 3 cm. from the top, and in these the reading is made. The determination is thought to be most accurate when the amount of nitrogen as nitrates in the quantity of water taken falls between the limits of the standard here employed. The tests have been usually made in duplicate, and the evaporation of eight of them—two for each of the four samples of water—and a set of standards has been simultaneous.

The regular determination of the nitrogen as nitrites was stopped in January. The method was essentially that described by Drown (Rep. Mass. Board of Health, 1890, pt. 1, p. 527), and called by him "Warrington's modification of the Griess method."

The water was decolorized before the test by treatment with a few drops of solutions of alum and of sodium carbonate, of about 10 and 33 per cent, respectively, and then filtering through filter paper, which had been washed to remove nitrous acid.

BACTERIOLOGICAL METHODS.

The water for the bacteriological determination was collected in ground glass stoppered bottles of about 300 cc. capacity. These were previously sterilized by keeping them in the steam sterilizer for an hour or longer.

For the estimation of the number of bacteria in 1 cc. Petri's dishes or plates were used and nutrient gelatin (10 per cent) of a neutral or slightly alkaline reaction has been the culture medium usually employed. The plates were prepared from the samples in nearly all cases within about an hour after their arrival at the laboratory. In the majority of instances two or more preparations were made from each sample. The quantity of water taken, often after having been diluted with sterilized distilled water in known proportions, was measured by means of a small sterilized pipette graduated to tenths of a cubic centimeter. The amount of the original water thus used has varied from 0.01 to 0.3 cc.

When the colonies are counted a hand lens and a glass plate ruled in square centimeters are used, and with probably two exceptions the numbers given in the table of analyses are based on actual count of the whole plate. The estimation of the number of bacteria to the cubic centimeter in a sample of water is subject to many errors, and the results obtained from two plates made from the same sample of waters at the same time may differ widely from one another. At best the estimations are only approximations. There are a number of reasons for this, some of which are as follows:

(1) The bacteria exist in the water as solid particles in suspension, and it can not be assumed, as in the case of a solution, that there is equal distribution throughout the whole volume of the liquid. It is therefore to be expected that there will be differences in determinations made under the same conditions from a given specimen of water.

(2) There is an error in measuring out the quantity of water which is mixed with the gelatin, most marked when small quantities are measured, such as 0.1 cc.

(3) Some of the bacteria remain behind with the residue of gelatin left in the tube after the plate has been made, so that not all of the organisms contained in the quantity of water taken are represented by the colonies which later develop.

(4) Not all of the bacteria develop under the conditions ordinarily surrounding them in the medium employed. Some may develop slowly, and their colonies may be obscured by more rapidly growing or rapidly liquefying organisms, so that a plate may be destroyed before many colonies have become visible. Moreover, it would appear from the work of Reinsch (Centralbl. Bakt. u. Parasit., Bd. X, 1891, p. 415) and of Dahmen (Centralbl. Bakt. u. Parasit., Bd. XII, 1892, p. 302) that the degree of alkalinity of the culture medium has an effect on the results obtained in these estimations.

(5) The number of colonies varies with the age of the plate, for some species grow more rapidly than others.

(6) The results may be vitiated by the development of colonies of bacteria derived from other sources.

The following table is given as illustrating some of the foregoing statements. It shows some of the differences observed in the number of colonies in plates made with equal quantities of the same water and at the same time, and also the variation in the counts, made at different times, of a given plate:

TABLE I.

Date.	District.	Quantities used.	Gelatin plate, room temperature. Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.	Eighth day.	Agar plates, 36° C. First day.	Second day.	Third day.	Fourth day.
		cc.											
Mar. 4	Belmont	1/10		108		123		138		24	34		
4	do	1/25		60		82		78		0	10		
4	do	1/20		44		68		67		3	37		
8	do	1/10				44		54		0	3		
8	do	1/10				94		105					
8	do	1/15				96		92		4	6		
10	Roxboro	1/10			439	434				24		39	
10	do	1/10			458	451				56		42	
10	Belmont	1/10			323	320				10		16	
10	do	1/10			270	290				40			
10	Frankford	1/10			125	122				4		7	
10	do	1/10			136	141				13		31	
10	Fairmount	1/10			70	80				9		6	
10	do	1/15			55	65				10		9	
11	Belmont	1/10		492		506					45		
11	do	1/10		366		475					61		
11	do	1/10		378		375					92		
13	do	1/15				323		302			116	122	
13	do	1/10				303		284			60	30	
13	do	1/10									91	66	
17	Fairmount	1/15			333	337					36		
17	do	1/10			266	258					51		
17	Belmont	1/25			91	79		91			23		
17	do	1/20			88	101		117					
17	Frankford	1/15			138	156		143			18		
17	do	1/10			144	143		138			16		
17	Roxboro	1/5			36	45		52			13		
17	do	1/20			25	29		32			30		
17	do	1/25			49	53		57					
24	Belmont	1/10		14	55		50					17	
24	do	1/10		12	33		47					18	
24	Frankford	1/10		17	28		51					11	
24	do	1/10		9	23		41					25	
24	Roxboro	1/20		15	30		46					16 18	
24	do	1/15		33	71		47						
24	Fairmount	1/10		45	108		129					16	
24	do	1/10		24	124		173					28	
31	do	1/10		357	361	358	354				19	15	
31	do	1/10		184	278	800	300				11	10	
31	do	1/10		621	626	634	637						
31	Roxboro	1/10		137	111	164					20	48	
31	do	1/10		123	128	128	126				13	16	
31	do	1/10		132	132	131	137						
31	Frankford	1/15		100	105	107	111				10	10	
31	do	1/10		89	101	103	103				14	13	
31	Belmont	1/10		115	127	119	131				11	12	
31	ko	1/10		105	108	114	115				4	(?) 2	
Apr. 7	Fairmount	1/2		17	50	56							
7	do	1/10		37	89	102						14 11	14 11
7	Belmont	1/10		28	59	61					1/5 cc	9	14
7	do	1/10		22	39	56						6	9
7	Roxboro	1/10		49	85	94						11	13
7	do	1/10		58	128	138						10	11
7	Frankford	1/15		30	66	69						8	10
7	do	1/10		48	74	80						5	4

TABLE I—Continued.

Date.	District.	Quantities used.	Gelatin plate, room temperature: Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.	Eighth day.	Agar plates, 36° C.: First day.	Second day.	Third day.	Fourth day.
		cc.											
Apr. 7	Frankford	1/10										(?)2	4
17	Fairmount	1/10		593								154	
17	....do	1/10										124	
17	Belmont	1/10		532								148	
17	....do	1/10		559								160	
17	Roxboro	1/10		317								109	
17	....do	1/10		228								102	
17	....do	1/10		275	235								
17	Frankford	1/10		539									
17	....do	1/10		312								79	
17	....do	1/10		283								71	
25	Belmont	1/10		50	75	75	82					10	9
25	....do	1/10		31	40							4	4
												5	6
25	Frankford	1/10		55	66	72	70					16	17
25	....do	1/10		40	58	68	60					18	20
25	....do	1/10		39	49	53	48						
25	Roxboro	1/10		140	175	188	(?)156					20	22
25	....do	1/10		99	141	199	201					15	16
25	Fairmount	1/10		200								28	34
25	....do	1/10		111	136	146	130					22	23
May 5	Belmont	1/10	597								163	(?)219	
5	....do	1/10	599								168	158	
5	Frankford	1/10	221	281							46	35	
5	....do	1/10	205	243							45	28	
5	Roxboro	1/10	477	554							245	177	
5	....do	1/10	473	516							209	184	
5	Fairmount	1/10	38	55	60	59					22	25	
5	....do	1/10	38	48	56	56					20	22	
15	Belmont	1/10	85	108		107	100				30	30	
15	....do	1/10	44	54		60	64						
15	Frankford	1/10	210	235							31	38	
											56	47	
											22	20	
15	Roxboro	1/10	53	62		74	75				11	9	
											38	36	
15	Fairmount	1/10	17	18		23	42				4	5	
15	....do	1/10	16	17		22	28	26			14	17	
23	Belmont	1/10	23	31	32	31	38	42	38		15	17	
23	....do	1/10	23	28	29	27	28	29			12	14	
23	Frankford	1/10	231	271									
23	....do	1/10	216	237	236								
23	....do	1/10	260	285									
23	....do	1/10	247	269	280	271							
23	Roxboro	1/10	30	42	58	62	79	83	89		29	28	
23	....do	1/10	30	39	45	46	58	65	60		16	16	
23	Fairmount	1/10	89	107	109						59	62	
23	....do	1/10	96	102							46	50	
30	Belmont	1/10	30	31							20	18	
30	....do	1/10	34	34							23	16	
30	Frankford	1/10	63	65	66						22	21	
30	....do	1/10	64	63	66						29	32	
30	Roxboro	1/10	25								14	12	
30	....do	1/10	14	16	16						11	(?)11	
30	Fairmount	1/10	35	38	43						29	29	
30	....do	1/10	34	40	43						23	21	

In the same table are the results obtained by counting the colonies which develop in "agar" plates made from the same samples of water and, unless otherwise specified, with the same quantities of water as the gelatin plates, but unlike these kept at a temperature of about 36° C. The figures refer to the number of colonies in the plates as ascertained by actual count with the hand lens, and it will be observed that more colonies develop, from a given quantity of a sample of water, at the room temperature than at a temperature of 36° C. In the course of the work the time of counting the plates has varied from the first to the ninth day, depending on the number and character of the colonies and the condition of the plate. Counts made later than the sixth day have been rather exceptional. In those cases where two or more counts were made of the same plate on different days the maximum number was taken for the estimation of the number of bacteria per cubic centimeter.

Efforts have been made to stop the progress of liquefaction in many cases, in order that later counts could be made, but these have been only partially successful. The best results seem to be given by the use of a solution of mercuric chloride, milligram 1:20 or 1:100, applied to the liquefying colony by means of a "swab."

In the study and differentiation of the various organisms hereafter described the culture media mainly employed have been nutrient gelatin (10 per cent), acid gelatin, sugar gelatin, agar-agar, bouillon, tube potato cultures, Dunham's peptone solution, "rosolic acid" solution, litmus milk, and to some extent sugar agar. The cultivations have been carried on in test tubes containing these media. In the preparation of the plain gelatin, agar-agar, and bouillon, meat infusion or Liebig's meat extract have been used. It would seem that the results are more satisfactory when the medium is prepared with the former. This is probably less true of the bouillon than of the other. The acid gelatin is prepared by adding to the medium, after neutralization in the usual manner with caustic potash, pure concentrated hydrochloric acid in the proportion of about 1:1000 or 1:600 by volume. The sugar gelatin contains 2 per cent glucose. In the preparation of this medium, as well as the preceding, Liebig's meat extract has been used. The Dunham's peptone solution contains 1 per cent peptone and 0.5 per cent sodium chloride. The "rosolic acid" solution consists of Dunham's solution colored with that indicator. The litmus milk is cow's milk, colored with neutral litmus tincture. For the study of colonies, "Esmarch" cultures, rolled on ice, and cultures in Petri's plates have been employed. The culture in "*deep stab*" mentioned in the description of the different species consists in inoculating a sugar gelatin tube in the manner of an ordinary "stab" and then filling the tube for some distance above the surface of the medium with melted gelatin or agar, which is then made to solidify. The tubes used for this have been rather narrow. The test for the production of indol has been made by adding a few drops of pure concentrated sulphuric acid to a culture in Dunham's solution and then after a time about 1 cc. of a 0.01 per cent solution of sodium nitrite. The appearance of the red color after the addition of the acid alone is considered as indicative of the coincident production of nitrites. In the staining of the flagella of the organisms the method of Löffler has been usually followed with slight modifications. The cover glasses are easily freed from grease by heating in the Bunsen flame It has not been found necessary to add alkali or acid to the mordant. Anilin water fuchsin has been the staining fluid mostly used. The cover glass with the mordant should be only slightly warmed over the flame and only for a few seconds. The chief cause of failure to obtain satisfactory results seems to be the overheating of the preparation while being treated with the mordant. Washing the preparation in water after the application of the mordant, and again after the staining, which should be rather deep, seems to be all that is necessary to obtain clear preparations, if there has not been overheating and consequent deposition of a fine precipitate. The ferrous sulphate solution, as well as the mordant and the staining fluid, should be freshly prepared.

Filtering the solution of ferrous sulphate and the solution of tannic acid before mixing in the making of the mordant probably gives clearer preparations.

RESULTS.

The results of the analyses are given in tables showing the date, distribution district from which the sample was collected, and the separate determinations, as well as the means and averages. In addition to these, charts (Nos. I, II, III, and IV) have been prepared for the four distribution districts to represent graphically the variations and approximate values of the results. Each mean or average determination of these four districts is indicated by a perpendicular stripe or heavy broad line, showing by its length the relative and approximate values of that determination, and by its position the general time relations of the same. Stripes placed directly above one another show that the determinations are of the same date. The charts are divided by vertical lines into spaces corresponding to the months which are named at the top. Under the name of the month are given the inches of rainfall, and also the number of cases of typhoid fever reported in the wards constituting the distribution districts during that month.

In cases where a ward lies only partly in the district, the number of cases for the whole ward is included in the calculation. The figures for the average rainfall, by months, have been furnished by Mr. John L. Ogden, chief of the bureau of water, from the regular observations conducted by his department on the watersheds of the water supply. For this and other courtesies the writer wishes to here make his acknowledgments.

The data of typhoid fever have been kindly given by Dr. J. Howard Taylor, chief medical inspector of the city board of health.

A curve (Diagram V) has also been constructed from daily determinations, in duplicate and triplicate, of the chlorine in the water of the laboratory (Table VII, Belmont district), extending, with some interruptions, from September 27, 1892, to August 9, 1893. In those places where the curve is deficient no determinations have been made. The monthly rainfall averages are given with this curve, as in the charts. All chemical results are expressed in parts per hundred thousand.

In the course of the work many accidents of various kinds have occurred, and of the determinations affected some have been thrown out, while others have been retained, some judgment being exercised in the matter. In the results here given it has also happened in several cases that doubt has arisen as to the dates of determinations or identity of samples and in the case of the determinations of ammonia a slight confusion has arisen among distillates on two or three occasions.

The nitrogen as nitrites has been determined mainly on samples collected prior to January, and has been found to vary from 0.00005 to 0.0013 parts per hundred thousand. This last number was exceptional, most of the results being below 0.0005 parts per hundred thousand.

With the idea of showing how the results of analyses of the water supply of Philadelphia compare with those of the water supplies of New York City and of Boston, the table given below has been prepared. The figures for the New York supply are taken from thirty-four chemical analyses made by the city board of health at intervals of about a week or more, from the first part of September, 1892, to the latter part of July, 1893, a period corresponding in general to that occupied by the present investigation. In addition to the chemical analyses, twenty one bacteriological estimations were made, generally at about the same intervals as the chemical analyses, extending from the former date to the latter part of March, 1893.

The data for the Boston supply are taken from the report of monthly analyses made of the water from a faucet in the Massachusetts Institute of Technology in that city during the year 1891 and published in the report of the Massachusetts State Board of Health for that year. The results of the examination of the Schuylkill are given separately from those of the Delaware. In the case of the Schuylkill the figures are based on all the analyses of that water herein reported.

For each of the cities the maximum and minimum and the average for each of the subjects of analyses is given.

It should be stated that the results for the nitrogen as nitrates in the New York water also include the nitrogen as nitrites.

[Results in parts per 100000.]

	Chlorine.			Free ammonia.			Albuminoid ammonia			Nitrogen as nitrates			Bacteria per cubic centimeter		
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum	Average.
New York City....	0.197	0.299	0.231	Trace.	0.0030	0.0008	0.0030	0.0205	0.0095	0.015	0.065	0.034	223	14,798	3,040
Philadelphia:															
Schuylkill.....	.160	.840	.406	.0000	.0099	.0025	.0936	.0231	.0112	.040	.220	.079	205	33,150	4,678
Delaware......	.120	.450	.240	.0006	.0155	.0031	.0082	.0223	.0130	.020	.085	051	390	14,385	3,475
Boston............	.310	.480	.370	.0000	.0022	.0005	.0126	.0190	.0161	.010	.040	.023	......	....	....

From these results it would appear that the water supply of Philadelphia does not differ very radically from the supplies of the other two cities. If averages alone are considered, the greatest differences are seen in the nitrates and in the "free ammonia," which are comparatively much higher in Philadelphia water than in the waters of New York and Boston. Considering the extremes alone, it will be observed that both the Schuylkill and the Delaware vary much more than either of the others, and exceed both in all maximal results. If the chemical standards for good or usable water, as given in reliable works on the subject, are applied to the results of the analyses of the water of both rivers the following statements may be made:

Some of the results for free ammonia, the averages for albuminoid ammonia, and all of the results for nitrates are excessive in both the Schuylkill and the Delaware waters, while all of the chlorine determinations and the averages for the free ammonia in both fall within the limits of a good or usable water. The standard given by Park for oxygen consumed is based on determinations made under conditions different from those employed in this work, and is therefore not available.

According to the German authority, in both waters the averages for the albuminoid ammonia and all of the nitrate determinations are not excessive. In the case of the Delaware the average oxygen consumed exceeds slightly the limit, while the average for the Schuylkill is below it, though some individual determinations are excessive. By the same standards the free ammonia for both is sometimes too high, but the averages are not, and no chlorine determination attains the limits.

The average number of bacteria per cubic centimeter in both waters is excessive.

Of the microorganisms of a bacterial nature met with in the course of the bacteriological work, fifty-two species and varieties are described elsewhere in this report.

These consist of two species of micrococci, two species of cladothrices, and forty-six species and two varieties of bacilli. Nearly all of these have been isolated from the plates of the water of the Schuylkill; but it should not be inferred from this that there are only a few species in the water of the Delaware. Many more plates have been made from Schuylkill water than from the Delaware, and, as many of the organisms described are by no means common, the opportunities to isolate the rare forms in the case of the latter have been comparatively limited. Moreover, the isolations were purposely made for some time from Schuylkill plates exclusively, with the idea of turning later to the Delaware and doing the same, but this was not carried out. The general impression acquired, however, has been that the number of species in the latter is not few, and that practically all of the organisms occurring in the Delaware plates occur also in those of the Schuylkill, but that the bacterial flora of the last named is the richer of the two.

In the description of the morphology the terms "large," "medium sized," and "small" have been used. In explanation it may be said that by a "large" bacillus is meant one which approaches the dimensions of the bacillus subtilis, while the term "medium sized" may be taken as indicating that the organism is about the size of the typhoid bacillus.

With the exception of the bacillus subtilis, ramosus exiguus, refractans, nebulosus, and the cladothrix rufula, all of the organisms which grow well at 36° C. have been inoculated into white mice subcutaneously with no definite results.

A rabbit was also inoculated subcutaneously with the cladothrix dichotoma, but no abscess formation was observed. In addition to the organisms here described a number of other species have been imperfectly studied and then abandoned for various reasons. Among these was a streptococcus which seemed to be identical in cultural characteristics with the ordinary pyogenic organism.

It seems very probable that a further study of these waters would show a number of other species not included in this report. That this number, fifty-two species, is not exceptional will be evident from the statement that Maschek has isolated fifty-five species from the Leitmeritz drinking water, and Tils, from the water supply of Freiburg, fifty-nine species. Only a few of the bacteria isolated in the course of this work have been identified by the published descriptions at hand with other water bacteria. It is very probable that many of them have been met with in the course of other investigations. Neither the "colon" bacillus nor the bacillus of typhoid fever have been found in the water. In regard to microscopic organisms other than bacteria which occur in the water little work has been done. The few examinations which have been made with reference to them would seem to indicate that these forms are not numerous. The suspended matter in the water as it flows from the tap of the laboratory is often so great in amount as to give the water a deep chocolate color. This material under the microscope seems to be of an earthy nature, and is both amorphous and crystalline, with a few diatoms scattered through it.

In conclusion, the writer desires to thank Dr. H. S. Warwick, assistant in chemistry in this laboratory, for aid rendered in the course of the chemical work. Thanks are also due to Dr. Amick, of Fifteenth and Indiana avenue; to Mr. Lacky, of Fifth and Lehigh avenue; and to Mr. Seeley, of 2407 Fairmount avenue, from whose respective pharmacies water has been obtained for facilitating the collection of the samples.

Micrococcus orbiculatus.

Isolated from the water of the Schuylkill River. Rare. A rather large *nonmotile* coccus, occurring in pairs, tetrads, and small clumps. Division takes place in two directions.

Colonies in gelatin.—About the fifth day the surface colonies are rounded, elevated, shining, whitish disks, about 1 mm. in diameter. After some time they may attain a diameter of 2 to 3 mm. and have a dark yellow color with a pale margin.

Under a low magnifying power they are granular, rather dense and refracting, and have a brownish to warm yellow brown color. Their outlines are rounded and sharply defined.

The deep colonies are rounded, rather opaque, yellowish, and have sharply defined outlines.

Gelatin slant.—Rather narrow, brownish yellow, shining, slightly rough stripe with scalloped and sharply defined margins. The growth is rather dense and sometimes the margins are paler in color.

Acid gelatin.—Good growth.

Agar slant.—Scanty, not widely spreading growth of discrete and confluent grayish or yellowish white colonies.

Bouillon.—Some yellowish, stringy sediment. The reaction is alkaline.

Potato.—A bright, warm yellow, shining, dense, slightly elevated layer, spreading somewhat irregularly, and with sharply defined irregular outlines.

Litmus milk.—No coagulation. After a number of weeks may be very slightly pink, and there may be seen a warm yellow-colored sediment at the bottom of the tube.

Sugar gelatin in deep stab.—No growth.

Rosolic acid.—Seems to be slowly decolorized. Reaction is alkaline.

Indol productions.—Negative. Very feeble growth.

Relation to temperature.—Grows at the temperature of the room and at 35° to 36° C.

Micrococcus simplex.

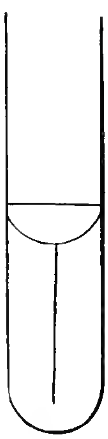


Fig. 1.

Isolated from the water of the Schuylkill River. It is probably not uncommon. A medium-sized, *nonmotile* coccus, occurring in pairs, tetrads, and clumps. Division seems to take place in two directions.

Colonies in gelatin.—About the third day the surface colonies are round, shining, white, semi-translucent disks, about 1 mm. in diameter. Under a low magnifying power they are dense, rather opaque and granular, thinner and sharply defined at their margins, while at their centers there may be a dark nucleus. The deep colonies, under a low power, are dark, brownish, granular, with rounded or slightly irregular sharply defined outlines. They may have a slightly greenish shimmer. In a few days the colonies, now somewhat larger, are seen to be lying in clear liquefactions, and may be more or less broken up.

Gelatin stab.—Liquefaction in saucer or cup form (fig. 1). The liquefied gelatin may be nearly clear or clouded, and there is an imperfect pellicle of white flocculi on the surface, while a whitish granular sediment is at the bottom. There is a fair development along the line of inoculation. After the liquefaction has reached the walls of the tube it has a level floor. An alkaline reaction is observed in the liquefied gelatin.

Acid gelatin.—Somewhat less vigorous growth. Liquefied gelatin acquires an alkaline reaction. There is little or no growth in the line of inoculation.

Agar slant.—A milk white shining stripe with irregular margins, sharply defined.

Bouillon.—Clouded. Some flocculi near surface and a whitish flaky sediment. Reaction is alkaline.

Potato.—Scanty growth of minute, discrete, and confluent whitish colonies.

Litmus milk.—After about two weeks the milk is viscid, pink above, decolorized below. Later there is a white or pink friable clot and cloudy serum. Reaction acid.

Sugar gelatin in deep stab.—No growth.

Rosolic acid.—Little or no change in color. Growth is not vigorous.

Indol production.—Doubtful reaction. The addition of nitrite is necessary.

Relation to temperature.—Grows at the temperature of the room and at 35° to 36° C.

Cladothrix dichotoma (Cohn.).

Isolated from the Schuylkill water. Long, slender, wavy, branching threads, which show segmentation when stained. Spherical, deeply staining enlargements have been seen in the continuity of the filaments. They are two or three times the width of the filament in their diameters.

Colonies in gelatin.—On the third day the colonies appear as spherical brownish gray bodies, about 1 mm. in diameter. The gelatin for some distance around each has a rich, dark brown color.

Under a low power the colony appears as a dark, spherical mass made up of fibrils radiating in all directions from a dark center. Later, as the colony increases in size, evidences of a very slow liquefaction appear, and the brown color in the gelatin spreads farther. The colonies are very dense and hard, and can be broken up only with difficulty.

Gelatin stab.—First a few discrete, brownish gray, spherical colonies near the surface. These increase in size, coalesce, and form an excavation in the gelatin, with some liquefaction, while the superficial layers of the medium acquire a rich brown color. There is some growth along the line of inoculation of discrete, hazy, grayish colonies, growing smaller toward the bottom. The growth in the excavation consists of irregular, dirty grayish clumps.

Acid gelatin.—Grows in acid gelatin producing an alkaline reaction. The growth is probably slower.

Agar slant.—Discrete and confluent round colonies, somewhat elevated and shining, and of a brownish white color, and rather dense. The agar acquires a brown smoky color. Later the colonies become larger and disk-like, and may present some wrinkling or crimping, while their color is a dirty brown. The growth is very tough and firmly adherent to the medium.

Bouillon.—The organism grows at the bottom in the form of spherical, hazy masses, which float upward when the tube is shaken. The medium is clear and acquires a deep brown color.

Potato.—Discrete and confluent, elevated, hemispherical, grayish colored colonies, which may be 2 mm. to 3 mm. in diameter. The potato acquires a deep black-brown color.

Litmus milk.—Viscid coagulation and subsequent dissolving of the casein. The liquid acquires a brown color, and a dense, dirty grayish membrane forms on the surface and adheres to the tube wall. The reaction is alkaline.

Sugar agar in deep stab.—Little or no growth.

Relation to temperature.—Grows at the temperature of the room and at 35° to 36° C.

Remarks.—This cladothrix has been frequently observed in the course of this work. It is undoubtedly identical with the cladothrix dichotoma of Cohn, as described by Macé (Comptes Rendus, T. CVI, 1888, p. 1622), who states that it is a common water organism.

Cladothrix rufula.

Isolated from the water of the Schuylkill River. Rare. Long, slender, wavy, branching threads, which in stained preparations are seen to be composed of rather long, sometimes undulating segments, separated by a clear interval.

In a mature culture, spherical, deeply staining bodies, of a diameter two or three times the width of the thread which bears them, may be seen. They are in the continuity of the filament or often at its end.

Colonies in gelatin.—About the fourth day the surface colonies are rounded, pinkish expansions, paler at their margins and usually ill defined in outlines. They may be slightly sunken in the gelatin and may be 2 mm., more or less, in diameter. Under a low power the surface colonies are seen to be matted masses of thin, irregular, and wavy filaments, rather dense, and of a reddish tint toward their centers, but growing less thick and losing the red color toward their margins, which are ill defined (see Pl. I, fig. 1). Probably in younger colonies their margins are sharply defined and wavy in outline; but this condition changes when the slow liquefaction has begun and the colony sinks somewhat in the gelatin.

The deep colonies are rounded, reddish, granular, and have a slightly uneven margin. Under some circumstances they may appear to be made up of closely packed filaments, and may be seen to have finny outlines.

Gelatin slant.—A narrow reddish stripe, rather dense. The gelatin is slowly liquefied beneath this and to some extent on each side, and more or less of the growth slips downward.

Gelatin stab.—Thin, flat, circular pinkish expansions, several millimeters in diameter. Faint growth along the line of inoculation. Slow liquefaction beneath the surface growth in funnel form.

Acid gelatin.—Apparently no development.

Agar slant.—Thin, translucent, slightly pinkish, shining growth; not widely spreading, usually composed of discrete and confluent colonies.

Bouillon.—Pinkish sediment and with strands more or less in suspension. The medium is not clouded to any extent, and there is no mycoderm.

Potato.—Elevated, pink or pale reddish, dense, circumscribed layer, sharply defined as to its margins, with a rather rough surface.

Litmus milk.—No coagulation or change in color after two weeks.

Sugar gelatin in deep stab.—No development.

Rosolic acid.—Little effect on the color.

Indol production.—Faint reaction.

Relation to temperature.—Grows at the temperature of the room and at 35° to 36° C.

Bacillus flavocoriaceus (Adametz-Wichmann).[1]

Sulphur-yellow bacillus (Eisenberg).[2]

Isolated from the water of the Schuylkill River. Observed but once. A small, short, *nonmotile*, bacillus, with rounded ends, occurring often in pairs, and showing a tendency to gather in small clumps.

No spore formation observed.

Colonies in gelatin.—About the fifth or sixth day the colonies on the surface appear as pale, yellow, rounded, shining, semitranslucent disks, 1 mm. to 2 mm. in diameter.

Under a low power they are finely granular and yellow in color, becoming thinner and colorless at the margin, which is smooth and sharply defined.

There is often a central nucleus of a brownish yellow or greenish yellow tint. The deep colonies under a low power are rounded, and have a smooth, sharply defined outline. They are granular, and yellow in color, sometimes with a greenish tint, and are somewhat refracting.

Gelatin slant.—Narrow, pale yellow, semitranslucent stripe, with a finely scalloped or dentated margin.

Acid gelatin.—Growth is less vigorous.

Agar slant.—Thin, pale, yellow, narrow stripe of discrete and confluent colonies.

Bouillon.—Clouded. Yellowish sediment.

Potato.—Scanty pale yellow, moist, rather thin growth.

Litmus milk.—No noteworthy effect.

Sugar gelatin in deep stab.—Very little growth, if any.

[1] Mittheilungen d. Oest. Versuchstation, 1888, Heft II. Reference given by Lustig. Diagnostica dei batteri delle acque.

[2] Bakteriologische Diagnostik.

Rosolic acid.—Growth not vigorous. Probably somewhat decolorized.

Indol production.—Reaction doubtful. The addition of nitrite is necessary. Growth is not vigorous.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus ovalis.

Isolated from the water of the Schuylkill River. Rare. A medium sized, short, rounded, *nonmotile* bacillus, occurring in pairs and occasionally in long forms.

No spore formation observed.

Colonies in gelatin.—After five or six days the surface colonies are shining, rounded, yellowish, elevated and semitranslucent, with sharply defined contours, and are of a diameter of about 1 mm. Under a low power they are highly refracting and of a warm yellow tint. The deep colonies, when magnified, are rather opaque and granular, with sharply defined, rounded outlines, and have a brownish color.

After a time the surface colonies may attain a diameter of about 2 mm. or so, and become more elevated and of a darker yellow or brown-yellow color, while the gelatin acquires a slight brown tint.

They are shining and smooth on the surface, are slightly translucent, and have a sharply defined, rounded outline.

Gelatin slant.—An elevated, brownish, yellow, dense, somewhat viscid looking growth, not spreading widely, but confined to the line of inoculation. The surface is shining and is sometimes smooth, though usually uneven and somewhat rugged, while the margin is slightly irregular but sharply defined. The gelatin acquires a brown tint after a time. When the growth is young it is of a pale yellow color.

Acid gelatin.—Grows well.

Agar slant.—Pale, yellow, irregular, rather dense, shining growth, not spreading widely.

Bouillon.—Whitish, flocculent sediment. The liquid is clear. There may be a ring of minute yellowish flocculi on the wall of the tube at the level of the liquid.

Potato.—Viscid, dirty brown-yellow, moist layer, spreading rather widely.

Litmus milk.—Decolorized, not definitely coagulated. A yellow scum adheres to the tube wall, and the milk has an acid reaction. A yellowish, viscid material has been noted on the surface.

Sugar agar in deep stab.—Only slight development; no gas production.

Rosolic acid.—Does not grow vigorously; effect uncertain.

Indol production.—Faint reaction; growth not vigorous; does not form nitrites.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus lacunatus.

Isolated from the water of the Schuylkill River. Rare. A small, short, rounded, *nonmotile* bacillus; occurring often in pairs and sometimes in small clumps. The length is somewhat variable. No spore formation observed.

Colonies in gelatin.—After about twenty-four hours the surface colonies are excessively thin, transparent expansions, slightly grayish toward the center, and have very irregular outlines. They may be 2 mm. or 3 mm. in diameter. (See Pl. II, fig. 11.)

Under a low power they are very transparent and thin, granular at their centers, and very irregular and deeply cleft in outline.

In some cases small, irregular open spaces or lacunæ may be seen where the growth is incomplete, and here and there, near the margins, faint, wavy, irregular lines, which recall the appearance of wood graining. The deep colonies are rounded, sharply defined in outline, faintly granular, and grayish brown in tint. By the second or third day the colonies have increased somewhat in size and may have a diameter of 4 mm. to 5 mm. They remain thin and translucent, but develop a yellow haziness about their centers.

Gelatin slant.—A thin, translucent, more or less wide stripe with very irregular, wavy, or dentated margins. The color is grayish at first, later becoming more or less yellow, usually along the central portion.

Acid gelatin.—Grows well. Does not seem to develop any yellow color.

Agar slant.—Whitish or grayish tint, not widely spreading stripe, with finely dentated or scalloped margins. The agar, after a time has a brownish green color. In sugar agar stab the medium becomes a deep brown color near the surface.

Bouillon.—Clouded. Some sediment. No pellicle.

Potato.—Thin, viscid, dirty brownish, widely spreading layer.

Litmus milk.—No coagulation. Milk is decolorized, and later acquires a brown color, which gets deeper and of a chocolate color as the culture grows older. There is a brownish ring on the wall of the tube, and above this a bluish red ring; the reaction is acid.

Sugar gelatin in deep stab.—Fair growth; no gas production; at the surface of the medium where there is good growth, a brown color is produced in the gelatin. This brown color is apparently due to the presence of the glucose in the culture medium, for it has also been observed in sugar agar, as noted above.

Rosolic acid.—Color is deepened.

Indol production.—Good reaction: does not form nitrites.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus latericeus (Eisenberg).[1]

Ziegelroter bacillus (Adametz).[2]

Isolated from the water of the Schuylkill River. Rare. A medium-sized, elongated, *non-motile* bacillus, with rounded ends, often somewhat curved and growing into short threads; no spore formation observed.

Colonies in gelatin.—After about a week the surface colonies are small, round, elevated, shining, reddish in color, semitranslucent, and have a sharply defined outline. The diameter of the largest is less than 1 mm. Under a low power they are refracting, of a warm, reddish brown or red tint, and have a rounded, smooth, sharply defined contour. The deep colonies are rounded and granular. The colonies never attain any size, and they grow slowly.

Gelatin slant.—Narrow, elevated, shining, viscid-looking stripe, of a brownish red to a dark vermilion color.

Acid gelatin.—Grows well.

Agar slant.—Pale, reddish brown or yellowish brown, narrow, smooth, moist, shining and semitranslucent stripe, with wavy, sharply defined margins.

Bouillon.—Clear, some stringy sediment; the reaction is alkaline.

Potato.—Thin, reddish, moist-looking, not very widely spreading growth.

Litmus milk.—Decolorized and coagulated. The clot forms a level floor for a layer of brownish red colored, cloudy serum above, and on this floor a reddish sediment accumulates as well as at the bottom of the tube. The layer of serum deepens very slowly. The reaction is neutral.

Sugar gelatin in deep stab.—No growth.

Rosolic acid.—Color somewhat deepened; reaction is slightly alkaline; growth is not vigorous.

Indol production.—Negative; does not grow vigorously.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus fluorescens incognitus.

Isolated from the water of the Schuylkill River. A medium-sized, *motile*, rather short bacillus, with rounded ends, occurring often in pairs and sometimes in threads. In fluid media grows in long chains. It has a polar flagellum. No spore formation observed.

Colonies in gelatin.—On the second or third day the surface colonies are thin, translucent expansions, with irregular, wavy, sharply defined outlines, and of a diameter of several millimeters. Sometimes a central, whitish nodule may be seen. Under a low magnifying power the colony is translucent and slightly granular, taking on a slight yellow-brown tint toward the center, where

[1] Sternberg, Man. Bact., 1892, p. 628.

[2] Adametz. Die Bacterien der Nutz- und Trinkwasser, Vienna, 1888.

there is often a small, rounded, sharply defined refracting nucleus of the same color. (See Pl. I, fig. 3.) The outline is sharply defined, but very irregular and sinuous, and the surface of the colony is marked by numerous delicate lines which sometimes branch, suggesting, in connection with the sinuous outline, the appearance of a leaf with its veins. The deep colonies are rounded or oval and sharply defined in outline. They have a yellowish brown tint, and are finely granular and not dense. In a day or two the colonies have a greenish tint, and few in number may attain a diameter of 6 mm. to 8 mm. The gelatin around them acquires a blue-green fluorescence.

Gelatin slant.—Thin, translucent, slightly greenish stripe, with wavy outlines, not spreading very widely. The gelatin takes on a blue-green fluorescence and becomes cloudy at the surface.

Acid gelatin.—Growth not so vigorous and less green color produced in medium.

Agar slant.—Moist, thin translucent grayish stripe, not widely spreading, and with wavy margins; the agar acquires a green color.

Bouillon.—Clouded; delicate grayish pellicle on surface and whitish sediment. After some time a greenish color may appear.

Potato.—Moist, viscid, spreading brown-colored growth.

Litmus milk.—Growth is apparently very slow; after a month or so may be somewhat decolorized or pinkish, with a pink ring on tube wall; no coagulation.

Sugar gelatin in deep stab.—Fair growth; no gas production.

Rosolic acid.—Probably decolorized.

Indol production.—Faint or doubtful reaction; does not produce nitrite.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus fluorescens foliaceus.

Isolated from the water of the Schuylkill River. Observed several times. A medium-sized, *motile* bacillus, of variable length, with rounded ends, occurring singly, in pairs, and in long, slender forms. It has a polar flagellum. No spore formation observed.

Colonies in gelatin.—About the third day the surface colonies are whitish, semitranslucent expansions, with irregular bulging outlines and a diameter of 2 mm. or 3 mm. Under a low power they appear rather thick, and marked by irregular, heavy, brown contorted bands and stripes, running in a radical direction from the center, where there is often a dark nucleus. (See Pl. I, fig. 4.) Between these markings the colony is clearer and of a warm brownish tint toward the center. At the margin the colony is thinner, and the outline is irregular and somewhat wavy, but sharply defined. After some days the colonies have become thicker, denser, pale green in color, and, if few in number, they may attain a diameter of a centimeter or more, while the gelatin acquires a blue-green fluorescence far beyond their margins. The colonies have a lobate outline and are marked by slight radiating furrows or ridges, so that they have the appearance of a broad, rounded, pale green leaf. These appearances are best seen when the colonies are very few and when the gelatin has been made with meat infusion.

The deep colonies are rounded, sharply defined in outline, brownish in color, and may be marked by indistinct radiating lines.

Gelatin slant.—A widely spreading, pale greenish, semitranslucent layer, with rather coarsely lobed margins, with a denser line or slight furrow corresponding to the line of inoculation, and smaller lines or furrows running laterally to the margin of the layer, the whole suggesting the appearance of a long, slender, pale green leaf; the gelatin acquires a marked blue-green fluorescence; these appearances are not well seen on gelatin made with meat extract.

Acid gelatin.—Good growth; no fluorescence.

Agar slant.—Grayish white, semitranslucent, rather elevated and shining, not very widely spreading layer, with wavy margins. The agar acquires a green color.

Bouillon.—Clouded with the formation of a thin, grayish pellicle and a flocculent sediment. The bouillon acquires a green color.

Potato.—Moist, viscid looking, brownish, rather thick and widely spreading layer. The growth may have a slightly mottled appearance.

Litmus milk.—Seems first to become a much deeper blue with a strong alkaline reaction. Later it is decolorized, and finally becomes pink, with an acid reaction. There is no coagulation, though the liquid may become viscid after some months.

Sugar gelatin in deep stab.—Fair growth: no gas production.

Rosolic acid.—Decolorized; reaction is alkaline.

Indol production.—Faint reaction: probably does not produce nitrites.

Relation to temperature.—Grows better at the temperature of the room than at 35° to 36° C.

Bacillus fluorescens convexus.

Isolated from the water of the Schuylkill River. A medium-sized, short, thick, *motile* bacillus, with rounded ends. It has a polar flagellum. No spore formation observed.

Colonies in gelatin.—About the third day the surface colonies are round, convex, smooth, shining, pale greenish, semitranslucent disks, perhaps 2 mm. or 3 mm. in diameter. Under a low power they are greenish and rather dense, becoming faintly granular and thin toward their margins, which are smooth, rounded, and sharply defined. The deep colonies under the low power are rounded and have sharp contours. They are finely granular at the center and show a slight greenish tint. In a short time the gelatin acquires a blue-green fluorescence.

Gelatin stab.—Rather narrow, elevated, shining, pale green, thick, smooth-surfaced, viscid-looking growth with sharp contours: the gelatin becomes blue green fluorescent.

Acid gelatin.—Grows well: no fluorescence in the gelatin.

Agar slant.—Semitranslucent, moist, viscid-looking, pale greenish, shining stripe, with irregular margins: the agar acquires a green color.

Bouillon.—Densely clouded and greenish in color; stringy flocculi collect near the surface and there is a whitish sediment.

Potato.—Pale brown, viscid-looking, irregular, rather widely spreading growth.

Litmus milk.—No coagulation and blue color deepened: reaction is alkaline: in milk not colored with litmus no color is produced.

Sugar gelatin in deep stab.—Only faint development: no gas production.

Rosolic acid.—Color is somewhat deepened.

Indol production.—Negative or doubtful.

Relation to temperature.—Little or no growth at 35° to 36° C.

Bacillus rugosus.

Isolated from the water of the Schuylkill River. Rare. A medium-sized, *motile* bacillus, with rounded ends, occurring singly, in pairs, and sometimes in chains and threads. It has one to four flagella situated at the ends; no spore formation observed.

Colonies in gelatin.—On the third day the surface colonies are semitranslucent, grayish, slightly elevated, shining expansions with irregular, sharply defined outlines, and, if few in number, may have a diameter of 3 mm. to 4 mm. Under a low power they are somewhat dense and finely granular and have a "cracked" appearance. Toward the center they have a yellowish brown tint. The margin is very irregular and sinuous, but sharply defined. In a few days they may have attained a diameter of 6 mm. to 8 mm., if not numerous, and they are then thin, semi-translucent, greenish gray expansions, with numerous delicate, somewhat radiating wrinkles throughout the central portions of the colonies. These wrinkles do not extend to the margin of the colony, but there is a smooth border zone all around the periphery. Under a low power the colony is rather refracting and granular and brownish in tint. The "wrinkles" in the central portion of the colony give the impression of a network of crossing beams or of a mass of coiled intestines. In other cases, again, the appearance may be that of a mosaic. This central portion fades out into a smooth border zone, brownish in color, which in turn is surrounded by a thinner and colorless, wavy outlined zone. Deep colonies are rounded, brownish in color, and sharply defined.

Gelatin slant.—A grayish green, rather dense stripe, not widely spreading, showing more or less numerous delicate wrinkles, which form a network. The margin is wavy and sharply defined in outline. The gelatin acquires a faint green color. This marked wrinkling of the growth does not seem to be present when the gelatin is made with Liebig's meat extract instead of the meat infusion, the growth in general being less vigorous and producing little or no green color in the gelatin.

Acid gelatin.—Good growth.

Agar slant.—Semitranslucent, not widely spreading, grayish or greenish white stripe, with irregular or scalloped margins; very delicate wrinkles are seen in the growth, which give it a granular appearance. The agar acquires a greenish color. On agar made with Liebig's extract the growth is much less typical.

Bouillon.—Clouded, with a whitish, thin, friable pellicle on the surface and a whitish sediment.

Potato.—Brown, moist, viscid looking, thick, and rather widely spreading. The growth has a somewhat mottled appearance.

Litmus milk.—Coagulated and pink in color above, with little or no serum and white below; reaction is acid; effect is slow. It would seem that at first there is a deepening of the blue color and an alkaline reaction; this is doubtful.

Sugar gelatin in deep stab.—No development.

Rosolic acid.—Color seems to be somewhat deepened.

Indol production.—Faint reaction; does not produce nitrites.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus ambiguus.

Isolated from the water of the Schuylkill River. A small, *motile* bacillus, with rounded ends, occurring singly, in pairs, and in long forms. It has a terminal flagellum.

Colonies in gelatin.—On the third or fourth day the surface colonies are grayish, translucent, shining, slightly elevated disks with slightly irregular, sharply defined outlines, and about 2 mm. in diameter. Under a low magnifying power they are finely granular toward their centers, darker and yellowish brown, where there is a small nucleus, but thin and translucent toward their margins, which are slightly wavy and sharply defined. About the centers of the colonies some coarser scattered granules or a few indistinct short lines may be seen. The deep colonies, under a low power, are rounded and sharply defined in outline, finely granular and brownish, becoming darker toward their centers. To the unaided eye they appear as small brownish spots, and are quite visible against a white background.

Gelatin slant.—A narrow, translucent, grayish stripe, with sharply defined, finely scalloped, or slightly irregular margins.

Acid gelatin.—Grows well.

Agar slant.—Narrow, translucent, grayish stripe, with sharply defined, finely scalloped margins.

Bouillon.—Clouded, stringy sediment; no pellicle.

Potato.—Thick, viscid looking, gray cream colored, widely spreading growth.

Litmus milk.—Pink above, white below; reddish ring on the tube wall; the milk is not coagulated until after about a month or more, and may not be then; reaction is acid.

Sugar gelatin in deep stab.—Fair growth; no gas production.

Rosolic acid.—Color is not markedly affected.

Indol production.—Gives an easily recognized but not marked reaction; does not produce nitrites.

Relation to temperature.—Grows at the temperature of the room and at 35° to 36° C.

Bacillus recuperatus.

Isolated from the water of the Schuylkill River. A small, *not actively motile*, bacillus, with rounded ends, occurring in short and long forms and sometimes in threads; often in pairs and showing a tendency to form clumps which are motile. Flagella could not be demonstrated; no spore formation observed.

Colonies in gelatin.—On the third or fourth day the surface colonies are grayish, translucent, rather irregular outlined expansions, somewhat elevated and shining, and about 2 mm. in diameter. Under a low power they are finely granular, translucent, somewhat refracting, with sharply defined, irregular, wavy outlines; a minute, central nucleus may be seen in them, and they may have a slight brownish tint toward their centers. The deep colonies are rounded and sharply defined in outline; they are finely granular, not dense, and have a brownish center, surrounded by a dark ring in some cases.

Gelatin slant.—Narrow, semitranslucent stripe, with slightly irregular, sharply defined margins; the growth is somewhat creamy gray in color, and has a yellowish tint by transmitted light.

Acid gelatin.—Good growth; but perhaps not so vigorous as in the ordinary gelatin.

Agar slant.—Thin, translucent, not widely spreading layer, with sharply defined, slightly irregular margins.

Bouillon.—Clouded; a thin grayish follicle forms on the surface, and there is some sediment.

Potato.—Brown, viscid, shining, semitranslucent, not very widely spreading layer, somewhat elevated and growing somewhat irregularly.

Litmus milk.—The blue color is much deepened; there is no coagulation, and the reaction is alkaline.

Sugar gelatin in deep stab.—Little or no growth.

Rosolic acid.—Little or no change in color.

Indol production.—Negative.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus sinuosus.

Isolated from the water of the Schuylkill River. At one time not uncommon. A medium-sized, short, *motile* bacillus, with rounded ends, occurring often in pairs and sometimes in longer forms. It has a polar flagellum; some individuals probably have two to four flagella; no spore formation observed.

Colonies in gelatin.—On the second or third day the surface colonies are very thin, delicate, grayish, translucent, and opalescent expansions, with very irregular, sinuous outlines, and of a diameter of several millimeters, if the colonies are not too numerous. Under a low power they are thin, translucent, very irregular and sinuous in outline, and show various waving and irregular lines, especially near the margins, which suggest the appearance of wood graining. Sometimes they are brownish toward their centers. If the colonies are widely separated they may attain a diameter of 6 mm. or more, and in such a large colony delicate radiating foldings have been observed running from a faint whitish nucleus toward the periphery. The outline in the large colonies is extremely irregular and sinuous, and they remain thin and translucent, while under the low power they are seen to have lost the "wood graining" appearance, and are finely granular. The deep colonies under a low power are finely granular and brownish, with rounded or slightly irregular, sharply defined outlines.

Gelatin slant.—Grayish white, smooth, shining, semitranslucent stripe, with sharply defined, irregular margins; does not spread widely.

Acid gelatin.—Grows well.

Agar slant.—Narrow, grayish white, thin, shining, semitranslucent stripe, with slightly scalloped margins.

Bouillon.—Clouded and has a whitish, stringy sediment; no pellicle on surface.

Potato.—Dirty brown-gray, moist, not thick, rather rough appearing growth, which spreads rather widely.

Litmus milk.—Pink, white at bottom; no coagulation after six weeks at the temperature of the room; reaction is acid.

Sugar gelatin in deep stab.—A thick cord of confluent whitish colonies forms along the line of inoculation, and there is an abundant production of gas.

Rosolic acid.—Color is deepened.

Indol production.—A faint reaction; the addition of nitrite solution is necessary.

Relation to temperature.—Grows well at the temperature of the room and at 35° to 36° C.

Bacillus nexibilis.

Isolated from the water of the Schuylkill River. A medium-sized, *motile* bacillus, with rounded ends, occurring often in pairs in long forms and sometimes in chains and clumps; it has a terminal flagellum; no spore formation observed.

Colonies in gelatin.—On the second or third day the surface colonies, if not numerous, are thin, grayish, translucent, somewhat opalescent expansions, with irregular sinuous outlines and diameters of several millimeters. Under a low power they are thin, slightly brownish in tint, and slightly granular, becoming more translucent at the margin, which is very irregular, finely sinuous or dentated, and sharply defined. The deep colonies under the low power are rounded or slightly irregular in outline, and have sharp contours. They are slightly granular, and are of a brownish color toward their centers. After a few days the surface colonies have become slightly denser and have acquired a faint greenish tint. Under a low power they may be seen to be marked near their margins by bundles of faint radiating lines. If they are well separated, under some circumstances broad lobe-like new growths on the surface of the gelatin may appear at different points on their margins; these have the appearance of the parent colony when it was younger, and they may grow to be nearly as large, so that a very irregular outline is given to the colonies.

Gelatin slant.—A nearly smooth, shining, not translucent stripe, grayish by reflected light, brownish white by transmitted light, not spreading widely, and with irregular, sharply defined margins. The gelatin may acquire a very faint, brownish green tint.

Acid gelatin.—Grows well.

Agar slant.—Thin, semitranslucent, grayish stripe, not spreading widely, and having irregular or scalloped margins; agar acquires a greenish tint after a time.

Bouillon.—Clouded; some stringy sediment at bottom and some flocculi near surface; bouillon acquires a faint greenish tint.

Potato.—Brown, viscid-looking, thick layer, spreading rather widely.

Litmus milk.—Becomes slowly pink; no coagulation after a month at the temperature of the room; reaction is acid.

Sugar gelatin in deep stab.—Little or no development.

Rosolic acid.—Color becomes less; reaction is neutral or slightly alkaline.

Indol production.—Faint reaction; does not produce nitrite.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus tiogensis.

Isolated from the water of the Schuylkill River. Rather common at one time. A medium-sized *nonmotile* bacillus, with rounded ends and generally rather plump. Occurs singly, in pairs, and sometimes in chains of three or four elements, as well as in long forms. No spore formation observed.

Colonies in gelatin.—About the second day the surface colonies are rounded, milk-white, shining, elevated, not translucent disks, about 2 mm. in diameter. Under a low power they are dark and rather opaque, with a slight greenish shimmer, becoming thinner, brownish, and granular toward their margins, where they are nearly clear. Their outlines are rounded, smooth, and sharply defined. The deep colonies, under a low power, are rounded or slightly irregular, dark, granular, and sharply contoured. They have a faint brown, greenish shimmer at their centers. In a roll culture five days old the main central portion of a surface colony could be removed with the platinum loop as a white disk.

Gelatin slant.—A thick, white, shining, smooth, narrow layer, with slightly irregular, sharply defined margins.

Acid gelatin.—Grows well.

Agar slant.—Semitranslucent, grayish, not widely spreading layer.

Bouillon.—Clouded and whitish stringy sediment.

Potato.—Dirty, brownish gray, moist, viscid-looking, not very thick, but widely spreading layer.

Litmus milk.—Decolorized. No coagulation after six weeks; the reaction is neutral; there may be a slightly pink ring on the tube wall.

Sugar gelatin in deep stab.—Very faint development.

Rosolic acid.—Does not seem to have much effect on the color.

Indol production.—Doubtful reaction.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus refractans.

Isolated from the water of the Schuylkill River. Rare. A short, thick, round-ended, *non-motile* bacillus, of medium size, generally in pairs, and sometimes occurring in somewhat larger forms. It shows a tendency to gather in clumps.

Colonies in gelatin.—On the second day the surface colonies are round, white, slightly elevated, refracting disks, about 1 mm. in diameter, with sharply defined outlines. Under a low power they are rather dark brownish and refracting, apparently made up of rounded, brownish masses, closely packed together. They have sharply defined outlines and sometimes darker centers. The deep colonies are rounded, brownish, granular, and sharply defined. After two or three days the surface colonies all seem to have increased somewhat in diameter and thickness, and show a marked "crimping" or radial folding near their margin, so that under a low power the colonies may have scalloped outlines.

Gelatin slant.—A narrow, white, shining, rather thick, membranous growth, which is thrown up into very numerous delicate wrinkles; the margin is finely irregular and sharply defined.

Acid gelatin.—Growth is thinner and much less wrinkled.

Agar slant.—Narrow, thin, semitranslucent stripe of confluent small colonies.

Bouillon.—Somewhat clouded, with some flocculi at surface and a whitish sediment at bottom; a thin, imperfect, delicate pellicle on the surface may be seen.

Potato.—Scanty growth of grayish or brownish gray, small, discrete colonies.

Litmus milk.—No effect after a month.

Sugar gelatin in deep stab.—Development only very faint, if any.

Rosolic acid.—No marked effect is produced; seems to be very slightly lighter in color after some time.

Indol production.—Negative; does not grow vigorously.

Relation to temperature.—Grows at the temperature of the room and at 35° to 36° C.

Bacillus dormitator.

Isolated from the water of the Schuylkill River. Observed but once. A medium-sized, *non-motile* bacillus, with conical ends. It is quite variable in length, generally rather long, and occurs singly, in pairs, and in threads; no spore formation has been observed.

Colonies.—On the second day the colonies appear as yellowish points, and there is evidence of liquefaction around them. Under a low magnifying power they are seen to be yellow, faintly granular, rough masses, with sharply defined bulging outlines. Some are surrounded by a zone of clear liquefied gelatin. The colonies never attain any considerable size, but usually are less than 1 mm. in diameter, and float in rather large, circular areas of clear liquefied gelatin.

Gelatin stab.—Liquefaction generally in funnel form, subject to a good deal of variation in different cultures. The liquefied gelatin is densely clouded and yellow in color, while at the bottom of the liquefaction there is a thick, flocculent deposit of a bright yellow color; just above this yellow mass the liquefied gelatin may be less densely clouded. The liquefied gelatin has a slightly alkaline reaction.

Acid gelatin.—No development.

Agar slant.—A bright yellow, shining, translucent growth, not spreading widely.

Bouillon.—Clouded and yellowish sediments; an imperfect yellowish pellicle may be formed on the surface.

Potato.—No growth.

Litmus milk.—Decolorized and coagulated after a week or two; the clot is jelly-like, and the serum is cloudy and of a yellow color; there is a yellow ring on the tube wall above the level of the liquid; the reaction is neutral.

Sugar gelatin in deep stab.—No growth.

Rosolic acid.—Little or no growth.

Indol production.—Negative.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus decidiosus.

Isolated from the water of the Schuylkill River. Has been seen in the Delaware water. A small, short, *nonmotile* bacillus with rounded ends, occurring often in pairs, and showing a tendency to gather in "clumps;" no spore formation observed.

Colonies in gelatin.—On the second or third day the colonies appear as small, yellow-brown, irregular clumps, about 1 mm. in diameter, usually lying in depressions containing clear liquefied gelatin; sometimes a brown spot may be seen at the center. Under a low magnifying power they are rather dense, granular, and of a brown-yellow color, sometimes with a dark brown area at the center. The outline is irregular and broken, while around some a refractive ring of liquefied gelatin may be observed. In a day or so the colonies have increased somewhat in size, and may appear to be partially split up into smaller, irregular, yellowish clumps, while the area of liquefaction around each is greater. (See Pl. 1, figs. 5 and 6.)

Gelatin stab.—Liquefaction extending down the line of inoculation in the form of a funnel constricted at the top and inclosing an air bubble (fig. 2). The liquefied gelatin contains yellowish flocculi in suspension, and is clouded. On the surface a yellow clump and at the bottom a yellowish precipitate; the reaction is alkaline.

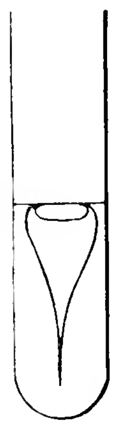


Fig. 2.

Acid gelatin.—Growth is slower and development along the line of inoculation is faint.

Agar slant.—Shining brown-yellow, semitranslucent, not widely spreading growth, composed of discrete and confluent rounded colonies.

Bouillon.—Clouded; in older cultures a brown greenish color may be observed, and the liquid may be clear, with a stringy sediment at the bottom.

Potato.—Brown-yellow, moist, elevated, rough, irregular growth, somewhat viscid looking.

Litmus milk.—Viscid clot with cloudy, yellowish serum above. A brown-yellow scum may form on the surface after some weeks; on tube wall a bluish ring above a yellow ring; the casein seems to be gradually dissolved; the reaction is alkaline or neutral.

Sugar gelatin in deep stab.—Some growth and liquefaction; no gas production.

Rosolic acid.—Effect is uncertain.

Indol reaction.—Faint or doubtful reaction; does not produce nitrites.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus annulatus.

Isolated from the water of the Schuylkill River. A rather small *motile* bacillus, with rounded ends, occurring singly, in pairs, and longer forms. It has several flagella, apparently situated at one or both ends.

Colonies in gelatin.—About the third or fourth day the colonies have formed round, saucer-shaped liquefactions, 2 mm. or 3 mm. in diameter; there is a yellowish mass at the center, and this is surrounded by a cloudy zone of liquefied gelatin. Under the low magnifying power a thick, opaque yellowish clump is seen at the center, around this dark granular material, and at the margin of the liquefaction sometimes an indistinct fringe of short hair-like processes, or the outline may be ill defined; motion of a circulating character may be observed in the liquefied area. The deeper colonies, under the low power, are oval or irregularly round, brownish, finely granular, and sharply defined. If the colonies are few in number the liquefactions may attain a diameter of 7 mm. or more, and may show one or two concentric, hazy, yellowish rings formed of yellowish flocculi.

Gelatin stab.—Liquefaction is saucer or cup form, with only faint development along the line of inoculation (fig. 3). The liquefied gelatin is clouded, and an abundant yellow flocculent deposit is seen at the bottom; there may be a delicate, somewhat iridescent pellicle on the surface; the liquefied gelatin has an alkaline reaction.

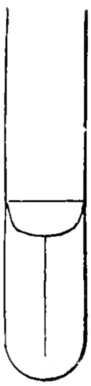


Fig. 3.

Acid gelatin.—Good growth; no growth in line of inoculation.

Agar slant.—Warm, yellow, semitranslucent stripe, with wavy margins and a smooth shining surface.

Bouillon.—Clouded, and flocculi in suspension. A yellow pellicle forms on the surface, and there is an abundant, thick, membranous sediment, of a yellow color; the reaction is alkaline.

Potato.—Thin, moist, spreading, brown-yellow colored growth.

Litmus milk.—Coagulated and decolorized; clot rather firm and serum clouded; pink ring on tube wall; yellowish deposit at bottom of tube; reaction is acid.

Rosolic acid.—Color much deepened; reaction is alkaline.

Indol production.—Faint reaction; does not produce nitrites.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus caudatus.

Isolated from the water of the Schuylkill River. Not frequent in occurrence. A rather small, slender, *nonmotile* bacillus with conical ends, occurring often in pairs and in longer forms, sometimes thread-like, which may show irregular segmentation; no spore formation observed.

Colonies in gelatin.—About the third or fourth day the surface colonies are rounded, yellow, semitranslucent disks, with smooth or slightly wavy, sharply defined outlines, and a diameter of 1 mm. to 2 mm. (See Pl. I, fig. 7.) Under a low power they are translucent and of a light yellow color, becoming colorless at the margin, which is sharply defined and smooth or slightly wavy. At the center a small nucleus may be observed, and from this delicate lines radiate toward the periphery. Sometimes various delicate indistinct markings may be made out in the colony in addition to these radiating lines. The deep colonies under the low power are seen to be yellow in color, irregularly rounded, and sharply defined in outline. They are semitranslucent, faintly granular, and may show faint radiating lines. Sometimes deep colonies may be seen which have short hair-like processes extending into the gelatin in an irregular manner. (See Pl. I, fig. 8.) In stiff gelatin these hair-like processes may be quite numerous and long, giving the colony a hazy appearance to the naked eye and extending into the gelatin on all sides from the colony as a center. In the course of a few days the colonies on the surface sink somewhat in the gelatin, and some may become surrounded by a zone of liquefied gelatin in which what appear to be yellow flocculi may be seen. Under the low power the typical and characteristic liquefying colony is seen to consist of a brown-yellow, somewhat refracting, coarsely granular central portion, surrounded by a broad zone consisting of coiled and twisted, more or less yellowish and translucent bands or cords, which lie in the liquefied gelatin and give the impression of yellowish flocculi to the naked eye, as above noted. This appearance seems to be brought about through a radial splitting of the surface expansion and a lengthening and twisting of the process thus formed. All grades of transition between this typical condition and the original colony are quite commonly to be observed. Sometimes in colonies, slightly sunken in the gelatin, short hair-like tufts may be observed springing from the margin at different points and projecting into the gelatin in an irregular manner; liquefaction is slow.

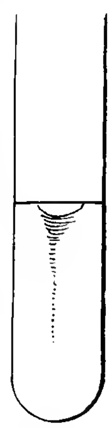


Fig. 4.

Gelatin stab.—Liquefaction is cup shape or deep saucer form, sometimes constricted at the top and inclosing an air space. (See fig. 4.) The liquefied gelatin is densely clouded and contains a thick, yellow, flocculent material, while a yellow scum may be observed on the surface. Beneath the liquefaction there is a yellow haziness in the gelatin, and this continues down the line of inoculation, gradually fading out. In some cases this haziness may be observed to take the form of ill-defined lateral outgrowths. The growth along the line of inoculation is feeble; liquefaction slowly extends to the tube wall and downward for a short distance, the bottom of the liquefaction becoming a horizontal plane on which a yellow sediment accumulates and further development ceases. The liquefied gelatin has an alkaline reaction.

Acid gelatin.—Grows feebly or not at all.

Agar slant.—Translucent, yellow, shining, not widely spreading growth, with wavy, not sharply defined margins.

Bouillon.—Clouded, yellowish sediment and yellowish flakes on the tube wall at the level of the liquid and sometimes on surface.

Potato.—Deep orange colored, thick, elevated, moist, and widely spreading, with a somewhat uneven surface.

Litmus milk.—Slowly decolorized; no coagulation after six weeks; a yellow scum forms on the surface, some yellow sediment and a brown-yellow ring on tube wall, with a bluish ring above, reaction neutral.

Sugar gelatin in deep stab.—No growth.

Rosolic acid.—Decolorized; reaction alkaline.

Indol production.—Reaction doubtful.

Relation to temperature.—Grows at the temperature of the room; does not grow at 35° to 36° C.

Bacillus pullulans.

Isolated from the water of the Schuylkill River. Not a rare species. A small, short, *motile* bacillus, with rounded ends, occurring often in pairs. It is provided with several flagella; no spore formation observed.

Colonies in gelatin.—About the second or third day the surface colonies are yellow, shining, slightly elevated, rounded, semitranslucent disks, thinner and whiter at the margins, with sharply defined outlines, and about 2 mm. in diameter. When the colonies first appear they are whitish and become yellow later. Under a low power they are yellow in color, finely granular and rather dense, but becoming thin and colorless at their margins, which are smooth or slightly wavy and sharply defined. A characteristic thing is the presence of coarse, rounded, or sausage-shaped granules on the under surface of the colony, sometimes scattered irregularly and sometimes collected at one or more points. The deep colonies are dark, granular, rounded, or slightly irregular in outline, and sharply defined. Sometimes buds or plaques develop on the surfaces of the deep colonies, and in older preparations like collections of small daughter colonies may be formed. The surface colonies slowly become surrounded by zones of hazy, liquefied gelatin, with well-defined circular outlines. A peculiar aromatic odor is developed in mature plates.

Gelatin stab.—First a yellow, shining, slightly elevated, rounded patch forms at the point of puncture, with a fair growth along the line of inoculation; later liquefaction occurs in the form of a cup funnel or inverted cone constricted at the top, where there is an air space, and all the gelatin is slowly liquefied. The liquefied gelatin contains yellowish flocculi in suspension, and there is a flocculent yellow deposit in the lower portions, while on the surface a yellow clump or scum may be seen (fig. 5).

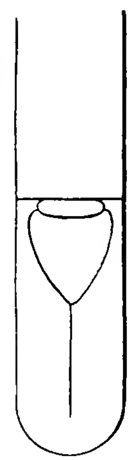


FIG. 5.

Acid gelatin.—Grows somewhat less vigorously with little or no liquefaction along the line of inoculation; but the liquefaction extends to tube wall and downward with a rounded flow; the liquefied gelatin has a slightly alkaline reaction.

Agar slant.—A narrow, yellow, semitranslucent stripe with finely wavy or finely scalloped margins.

Bouillon.—Clouded; grayish sediment at bottom; grayish flakes on the surface, which may form an imperfect pellicle.

Potato.—Moist, viscid-looking, brownish yellow, shining, widely spreading, rather thick growth.

Litmus milk.—Decolorized and yellow ring on tube wall, with a yellow scum on the surface; coagulation also occurs, with some cloudy yellowish serum above; the reaction is uncertain.

Sugar gelatin in deep stab.—Fair growth, extending all along the line of inoculation as a narrow cylinder; no gas is produced.

Rosolic acid.—The color is deepened.

Indol production.—A good reaction; does not form nitrites.

Relation to temperature.—Grows well at 35° to 36° C.

Bacillus arborescens (Frankland.)

Varieties *a* and *b*.

Isolated from the water of the Delaware River. A medium-sized, slender, *nonmotile* bacillus, occurring often in pairs and indistinctly segmented threads; no spore formation observed.

Colonies in gelatin.—About the third day the surface colonies may be several millimeters in diameter, and consist of yellowish collections of flocculi lying in depressions containing liquefied gelatin, each surrounded by a translucent, almost invisible, hazy zone. The deep colonies are rounded, hazy, translucent spots. Under a low power the surface colonies are seen to consist about their centers of irregular, broken, semitranslucent, yellow, granular masses, while toward the periphery they form thin translucent zones, marked here and there with delicate lines, and lying on the surface of the nonliquefied gelatin. These thin, peripheral expansions in turn are continuous with anastomosing networks or plexuses of numerously branching, thin, delicate, translucent processes of varying widths, which extend for some distance on the surface of the gelatin. The surface colonies are subject to some variation in appearance, dependent on the gelatin used, but the characteristic thing is the anastomosing peripheral zone, and it will usually be seen more or less well developed; the deep colonies also vary in their appearance. The typical deep colony, under a low power, when very young and almost invisible to the naked eye, may be seen to consist of a translucent, axial trunk, breaking up at both ends into more or less numerous branches, which, in turn, break up into smaller ones. By the third day the colony has a bushy appearance (see Pl. I, fig. 9), consisting of a yellow, semitranslucent, gnarled-looking, central axis, which expands at either pole into a rapidly branching and rebranching tree-like structure. The colony thus seems, in typical cases, to be composed of two symmetrical halves, the outlines of the growth being in general rounded or spherical and well defined. A rather slow liquefaction of the gelatin, which has been permeated by the growth, occurs. In some cases the characteristic bushy appearance of the deep colonies may be absent, and they may be seen under a low power to be yellow, refracting, granular masses, sometimes in pairs, and may be provided with numerous short, irregular, hair-like processes, extending into the gelatin.

A probable variety of this bacillus has been isolated from the same source, the colonies of which seem to liquefy more rapidly and differ from the above in their appearance. They form liquefactions several millimeters in diameter, containing yellow flocculent material, and show fine delicate lines or threads radiating toward the periphery. The deeper colonies consist of yellowish points, surrounded by wide, well-defined, hazy zones, through which radiate delicate lines. The larger colonies under the low power show filaments and bundles of filaments running in a radial direction in the liquefied gelatin, sometimes twisted and contorted, and becoming smaller toward the periphery. In some cases indications of the formation of the characteristic anastomosing peripheral zone of the colony first described may be seen. In addition to these elements granular clumps and masses of a yellow or brown color will be seen, especially about the centers. The deep colonies under the low power have a yellow granular central nucleus, from which filaments extend into a wide, faintly granular zone with a circular outline and a faint fringe at the periphery. These filaments in some cases form delicate threads running to the periphery of the surrounding zone, giving the radiating appearance seen by the naked eye. In other cases these radiating lines may be absent, as in fig. 9, Pl. I. It would seem that this zone is really formed by an extensive branching of the filamentous outgrowths from the central nucleus, together with the liquefaction or semiliquefaction of the gelatin threads permeated by them.

Gelatin stab.—Liquefaction in cup shape or deep saucer form, with haziness along the line of inoculation (fig. 6). The liquefaction extends to the tube wall, and slowly downward, the flow becoming level. The liquefied gelatin is clouded, and yellow in color, with a yellow sediment at the bottom. In the case of the variety *b* of this bacillus, before mentioned, liquefaction proceeds near the surface in a manner similar to the above, but in addition extends along the inoculation line (fig. 7). The gelatin along the line of inoculation has a hazy appearance for some distance on each side. The liquefied gelatin in both varieties has an alkaline reaction.

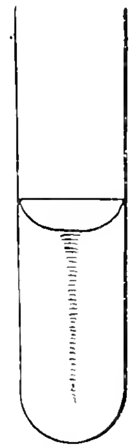


Fig. 6.

Acid gelatin.—No growth.

Agar slant.—Translucent, yellow, iridescent layer, with ill defined transparent margins.

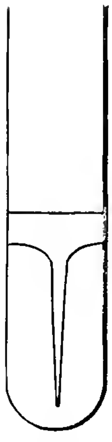


Fig. 7.

Bouillon.—Clouded: yellowish sediment at the bottom, while on the surface a broken yellowish pellicle forms; the bouillon acquires a yellow tint.

Potato.—A warm, orange-colored, viscid-looking, thick, shining, widely spreading layer.

Litmus milk.—Decolorized and slowly coagulated; yellow flakes at the surface; the reaction is neutral.

Sugar gelatin in deep stab.—No growth.

Rosolic acid.—Decolorized; reaction alkaline.

Indol production.—Negative or doubtful.

Relation to temperature.—Does not grow at 35° to 36° C.

Remarks.—This organism was first described by the Franklands (Ueber einige typische Mikro-organismen im Wasser und im Boden, Zeitschrift für Hygiene, Band VI, pp. 379, 380, 1889), who found it in the water supply of London. Tils met with it in the Freiburg water supply (Bakteriologische Untersuchung des Freiburger Leitungswassers, Zeitschrift für Hygiene, 1890, Band IX), and Tataroff includes it in his list of organisms isolated from the supply of Dorpat (Die Dorpater Wasserbakterien, Inaugural Dissertation, Dorpat, 1891). It has been observed both in the Delaware and Schuylkill in the course of this work.

Bacillus exiguus.

Isolated from the Schuylkill water. Observed but once. A small *nonmotile* bacillus, with rounded ends, occurring singly, in pairs, and in small clumps. No spore formation observed.

Colonies in gelatin.—On the third day the surface colonies are round, pinkish, semitranslucent, shining disks, with sharply defined outlines. Under a low magnifying power they are granular and have a pink color, which disappears near the margin, where they are thin and translucent. The outline is smooth, rounded, and sharply defined. The deep colonies are rounded or oval, dense, greenish at the center, granular at the margins, and have smooth, sharply defined outlines. About the sixth day liquefaction may have become well marked and the colonies have acquired a salmon-pink color. The liquefying colony has a less sharply defined outline and is surrounded by a zone of cloudy liquefied gelatin. Under a low power the colony is seen to be denser, reddish in color, and granular, and to have rough, ragged outline. The liquefied zone is filled with rather course granules of a brownish tint, and gradually fades out into the surrounding gelatin.

Gelatin stab.—Liquefaction in saucer form extending to tube wall and downward; the bottom of the liquefaction is rounded for some time after the wall of the tube has been reached, but eventually becomes a horizontal plane (fig. 8). There is only slight growth in the line of inoculation; the liquefied gelatin is clouded and there is a pinkish yellow sediment; the reaction is slightly alkaline.

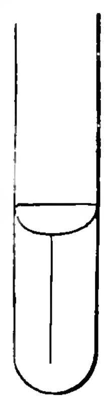


Fig. 8.

Acid gelatin.—Growth is slower and there is less liquefaction.

Agar.—Very thin, moist, translucent growth, of a pale pinkish tint, not widely spreading, and with irregular margins.

Bouillon.—Clouded; a whitish viscid sediment.

Potato.—Widely spreading, moist, shining growth, of a red-yellow color.

Litmus milk.—Coagulated and decolorized; clot is jelly-like and is gradually dissolved; serum is cloudy, and of a red yellow color; there is an orange-yellow ring on wall; the reaction is neutral.

Sugar gelatin in deep stab.—No growth.

Rosolic acid.—Decolorized slowly: reaction is alkaline.

Indol production.—Faint reaction: does not produce nitrites.

Relation to temperature.—Grows at temperature of the room and at 35° to 36° C.

Bacillus hæmatoides.

Isolated from the water of the Schuylkill River. Rare. A medium-sized, elongated, *nonmotile* bacillus, with blunt ends. It shows irregularity in staining and in form. No spore formation observed.

Colonies in gelatin.—After about five or six days the surface colonies are small, shining, slightly elevated, semitranslucent, vermilion-colored disks, with sharply defined, smooth, rounded outlines. Under a low power they are homogeneous, refracting, and of a bright red color, and have sharp contours. Deep colonies are rounded, sharply defined in outline, granular, and yellowish red in tint. The gelatin is slightly liquefied after a long time.

Gelatin slant.—A bright red, rather rough, shining, and dense membranous stripe, with sharply defined, somewhat irregular margins. It seems to be formed by the fusion of small rounded colonies, and thus has a rough or granular surface. After some time the gelatin is slowly liquefied beneath the growth.

Acid gelatin.—Grows well.

Agar slant.—Pink-colored, rough growth, composed of confluent, pink, shining, rounded, and elevated colonies; does not spread widely.

Potato.—Bright red, elevated, numerously wrinkled or coarsely granular looking growth, spreading fairly well.

Litmus milk.—Not decolorized or coagulated. There is a rich red wing of the growth on the tube wall and a red sediment at bottom, where there appears to be some decolorization. The reaction is alkaline.

Sugar gelatin in deep stab.—Very slight development. No gas production.

Rosolic acid.—Color deepened slowly.

Indol production.—Negative.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus fluorescens Schuylkilliensis.

Isolated from the water of the Schuylkill River. A rather small, short, *motile* bacillus, with rounded ends, occurring often in pairs and sometimes in threads and long forms. It has a polar flagellum. No spore formation observed.

Colonies in gelatin.—On the second day the surface colonies appear as grayish white, semitranslucent disks, with smooth, sharply defined outlines, and a diameter of about 1½ mm. Under a low magnifying power the colony is seen to be brownish and granular toward the center, but thin and translucent toward the periphery. (See Pl. I, fig. 10.) The outline is smooth or slightly wavy, and sharply defined. From the center of the colony brownish, indistinct, wavy, broken lines are seen to radiate toward the margin. The deep colonies are rounded or oval, dark brownish and granular, with sharply defined outlines. In these, also, faint brownish lines are seen radiating from the center. Later the surface colonies get thicker and larger and may have a greenish white color, while the surrounding gelatin acquires a blue-green fluorescence. The colonies gradually sink into the gelatin and a slow liquefaction begins, the colony losing its sharply defined outlines and being surrounded by a narrow zone of cloudy liquefied gelatin.

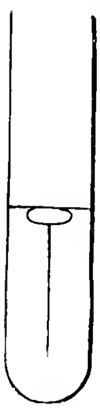


FIG. 9.

Gelatin stab.—Slow liquefaction: first an excavation in deep saucer form, several millimeters in diameter and lined by a gray-white, thick layer, which is fairly smooth and shining (fig. 9). This excavation increases somewhat in size and liquefaction slowly occurs beneath the lining membrane, while the nonliquefied gelatin near the surface acquires a marked blue-green fluorescence. There is only a faint growth along the line of inoculation.

Acid gelatin.—Good growth; less fluorescent.

Agar slant.—Grayish, semitranslucent stripe, with sharply defined, wavy margins; the agar becomes fluorescent.

Bouillon.—Clouded; on the surface a delicate grayish pellicle forms, while the bouillon is blue-green fluorescent; there is a stringy sediment.

Potato.—Chocolate-colored, viscid-looking, rather thick, and rather widely spreading growth.

Litmus milk.—Slow coagulation and cloudy serum containing flocculi in suspension; the clot is jelly-like and decolorized, and is slowly dissolved; there is a pink ring on tube wall above a pale bluish ring; the reaction is alkaline.

Sugar gelatin in deep stab.—Very faint development.

Rosolic acid.—Color is deepened.

Indol production.—The reaction is doubtful or faint; the addition of nitrite is necessary.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus fluorescens mutabilis.

Isolated from the water of the Schuylkill River. A medium-sized, *motile* bacillus, with rounded ends, occurring often in pairs. It has one or two flagella at one end; no spore formation observed.

Colonies in gelatin.—On the second or third day the surface colonies appear to consist of whitish, sometimes greenish flocculi, lying in saucer-shaped liquefactions several millimeters in diameter; in some cases the colonies are more or less sunken, greenish, membranous expansions. This difference seems to be dependent on the gelatin used. A blue-green fluorescence may sometimes be observed in the medium. Under a low-magnifying power a dark, dense mass is seen at the center of the liquefaction; around this a zone densely filled with granular brownish material, often in clumps, and this, in turn, bounded at the periphery by a more or less distinct fringe of closely lying, parallel filaments. In other preparations the colony is seen under the low power to be membranous in character, and to consist of a dark greenish, central, dense mass, which merges into a thin peripheral zone, with wavy, sharply defined margins, and marked by numerous dark wavy and irregular radiating lines. The colony is sunken in the gelatin at the center, from which liquefaction seems to spread to the periphery and the colony is broken up. The deep colonies are rounded or oval, dark brown, sometimes greenish, and have sharply defined contours; they are often marked by irregular, dark, radiating lines; when they come to the surface they form an expansion which seems to be made up of closely packed, coiled and twisted, brownish cords, and this may become limited by a short fringe of radiating fibrils.

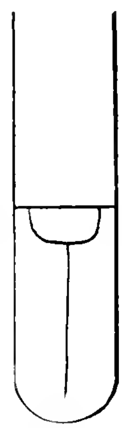


FIG. 10.

Gelatin stab.—Liquefaction in cup or deep saucer form, extending to the tube wall, and afterwards having a level floor (fig. 10). The liquefied gelatin is clouded, and a more or less well-defined mycoderm of a gray or sometimes greenish color forms on the surface, while there is a whitish sediment at the bottom; the growth produces more or less of a green color; the development along the line of inoculation consists of confluent, brownish white colonies, and in older cultures a faint but distinct brownish coloration may be seen in the gelatin around them if the tube be held against a white surface; this coloration is characteristic, and takes the form of a sharply defined, narrow zone, running all along the growth on each side.

Acid gelatin.—Grows well; no green color is produced, and the growth in line of inoculation is faint; the liquefied gelatin is alkaline.

Agar slant.—Grayish, semitranslucent stripe and irregular margins; the agar acquires a greenish tint.

Bouillon.—Clouded, with a thin grayish pellicle on the surface, and some sediment; the bouillon acquires a green color.

Potato.—Brown, thick, viscid looking, uneven, not very widely spreading growth.

Litmus milk.—Coagulated and decolorized; the clot is firm and the serum is clouded, holding flocculi in suspension; there is a bluish ring on the tube wall, and the reaction is alkaline; the casein seems to be slowly dissolved.

Sugar gelatin in deep stab.—Fair development with the production of gas; there is no liquefaction.

Rosolic acid.—Grows well without producing any marked change in color.

Indol production.—Negative.

Relation to temperature.—It seems to grow very slowly at 35° to 36° C.

Bacillus janthinus (Zopf).

Isolated from the water of the Schuylkill River. A medium-sized, generally short, *motile* bacillus, with rounded ends, sometimes growing in long forms and threads; it has a polar flagellum; no spore formation observed.

Colonies in gelatin.—On the second or third day the surface colonies are thin, translucent, slightly opalescent expansions, with irregular, sharply defined outlines, and a diameter of several millimeters; toward the center a grayish haziness may be seen. Under a low power the colony is thin and translucent, and shows very numerous fine lines, running in various directions and sometimes branching; the outline is irregular but sharply defined. Toward the center the colony has a slightly yellowish tint, and there may be a refractive central nucleus of the same color; the deep colonies are rounded or slightly irregular, brownish in color, finely granular, with smooth, sharply defined outlines. The surface colonies soon become grayish white throughout and denser; later a violet color appears, generally at the center, and the colony begins to sink into the gelatin, which is slowly liquefied beneath it. After a few days the colonies have a deep black-violet color, and are sunken in the gelatin, the liquefaction of which never spreads very far beyond the colony.

Gelatin slant.—Forms a deep furrow lined by a membrane; at first grayish and later becoming violet in color.

Gelatin stab.—At first a smooth, shining, grayish white surface expansion, which spreads rather widely and has irregular margins; this soon becomes violet in color and sinks in the gelatin, forming, after some time, a deep, rather irregular excavation, lined by a violet-colored membrane, beneath which slow liquefaction occurs; the excavation is usually narrower at the top, so that when it has reached the tube wall a ring of nonliquefied gelatin remains above; the liquefied gelatin is somewhat clouded, and there is some grayish or violet colored sediment; there is a fair growth in line of inoculation of confluent brownish colonies.

Acid gelatin.—Grows well; produces an alkaline reaction.

Agar slant.—Grayish, semitranslucent, smooth, shining growth, with wavy, sharply defined outlines, spreading rather widely below; this later becomes deep violet in color and membranous in character.

Bouillon.—Clouded; a dark, violet-colored membrane forms on the surface; after a time the bouillon acquires a smoky violet tint and there may be a violet-colored sediment.

Potato.—Dense black, violet, membranous, coherent layer, sometimes shining, and in some places having a granular appearance, due to minute and numerous delicate wrinkles.

Litmus milk.—Decolorized with the formation of a dense, coherent, wrinkled, dark violet-colored membrane on the surface, and the milk acquires a violet color; there is no coagulation; the reaction is alkaline.

Sugar gelatin in deep stab.—Fair growth of discrete and confluent colonies; no gas is produced.

Rosolic acid.—Color is deepened; a violet-colored membrane forms on the surface.

Indol production.—Negative or doubtful.

Relation to temperature.—Does not grow at 35° to 36° C.

Remarks.—This bacillus was observed quite frequently in the early spring when it was first seen; it has not appeared for some months. The bacillus janthinus seems to be a widely distributed species. According to Flügge (Die Mikroorganismen) it was generally described by Zopf, and is probably identical with a bacillus described by Hueppe and a species found in the Hygienic Institute at Goettingen. Plagge and Proskauer met with it in the water supply of Berlin (Bericht über die Untersuchungen des Berliner Leitungswasser, Zeitschrift für Hygiene, Bd. II, 1887, p. 463). Maschek and Zimmermann each found it in their respective investigations (Lustig, Diagnostica dei batteri delle acque). Jordan (Report of the State Board of Health of Massachusetts, 1890, Pt. II, pp. 840, 841) studied it in his work on sewage at Lawrence, Mass., and has given an excellent description of it. Schmelk (Centralblatt für Bacteriologie und Parasitenkunde, Bd. IV, 1888, p. 195) found it in the water supply of Christiania, which is derived from the melted snow of neighboring mountains, and Bujwid isolated it from a hailstone. (Centralblatt für Bakteriologie und Parasitenkunde, Bd. III, 1888, p. 1.) Moreover, an organism isolated by the writer from the water supply of Madison Barracks, N. Y., is thought to have been the bacillus janthinus.

Bacillus coeruleus (Smith).

Isolated from the water of the Schuylkill River. A rather small, *motile* bacillus, with rounded ends occurring singly, in pairs, and occasionally in long forms: it has several flagella, probably normally about four; no spore formation observed.

Colonies in gelatin.—About the third day the surface colonies are thin, translucent expansions, with irregular, sharply defined outlines, and a diameter of about two 2 mm.: they have a slate-blue color. Under a low power they are thin and finely granular, and, in younger colonies, a few delicate branching lines may be observed. The outlines are irregular and leaf-like, and sharply defined. The deep colonies, under a low power, are irregularly oval, finely granular, slightly yellowish or brownish toward the center, and sharply defined in contour. The surface colonies may increase somewhat in size, grow thicker and more bluish in color, and slowly liquefy the gelatin. About the fifth day they may appear as rounded, bluish gray masses, with margins no longer sharply defined, lying in round, saucer-shaped depressions, containing clear liquefied gelatin, which surrounds the colony on all sides. Under a low power the colony is made up of dense dark brown masses, and is rather opaque and coarsely granular; the margin is ragged and broken, and in the liquefied gelatin around it detached clumps are seen. The liquefaction proceeds slowly for some distance around the colonies and forms a wide zone, if the colonies are not numerous.

Gelatin stab.—Liquefaction in deep saucer form, constricted at the top and inclosing an air space (fig. 11). On the surface of the liquefied gelatin a bluish gray membrane; the liquefied gelatin is clouded, and there is a bluish sediment; there is some development in the line of stab; the liquefaction is slow, and practically ceases when about a fourth of the gelatin in the tube has been liquefied.

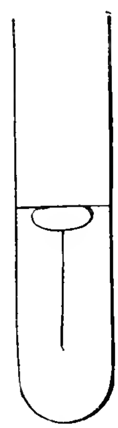


FIG. 11.

Acid gelatin.—Grows well.

Agar slant.—A slate bluish, smooth, shining, narrow stripe, with wavy margins; growth is rather dense by transmitted light; after a short time the bluish color gives place to a gray.

Bouillon.—Clouded and whitish flocculent sediment; a few scattered bluish flocculi may be seen on the surface, and there may be a bluish ring on the tube wall at the level of the liquid.

Potato.—Slate-blue, irregular, dense, somewhat viscid-looking growth; in older cultures becomes dirty brown in color.

Litmus milk.—Coagulated and decolorized; the clot is firm and the cloudy serum is bluish, with blue flakes in it; there is a blue ring on the wall of the tube; the reaction is neutral.

Sugar gelatin in deep stab.—Fair growth; no gas production.

Rosolic acid.—Color is deepened.

Indol production.—Marked reaction *with the coincident* production of nitrites.

Relation to temperature.—Grows well at the temperature of the room and at 35° to 36° C.

Remarks.—This bacillus (vide Sternberg, *Man. Bact.*, p. 635) was first described by Allen J. Smith, who states (The Medical News, 1887, Vol. II, p. 758) that he observed it in considerable numbers in the Schuylkill water. In the course of this work it has been observed but once.

Bacillus subtilis (Ehrenberg).

Isolated from the water of the Schuylkill River; seems to be a common organism. A large, *motile* bacillus, occurring singly, in pairs, and in threads, which break up into short segments, each of which develops a large oval spore at its center; it is provided with numerous flagella.

Flügge, Die Microorganismen.

Colonies in gelatin.—On the second day the surface colonies have formed saucer-shaped liquefactions, which are cloudy and contain more or less whitish material in clumps; their outlines are sharply defined and circular. Under a low magnifying power the liquefied gelatin is seen to be permeated by a more or less dense network of fibrils, and to be limited at the periphery by a fringe of short, hair-like processes which radiate into the nonliquefied gelatin. (See Pl. I, fig. 11.) In some cases a coarsely granulated appearance of the liquefied gelatin may be observed and motion of a circulating character may be seen in it. The deep colonies under the low power appear as dense, opaque, rounded bodies, sometimes having a greenish shimmer, from which numerous hair-like processes, some of which may be quite long, extend into the gelatin in a somewhat irregular manner; liquefaction progresses rapidly.

Gelatin stab.—Liquefaction quickly spreads to the tube wall at the surface and more slowly extends along the line of inoculation; liquefaction extends downward and laterally from the line of inoculation until all the gelatin is liquefied. (See fig. 12.) A thick, wrinkled, white mycoderm forms on the surface; immediately beneath this the liquefied gelatin is clear, while thick, flocculent, whitish masses collect in the lower portions of the liquefaction. The reaction of the liquefied gelatin is alkaline.

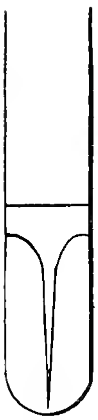


FIG. 12.

Acid gelatin.—Grows well; no liquefaction along line of inoculation; liquefaction is retarded and proceeds from above downward with a level flow.

Agar slant.—Gray, white frosted, or velvety felt-like membranous layer with somewhat furred margins; in older cultures it becomes denser, smooth and shining, and the margins more sharply defined and wavy, while the agar acquires a slight smoky brown-green color; a few wrinkles may sometimes be observed in the growth.

Bouillon.—Clouded at first; later a thick, white, friable mycoderm, which sinks to the bottom when the tube is shaken, forms on the surface.

Potato.—White, moist, velvety, rather thick, and widely spreading layer; later it becomes shining, and may have a slimy appearance.

Litmus milk.—Coagulated and decolorized; the coagulum is viscid or jelly-like, and the serum is dark colored and clouded with flocculi and irregular clumps in suspension; there is a bluish ring on the tube wall above the level of the liquid, and the reaction is alkaline; the casein seems to be slowly dissolved.

Sugar gelatin in deep stab.—Good growth with liquefaction; no gas is formed.

Rosolic acid.—No growth.

Indol production.—Faint reaction; does not produce nitrites.

Relation to temperature.—Grows well at room temperature and at 35° to 36° C.

Remarks.—Tils found this organism among the many species described by him in his report on the water supply of Freiburg. (Zeitsch. für Hygiene, Bd. IX, p. 315, 1890.)

Bacillus detrudens.

Isolated from the Schuylkill water. Seems to be a common contaminating organism, especially in potato cultures. A medium-sized *motile* bacillus, with blunt ends, about two or three times as long as broad, occurring singly, in pairs, and in long forms. It has numerous flagella. Forms rather small, oval spores, about as broad as the bacillus, usually situated nearer one end of the rod. (See fig. 13.)

FIG. 13.

Colonies in gelatin.—On the second or third day the surface colonies appear as whitish, rounded, semitranslucent disks, with smooth, sharply defined outlines, 1 mm. to 2 mm. in diameter. Under a low power the colony is seen to be brownish and granular, growing more translucent toward the edge, which is smooth and sharply defined. Toward the center the colony is much darker and may have a greenish shimmer, and a central nucleus may be observed. Between the center and the periphery scattered coarser granules or faint lines may sometimes be seen. The deep colonies are generally rounded, oval, or slightly irregular in outline. (Pl. I, figs. 14 and 15; Pl. II, fig. 3.) They are rather dense, brownish in tint, and highly granular, with sharply defined outlines. Sometimes, apparently in soft gelatin, the deep colonies may form very irregular figures by the outgrowth of daughter colonies as plaques and buds. Tuft like outgrowths of short fibrils may be seen on these. Liquefaction soon occurs, and the surface colony becomes surrounded by a wide zone of cloudy, liquefied gelatin. Under a low power the colony is now seen to be much denser and may have a greenish brown shimmer. It may present the appearance of being broken up into a mass of closely packed clumps or marked by indistinct crooked lines. The liquefied area is dense, brownish, and granular, and is limited at the periphery by a zone of closely packed, radiating brown lines. Beyond this, again, a thin, translucent, almost invisible border lies on the nonliquefied gelatin. This has a very irregular outline. (See Pl. II, fig. 1.) In the liquefied zone motion of a circulatory character may be made out. In older colonies the growth in the liquefied area is seen to have acquired a membranous character and to be continuous with the original colony at the center, so that the whole colony consists of a rather viscid membrane lying in a depression containing liquefied gelatin. If a plate containing numerous colonies be examined with a low power after about thirty hours (Pl. II, fig. 2), the young surface colonies may be seen to have very grotesque and irregular outlines.

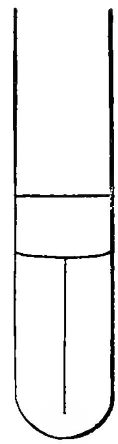


FIG. 14.

Gelatin stab.—On the third day a rounded, rather deep, saucer-shaped liquefaction has formed not yet extending to the tube wall. The liquefied gelatin is clouded, and there is a mycoderm on the surface which recalls in its appearance frosted glass. By the sixth day liquefaction has extended to the tube wall and downward for a considerable distance, the liquefied gelatin being separated from the nonliquefied by a nearly horizontal plane. (See fig. 14.) The liquefied gelatin is nearly clear, and there is a tough, yellowish white, coarsely wrinkled mycoderm on the surface and some sediment at the bottom. There is only slight growth in the line of inoculation. The reaction of the liquefied gelatin is alkaline.

Acid gelatin.—Growth is retarded.

Agar slant.—Creamy white layer extending to the wall of the tube on each side, except near the top of the slant, where it becomes narrow. The growth is smooth, homogenous, and shining. A few slight wrinkles may sometimes be observed. By transmitted light the growth is white and not translucent. The agar may take on a faint green tint after a time.

Bouillon.—Clouded. A thin, imperfect pellicle forms on the surface and there is some sediment.

Potato.—A rapidly growing, widely spreading, light brown, rather thin but dense and coherent layer which is thrown up into very numerous delicate wrinkles and folds which cross one another in various directions, giving the potato the appearance of being covered by a network.

Litmus milk.—Action is slow; after a week partly decolorized from the bottom; later, coagulation and complete decolorization; the coagulum is viscid and above it is seen a layer of cloudy serum; there is a slightly bluish ring on the wall of the tube above the level of the liquid; the reaction is neutral.

Sugar gelatin in deep stab.—Slight development; no gas production.

Rosolic acid.—No vigorous growth; little or no change in color.

Indol production.—Reaction is faint or doubtful; does not produce nitrites.

Relation to temperature.—Grows well at the temperature of the room and at 35° to 36° C.

Bacillus crinitus.

Isolated from the water of the Schuylkill River. Not common. A large, *nonmotile* bacillus with blunt ends, occurring usually in chains and segmented threads. Forms oval or rounded spores, which are situated near one end of a short segment or rod. (See fig. 15.)

FIG. 15.

Colonies in gelatin.—About the second day or earlier the surface colonies appear as round, shining, whitish, semitranslucent disks, 1 mm. to 2 mm. in diameter, and with a smooth, sharply defined outline; they have a viscid consistency, adhering to the "loop" and stringing out into viscid threads. Under a low magnifying power they are dark, highly granular, and have a smooth, sharply defined outline; the deep colonies are dark and opaque, usually coarsely granular at margin; the outline is rounded or oval and sharply defined. On the third day the colonies are larger, and consist of more or less dense, felt-like pellicles, with slightly crimped or folded margins, and are somewhat sunken in liquefied gelatin. (Pl. II, fig. 5.) Under the low power they are dense and opaque, with a greenish shimmer in some places. At margins they are seen to be made up of a felt-work of rather coarse fibrils, some of which project from the margin, giving it a "frayed" appearance, while others may be seen floating in the liquefied gelatin as short fragments.

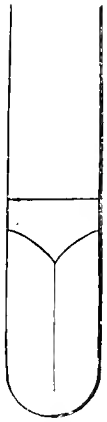


FIG. 16.

Gelatin stab.—Liquefaction begins in cupshape and spreads to the tube wall and also downward. (See fig. 16.) When the liquefaction has extended to the tube wall the floor of the liquefaction has the form of a wide-angled funnel. There is a faint growth in stab; the liquefied gelatin is clouded except in upper layer, which may be nearly clear, while at the bottom there is an abundant yellowish white flocculent sediment.

Acid gelatin.—Growth retarded.

Agar slant.—Grayish white, frosted looking, rather dense stripe, with wavy, irregular margins; it is yellowish white by transmitted light; the agar requires a smoky greenish color.

Bouillon.—Clouded with whitish flocculi at surface and a whitish sediment.

Potato.—Thick creamy white, viscid, widely spreading layer, becoming soon yellowish, and later caseous in appearance.

Litmus milk.—Decolorized and a smoky bluish colored layer of cloudy serum at surface and bluish ring on wall of tube; the white portion becomes viscid and jelly-like, and is gradually dissolved, the layer of serum above gradually increasing in depth; the reaction is neutral.

Sugar gelatin in deep stab.—Some growth and liquefaction; no gas production.

Rosolic acid.—Somewhat decolorized; growth is not vigorous.

Indol production.—Faint or doubtful reaction; the addition of nitrite is necessary.

Relation to temperature.—Grows well at the temperature of the room and at 35° to 36° C.

Bacillus ramosus.

(Wurtzel bacillus.)

Isolated from the water of the Schuylkill River. Not uncommon. It has also been observed in the Delaware water. A large *nonmotile* bacillus, growing into long segmented threads. In stained preparations these segments are separated by a clear interval, and have square ends. Forms oval spores in the middle of a segment.

Colonies in gelatin.—After twenty-four hours the colonies appear as hazy, ill-defined spots, with small, indistinct, slightly denser centres. On close inspection they are seen to consist of a loose feltwork; the gelatin is liquefied in a short time. Under a low power a loose network is seen, formed of very long, fine, hair-like filaments, which are sometimes straight and sometimes delicately undulating, running in all directions, and crossing one another at all angles. Toward the center of the "spot" the network is somewhat denser, and here a dark, ill-defined "nucleus" may be found. If the colonies are few in number they may very soon attain a diameter of a centimeter or more.

Gelatin stab.—The gelatin is permeated by very numerous, long, delicate filaments, which grow out at right angles to the line of inoculation, giving the well-known "inverted fir-tree" appearance which has been described, while a thick, wrinkled, whitish layer forms on the surface; liquefaction of all the gelatin occurs after a time.

Acid gelatin.—Grows less vigorously; there is less development of lateral outgrowths from the line of inoculation; an alkaline reaction is produced in the liquefied gelatin.

Agar slant.—Rather thick, whitish, dense, felt-like layer, widely spreading and somewhat wrinkled; about the margins thread-like processes may be seen forming more or less of a network; the agar becomes slightly greenish.

Bouillon.—Veil-like sheets form a thick, wrinkled, more or less complete whitish mycoderm on the surface, while a membranous sediment settles to the bottom; the reaction is alkaline.

Potato.—Grayish white, dense, rough, widely spreading layer.

Litmus milk.—Coagulated and decolorized; the clot is firm and the serum more or less clouded; there may be more or less pink coloration in the clot; the reaction is neutral or slightly acid.

Sugar gelatin in deep stab.—Good growth, similar in appearance to the growth in plain gelatin; no gas production.

Rosolic acid.—Decolorized; reaction alkaline.

Indol production.—Negative.

Relation to temperature.—Grows at the temperature of the room and at 35° to 36° C.

Remarks.—This bacillus has been described by the Franklands (Zeitschrift für Hygiene, Bd. VI, 1889, p. 388) under the name B. ramosus. They state that they have frequently met with it in the waters of the Thames and the Lea, and consider it to be identical with the Wurtzel bacillus of Eisenberg (Bacteriologische Diagnostik) and of C. Frankel (Grundriss der Bacterienkunde). Under the latter name it is mentioned by Tils (Zeitschrift für Hygiene, Bd. IX, p. 291, 1890) as being one of the more common organisms in the Freiburg water supply. Pokrowsky found it in the water of the Kura River. (Centralblatt für Bact. u. Par., Bd. X, 1891, p. 566.)

Bacillus subfanatus.

Isolated from the water of the Schulykill River. A medium-sized, *motile* bacillus, with rounded ends, occurring sometimes in pairs and in long forms; it has several flagella; forms rounded, spores situated in swellings near the ends of the rods. (See fig. 17.)

FIG. 17.

Colonies in gelatin.—About the second day the surface colonies appear as rounded grayish disks, 1 mm. to 2 mm. in diameter. Under a low power they are granular, rather dense toward their centers, but become more translucent at their margins, which are sharply defined and nearly smooth. The deep colonies are generally round, brownish and granular, not dense, and sharply contoured; under some circumstances they may form colonies or aggregations of small daughter colonies. The original colony in the "water" plate was a radiating figure formed of columns of these daughter colonies; but no such characteristic appearance has been seen in the colonies derived from this. About the third day liquefaction is present, and the surface colonies have formed round, saucer-shaped liquefactions, which are yellowish white at their centers, while in the cloudy, liquefied gelatin which they contain a hazy ring may be seen. Under a low power these liquefied areas are dense and granular, toward their centers brownish, while at their margins a fringe of radiating fibrils may be seen.

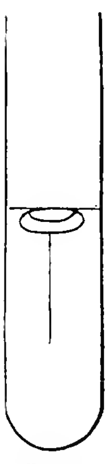


FIG. 18.

Gelatin stab.—Liquefaction in deep saucer form constricted at the top (fig. 18). This gradually extends to the wall of the tube and also downward with a rounded floor, eventually becoming level. There is faint growth along the line of inoculation; the liquefied gelatin is clouded with a whitish mycoderm at the surface, and after a time an abundant, whitish sediment; an alkaline reaction is produced.

Acid gelatin.—Growth is perhaps less vigorous and the liquefied gelatin acquires a neutral reaction.

Agar slant.—Translucent, thin, grayish, narrow stripe, with sharply defined margins; the growth seems to thrive better beneath the surface of the agar; the medium acquires a brownish green color.

Bouillon.—Clouded with a whitish sediment; the bouillon acquires a greenish tint.

Potato.—Brownish, thin, granular looking, rather widely spreading moist growth.

Litmus milk.—No coagulation; the milk is decolorized and the casein seems to go into solution; there is a bluish ring in the tube wall and the reaction is alkaline.

Sugar gelatin in deep stab.—Only very faint development after some weeks; no gas.

Rosolic acid.—Apparently no growth.

Indol production.—Does not grow vigorously; reaction faint or doubtful; the addition of nitrite solution is necessary.

Relation to temperature.—Grows at the temperature of the room and at 35° to 36° C.

Bacillus capillaceus.

Isolated from the water of the Schuylkill River. Not common. A large *motile* bacillus with square or blunt ends, growing into segmented threads; it has a number of flagella; forms oval spores, which develop in the centers of the short rods or segments. (See fig. 19.)

FIG. 19

Colonies in gelatin.—On the surface, about the second or third day, saucer-shaped liquefactions of a hazy appearance, 2 mm. or so in diameter and growing larger, may be seen. They are denser and grayish at their centers, and their margins are well-defined as grayish circles. Deep colonies are seen to consist of small spheres and hazy spots. The liquefied areas, under the low power, are dark, dense, and granular (Pl. II, fig. 4), with darker clumps at the centers and at the peripheries a fringe of radiating fibrils. A circulating motion may be seen in them. In some cases the liquefied gelatin seems to contain broken filaments. When the deep colonies are examined with the low power great variation is seen in their appearance. (Pl. II, figs. 6, 7, and 8.) The most common colonies are rounded, dark, and granular, with a few fibrils projecting into the gelatin; other colonies, and the most characteristic, are irregular radiating or stellate branching figures, formed of columns of small "daughter" colonies and filamentous outgrowths. Between these and the simpler forms there may be found all grades of transition. The deep colonies seem to send out more and more numerous fibrillar processes into the gelatin and cause its liquefaction. After a few days the areas of liquefaction contain grayish, felt-like layers.

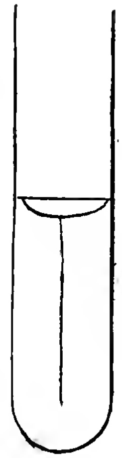


FIG. 20.

Gelatin stab.—Liquefaction in saucer form, extending to the tube wall and slowly downward with a nearly level floor. (See fig. 20.) There is only a faint development along the line of inoculation. The liquefied gelatin after a time contains flocculi and has a wrinkled pellicle at the surface, which is partly sunken in the gelatin. At the bottom of the liquefaction there is a flocculent whitish sediment. In cultures of several weeks this may be much increased in amount and of a sheet-like character, apparently due to the repeated formation of mycoderms at the surface and their consequent sinking.

Acid gelatin.—Some growth; seems to produce an alkaline reaction.

Agar slant.—Grayish, dense, rather widely spreading layer, with wavy, sharply defined margins. At first the surface is like frosted glass, but later it becomes smooth and shining, and may show a few slight wrinkles; the agar acquires a brown-green color.

Bouillon.—Clear; at the bottom a sediment of sheet-like masses and a collection of similar material at the surface; the reaction is alkaline; a mycoderm may form which falls to the bottom very readily.

Potato.—Thick, rough, granular, widely spreading growth; it has more or less of a purple-pink color, becoming later grayish; the growth on potato is characteristic.

Litmus milk.—Decolorized and coagulated; a deep layer of cloudy serum above and a bluish ring on the tube wall; the clot is somewhat jelly like; the reaction is neutral.

Sugar gelatin in deep stab.—Good growth of discrete and confluent minute colonies; no gas production nor liquefaction.

Rosolic acid.—Apparently no growth.

Indol production.—Faint or doubtful; addition of nitrite solution is necessary.

Relation to temperature.—Grows at the temperature of the room and at 35° to 36°.

Bacillus delabens.

Isolated from the water of the Schuylkill River. Common. A rather small *motile* bacillus, with rounded ends, occurring in short rounded and long forms and in pairs; it has a terminal flagellum; no spore formation observed.

Colonies in gelatin.—About the second day the surface colonies are thin, translucent, shining expansions, with wavy, irregular, sharply defined outlines and grayish centers. Under a low magnifying power the colony is thin and translucent, and the surface is marked by numerous delicate lines which run in various directions, and which sometimes branch. (See Pl. I, fig. 12.)

The outline is sharply defined, wavy, and irregular; toward the center a brownish yellow color appears, and a sharply defined, yellow-brown refractive central nucleus may be observed. The colony soon becomes denser and grayish white throughout, and sinks into the gelatin, which is slowly liquefied. The deep colonies, under a low magnifying power, are rounded or slightly irregular in outline and sharply defined; they are slightly granular and of a brownish yellow tint, often darker toward the center. A dark ring may sometimes be observed between the center and the periphery.

Gelatin slant.—A smooth, gray-white stripe with wavy margins is formed at first; this sinks into the gelatin, and a furrow is formed lined by a grayish white, viscid layer; liquefaction slowly occurs and the growth to some extent gradually slips downward; the surface of the nonliquefied gelatin acquires a hazy appearance.

Gelatin stab—A thin, grayish white surface expansion with irregular outlines is formed; this slowly sinks into the gelatin, which is slowly liquefied; there is a fair growth along the line of inoculation of brownish gray, discrete, and confluent colonies.

Acid gelatin.—The growth is perhaps less vigorous.

Agar slant.—Whitish, semitranslucent, shining growth, not widely spreading; the agar after a time acquires a slight green tint.

Bouillon.—Clouded; whitish flocculi may form an imperfect pellicle on the surface; there is a whitish sediment, and the bouillon may acquire a slight green tint.

Potato.—Brownish, viscid, rather thick growth, spreading rather widely and becoming darker in older cultures.

Litmus milk.—Decolorized; after a few weeks there is a smoky bluish layer at the top, while below this the milk has a brownish white color; there may form a tough membrane on the surface which permits the tube to be inverted without disturbing the liquid; above this there is a bluish ring on the tube wall; there is no coagulation, but the milk may be viscid in old cultures; the reaction is alkaline.

Sugar gelatin in deep stab.—No growth.

Rosolic acid.—Rose color much deepened.

Indol production.—Faint reaction; no nitrite production.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus duplicatus.

(Variety *a*.)

Isolated from the water of the Schuylkill River. A medium-sized, rather short, *motile* bacillus with rounded ends, occuring singly, in pairs, and in threads; it has a terminal flagellum; no spore formation observed.

Colonies in gelatin.—On the second day the surface colonies appear as gray, white, translucent, shining, slightly elevated disks 1 mm. to 2 mm. in diameter, with smooth or slightly irregular rounded outlines, sharply defined. Under a low magnifying power the colony is of a dark brownish color toward the center, but becoming translucent and colorless toward the margin; the outline is smooth or slightly wavy, and is sharply defined; near the center a brownish or brownish green nucleus is seen, and between this and the periphery indistinct, radiating, brownish lines may be observed. As development proceeds the colony, as observed with the low magnifying power, becomes darker and more opaque from the center to the periphery, and a greenish shimmer appears; near the margin, which remains thin and translucent, a brownish mottling may be seen. The deep colonies under the low power are rounded, dark, granular, somewhat refracting, brown or brownish green at the center, and have a smooth, sharply defined outline. About the third day the colony becomes denser, slightly greenish white in color, sinks slightly into the gelatin, and liquefaction slowly occurs; the gelatin may become slightly green, fluorescent; sometimes one or two thick, club-shaped processes may be seen extending into the gelatin from the under surface of the colony.

Gelatin stab.—Liquefaction in deep saucer form, constricted at the top and extending to the tube wall in about a week, and slowly downward; the flow of the liquefaction, after the tube wall has been reached, becomes level. (See fig. 21, *a*) On the surface there is a very thin, almost invisible pellicle, with one or more dense whitish patches in it; the liquefied gelatin is densely clouded, and may have a slight green tint; on the flow of the liquefaction there is a thick flocculent deposit; there is only slight growth in the line of inoculation.

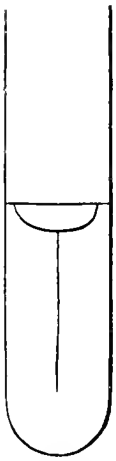


Fig. 21*a*.

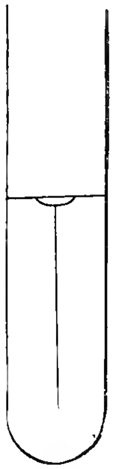


Fig. 21*b*.

Acid gelatin.—Grows less vigorously and with little or no liquefaction.

Agar slant.—Smooth, shining, whitish, semitranslucent stripe with slightly irregular margins, not spreading widely; the agar acquires after a time a faint green tint.

Bouillon.—Clouded; a delicate pellicle may form on the surface; there is a somewhat viscid sediment, and a greenish tint may appear in the liquid.

Potato.—Moist, viscid-looking, brownish growth, spreading rather widely.

Litmus milk.—Coagulation and separation of a cloudy serum after a time. The milk is discolorized; there is a pink ring on the tube wall above the level of the liquid, and the upper layer of the coagulated milk may be pink also. The clot is firm.

Sugar gelatin in deep stab.—Only faint development; no gas is formed.

Rosolic acid.—Decolorized; the reaction is neutral or alkaline

Indol production.—Fair reaction; does not produce nitrites.

Relation to temperature.—Does not grow at 35° to 36° C.

Remarks.—A variety, *b*, of this bacillus has been isolated from the same source. It is also a polar flagellated bacillus and resembles the one above described in its morphology and biological characters, but shows the following main points of difference: In gelatin stab cultures it liquefies much less rapidly than the variety *a* (see fig. 21 *b*), and it requires a longer time to coagulate milk. It also gives a less marked or doubtful indol reaction and seems to have a less active effect on rosolic acid. In its colony growth in gelatin the same slowness in liquefaction is observed when compared with the other organism.

Bacillus Fairmontensis.

Isolated from the water of the Schuylkill River. A medium-sized, generally short, *motile* bacillus with rounded ends, often in pairs and sometimes in long forms and threads. It has a terminal flagellum; no spore formation observed.

Colonies in gelatin.—By the second day the colonies on the surface appear as rounded, whitish, semitranslucent disks, about 1 mm. or 2 mm. in diameter. Under a low magnifying power they are seen to be rather dark at the center, with a greenish shimmer, but becoming thinner, granular, and brownish toward the periphery, where they are quite thin and translucent. The outline is smooth and sharply defined. Between the center and the periphery some faint radiating lines may sometimes be observed, or near the margin an indistinct mottled appearance. There is often a rounded, opaque, greenish nucleus at the center. The deep colonies are rounded or oval, dense and granular, often showing a dark greenish brown tint at the center, and have smooth, sharply defined outlines. By the third day liquefaction may be well marked and the colonies are seen to be denser, to have lost their sharply defined outlines, and to be surrounded by a zone of cloudy liquefied gelatin. Under some circumstances the colony may now appear as a dirty grayish membrane with folded or crimped margins lying in a saucer-shaped liquefaction. The colonies of this bacillus in their early stages are nearly identical in appearance with B. duplicatus.

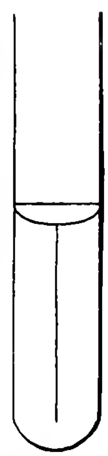


Fig. 22.

Gelatin stab.—Saucer-shaped liquefaction extending to tube wall in about three or four days with slight growth in line of inoculation (fig. 22). Liquefaction gradually extends downward, the liquefied gelatin being separated from the solid gelatin by a horizontal plane on which collects a whitish sediment. The liquefied gelatin is clouded, and a thin, easily detached, grayish membrane may be seen at the surface, more or less sunk in the liquefied gelatin.

Acid gelatin.—Liquefaction retarded. The reaction of the liquefied gelatin is alkaline.

Agar slant.—Grayish white, shining, somewhat elevated, semitranslucent stripe, with rather irregular and wavy, sharply defined margins. The growth shows some inequalities on the surface, and does not spread widely. The agar acquires a slight green tint after a time.

Bouillon.—Clouded; a delicate, almost invisible pellicle forms on the surface, and there is a flocculent, whitish sediment at the bottom. The bouillon acquires a faint green color.

Potato.—Rather dry, granular, elevated, widely spreading growth of about the same color as the potato; the granular appearance seems to be due to minute wrinkles or folds; later the growth may become brownish in color and viscid looking.

Litmus milk.—Coagulated and decolorized; the clot is firm and the serum is clouded; there is a pink ring on the wall of the tube and the clot may show some pink coloration after a time.

Sugar gelatin in deep stab.—Very slight development.

Rosolic acid.—Decolorized; reaction is neutral or alkaline.

Indol production.—Fair reaction; does not produce nitrites.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus geniculatus.

Isolated from the water of the Schuylkill River. Rare. A medium-sized *motile* bacillus, occurring singly, in pairs, and sometimes in threads. It is a polar flagellated bacillus, the number of flagella varying from one to probably four; no spore formation observed.

Colonies in gelatin.—About the second day the surface colonies are rounded, semitranslucent, whitish disks, somewhat denser at the center and 1 mm. to 2 mm. in diameter. (Pl. 11, fig. 9.) They may already be slightly depressed in the gelatin; under a low power they are brownish and granular about their centers, thinner at their margins, which are smooth or slightly wavy, and sharply defined in colonies not yet beginning to liquefy the gelatin, while in those which are, the margins are rugged and surrounded by a finely granular zone, apparently made up of delicate, radiating fibrils; the colonies soon get denser as liquefaction begins, and may have a greenish shimmer. The deep colonies appear to the naked eye as yellow points; under a low magnifying power they are spherical, sharply defined, faintly granular, and are studded here and there by small plaques or buds. About the third day the colonies are circular in outline, grayish white with yellowish centers, and several millimeters in diameter; they lie in saucer-shaped depressions containing liquefied gelatin, a narrow zone of which surrounds them; later a pinkish tint may be observed at their centers; under a low power they are now granular, dark, and dense, with a greenish shimmer, breaking up at the margin into a granular zone, which is bounded by a more or less distinct fringe of radiating fibrils. Motion of a circulatory character has been observed in the liquefied gelatin; the deep colonies, when examined with the low power about this time, are rough looking, apparently being made up of aggregations of small irregular clumps, an appearance which seems to be the result of the budding process noted above. Many have a dark center and may show a reddish brown tint or a greenish shimmer.

Gelatin stab.—Liquefaction in funnel form extending slowly down the line of inoculation; there may be a constriction at the top inclosing an air space (fig. 23). The liquefied gelatin is clouded and there is an abundant whitish to pinkish deposit; there may be a thin pellicle on the surface; the growth along the line of inoculation preceding liquefaction has a pinkish tint, and may be composed of discrete and confluent spherical colonies.

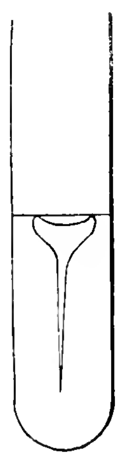


FIG. 23.

Acid gelatin.—Grows less vigorously and with slow liquefaction, which does not extend along the line of inoculation.

Agar slant.—Grayish, shining, smooth surface growth, not spreading widely, with wavy, bulging margins; it is semitranslucent by transmitted light. The agar acquires a brownish green tint.

Bouillon.—Clouded with flocculi in suspension, which at the surface may form an imperfect pellicle; the bouillon acquires a slight greenish tint; there is a whitish sediment at the bottom.

Potato.—Thin, viscid looking; moist, shining, brownish growth, not widely spreading.

Litmus milk.—Coagulated and decolorized; there is a pinkish yellow serum on some cloudy serum; the clot is jelly-like; the serum after a time may have a slightly greenish tint; there is a bluish ring on the tube wall; the reaction is alkaline.

Sugar gelatin in deep stab.—Points of liquefaction containing pinkish flocculi along the line of inoculation; later liquefaction all along the line irregularly, and here and there pinkish clumps; in places groups of delicate lateral furry outgrowths; no gas is produced.

Rosolic acid.—Color deepened.

Indol production.—Negative.

Relation to temperature.—Does not grow at 35° to 36° C.

Bacillus flexuosus.

Isolated from the water of the Schuylkill River. Not a common species. It has been observed in the water of the Delaware also. A medium-sized, short, thick bacillus with rounded ends, occurring often in pairs, and may grow into long forms, threads, and chains.

The motility is doubtful; usually not motile; no spore formation observed.

Colonies in gelatin.—About the second day the surface colonies appear as whitish, somewhat irregularly outlined clumps in a depression containing clear, liquefied gelatin. Under a low power they give the impression of being made up of looped and twisted granular strands or cords closely packed together. (Pl. II, fig. 10.) At their centers they are dark and opaque with sometimes a greenish glimmer, while at their peripheries the arrangement of the strands is somewhat looser and they are less dense.

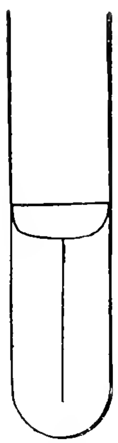


Fig. 24.

The outlines, being determined by the marginal strands, are irregular, but sharply defined.

In some colonies two or three of the component strands may become loosened from the rest and may appear as long, slender threads, finely undulating in places and sometimes looped or twisted, floating in the surrounding liquefied gelatin.

The deep colonies are rounded or slightly irregularly oval, brownish, and finely granular, with sharp contours.

Gelatin stab.—Liquefaction in deep saucer form extending to the tube wall and downward, the liquefied gelatin coming to be separated from the nonliquefied by a horizontal plane on which a whitish sediment is seen (fig. 24). The liquefied gelatin is clouded and there is a thin pellicle on the surface.

There is faint growth in line of inoculation.

The reaction of the liquefied gelatin is alkaline.

Acid gelatin.—Grows less vigorously; the reaction is nearly neutral.

Agar slant.—Narrow semitranslucent grayish stripe with slightly scalloped, sharply defined margins; the agar acquires slight greenish tint.

Bouillon.—Clouded and contains flocculi; it acquires a slight greenish tint; at the bottom there is a stringy sediment.

Potato.—Brown, viscid-looking, moist, uneven growth, not widely spreading.

Litmus milk.—Coagulated; pink in upper layers and white below; some cloudy serum after a time; pink ring on tube wall; the reaction is acid.

Sugar gelatin in deep stab.—Very faint development.

Rosolic acid.—Effect is uncertain.

Indol production.—Doubtful or faint reaction; the addition of nitrite is necessary.

Relation to temperature.—Very slight development, if any, at 35° to 36° C.

Bacillus coadunatus.

Isolated from the water of the Schuylkill River. A medium-sized, generally short, *motile* bacillus, with rounded ends, occurring singly, in pairs, and in threads and chains; it has a polar flagellum; no spore formation observed.

Colonies in gelatin.—About the third or fourth day the colonies are brownish white, round, rather dense and less than 1 mm. in diameter, some of them being sunken in the gelatin with evidences of liquefaction.

Under a low power they are highly granular, dark brownish, sometimes brown-green in tint at the center, with rough, ill-defined frayed margins, in some cases showing irregular, short, hair-like projections. (Pl. I, fig. 13.) Typical and characteristic colonies are surrounded by a narrow, sharply defined zone of liquefied gelatin, in which scattered granules may be seen. This zone of liquefaction, with its sharply defined circular outline, may give the colony the appearance of being encircled at its periphery by a well-marked line.

In some cases the area of liquefaction may become much wider and the colony, lying in a depression containing clear, liquefied gelatin, appears, under the low power, to be surrounded by a more or less well defined refraction ring.

The colonies do not increase in size, or very little, and liquefaction is not rapid.

Gelatin stab.—Liquefaction in deep saucer form extending to the tube wall and slowly downward (fig. 25). After the tube wall has been reached the flow of the liquefaction becomes a horizontal plane, and liquefaction slowly occurs along the line of inoculation. The liquefied gelatin is clouded and there is an abundant whitish flocculent deposit in the lower portions. After some time a greenish color may be observed in it.

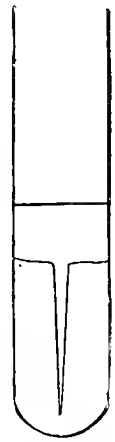


Fig. 25.

Acid gelatin.—Growth feeble; no liquefaction.

Agar slant.—Semitranslucent grayish stripe, not widely spreading, with irregular, sharply defined margins. The agar acquires a brown greenish tint.

Bouillon.—Clouded, whitish sediment. It seems probable that a slight pellicle may form on the surface. The bouillon acquires a slight green tint.

Potato.—Brown, viscid, moist, shining, rather widely spreading layer.

Litmus milk.—Coagulated with clouded serum. Clot is firm and of a pink and white color; reaction is acid.

Sugar gelatin in deep stab.—Good growth of discrete and confluent whitish colonies. Marked gas production; no liquefaction.

Rosolic acid.—Color markedly deepened.

Indol production.—Marked reaction; does not produce nitrites.

Relation to temperature.—Does not grow well at 35° to 36° C.; development is very faint at this temperature.

Bacillus convolutus.

Isolated from the water of the Schuylkill River. Not common. A large bacillus, generally long, occurring in twisted chains and threads; also singly and in pairs. It seems to have some motility under certain circumstances, but it is ordinarily *nonmotile;* no spore formation observed; in old cultures the protoplasm seemed to be shrunken away from its envelope.

Colonies in gelatin.—On the second day the surface colonies are rounded, grayish white, wooly looking, translucent, glistening, and somewhat opalescent. They may be 2 mm. or 4 mm. in diameter. Under a low power they resemble the external aspect of the cerebral cortex, being made up of coiled and twisted broad bands, between which slight branching fissures or dark lines are seen. (Pl. I, fig. 2.) These bands seem to be composed of closely packed parallel lying threads. The outline is sharply defined and wavy, corresponding to the external or peripheral "bands." Toward the center the colony may be darker, where there may be a rounded, dark nucleus. The deep colonies under a low power are rounded, sharply defined, dark, granular, and sometimes have a greenish shimmer. In the course of a few days the colonies become thicker and denser and sink into the gelatin, which is slowly liquefied. Under the low power they now have a greenish shimmer.

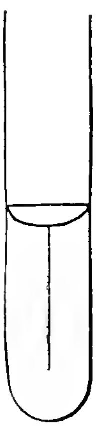


Fig. 26.

Gelatin stab.—Saucer-shaped, slow liquefaction, with only faint growth in the line of inoculation. (Fig. 26.) Liquefied gelatin is densely clouded and there is an abundant, thick, whitish sediment. The reaction is alkaline.

Acid gelatin.—Grows somewhat less vigorously, and there is little or no growth along the line of inoculation. The reaction of the liquefied gelatin is alkaline.

Agar slant.—A grayish, semitranslucent, not widely spreading stripe, with scalloped margins. The agar acquires a brown-green color.

Bouillon.—Clouded and thick, flocculent deposit. An imperfect pellicle and wooly shreds may form at the surface; the bouillon acquires a greenish tint.

Potato.—Growth varies; it is generally elevated and dense.

Litmus milk.—Seems to become a deeper blue and to be decolorized from the bottom up; it is probably not coagulated. After some time the milk becomes alkaline.

Sugar gelatin in deep stab.—No growth.

Rosolic acid.—Somewhat decolorized after some time; reacts alkaline.

Indol production.—Negative.

Relation to temperature.—Grows at the temperature of the room and at 35° to 36° C.

Bacillus multistriatus

Isolated from the water of the Schuylkill River. Not common. A medium-sized short, *motile* bacillus with rounded ends. Somewhat variable in length and occurring often in pairs. It has a polar flagellum; no spore formation observed.

Colonies in gelatin.—About the second day the surface colonies are rounded grayish, white, semitranslucent disks, 1 mm. to 2 mm. in diameter. (Pl. II, fig. 12.) Under a low power they are more or less dark brownish in color, rather dense toward the center, but becoming thinner toward the margin. The outlines are smooth or slightly irregular, and sharply defined. A striking thing in the appearance of these colonies under the low power is the presence of dark brownish zigzag and wavy lines and bundles of lines of various lengths, streaming toward the periphery from their centers, where there is often a dark nucleus. The deep colonies under a low power are dense, granular, brownish in color, and in some cases slightly greenish toward their centers. They are rounded or irregularly oval and sharply defined in outline. In some deep colonies dark, radiating, wavy lines have been observed. In a few days the surface colonies become denser and yellowish white in color and may increase somewhat in size. They very slowly liquefy the gelatin into which they slowly sink, but no zone of liquefaction is seen around them.

Gelatin stab.—Thick-beaded, whitish cord first forms along the line of inoculation, while there is an irregularly outlined, thick, whitish expansion which sinks gradually into the gelatin. After about ten days liquefaction begins all along the line of inoculation and spreads laterally to the tube wall, all the gelatin being eventually liquefied. The liquefied gelatin is filled with scattered whitish flocculi and there is a dense, whitish deposit at the bottom, while on the surface a dense, thick, whitish clump may be seen.

Acid gelatin.—Good growth, though liquefaction is not so vigorous along the line of inoculation. The liquefied acid gelatin is neutral or slightly alkaline.

Agar slant.—Semitranslucent narrow stripe with scalloped or wavy margins.

Bouillon.—Clouded and a stringy sediment. A thin pellicle which may have whitish, dry flakes in it forms after a time.

Potato.—Grayish or creamy, viscid-looking, thick, shining, widely spreading growth.

Litmus milk.—Decolorized and coagulated; the clot is friable and more or less pink, and the serum is clouded. There is a reddish ring in the tube wall. Reaction is acid or neutral.

Sugar gelatin in deep stab.—Vigorous growth with marked gas production; there is also liquefaction.

Rosolic acid.—Color is deepened.

Indol production.—Fair reaction; does not produce nitrites.

Relation to temperature.—Grows at the temperature of the room and at 35° to 36° C.

Bacillus centrifugans.

(Variety *a*.)

Isolated from the water of the Schuylkill River. In the summer occurs abundantly, both in the Schuylkill and Delaware water. A medium sized *motile* bacillus with rounded ends, sometimes in pairs and in long forms. It has a polar flagellum; no spore formation observed.

Colonies in gelatin.—After twenty-four to forty-eight hours the surface colonies are round, saucer-shaped depressions, containing faintly hazy, liquefied gelatin, several millimeters in diameter, which rapidly increase in size. About the center there may be a few grayish flocculi, while at the margin they are well defined by a grayish line. Under a low power the liquefied gelatin is granular in appearance, and a circulating motion may be seen in it, while scattered, dark, granular clumps, more closely gathered together about the center may be sometimes observed. At the margin there is a fringe of short radiating fibrils. The deep colonies are rounded, dark, and granular, and may have a greenish shimmer. They soon become surrounded by a zone of liquefaction, and break through the gelatin to form colonies similar to those described above. When they are just beginning to liquefy they are subject to some variation in their appearance.

Gelatin stab.—Liquefaction rapidly extends to the wall of the tube at the surface, and also all along the inoculation line, in a form varying from that of a funnel to that of a champagne glass. (See fig. 27.) The liquefied gelatin is clouded, and when the liquefaction is well advanced along the line of inoculation a thick, whitish, flocculent mass is seen at the bottom. On the surface there is a delicate pellicle, and in completely liquefied cultures beneath this a greenish tint may be observed. The reaction of the liquefied gelatin is alkaline.

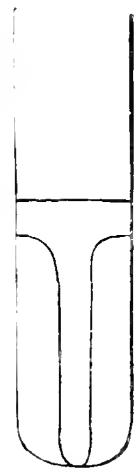


FIG. 27

Acid gelatin.—Grows less vigorously.

Agar slant.—Semitranslucent, shining, grayish, rather thin stripe, with scalloped margins. In older culture becomes a dirty brown color, while the agar acquires a marked brown-green tint.

Bouillon.—Clouded. A broken, imperfect pellicle forms on the surface and the bouillon acquires a brown green tint.

Potato.—Variable, thick, widely spreading, dense growth, somewhat rough or granular on the surface; the color varies from cream gray to pinkish.

Litmus milk.—Coagulated and decolorized; cloudy serum, containing flocculi; reaction is neutral or slightly acid.

Sugar gelatin in deep stab.—Fair growth with some gas production.

Rosolic acid.—Color deepened.

Indol production.—Marked reaction; does not produce nitrites.

Relation to temperature.—Grows at the temperature of the room and at 35° to 36° C.

Remarks.—This bacillus and its varieties, owing to the rapid and widely spreading liquefaction of the colonies, interfere more than any of the other liquefiers with the satisfactory study of the "water" plates.

Bacillus centrifugans.

(Variety β.)

A polar, flagellated bacillus, which is probably to be considered as a variety of the bacillus, has been isolated from the same source. With the exception of the differences noted below, the description given above applies equally well to this organism, point for point.

Colonies in gelatin.—To the naked eye the colonies are hardly to be distinguished from those of the preceding, but under a low power they are seen to have no dark, granular clumps in their interiors, but instead may show some dark streaks about their centers, while their margins do not have the radiating fringe so well defined, and it may be absent.

These differences, although trivial when analyzed for description, are well marked to a practiced eye. The deep colonies, when examined with a low power, are seen to be rounded, dark, granular, and sometimes have a greenish shimmer. The margins are rather uneven and not very sharply defined, in some cases broken. They soon become surrounded by a granular zone, become disintegrated, and form rounded liquefactions.

Gelatin stab.—The manner of liquefaction is very similar to that of the preceding, but with the following differences in other respects. The liquefied gelatin is more homogeneously clouded and has a different appearance, while the most marked characteristic of this variety is the absence of the thick, flocculent, whitish deposit at the bottom of the liquefaction.

Bacillus fimbriatus

Isolated from the water of the Delaware River. A medium sized, *motile* bacillus, with rather blunt ends, generally rather short, but occurring in long forms and sometimes in chains. It has several flagella; no spore formation observed.

Colonies in gelatin.—About the second day the surface colonies are rounded in outline, yellowish white in color, sunken in the gelatin, and in some cases surrounded by a cloudy liquefied zone.

They are about 1 mm. to 2 mm. in diameter. Under a low power they are rather dense, dark, brownish, and granular about their centers. Toward their peripheries they are less dense, and have a delicate radiating fringe at the margin. The deep colonies are round, granular, and have a greenish tint at their centers, where they are denser; their outlines are sharply defined.

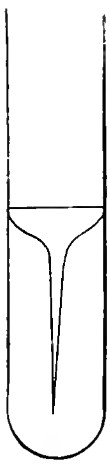


FIG. 28.

Gelatin stab.—Liquefaction in wineglass form, extending down the line of inoculation. (See fig. 28.) The liquefied gelatin is clouded and there are whitish flocculent deposits in the lower portions. A delicate, slightly iridescent pellicle forms on the surface. The liquefaction is slower than in the case of *B. centrifugans.* In completely liquefied cultures there is a greenish tint near the surface.

Acid gelatin.—Does not grow well.

Agar slant.—Smooth, dirty gray, shining stripe, with wavy or scalloped, sharply defined margins; agar acquires a brownish tint.

Bouillon.—Clouded and whitish sediment. An imperfect delicate pellicle may form on the surface; the bouillon acquires a dark greenish tint.

Potato.—Thick grayish or pale brownish, dense, rather rough surface growth, spreading widely; more or less of a pinkish tint may be seen. The growth on potato is essentially the same as that of *B. centrifugans.*

Litmus milk.—Coagulated, decolorized, with separation of cloudy serum witl flocculi in suspension; there is a bluish ring on tube wall; the reaction is neutral.

Sugar gelatin in deep stab.—Some growth with little or no liquefaction; no gas is produced.

Rosolic acid.—Color is deepened.

Indol production.—Good reaction; does not produce nitrites.

Relation to temperature.—Grows at 35° to 36° C., but seems to grow better at the temperature of the room.

Bacillus cohærens.

Isolated from the water of the Schuylkill River. Seems to be a common organism. A medium-sized, short, *motile* bacillus with rounded ends, occurring often in pairs and sometimes in long forms; it has a polar flagellum; no spore formation observed.

Colonies in gelatin.—About the fourth or fifth day the surface colonies are round, elevated, grayish, semitranslucent disks, about 1 mm. to 2 mm. in diameter, with sharply defined outlines. Under a low power they are finely granular, refracting and slightly yellowish brown in tint toward their centers, where there is a nucleus. The outline is smooth and rounded and sharply defined. The deep colonies under the low power are round or oval granular, brownish, and sharply defined in outline. The surface colonies may increase somewhat in size, becoming thicker, denser, and whiter, with an elevated brownish nodule at their centers. Later they sink into the gelatin and their margins may have a "crimped" appearance. The deep colonies after some days become more brown in color, when examined under a low power, and there may be a slight brownish tint in the gelatin immediately surrounding them, which is not apparent to the naked eye. Sometimes the deep colonies may form morula-like aggregations of daughter colonies.

Gelatin slant.—A more or less wrinkled, viscid-looking, grayish white membrane lining a rather deep furrow in the gelatin, which is very slowly liquefied.

Acid gelatin.—Grows well.

Agar slant.—An irregular, somewhat elevated, grayish white, semitranslucent, shining growth with irregular margins.

Bouillon.—Clouded. A coherent, viscid looking, tenacious, much-wrinkled membrane forms on the surface and adheres to the wall of the tube. In older cultures the bouillon seems to become quite clear.

Potato.—A rather thick, granular-looking, widely spreading growth of the color of the potato.

Litmus milk.—Decolorized and a viscid coagulation with a layer of smoky, bluish-colored serum at the top and a coherent, thick, tough membrane on the surface. The milk acquires a dirty, brownish white color and there is a bluish ring on the tube wall. The casein seems to be slowly dissolved; the reaction is alkaline.

Sugar gelatin in deep stab.—Fair growth of discrete colonies; no gas production.

Rosolic acid.—Color deepened.

Indol production.—Negative.

Relation to temperature.—Grows at the temperature of the room; its growth at 35° to 36° C. is doubtful.

Bacillus nebulosus.

Isolated from the water of the Schuylkill River. A medium-sized, *motile* bacillus, with rounded ends, occurring singly and in pairs; in length it is somewhat variable. It has a polar flagellum; no spore formation observed.

Colonies in gelatin.—On the third day the typical surface colony is a thin, gray, translucent, hazy, round, outlined expansion, with a well-marked whitish center, surrounded by a whitish ring. (See Pl. II, fig. 13.) The diameter may be about 3 mm. Under a low power a dark brownish, granular nucleus is seen at the center, around which a dark, finely granular zone extends about halfway to the periphery and then gives way rather abruptly, by the appearance in it of discrete and confluent, sharply defined, translucent areas, to a very thin, transparent zone, which ends at the well-defined, nearly smooth margin. The deep colonies are rounded, dark, and granular, sometimes brown-green in tint.

Gelatin slant.—A viscid whitish layer lines a shallow furrow, on each side of which thin, hazy, short, lateral outgrowths on the surface of the gelatin are seen, giving the growth a feathered appearance. By transmitted light the layer in the fissure is yellowish white. There is slow liquefaction.

Acid gelatin.—Does not seem to grow.

Agar slant.—A very thin, translucent stripe with irregular margins.

Bouillon.—Clouded and whitish sediment.

Potato.—Very scanty growth, if any.

Litmus milk.—No definite coagulation; it is decolorized and the casein seems to be dissolved. On the surface a broken, wrinkled, whitish mycoderm. The reaction is alkaline.

Sugar gelatin in deep stab.—Fair growth, with some gas formation.

Rosolic acid.—The effect is doubtful. The color is probably deepened.

Indol production.—Negative.

Relation to temperature.—Grows at the temperature of the room and at 35° to 36° C.

Proteus mirabilis (Hauser).[1]

Isolated from the water of the Schuylkill River. A rather small, *motile* bacillus with blunt ends, occurring singly, in pairs, and in long forms. It has a number of flagella; no spore formation observed.

Colonies in gelatin.—After twenty-four to forty-eight hours, saucer-shaped liquefactions, which are clouded and may have a whitish spot at their centers, are seen. They may have a diameter of several millimeters. (See Pl. II, fig. 14.) Under a low power the liquefied gelatin is coarsely granular, brownish, and dense toward the center, somewhat less so toward the periphery, where it is limited by a more or less distinct fringe of radiating fibrils. The deep colonies are rounded, granular, and brownish, not dense, and have sharp contours. In addition to these, this bacillus forms also other kinds of colonies which are highly characteristic. If a well developed plate be examined with a low magnifying power, small, translucent, elongated, generally spindle-shaped bodies may be seen in great numbers scattered through the gelatin among the other colonies. They usually taper at one or both ends into a sometimes branching filament and often have the appearance, in their thicker positions, of being made up of rouleaux of minute rounded colonies. Other irregular forms are seen. These growths are essentially like the photographs of *Proteus mirabilis* given by Hauser.

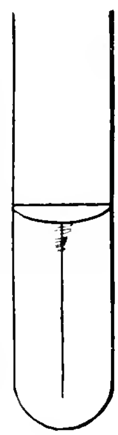


FIG. 29.

Gelatin stab.—Liquefaction in saucer form extending to the tube wall and slowly downward, the flow becoming level. Along the line of the stab there is a fair growth of discrete and confluent colonies. Near the surface a few short lateral outgrowths from the line of inoculation may appear. (See fig. 29.) The liquefied gelatin is clouded and there is a thick, flocculent, whitish sediment after a time. Liquefaction does not progress rapidly.

[1] HAUSER, G. Ueber Fäulnissbakterien und deren Beziehungen zur Septicämie. Leipzig, 1885.

Acid gelatin.—Growth is not so vigorous.

Agar slant.—The growth spreads over the surface to the wall of the tube as a thin hazy layer. The agar acquires a brownish green color.

Bouillon.—Clouded and whitish sediment; acquires a slightly greenish tint and a thin pellicle.

Potato.—Thin, moist, viscid looking, widely spreading, dirty, grayish growth.

Litmus milk.—Does not seem to coagulate or decolorize the medium. There is a whitish sediment at the bottom. After three weeks the milk is still blue, but perhaps lighter in tint.

Sugar gelatin in deep stab.—Fair growth of discrete and confluent minute colonies. There is some gas production; no liquefaction.

Rosolic acid.—The color seems to be deepened after some time.

Indol production.—Good reaction; does not produce nitrites.

Relation to temperature.—Grows at the temperature of the room and at 35° to 36° C.

Summary of the organisms described.

Micrococci	Not liquefying the gelatin; chromogenic; yellow.		M. Orbiculatus.*
	Liquefying the gelatin; nonchromogenic.		M. Simplex.*
Cladothrices	Liquefying the gelatin; chromogenic.	Brown.	C. Dichotoma (Cohn).*
		Red.	C. Rutula.*
Bacilli not liquefying the gelatin and not forming spores.	Chromogenic.	Yellow.	B. Flavocoriaceus.*
			B. Ovalis.*
			B. Lacunatus.*
		Red.	B. Latericeus.*
		Green.	B. Fluorescens incognitus.
			B. Fluorescens foliaceus.
			B. Fluorescens convexus.
			B. Rugosus.
	Nonchromogenic.		B. Ambiguus.
			B. Recuperatus.
			B. Sinuosus.
			B. Nexibilis.
			B. Tiogensis.*
			B. Refractans.*
Bacilli liquefying the gelatin.	Chromogenic.	Yellow.	B. Dormitator.*
			B. Desidiosus.*
			B. Annulatus.
			B. Caudatus.*
			B. Pullulans.
			B. Arborescens. (*a*)*
			B. Arborescens. (*b*)*
		Red.	B. Exiguus.
			B. Hæmatoides.
		Green.	B. Fluorescens Schuylkilliensis.
			B. Fluorescens mutabilis.
		Blue.	B. Janthinus.
			B. Cœruleus.
	Nonchromogenic.	Form spores.	B. Subtilis.
			B. Detrudens.
			B. Crinitus.*
			B. Ramosus.
			B. Sublanatus.
			B. Capillaceus.
		No spore formation.	B. Delabens.
			B. Duplicatus. (α)
			B. Duplicatus. (β)
			B. Fairmontensis.
			B. Geniculatus.
			B. Flexuosus.*
			B. Coadunatus.
			B. Convolutus.*
			B. Multistriatus.
			B. Centrifugans. (α)
			B. Centrifugans. (β)
			B. Fimbriatus.
			B. Cohaerens.
			B. Nebulosus.
			B. Proteus mirabilis.

NOTE.—Those marked * are nonmotile or doubtful.

TABLE II.—*Roxboro district, upper Schuylkill.*

[Results in parts per 100,000.]

Date	Chlorine.	Chlorine. Mean.	Oxygen consumed.	Oxygen consumed. Mean.	Free ammonia. Tin tube.	Free ammonia. Glass tube.	Free ammonia. Mean.	Albuminoid ammonia. Tin tube.	Albuminoid ammonia. Glass tube.	Albuminoid ammonia. Mean.	Nitrogen as nitrates.	Nitrogen as nitrates. Mean.	Bacteria in one cubic centimeter.	Bacteria in one cubic centimeter. Mean.
Nov. 25	.40 .37	0.385	0.20 .22	0.210	0.0030	0.0027	0.0029	0.0130	0.0133	0.0132	0.075 .090 .090	0.085	2,200 2,250 2,150 1,950	2,648
Dec. 5	.40 .40	.400	.18 .18	.180	.0025	.0021	.0023	....	.0138	.0138	.120 .150 .180	.150	5,010 5,960 6,400 4,750	5,528
Jan. 11	....	....	...	....	....	....	....	....	....	....	....	....	18,200 26,900	22,550
13	.40 .41	.405	....	....	....	.0066 .0058	.0062	....	.0072 .0086	.0079	....	.....	30,500 35,800	33,150
24	.35 .38	.365	.05 .03	.040	.0062	....	.0062	....	.0036	.0036	.130 .108	.119	2,200 1,900	2,050
Feb. 7	.27 .33	.300	.18 .18	.180	.0054	.0052	.0053	.0159	....	.0159	.084 .088	.086	1,400 1,950	1,675
17	.27 .22	.240	.15 .13	.140	.0069	.0060	.0065	.0107	.0096	.0102	.100	.100	2,350 5,750	4,050
20	.36 .31	.340	.12 .11	.115	.0061	.0047	.0054	.0122	....	.0122	.080 .080	.080	1,750 1,750	1,750
27	.29 .27	.280	.05 .06	.055	....	.0030 .0023	.0027	......	.0088 .0078	.0083	.100 .100	.100	550 450	500
Mar. 10	.28 .25	.265	.14 .15	.145	.0018	.0023	.0021	.0194	.0189	.0192	.090 .090	.090	4,290 4,580	4,435
17	.23 .23	.230	.12 .10	.110	.0007	.0012	.0010	.0099	.0085	.0092	.070 .090	.080	2,600 1,610 2,750	2,320
24	.23 .26	.245	.07 .06	.065	.0000	.0000	.0000	.0054	.0055	.0055	.090 .090	.090	460 355	480
31	.27 .28	.275	.07 .05	.050	.0000	.0000	.0000	.0062	.0061	.0062	.090 .090	.090	1,640 1,280 1,370	1,430
Apr. 7	.25 .27	.260	.05 .05	.050	....	.0005 .0006	.0006	....	.0072 .0039	.0056	.090 .090	.090	1,380 940	1,160
					100 cc. determinations.			100 cc. determinations.						
17	.23 .21	.220	.22 .22 .20	.213	0.0025	.0007	.0016	0.0235	.0227	.0231	.060 .060	.060	3,170 2,280 3,750	3,067
25	.29 .27 .26	.273	.08 .10	.090	....	.0018	.0018	....	.0094	.0094	.070 .070	.070	1,880 2,010	1,945
May 5	.14 .18	.160	.26 .27	.265	.0042	.0023	.0033	.0192	.0218	.0205	.040 .040	.040	5,540 5,160	5,350
15	.27 .27	.270	.07 .06 .06	.063	.0015	.0005	.0010	.0059	.0076	.0068	.070 .070	.070	750	750
23	.29 .30 .32 .32	.308	....	...	.0000	.0000	.0000	.0060	.0046	.0053	.054 .054	.054	890 650	770
30	.30 .31	.305	.07 .05 .09	.070	.0003	.0006	.0005	.0055	.0054	.0055	.050 .050	.070	250 160	205
June 13	.29 .33	.310	.11 .11	.110	.0027	.0000	.0014	.0105	.0083	.0094	.060 .070	.065	590 360	475
23	.47 .45	.460	.05 .07	.060	.0019	.0004	.0012	.0080	.0054	.0067	.060 .060	.060	560 460 410	477
30	.43 .42	.425	.10 .10	.100	.0022	.0005	.0014	.0103	.0074	.0089	.080 .060	.070	1,640 2,030	1,835
July 17	.47 .50	.485	.14 .12	.130	.0020	.0007	.0014	.0102	.0066	.0084	.060 .060	.060	500 610	555
31	.50 .48 .45 .46	.473	.18 .16	.170	.0050	.0037	.0044	.0217	.0180	.0199	.040 .040	.040	....	....
Average	....	.320	....	.113	...	....	.0025	....	....	.0106	....	.078	.....	4,128

TABLE III.—*Fairmount [illegible], [illegible] Schuylkill.*

[Results in parts per [illegible].]

Date.	Chlorine.		Oxygen consumed.		Free ammonia.			Albuminoid ammonia.			Nitrogen as nitrates.		Bacteria in one cubic centimeter.	
		Mean.		Mean.	Tin tube.	Glass tube.	Mean.	Tin tube.	Glass tube.	Mean.		Mean.		Mean.
Nov. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.106	.065 [illegible]	[illegible]	12,2[illegible] 9,[illegible] 9,240	10,430
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.121	[illegible]	.112	[illegible]	[illegible]	3,[illegible] 1,[illegible] [illegible]	7,4[illegible]
Dec. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.142	.0[illegible]	[illegible]	[illegible]	[illegible]	....	....
Jan. [illegible]	[illegible]	[illegible]	[illegible]	......	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	......	......	26,5[illegible] 1[illegible]	22,7[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	......	[illegible]	[illegible]	......	[illegible]	[illegible]	[illegible]	.117	[illegible]	1,950
Feb. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	......	[illegible]	[illegible]	......	[illegible]	[illegible]	[illegible]	[illegible]	3,[illegible] 4,4[illegible]	3,725
17	[illegible]	[illegible]	[illegible]	[illegible]	......	[illegible]	[illegible]	......	[illegible]	[illegible]	[illegible]	[illegible]	4,[illegible]	4,[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2,925 5,675 4,[illegible]	4,467
Mar. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	......	[illegible]	[illegible]	......	[illegible]	[illegible]	.110 .110	.110	[illegible]	725
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 2,[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,260 1,750	1,510
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4,[illegible]
Apr. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,12[illegible] 1,020	1,070
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.41	......	[illegible]	[illegible]	[illegible]	[illegible]	1,4[illegible]	1,7[illegible]
May [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	......	[illegible]	[illegible]	......	......	[illegible]	[illegible]	[illegible]	420 [illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	......	[illegible]	[illegible]	[illegible]	1,090 1,020	1,055
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.14	[illegible]	[illegible]	.14	[illegible]	[illegible] .050	.050	430 430	43[illegible]
June [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.149	[illegible] .066	.066	770 750	760
[illegible]	.47 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.15	.14	[illegible]	[illegible]	[illegible]	[illegible] .070	[illegible]	[illegible]	[illegible]
[illegible]	.47 .45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.172	.0167	.077	[illegible]	[illegible]	390	390
June 17.	[illegible]	[illegible]	[illegible]	.12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.060	790 920	855
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.071	[illegible]	.144	.060 .060	[illegible]	....	....
Average	......	[illegible]	......	[illegible]	......	......	[illegible]	......	......	[illegible]	......	.076	....	3,510

TABLE IV.—*Lamont Terrace, Laboratory of H[illegible]*

[illegible]

Date.	Mean.		Mean.				Mean.					Mean.		Mean.
1892.														
[illegible] 7	....	....	[illegible]	[illegible]	....	....	....	....	....	....	....	....	....	....
. 7	....	....	[illegible]	[illegible]	....	....	....	....	....	....	....	....	....	....
[illegible]	....	....	[illegible]	[illegible]	....	....	....	....	....	....	....	....	....	....
[illegible]	....	....	[illegible]	....	....	....	....	....	....	....	....	....	....	....
[illegible]	....	....	....	....	....	....	....	....	....	....	....	....	[illegible]	[illegible]
[illegible]	....	....	....	....	....	....	....	....	....	....	[illegible]	....	....	....
[illegible]	....	....	....	....	....	[illegible]	[illegible]	....	[illegible]	[illegible]	[illegible]	[illegible]	....	....
27	....	....	....	....	....	[illegible]	[illegible]	....	[illegible]	[illegible]	[illegible]	....	....	....
[illegible]	....	....	....	....	....	[illegible]	[illegible]	....	[illegible]	[illegible]	....	....	....	....
2[illegible]	....	....	....	....	....	[illegible]	[illegible]	....	[illegible]	[illegible]	....	....	....	....
Nov. [illegible]	....	....	[illegible]	[illegible]	....	....	....	....	....	....	....	....	....	....
[illegible]	....	....	....	....	....	[illegible]	[illegible]	....	[illegible]	[illegible]	....	....	....	....
4	....	....	....	....	....	....	....	....	....	....	[illegible]	[illegible]	....	....
[illegible]	....	....	[illegible]	[illegible]	....	....	....	....	....	....	[illegible]	[illegible]	....	....
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....	[illegible]	[illegible]
Dec. 5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1893.														
Jan. 1[illegible]	....	....	....	....	....	....	....	....	....	....	....	....	[illegible]	[illegible]
[illegible]	[illegible]	.336	....	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....	....	[illegible]	[illegible]
2	....	....	[illegible]	[illegible]	....	....	....	....	....	....	....	....	....	....
24	[illegible]	.345	....	....	[illegible]	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Feb. [illegible]	[illegible]	.265	....	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	....	....	[illegible]	[illegible]	....	....	....	....	....	....	....	....	....	....
17	[illegible]	.220	[illegible]	.165	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	.145	....	[illegible]	[illegible]	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mar. 4	....	....	....	....	....	....	....	....	....	....	....	....	[illegible]	[illegible]
8	....	....	....	....	....	....	....	....	....	....	....	....	[illegible]	[illegible]
10	.26 .29	.275	.19 .16	.175	[illegible]	[illegible]	[illegible]	[illegible]	.0179	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	....	....	....	....	....	....	....	....	....	....	....	....	[illegible]	[illegible]
13	....	....	....	....	....	....	....	....	....	....	....	....	[illegible]	[illegible]
17	.22 .22	.220	.12 .11	.115	....	[illegible]	[illegible]	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE IV.—*Belmont district, Laboratory of Hygiene, lower Schuylkill water*—Continued.

[Results in parts per 100,000.]

Date.	Chlorine.	Chlorine Mean.	Oxygen consumed.	Oxygen consumed Mean	Free ammonia. Tin tube.	Free ammonia. Glass tube.	Free ammonia. Mean.	Albuminoid ammonia. Tin tube.	Albuminoid ammonia. Glass tube.	Albuminoid ammonia. Mean.	Nitrogen as nitrates.	Nitrogen as nitrates. Mean.	Bacteria in one cubic centimeter.	Bacteria in one cubic centimeter. Mean
1893.														
Mar. 24	.27 .26	.265	.07 .06	.065	.0002	.0001	.0002	.0054	.0065	.0060	.110 .110 .100	.107	600 470	535
31	.24 .27	.255	.06 .05	.055	....	0002 .0002	.0002	....	.0093 .0064	.0079	.070 .070	.070	1,310 1,150	1,230
Apr. 7	.29 .25	.270	.05 .05	.050	.0006	.0000	.0003	.0090	.0067	.0079	.080 .080	.080	560 610	585
17	.26 .24	.250	.19 .18	.185	....	.0007	.0007	....	.0205	.0205	.060 .060	.060	5,320 5,590	5,455
					100 cc. determinations.			100 cc. determinations.						
25	.23 .23	.230	.11 .10	.105	0.0035	.0007	.0021	0.0145	.0106	.0126	.050 .050	.050	400 820	610
May 5	.20 20	.200	.18 .15	.165	.0015	.0011	.0013	.0185	.0228	.0207	.050 .050	.050	5,970 5,990	5,980
15	.26 .28	.270	.06 .08	.070	.0010	.0000	.0005	.0092	....	.0092	.070 .070	.070	1,080 640	860
23	.29 .29	.290	.04 .06	.050	.0010	.0000	.0005	.0051	.0046	.0049	.070 .070	.070	420 290	355
30	.36 .32	.340	.07 .07 .07	.070	.0004	.0015	.0010	.0068	.0080	.0074	.090 064	.077	390 340	365
June 13	.39 .41	.400	.12 .11	.115	.0031	.0000	.0016	.0134	.0113	.0124	.070 .070	.070	250 225	238
23	.50 .49	.495	.06 .09	.075	.0020	.0000	.0010	.0159	.0082	.0121	.070 .080	.075	700 600 860	720
30	.48 .48	.480	.09 09	.090	.0017	.0000	.0069	.0120	.0105	.0113	.090 .090	.090	580 620	600
July 17	.57 .61	.590	.08 .10	.090	.0032	.0005	.0019	.0109	.0098	.0104	.070 .070	.070	540 470	505
31	.67 65	.660	.09 .10	.095	.0025	.0005	.0015	.0146	.0082	.0114	.060 .060	.060	....	....
Average	....	.335	....	.116	....	....	.0022	....	....	.0114	....	.079	....	3.745

TABLE V.—*Frankford district, Delaware water.*

[Results in parts per 100,000.]

Date.	Chlorine.		Oxygen consumed.		Free ammonia.			Albuminoid ammonia.			Nitrogen as nitrates.		Bacteria in one cubic centimeter.	
		Mean.		Mean.	Tin tube.	Glass tube.	Mean.	Tin tube.	Glass tube.	Mean.		Mean.		Mean.
1892.														
Nov. 19	0.34 .34	0.340	0.24 .23	0.235	0.0033	0.0034	0.0034	0.0173	0.0167	0.0170	0.055 .070	0.063	15,700 15,100 8,000 7,550	11,588
Dec. 1	.26 .27	.265	.49 .49	.490	....	.0038	0038	....	.0158	.0158	.045 .040 .040	.042	6,450 8,150 5,680	6,760
22	.21 .21	.210	.25 .22	.235	.0032	.0037	.0035	.0095	.0083	0089	.040 .040 .045	.042	....	....
1893.														
Jan. 11	....	....	....	....	....	....	....	....	....	....	....	....	5,700 5,700	5,700
13	.20 .18	.190	....	....	.0040	.0051	.0046	.0162	.0124	.0143	....	....	8,200 12,400	10,300
24	.24 .23	.235	.17 .16	.165	.0019	.0028	.0024	.0091	.0073	.0082	.070 .100	.085	300 500	400
Feb. 7	.30 .32	.310	.18 .15	.165	.0155	.0152	.0154	.0154	.0147	.0151	.070 .070	.070	2,900 2,500 3,250	2,886
17	.20 .18	.190	.23 .21	.220	.0071	.0076	.0074	.0114	.0101	.0107	.050 .060	.055	5,600	5,600
20	.21 .20	.205	.18 .18	.180	.0061	.0052	.0057	.0101	.0084	.0093	.060 .060	.060	2,750 4,250	3,500
27	.21 .22	.215	.18 .18	.180	.0071	.0074	.0073	.0146	.0141	.0144	.050 .060	.055	1,350 1,240	1,295
Mar. 10	.24 .27	.255	.15 .14	.145	.0056	.0054	.0055	.0150	.0117	.0134	.065 .065	.065	1,250 1,410	1,330
17	.16 .15	.155	.24 .23	.235	.0050	.0047	.0049	....	.0109	.0109	.060 .050 .060	.057	1,560 1,440	1,500
24	.14 .12	.130	.21 .17	.190	....	.0017	.0017	.0144	.0100	.0122	.050 .050	.050	510 410	460
31	.16 .15	.155	.24 .22	.230	.0020	.0011	.0016	.0099	.0109	.0104	.050 .050	.050	1,110 1,030	1,070
Apr. 7	.12 .17	.150	.16 .17	.165	.0010	.0006	.0008	.0108	.0089	.0099	.050 .050	.050	690 800	745
17	.27 .28	.275	.21 .21	.210	100 cc. determination. 0.0005	.0006	.0006	100 cc. determination. 0.0270	.0175	.0223	.060 .060	.060	3,120 2,830 2,695	2,882
25	.12 .14 .14	.133	.25 .27	.260	.0035	.0017	.0026	.0200	.0135	.0168	.050 .050	.050	530 680 720	643
May 5	.13 .17	.150	.22 .21	.215	.0032	.0007	.0020	.0140	.0156	.0148	.040 .040	.040	2,810 2,430	2,620
15	.12 .12	.120	.24 .26	.250	.0025	.0006	.0016	.0138	.0142	.0140	.040 .040	.040	2,350	2,350
23	.15 .18 .19 .19	.178	.29 .32	.305	.0010 .0005	.0006	.0007	.0131	.0127	.0129	.020 .020	020	2,800 2,370 2,710 2,850	2,683
30	.23 .19	.210	.22 .21 .23	.220	.0019	.0016	.0018	.0108	.0110	.0109	.030 .030	.030	660 660	660
June 13	.32 .34	.330	.10 .10 .08	.093	.0021	.0006	.0014	.0106	.0083	.0095	.060 .060	.660	450 330	390
23	.29 .29 .33	.303	.15 .17	.160	.0022	.0007	.0015	.0163	.0133	.0148	.020 .020	.020	1,710 1,860 1,965	1,845
30	.42 .48	.450	.08 .11	.095	.0018	.0007	.0013	.0097	.0104	.0101	.070 .070	.070	1,520 1,880 2,010	1,803
July 17	.38 .41	.395	.16 .19	.175	.0025	.0013	.0019	.0206	.0182	0.194	.040 .040	.040	17,110 11,660	14,385
31	.44 .46	.450	.19 .18 .19	.187	.0044	.0028	.0036	.0194	.0173	.0184	.040 .040	.040	....	....
Average	....	.240	....	.209	....	....	.0035	....	....	.0134	....	.051	....	3,475

TABLE VI.

District and date.	Chlorine.	Chlorine. Mean.	Oxygen consumed.	Oxygen consumed. Mean.	Free ammonia. Tin tube.	Free ammonia. Glass tube.	Free ammonia. Mean.	Albuminoid ammonia. Tin tube.	Albuminoid ammonia. Glass tube.	Albuminoid ammonia. Mean.	Nitrogen as nitrites.	Nitrogen as nitrites. Mean.	Bacteria in one cubic centimeter.	Bacteria in one cubic centimeter. Mean.
LOWER SCHUYLKILL.														
Direct pumpage, Nov. 11	0.60 .60	0.600	0.17 .16 .18	0.170	0.0020	0.0018	0.0019	0.0161	0.0140	0.0151	0.065 .060	0.063	9,220 9,380 3,510 6,200	7,078[1]
Direct pumpage, Nov. 28	.42 .43	.425	.14 .14	.140	.0032	.0031	.0032	....	.0109	.0109	.110 .130	.120	8,140 8,180 5,800 5,450	6,893
Direct pumpage, Dec. 17	.41 .42	.415	.26 .28	.270	....	....	....	....	....	....	.070 .070	.070	19,100 26,500	22,800
East Park, Nov. 15	.55 .55	.550	.12 .13	.125	.0019	.0017	.0018	.0109	.0121	.0115	.055 .060	.058	4,130 5,970 6,100	5,400
East Park, Nov. 30	.42 .40	.410	.14 .15	.145	.0025	.0021	.0023	.0120	.0148	.0134	.130 140 .130	.133	4,640 3,880 7,550 4,750	5,155
East Park, Dec. 20	.34 .35	.345	.18 .19	.185	.0026	.0021	.0024	.0141	....	.0141	.070 .070 .070	.070	....	....
UPPER SCHUYLKILL.														
High service, Nov. 23	.34 .36	.350	.24 21	225	0043	.0033	.0038	.0150	.0156	.0153	.080 .080 .090	.083	32,100	32,100
High service, Dec. 3	.39 .40	.395	.25 .24	245	.0020	.0023	.0022	.0135	.0177	.0156	.090 .090 .080	.087	12,340 20,750 24,900	19,330
Chestnut Hill, Nov. 21	.79 .89	.840	16 .16	160	.0019	.0024	.0022	.0102	.0119	.0111	.220 .220	.220	5,400 7,000 7,000 6,920	6,580
Chestnut Hill, Dec. 2	.45 .43	.440	.23 .20 .22	217	.0008	.0016	.0012	.0171	.0162	.0167	.100 .100 .100	.100	5,320 6,930 7,700 8,400	7,088
Chestnut Hill, Jan 14	.32 .33	.325	.06	.060	.0074	0076	0075	.0081	.0083	.0082	.110 .180 .110 .130	.133	15,400 22,400	18,900

[1] Agars, twenty four hours thermostat.

TABLE VII.—*Chlorine, laboratory tap.*

[Parts per 100,000.]

Date.	Chlorine.	Mean.
1892.		
Sept. 27	5 obs.	0.770
28	0.70, .73, .76	.730
29	.60, .64, .62	.620
30	.65, .62, .59	.617
Oct. 1	.66, .66, .71	.677
2	.73, .71, .68	.707
3	.71, .73, .70	.713
4	.65, .73, .67	.683
5	.68, .58, .63	.630
6	.69, .65, .69	.667
7	.66, .63, .65	.647
8	.67, .70, .68	.683
9	.68, .64, .64	.653
10	.68, .73, .65	.687
11	.65, .65, .67	.657
13	.57, .62, .65	.613
14	.68, .71, .69	.693
15	.60, .64, .64	.627
16	.71, .71, .67	.697
17	.73, .73, .72, .67, .70	.710
18	.66, .66, .70	.673
19	.68, .66, .63	.657
20	.70, .66, .62	.660
21	.63, .61, .60	.613
22	.67, .62, .60	.630
23	.64, .61, .59	.613
24	.65, .64, .63	.640
25	.69, .67, .60	.653

Date.	Chlorine.	Mean.
1892.		
Oct. 26	.66, .62, .62	.633
27	.63, .63, .58	.613
28	.66, .64, .70	.667
29	.67, .66, .70	.677
30	.66, .67, .66	.663
31	.70, .70, .68	.693
Nov. 1	.70, .70, .71	.703
2	.67, .69, .71	.690
3	.67, .69, .71	.690
4	.69, .70, .71	.700
5	.71, .71, .71	.710
6	.71, .72, .75	.727
7	.71, .71, .71	.710
8	.71, .73, .75	.730
9	.66, .65, .63	.647
10	.66, .64, .63	.643
11	.68, .67, .70	.683
12	0.61, .65	0.630
13	.60, .60	.600
14	.59, .54	.565
15	.55, .52	.535
16	.57, .54	.555
17	.54, .53	.535
18	.48, .49	.485
19	.43, .42	.425
20	.52, .47	.495
21	.40, .42	.410
22	.46, .45	.455
23	.44, .42	.430
24	.38, .35	.365
25	.37, .40	.385
26	.43, .38	.405
27	.43, .38	.405

Date.	Chlorine.	Mean.
1892.		
Nov. 28	.40, .41	.405
29	.38, .39	.385
30	.45, .39	.420
Dec. 1	.38, .42	.400
2	.40, .47	.435
3	.43, .42	.425
4	.40, .41	.405
5	.46, .42	.440
6	.42, .44	.430
7	.41, .41	.410
8	.41, .47	.440
9	.46, .45	.455
10	.40, .39	.395
11	.42, .44	.430
12	.39, .41	.400
13	.37, .38	.375
14	.37, .40	.385
15	.37, .39	.380
16	.38, .38	.380
17	.35, .36	.355
18	.37, .35	.360
19	.32, .34	.330
20	.37, .33	.350
21	.31, .34	.325
22	.35, .34	.345
23	.33, .34	.335
1893.		
Jan. 6	.37, .33	.350
7	.30, .31	.305
8	.34, .34	.340
9	.28, .30	.290
10	.28, .31	.295
11	.29, .33	.310
13	.34, .34, .32	.333
14	.32, .32	.320
15	.32, .31	.315
16	.36, .31	.335
17	.31, .31	.310
18	.33, .32	.325
19	.33, .34	.335

Date.	Chlorine.	Mean.
1893.		
Jan. 20	.33, .34	.335
21	.33, .35, .35	.343
22	.37, .33	.350
23	.35, .33	.340
24	.37, .32	.345
25	.35, .35	.350
26	.35, .36	.355
27	.37, .38	.375
28	.39, .38	.385
29	.37, .39	.380
30	.37, .36	.365
31	.37, .39	.380
Feb. 1	.35, .33	.340
2	.36, .34	.350
3	.32, .35	.335
4	.30, .30	.320
5	.31, .31	.310
6	.28, .31	.295
7	.27, .26	.265
8	.24, .25	.245
9	.24, .26, .27	.257
10	.26, .22	.240
11	.23, .27	.250
12	.22, .24	.230
13	.23, .24	.235
14	.22, .24	.230
15	.21, .24	.225
16	.25, .23	.240
17	.20, .23	.215
18	.20, .24	.220
19	.20, .16	.180
20	.22, .26	.240
21	.20, .21	.205
23	.25, .29	.270
24	.26, .26	.260
25	.29, .25	.270
26	.30, .31	.305
27	.29, .31	.300
28	.25, .25, .27	.257

TABLE VII.—*Chlorine, laboratory tap*—Continued.

Date.	Chlorine.	Mean.
1893.		
Mar. 1	.27, .28	.275
2	.31, .29	.300
3	.27, .29	.280
4	.28, .29	.285
5	.30, .30	.300
6	.29, .31	.300
7	.30, .31	.305
8	.32, .30	.310
9	.31, .28	.295
10	.26, .29	.275
11	.25, .21	.230
12	.21, .22	.215
13	.21, .19	.200
14	.26, .24	.250
15	.21, .18	.195
16	.20, .19	.195
17	.22, .22	.220
18	.20, .21	.205
19	.22, .23	.225
20	.21, .25	.230
21	.28, .24	.260
22	.22, .25	.235
23	.23, .25	.240
24	.26, .27	.265
25	.22, .28	.250
26	.20, .24	.220
27	.25, .27	.260
28	.25, .23	.240
29	.25, .26	.255
30	.24, .26	.250
31	.24, .27	.255
Apr. 1	.25, .26	.255
2	.23, .24	.235
3	.23, .25	.240
4	.24, .25	.245
5	.24, .25	.245
6	.27, .25	.260
7	.29, .25	.270
8	.25, .25	.250
9	.26, .24	.250

Date.	Chlorine.	Mean.
1893.		
Apr. 10	.27, .27	.270
11	.29, .27	.280
12	.29, .28	.285
17	.26, .24	.250
18	.26, .27	.265
19	.22, .23	.225
20	.27, .22	.245
21	.25, .23	.240
22	.25, .25	.250
23	.26, .23	.245
24	.24, .24	.240
25	.23, .23	.230
26	.23, .25	.240
27	.21, .22	.215
28	.22, .24	.230
29	.23, .23	.230
30	.24, .28	.260
May 1	.21, .26	.235
2	.24, .26	.250
3	.23, .24	.235
4	.25, .27	.260
5	.20, .20	.200
6	.22, .25	.235
7	.21, .21	.210
8	.24, .21	.225
9	.21, .25	.230
10	.23, .22	.225
11	.24, .26	.250
12	.21, .28	.245
13	.28, .26	.270
15	.28, .26	.270
16	.28, .27	.275
17	.28, .28	.280
18	.26, .30	.280
19	.29, .27	.280
20	.27, .27	.270
21	.32, .27	.295
22	.26, .29	.275
23	.29, .29	.290
24	.31, .31	.310

Date.	Chlorine.	Mean.
1893.		
May 25	.30, .30	.300
26	.29, .32	.305
27	.30, .32	.310
28	.36, .33	.345
29	.32, .33	.325
30	.32, .36	.340
31	.31, .35	.330
June 1	.32, .36	.340
2	.34, .33	.335
3	.33, .36	.345
4	.34, .38	.360
5	.36, .38	.370
6	.43, .40	.415
7	.40, .42	.410
8	.39, .38	.385
9	.39, .39	.390
10	.36, .40	.380
12	.39, .41	.400
13	.39, .41	.400
14	.40, .41	.405
15	.43, .48	.455
16	.42, .41, .42, .45, .44	.428
17	.46, .42	.440
18	.48, .50	.490
19	.49, .52	.505
20	.50, .50	.500
21	.50, .51	.505
22	.55, .50, .55, .52	.530
23	.50, .49	.495
24	.56, .50	.530
25	.50, .52	.510
26	.50, .51	.505
27	.50, .48	.490
28	.50, .53	.515
29	.54, .53	.535
30	.48, .48	.480
July 1	.50, .56	.530
2	.50, .53	.515

Date.	Chlorine.	Mean.
1893.		
July 3	.50, .57	.535
4	.58, .57	.575
5	.57, .59	.580
6	.58, .58	.580
7	.55, .58	.565
8	.56, .56	.560
9	.56, .54	.550
10	.54, .58	.560
11	.57, .58	.575
12	.54, .54	.540
13	.55, .57	.560
14	.59, .54	.565
15	.58, .59	.585
16	.60, .61	.605
17	.57, .61	.590
18	.58, .60	.590
19	.58, .54	.560
20	.54, .55	.545
21	.53, .56	.545
22	.58, .59	.585
23	.60, .65	.625
24	.65, .63	.640
25	.57, .66	.615
26	.65, .64	.645
27	.66, .68	.670
28	.64, .68	.660
29	.66, .65	.655
30	.70, .70	.700
31	.67, .65	.660
Aug. 1	.69, .72	.705
2	.68, .65, .70, .65	.670
3	.65, .63	.640
4	.65, .63	.640
5	.62, .60	.610
6	.69, .69	.690
7	.66, .64	.650
8	.65, .71	.680
9	.70, .70	.700
Average		.417

APPENDIX.

EXAMINATION OF THE WATER OF THE SCHUYLKILL RIVER FOR THE COLON BACILLUS OF ESCHERICH.

By Dr. Olmstead, *Assistant Bacteriologist, Laboratory of Hygiene, University of Pennsylvania.*

Advantage was taken of the fact that many forms of water bacteria will not grow at the temperature of 37° C. Thirty samples of water were examined during February and the early part of March of this year.

The tap was opened, and after the water had been running an hour 80 cc. were collected in a sterilized Erlenmeyer's flask, containing 20 cc. of sterilized alkaline sugar bouillon, quadruple the ordinary strength. The mixture, after the addition of the sample of water, was composed of—

Sodium chloride	grains..	0.4
Peptone	do....	0.8
Liebig's extract of meat	do....	0.15
Glucose	do....	1.5
Sterilized water	cubic centimeter..	20
Water for examination	do....	80
Caustic solution sufficient to make alkaline.		

The flask was then placed in a thermostat and kept at a temperature of 37° C. for twenty-four hours, when, as a rule, there was a prolific growth in the flask. A set of agar-agar plates was made from this growth and placed in the thermostat. In about twenty-five samples pure cultures of only one organism were obtained on the plates; in the other five samples two, or perhaps three, varieties of germs were present. Only those with a morphology similar to the colon bacillus were taken for further examination.

For identification the following media were used:

1. Agar-agar.
2. Potato.
3. Gelatin, stick and plate.
4. Peptone, for indol and motility.
5. Litmus milk.
6. Sugar bouillon in Einhorn's fermentation tubes, as recommended by Smith.

The growths were all compared with those of a typical culture of colon bacillus obtained from the intestinal tract. The germs found may be divided into four groups:

Group I.—In this are placed bacilli obtained from three specimens whose morphology and cultural peculiarities resemble in every particular those of the colon bacillus and, we believe, are identical with it. Thus they formed a whitish band-like growth on agar-agar; a yellowish, slightly raised growth on potato; reddened and coagulated litmus milk; produced indol; caused fermentation of glucose in bouillon. The colonies in gelatin were of two principal varieties, the deep ones being round, yellowish brown, finely granular, with some circular markings. The superficial colonies were irregular in outline at the end of about three days, yellowish brown color more marked in the center and gradually fading from this point toward the top of the colony. The surface presented a complex network of coarse and fine grooves and markings. The colonies varied in size, being from 2 mm. to 5 mm. in diameter, and to the naked eye had the white mother-of-pearl appearance. There was no liquefaction of the gelatin. In the stick cultures the growth extended along the line of inoculation, had a granular appearance, and grew on the surface of the gelatin around the point of inoculation in the irregular leafy manner like the superficial colonies just described. The movement of the bacilli in the hanging drop were not distinct, and in only one of the three organisms of this group could it be said that there was positive motility. It was demonstrated, however, that all possessed flagella. Flagella were also shown to be on the colon bacillus used as the standard (in small numbers), although its motility appears doubtful.

Group II comprises those organisms obtained from two specimens, and which differed from the colon bacillus in having a rather more prolific growth on agar-agar and gelatin.

Group III.—The bacilli placed in this group differed from the bacillus of Escherich in the appearance of the colonies in gelatin. They had the appearance of several pale yellow disks superimposed in an irregular, rosette like manner upon each other, giving one the idea that there were several colonies together. At the end of a week there were a number of smaller colonies joined to the original one by a series of these pale-yellow disks. These bacteria were found in four of the samples.

Group IV.—All of the bacteria that could not possibly be mistaken for the colon bacillus were placed here. One of the organisms grew invisibly on potato, and in this respect resembled the typhoid bacillus, but was easily differentiated from that germ by its action with other media. Of the thirty organisms examined, twenty-five produced gas in the fermentation tube. The tubes used were supplied by Eimer & Amend, of New York, and had the upright limb divided off into five equal parts, numbered from above downward. The readings of the amount of gas were made daily, the tubes remaining in the thermostat. The maximum amount of gas was observed at about the third day. It diminished a little by the fourth or fifth day. This gas was treated with a solution of caustic potash to absorb the carbon dioxide; the amount of residual gas was then noted and ignited in the presence of air. There was always an explosion, showing it to be, probably, composed chiefly of hydrogen.

The composition of the medium used in the tubes was—

Chloride of sodium	grains	5
Peptone	do	10
Liebig's meat extract	do	3
Glucose	do	20
Water	liter	1

Caustic soda sufficient to make distinctly alkaline.

The subjoined table gives the readings for the different days for the colon bacillus and the first three groups of organisms:

	First day.	Second day.	Third day.	Fourth day.	Fifth day.	After addition of KaII.	Explodes
Colon bacillus	2.2	2.2	2.1	2.1	2	1.2	Yes.
Group I							
No. 1	2.3	2.3	2.4	2.3	2.2	1.3	Yes.
No 2	2.1	2.2	2.2	2.1	2.1	1.3	Yes.
No. 3	2.1	2.1	2.1	2	2	1.2	Yes.
Group II.							
No. 1	2.1	2.1	2.1	2.1	2	1.2	Yes.
No. 2	2.1	2.1	2	1.9	1.9	1	Yes.
Group III							
No. 1	2.6	2.6	2.6	2.4	2.3	1.5	Yes.
No. 2	2.6	2.6	2.5	2.2	2.2	1.5	Yes.
No. 3	2.3	2.3	2.3	2.1	2.1	1.6	Yes.
No. 4	2.4	2.4	2.5	2.4	2.3	1.7	Yes.

THE INFLUENCE OF LIGHT UPON THE BACILLUS OF TYPHOID AND THE COLON BACILLUS.

By John S. Billings,

Presenting results of an investigation by Adelaide W. Peckham.

[Read before the National Academy of Sciences April 19, 1894.]

In 1877 Downes and Blunt presented to the Royal Society of London a report on "Researches on the effects of light upon bacteria and other organisms." (Proceedings of the Royal Society of London, Dec., 1877, vol. 26, p. 488.)

Their conclusions were that light affects unfavorably the development of the bacteria and microscopical fungi associated with putrefaction and decay, the action being greatest on the former; that the direct rays of the sun are much more powerful in this respect than diffused light; that the action is chiefly due to the actinic rays, and that the nutritive power of the culture medium is not impaired by insolation.

Since that date a number of papers on the subject have been published. These were summed up by Raum in his paper published in 1889 ("Der gegenwärtige Stand unserer Kenntnisse über den Einfluss des Lichtes auf Bakterien, etc.," Zeitschr. f. Hyg., VI, 1889, 312), and since then several other papers have appeared, the most important in relation to the observations here reported being that by Janowski, "Zur Biologie der Typhus Bacillen (Centralbl. f. Bakteriologie, etc., VIII, 1890, 167, 193, 230, 262).

In a research now in progress under the direction of Dr. Weir Mitchell and myself, in the Laboratory of Hygiene of the University of Pennsylvania, with the aid of a grant of funds for the purpose made by the trustees of the Bache fund, the influence of light, of desiccation, and of the products of certain ordinary water bacteria upon the growth and development of the bacillus of typhoid and of the colon bacillus are being investigated, and there is now presented to the academy a brief statement of the results obtained by the experiments bearing on the first part of this inquiry, namely, the effects of light upon these microorganisms. These experiments were made in accordance with a general scheme prepared by Dr. Mitchell and myself, the details being carried out by Dr. Adelaide W. Peckham, under the immediate supervision of Dr. A. C. Abbott, first assistant in the Laboratory of Hygiene.

The first series of experiments to determine methods was made on the *staphylococcus pyogenes aureus*, which was inoculated in the usual manner on agar spread in a thin layer in Petri dishes, which were then placed in sunlight for definite periods of time, varying from fifteen minutes to two hours, after which they were placed in the incubator to remain until the next morning. In some cases one-half the plate was shielded from the direct rays of the sun by a sheet of colored glass, the colors selected being as near to the principal ones of the spectrum as could be obtained. The results corresponded with those obtained by previous observers, some colors evidently giving much more protection than others, but it was not possible to obtain in this way an accurate measure of the effects produced by different colored lights in certain definite periods of time, and hence the following methods were devised and used by Dr. Peckham:

1. Preparation of cultures used for inoculation of agar-agar.—Tubes of bouillon, each containing 10 cc., are inoculated with one drop of a bouillon culture and placed in the incubator for twenty four hours. A small quantity of sterilized gravel is then added to the culture tube and it is shaken thoroughly, so as to separate the germs and disperse them evenly throughout the bouillon. Ten cubic centimeters of a one-half per cent salt solution are then added, and the culture is drawn into a dropping apparatus like the one used by Nuttall for counting tubercle bacilli, which he describes as follows (Bulletin of the Johns Hopkins Hospital, May–June, 1891): "It consists of a finely graduated burette, to which a finely drawn-out dropper is attached by a rubber coupling. From the upper end of the burette proceeds a piece of rubber tubing which leads—a glass stopcock intervening—to a mouthpiece, which can be placed at the highest point of the apparatus out of danger of any possible contamination." By simply filing a small groove with a triangular file on one side of the aperture in the stopcock, the groove gradually fading as it proceeds away from the opening, a most effective and simple means of controlling the rate of dropping was found. When ready to use the stopcock is turned enough to allow about twenty drops to a cubic centimeter.

2. Inoculation of agar-agar.—One drop of the bouillon culture was dropped into a tube of melted agar-agar, which was slowly and thoroughly agitated, and then poured into a Petri plate placed upon a leveling tripod over ice water.

3. Isolation of cultures.—The plates, when solidified, were placed in an east window, bottom upward, and half of each plate covered with black paper or glass of different colors. A thermometer with a blackened bulb was placed in the sun to note the temperature. At intervals of fifteen minutes a plate was removed and placed in the incubator. A control plate made at the same time as the others was placed immediately in the incubator.

4. Counting the colonies on plates.—An eyepiece was divided into fields, as done by Nuttall, by introducing a disk of black cardboard, which has a square opening divided into four parts by two hairs placed at right angles. This eyepiece and an objective of low power were used in counting. The colonies in each field were counted in exactly the same portion of each half of the plate and from the sum of these numbers the per cent was estimated. Thus the per cent destroyed by insolation was ascertained, and also an estimate of the difference of protection afforded by the different colors used. The plates were insolated on clear, sunny, still days. If the sun became obscured during the period of insolation the plates were counted to note the effect, but the per cent was not used in the final estimation. The temperature of the plates during the insolation was kept below 34° C. in every instance. Each plate used for counting was insolated for either fifteen, thirty, forty-five, sixty, ninety, one hundred and five, or one hundred and twenty minutes, and then placed in the incubator. Plates uniform in size and as level as could be obtained were used, so that 10 cc. of the medium would be evenly distributed by using the leveling apparatus.

Cultures were also insolated for varying periods of time. A culture of the *staphylococcus pyogenes aureus* exposed to the rays of the sun for nine hours gave six colonies on the insolated portion. The number of colonies on the other half, protected by red glass, was also lessened. Plates of the *bacillus coli communis* were insolated for six hours, one-half of each plate being covered with either red, yellow, or blue glass. Five colonies were found on the insolated portion of the plate protected by red glass and a few colonies at one edge of the plate covered with yellow glass. Under the glass the number of colonies had decreased somewhat. On the plate with a blue-glass shade eight colonies were found on the insolated half and the same number on the protected part, the result being that at the end of six hours the colonies had been equally destroyed on both sides of the plate. Four plates of the *bacillus typhi abdominalis* shaded with black, red, orange, or blue glass were insolated three hours. From these, six colonies were found on the insolated half of the plates, protected by black, red, and orange. Not a colony was found on the entire plate, which was half shaded with blue.

Diffused light.—Plates were made and exposed in the same manner as used for sunlight. Clear, sunny days were taken for the experiments, the plates being placed in a light part of a room and exposed for periods varying from fifteen minutes to two days, and then placed in the incubator for twenty-four hours and counted as before. Many plates were made, using the different organisms, but the result was negative. On counting, the colonies on each side of the plate they were approximately the same.

Gaslight.—Plates were exposed in the light afforded by an ordinary gas burner and in a dark room, one-half of each plate shaded as before. On counting the colonies on plates illuminated two and one half hours, the number on the protected side was slightly larger than on the illuminated side. Many other plates were made with varying results, and, finally, some plates exposed for sixteen hours were counted and gave about the same number of colonies on each side.

Electric light.—Plates were exposed to an incandescent light for varying periods, the longest illumination being for four and a half hours. The colonies numbered approximately the same on both halves of the plate.

Comparative absence of light.—Plates of agar-agar were inoculated, placed in a closet for some hours, and then incubated. The number of colonies did not vary in any noticeable degree from those on the control plate.

A series of experiments were made with tubes of bouillon inoculated with the different organisms and then inclosed in larger tubes containing fluids of different colors—red, orange, yellow, and blue. These tubes were exposed to sunlight and control tubes were also exposed, one being placed in water and the other in a tube of water covered closely with black paper. The materials used for making the colored solutions were corallin, chromate and bichromate of potassium, and methylene blue. The solutions were filtered and then placed in the sun several days to see if they remained clear.

The tubes were made in sets of seven for each organism—one for each color—and two control tubes. They each contained 15 cc. of bouillon, were plugged with cotton through which pipettes passed, and the whole top was covered with cotton fastened around the tube with a wire.

From the first set of tubes plates were made each day, but the constant opening allowed contamination, so that a new set was begun. The number of colonies increased from an average of twenty at the first counting to about one hundred at the end of seven days. Three sets of tubes of bouillon cultures—seven for each organism—were insolated as before, beginning on December 26. Each tube had received from a dropping apparatus one drop of a bouillon culture of the organism used, had been incubated twenty four hours, and then placed in the glass tube containing the colored solution and exposed to the sun. A control plate was made immediately after inoculation and counted on the following day. After insolation for seven days three sets of plates were made, each set containing five plates, or one for each color used. These plates were incubated for twenty-four hours and then counted—the average of four counts being made. All the plates showed great increase in the number of colonies. After eighteen days' insolation new plates were made and counted and still showed an increase in the number of colonies. After fifty-eight days of insolation there was a great decrease in the number of colonies and in many of the tubes molds had appeared which had probably grown through the cotton plugs. Rubber caps were not used for the reason that such a limitation of the amount of oxygen in the tube would not maintain the conditions desired.

A second and third set of tubes treated in the same manner and capped closely with paper remained undisturbed for a month and then showed contaminations as in the set first noted.

The chart gives the duration of insolation, the dates upon which plates were made, the colors used for the protecting fluids, and the number of colonies found as an average of four counts made in different portions of the plate.

The results of this study upon the effect of light on the *bacillus typhi abdominalis*, the *bacillus coli communis*, and the *staphylococcus pyogenes aureus*, in which several hundred plates have been insolated and a considerable number exposed to diffuse light, gaslight, and electric light, are summed up in the following statements:

Insolation for even the short period of fifteen minutes destroys to some extent all three of the organisms named above. Three to six hours' insolation kills nearly every colony on the plate. The *bacillus coli communis* is more easily destroyed by insolation than the *bacillus typhi abdominalis*. On plates covered with black paper, producing complete shadow during the insolation, no destructive effect is produced, as shown by the number of colonies being the same as on the control plate. The heat absorbed by the black paper does not destroy the organisms.

Red, orange, yellow, and green afford nearly as much protection against insolation as complete shadow. Blue and violet give much less protection, and if the insolation continues for four or five hours all the colonies are killed. In the articles referred to in the literature collected on this subject the authors attribute this protective power to the opaqueness of red, orange, yellow, and green to the actinic rays, while blue and violet are perfectly transparent to these rays. Glass affords some protection from the sun, but as a constant factor in this experiment it does not alter the result as far as comparison of the effect on the different organisms is concerned.

If during insolation the sun becomes obscured for even a short time, as from wind clouds, the effect is seen by diminution of the number of colonies destroyed.

Diffuse light has very little destructive effect upon the organisms studied.

Gas and electric light as used in the illumination of houses have little if any effect upon these organisms.

Under ordinary circumstances one might be tempted to explain the effect of sunlight as a disinfectant as produced by the drying of the substances exposed to it, especially in the case of those bacteria which do not form spores; but desiccation for a considerable period of time has little effect upon the bacillus of typhoid or the colon bacillus, neither of which is known to form spores.

Geisler (*Zur Frage über die Wirkung des Lichtes auf Bakterien, Centralbl. f. Bakteriol.*, Jena, 1892, XI, p. 161) reports that he found no qualitative difference between the effects of the electric arc light and the direct sunlight; but that sunlight has a greater effect in checking the development of the bacillus of typhoid; that all the rays of the spectrum, except the red, exercise some inhibitory effect; that the heat of the sun's rays has some effect, and that perhaps changes in the culture medium must be taken into account.

Light affects some of the bacteria which it does not destroy. For example, it diminishes the pigment-producing power of some of the chromogenic bacteria, such as the *bacillus pyocyaneus* and the *bacillus prodigiosus*, and it probably lessens the pathogenic power of such organisms as the bacillus of typhoid and the bacillus of tubercle, because it not only diminishes the rapidity of their multiplication and hence the amount of their products, but so modifies them that, for a time at least, when placed in the dark or inoculated into an animal the successive generations are less vigorous and prolific and give rise to less of their characteristic products. Some bacteria seek the light and some produce light, especially some forms resembling the cholera spirillum.

The practical importance of sunlight in preventing disease and destroying contagion has long been known, but it is only recently that we have obtained any definite knowledge as to how it acts. Recently Von Esmarch (*Ueber Sonnen-Desinfection, Zeitschr. f. Hyg*, XVI, 1894, 257) has given the results of a number of trials in disinfecting bedding, skins, etc., by sunlight, and while the action of the light was, as might be expected, mainly confined to the surface, yet it extended more deeply into a pillow containing the diphtheria bacillus than one would have anticipated. It has been proposed to employ a powerful movable arc light to disinfect rooms, and it is possible that good results may be thus obtained. The bacillus of tuberculosis appears to be more quickly destroyed by light than some other forms, and is killed by diffuse daylight in about a week.

The following tables and charts show the results obtained by Dr. Peckham. In the charts each color is that of the glass used during insolation. Charts are given also to show percentage destroyed as compared with the half protected by the different colors.

Chart showing the protection from insolation given by black.

	Percentage of organisms destroyed in the insolated half of the plate as compared with the protected half.							
Number of minutes insolated	15	30	45	60	75	90	105	120
Typhoid	17	28	33	34	65	63	90	98
Colon	25	15	25	71	83	88	97	99
Aureus	....	....	55	....	72	72	80	90

Chart showing the protection from insolation given by blue.

Number of minutes exposed	15	30	45	60	75	90	105	120
	Percentage of organisms destroyed in the insolated half of the plate as compared with the protected half							
Typhoid	7	14	30	32	24	38	35	52
Colon	13	29	32	37	56	59	60	52
Aureus	......	38	34	54	51	41	48	50

Chart showing the protection from insolation given by red.

Number of minutes exposed	15	30	45	60	75	90	105	120
	Percentage of organisms destroyed in the insolated half of the plate as compared with the protected half.							
Typhoid	7	27	40	60	69	87	92	95
Colon	25	24	27	80	88	88	89	96
Aureus	......	40	....	65	84	96	95	97

Chart showing the effect of insolation through colored fluids.

	Typhoid.				Colon.				Aureus.			
	Beginning—				Beginning—				Beginning—			
	Dec. 26	Jan. 3.	Jan. 14	Feb. 12.	Dec. 26.	Jan. 3	Jan. 14	Feb. 12.	Dec. 26	Jan. 3.	Jan. 14	Feb. 12
Shadow	3	16.4	12.6	(a)	4	73	48.2	43	3	57	(a)	......
Red	3	25.5	24.4	(a)	4	61	55.5	(a)	3	50	48.5	(a)
Orange	3	11	17.8	4	4	54	51.5	45	3	39	49.5	9
Yellow	3	8	19.5	4	4	72	76	(a)	3	41	84	(a)
Blue	3	....	16.3	(b)	4	25	53.4	17	3	28	70	None

a Contaminated. *b* Six colonies in whole plate.

Chart showing the protection from insolation given by green.

Number of minutes exposed	15	30	45	60	75	90	105	120
	Percentage of organisms destroyed in the insolated half of the plate as compared with the protected half.							
Typhoid	17	11	40	53	62	86	87	92
Colon	7	6	35	44	84	83	95	99
Aureus	......	41	36	51	51	80	75	95

Chart showing the protection from insolation given by orange.

Number of minutes exposed.	15	30	45	60	75	90	105	120
	Percentage of organisms destroyed in the insolated half of the plate as compared with the protected half							
Typhoid	1	22	39	46	...	69	86	91
Colon	17	23	29	31	58	....	91	96
Aureus	......	39	51	63	73	72	84	99

Chart showing the protection from insolation given by yellow.

	Percentage of organisms destroyed in the insolated half of the plate as compared with the protected half							
Number of minutes exposed...	15	30	45	60	75	90	105	120
Typhoid	1	22	25	58	66	69	77	94
Colon	18	30	35	40	83	88	89	99
Aureus	....	44	55	62	50	89	90	84

ON THE INFLUENCE OF INSOLATION UPON CULTURE MEDIA AND OF DESICCATION UPON THE VITALITY OF THE BACILLUS OF TYPHOID, OF THE COLON BACILLUS, AND OF THE STAPHYLOCOCCUS PYOGENES AUREUS.[1]

By Dr. J. S. Billings, U. S. A.

At the meeting of the National Academy in Washington in April, 1894, I presented a paper upon the influence of light upon the bacillus of typhoid and the colon bacillus, giving the results of experiments made at the Laboratory of Hygiene of the University of Pennsylvania by Dr. Adelaide W. Peckham, in accordance with a general scheme of investigation prepared for that purpose by Dr. Weir Mitchell and myself.

This paper has not yet been published, and within the last three months there has appeared in the third Heft of the ninth volume of the *Arbeiten aus dem Kaiserlichen Gesundheitsamte* a paper by Dr. A. Dieudonne, entitled "*Beiträge zur Beurtheilung der Einwirkung des Lichtes auf Bakterien*," in which he gives, as the results of experiments on the effects of sunlight on bacteria by methods which are almost identical with those used by Dr. Peckham, results which are substantially the same as those announced in my paper above referred to.

I desire now to present to the Academy certain results which have been obtained since last April in experiments upon the influence upon certain microorganisms of culture media which have been exposed to sunlight, and of desiccation of the bacteria themselves. These experiments, like those previously reported, were made in the Laboratory of Hygiene of the University of Pennsylvania by Dr. Adelaide W. Peckham, in accordance with the general scheme prepared by Dr. Mitchell and myself, the expenses of the investigation having been borne by an appropriation from the Bache fund.

I. RESULTS OF INSOLATION OF CULTURE MEDIA.

Sterile bouillon insolated from one to ten days and then inoculated with the *bacillus typhi abdominalis* showed no diminution in the number of colonies as compared with a control plate. Twenty days' insolation and then inoculation with the typhoid bacillus showed great decrease in the number of colonies on all the plates; some of them were perfectly sterile. Insolation of forty days and inoculation in the same manner gave very few colonies for each plate, probably the same as the number of germs introduced, i. e., there had been no development. Bouillon insolated fifty to sixty days and inoculated gave perfectly sterile tubes. This insolated bouillon, after inoculation and incubation, remained perfectly clear, and plates made after a week of incubation gave no more colonies than those made at the end of twenty-four hours. Its reaction was alkaline, but not intensely so.

Insolated agar-agar.—Of twenty-three tubes of agar-agar insolated twenty days and then inoculated with the *bacillus typhi abdominalis*, all except one remained sterile, and neither the *bacillus typhi abdominalis* nor the *bacillus coli communis* grew when inoculated in stripes on these

[1] Presented to the National Academy of Sciences at its meeting October 30, 1894.

plates. Of seven tubes of agar-agar insolated forty days and then inoculated with the bacillus of typhoid, all remained sterile. On four of these plates molds appeared after some days. Of seven tubes of agar-agar insolated forty days and then inoculated and incubated as before, all remained sterile.

Insolated gelatin.—Of ten gelatin tubes insolated forty days and then inoculated with the *bacillus typhi abdominalis*, six remained sterile, two contained a few colonies of *bacillus typhi abdominalis*, and two were contaminated.

It will be seen from these experiments that the long continued exposure to sunlight of culture media makes them incapable of supporting the growth of the bacillus of typhoid and of the colon bacillus.

II. DESICCATION.

Bouillon cultures of the *bacillus typhi abdominalis*, the *bacillus coli communis*, and the *staphylococcus pyogenes aureus* were roughly dried on threads 1 cm. long and then desiccated, a portion being placed in a vacuum, another portion in a desiccator over sulphuric acid, and a third in a closet; all were kept in the dark. The result of the desiccation under the three different conditions is as follows:

Bacillus typhi abdominalis:

Lived in a vacuum from December 30 until July 24, or 207 days.

Lived in a desiccator over sulphuric acid from January 3 until July 24, or 203 days.

Lived in a closet from December 18 until July 24, or 219 days.

Bacillus coli communis:

Lived in a vacuum from November 29 to May 30, or 183 days.

Lived in a desiccator over sulphuric acid from January 3 until July 24, or 203 days.

Lived in a closet from December 30 until May 30, or 152 days.

Staphylococcus pyogenes aureus:

Lived in a vacuum from November 29 until July 24, or 238 days.

Lived in a desiccator over sulphuric acid from October 25 until April 19, or 177 days.

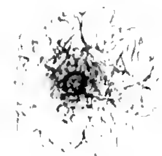
Lived in a closet from February 13 until July 24, or 162 days.

In will be seen from these experiments that the organisms experimented on endure desiccation for five months or more without losing their vitality, and hence that what little desiccation may have occurred in the insolation experiments had probably no influence on the results.

Fig. 1.

Cladothrix Rufula. Surface colony.
Roll tube culture. 5th day.

Fig. 2.



B. Convolutus. Surface colony.
Gelatin roll culture. 2 days.

Fig. 3

B. Fluorescens Incognitus.
Young surface colony. Gelatin plate. 2 days.

Fig. 4.

B. Fluorescens Foliaceus
Surface colony. Roll tube culture. 3 days.

Fig. 5.

B. Desidiosus.
Young colony. 2 days.

Fig. 6

B. Desidiosus.
Gelatin roll tube. 5 days.

Fig. 7.

B. Caudatus.
Surface colony. Gelatin plate. 3 days.

Fig. 8.

B. Caudatus. Liquefying colony.
Gelatin plate. 4 days.

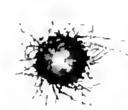
Fig. 9

B. Arborescens. Var. B.
Deep colony. Gelatin plate. 2 days.

Fig. 10.

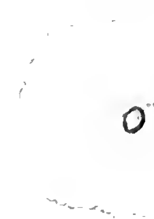
B. Fluorescens Schuylkiliensis.
Surface colony. Roll tube. 2 days.

Fig. 11.



B. Subtilis.
Deep colony in gelatin. 24 hours.

Fig. 12



B. Delabens. Gelatin roll culture.
Surface colony. 2 days.

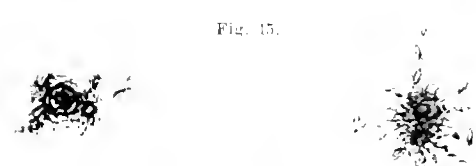
Fig. 13.

B. Coadunatus.
Deep colony. Gelatin roll culture.

Fig. 14.

B. Detrudens.
Deep colonies. Gelatin plate. 2 days.

Fig. 15.



B. Detrudens. Deep colonies.
Unusual forms. Gelatin. 2 days.

A. HOEN & CO., LITH., BALTIMORE.

Fig. 1.

B. Detrudens. Surface colony
Gelatin plate. 2 days.

Fig. 2

B. Detrudens
Small surface colonies.
Gelatin plate. 30 hours.

Fig. 3.

B. Detrudens. Deep colony
Gelatin plate. 2 days

Fig. 4

B. Capillaceus
Surface colony. 24 hours.

Fig. 5

B. Crinitus.
Margin of colony in liquefaction
Gelatin plate. 2 days

Fig. 6.

B. Capillaceus. Deep colony
Gelatin roll tube. 3 days.

Fig. 7.

B. Capillaceus. Deep colony.
Gelatin plate. 2 or 3 days.

Fig. 8.

B. Capillaceus. Deep colony.
Gelatin roll culture. 3 days

Fig. 9

B. Geniculatus.
Surface and deep colonies.
Gelatin plate. 2 days.

Fig. 10.

B. Flexuosus.
Colony in gelatin plate. 2 days

Fig. 11.

B. Lacunatus. Surface colony
Gelatin plate. 24 hours

Fig. 12.

B. Multistriatus. Surface colony
Gelatin plate. 2 days.

Fig. 13.

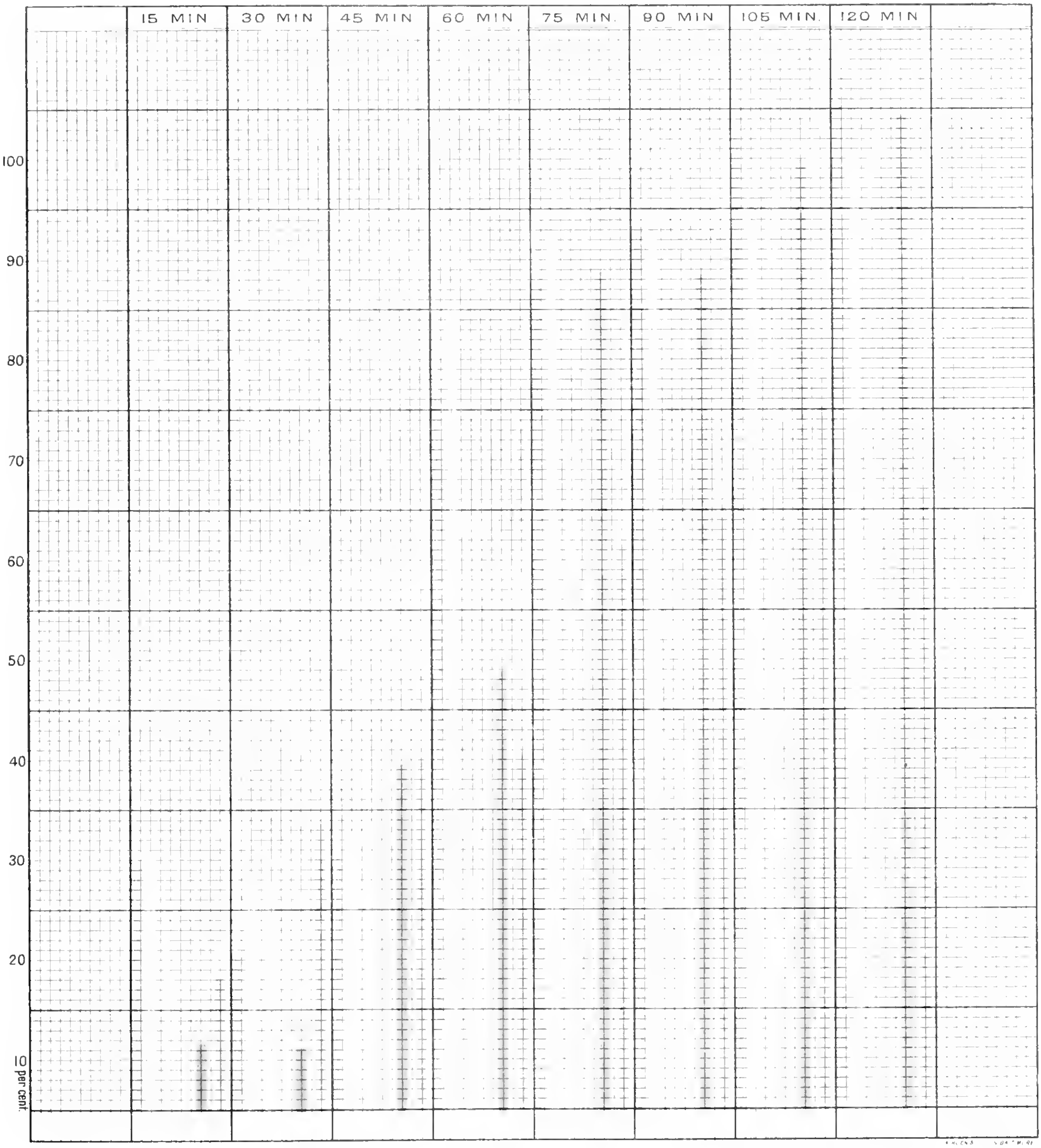
B. Nebulosis. Surface colony.
Gelatin roll culture. 3 days

Fig. 14.

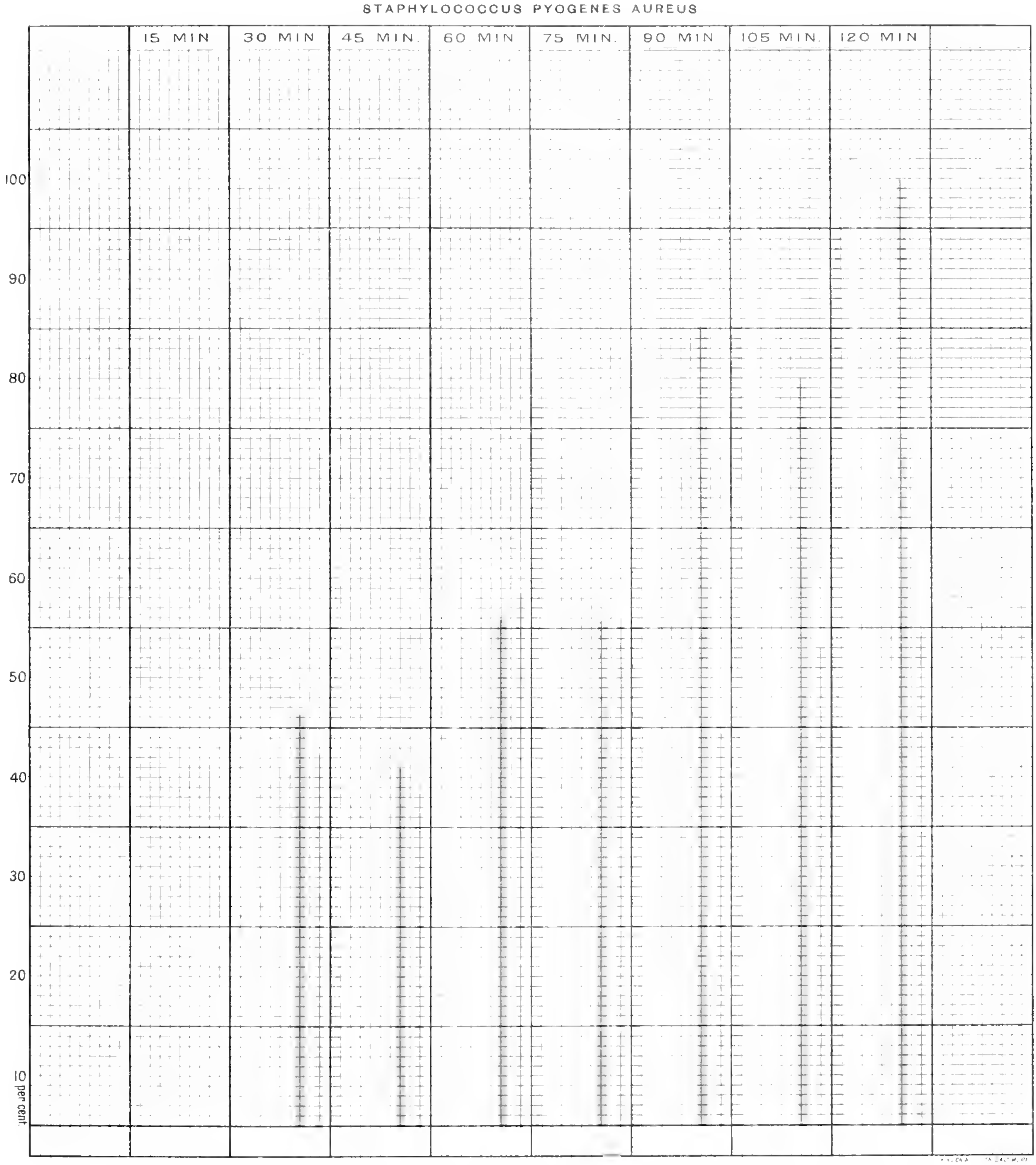
Proteus Mirabilis. Surface colony
Gelatin plate. 24 hours

A. HOEN & CO., LITH., BALTIMORE

CHART OF BAC. COLI COMMUNIS.

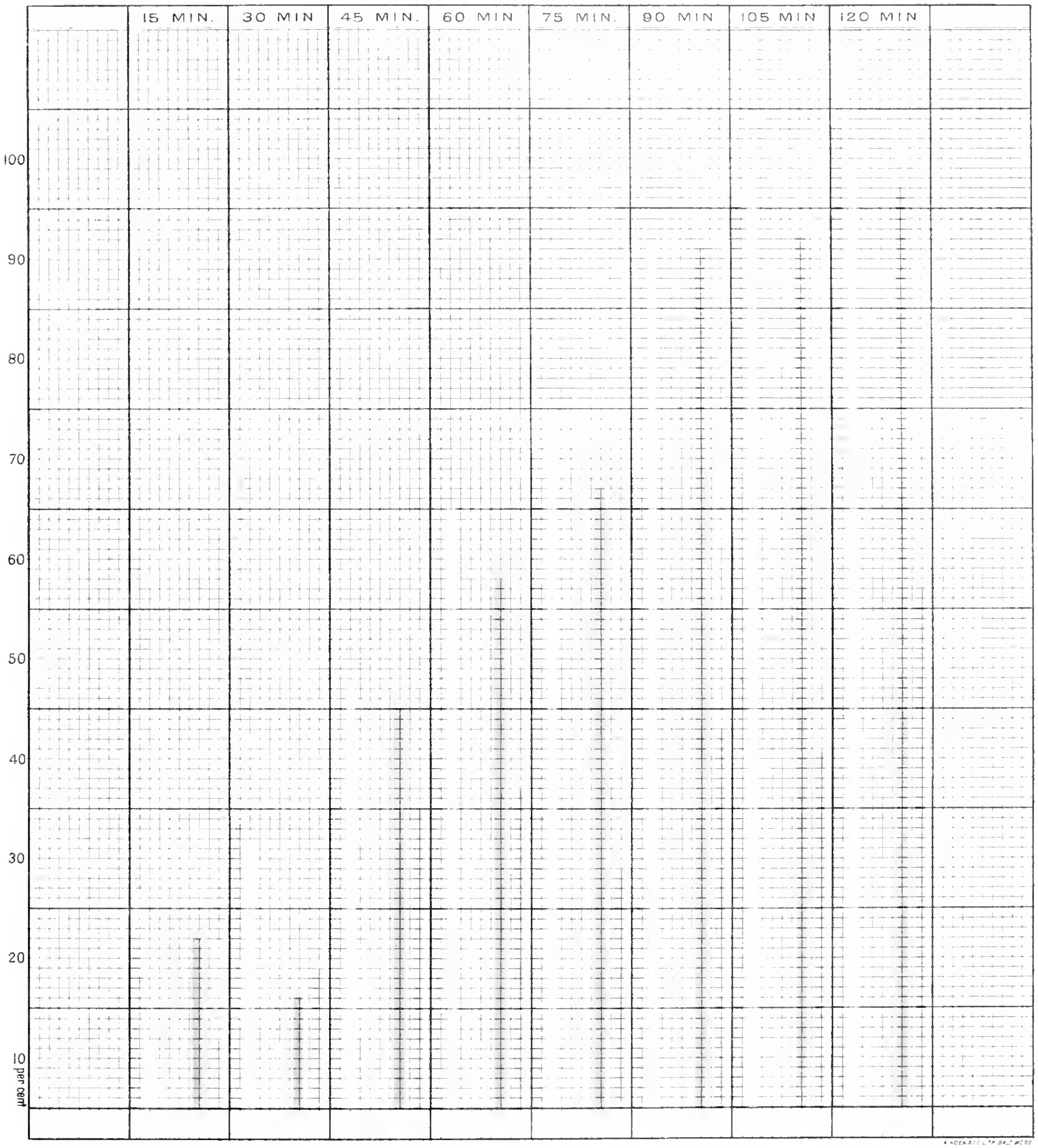


The different colors on the chart represent the amount of protection afforded by glass of the same color.



The different colors show the amount of protection afforded during insolation by glass of the same color.

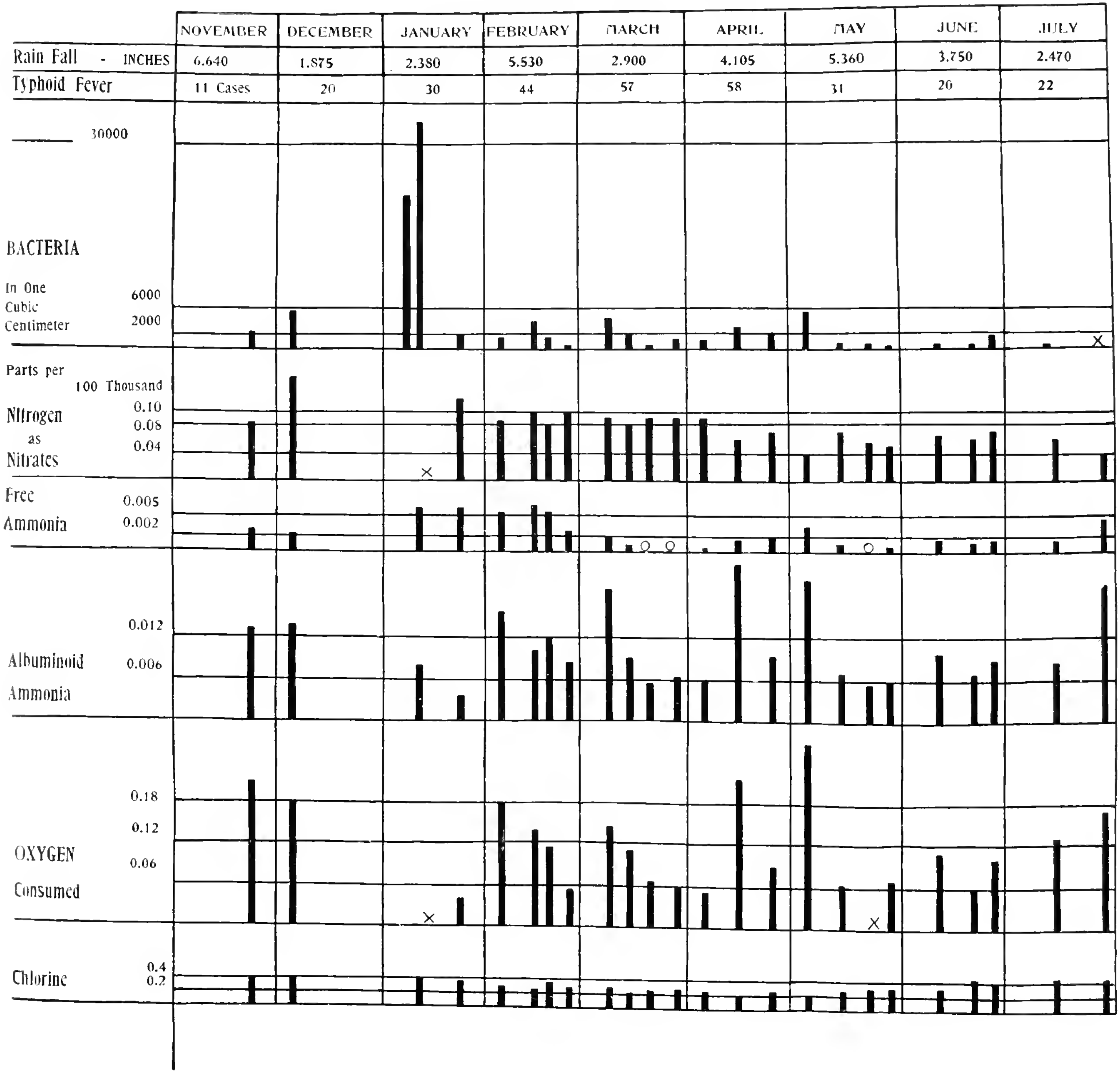
BAC. TYPHI ABDOMINALIS.



The different colors show the amount of protection afforded during insolation by glass of the same color.

ROXBOROUGH DISTRICT. UPPER SCHUYLKILL.

21st and more than half of 22nd and 28th Wards.

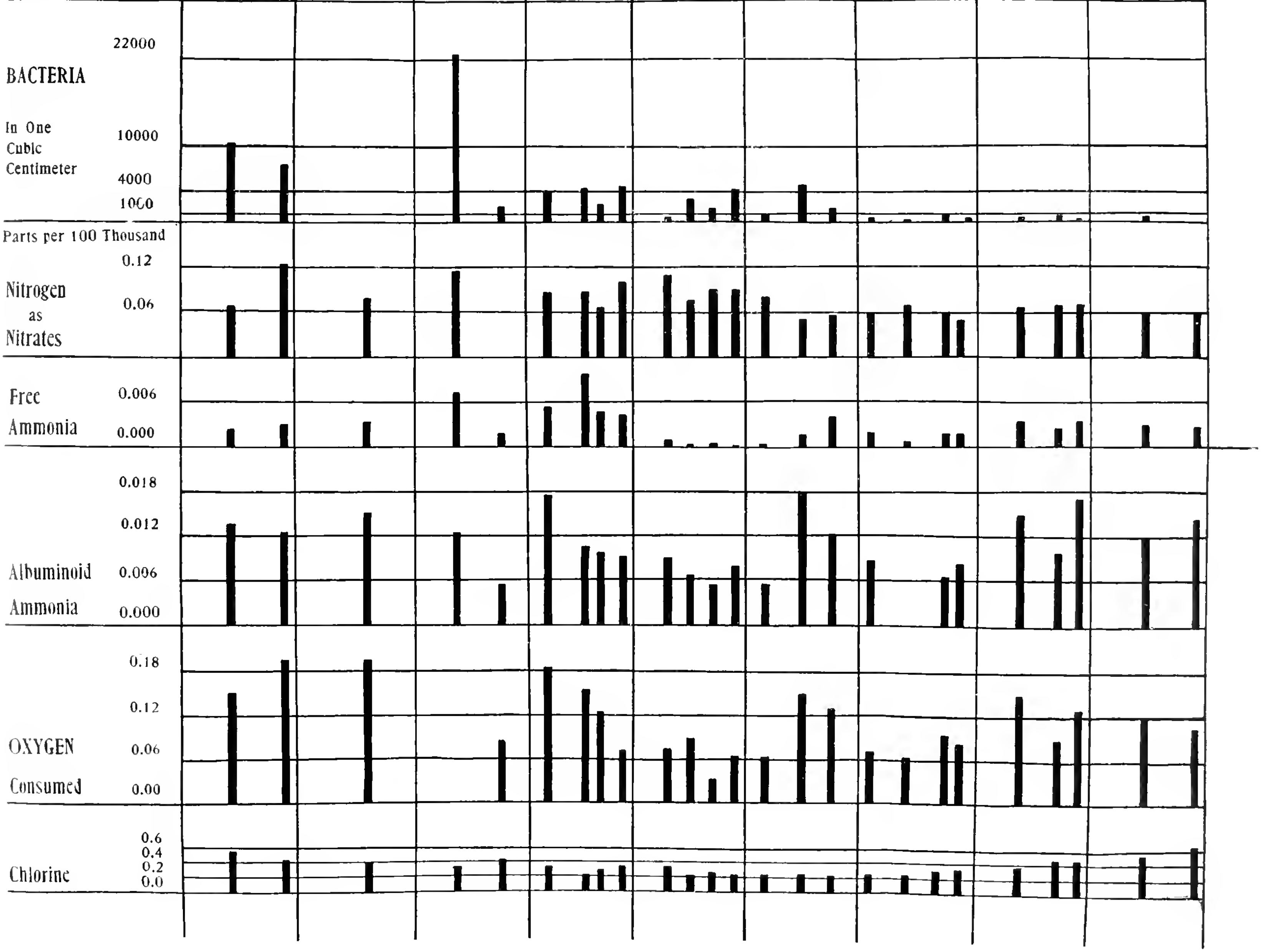


FAIRMOUNT DISTRICT.

LOWER SCHUYLKILL.

1st. 2nd. 3rd. 4th. 26th. 30th and 36th Wards.

	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY
Rain Fall	6.640	1.875	2.380	5.530	2.900	4.105	5.360	3.750	2.470
Typhoid Fever	22 Cases	23 Cases	22	22	23	29	43	36	32



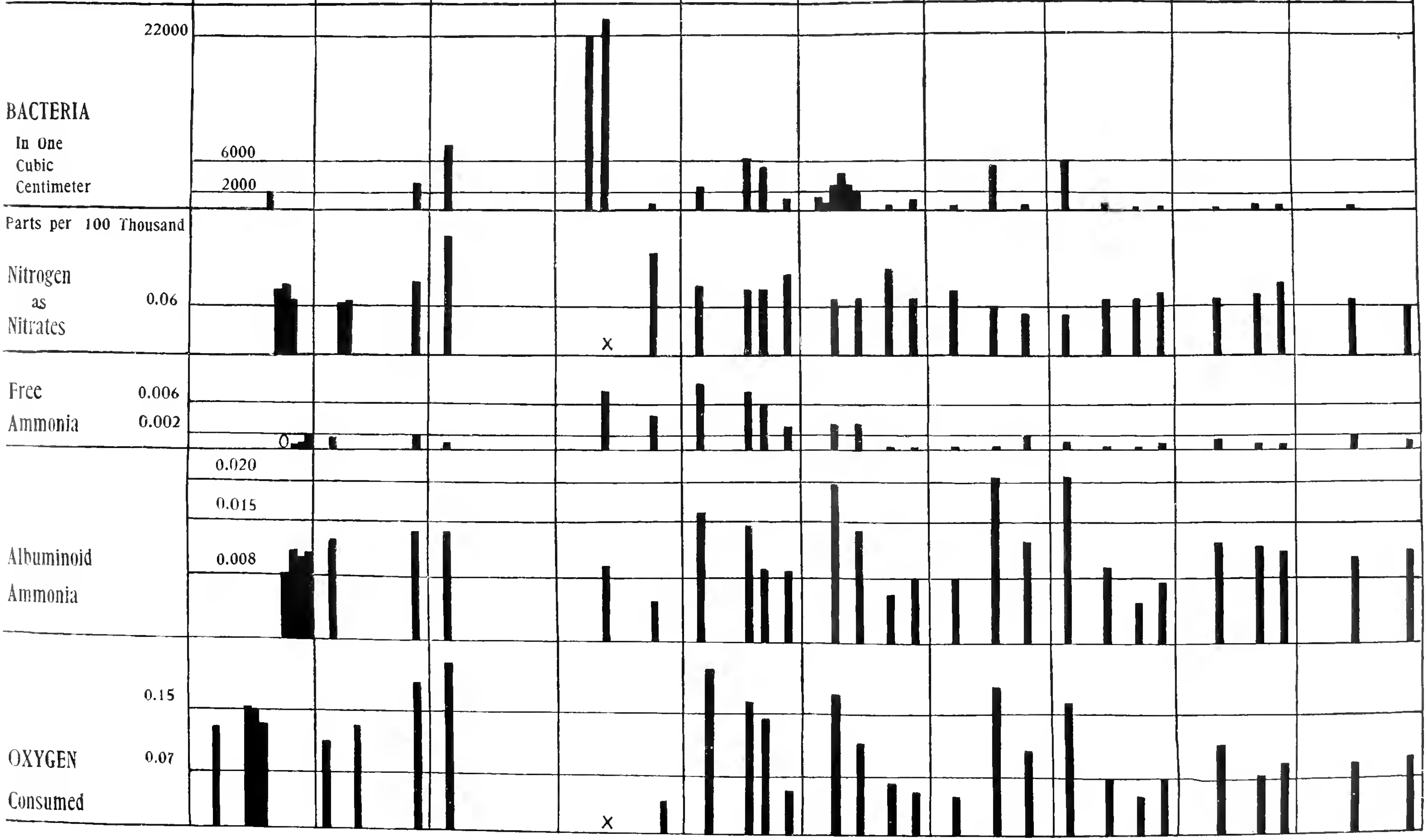
BELMONT DISTRICT.

Laboratory of HYGIENE.

LOWER SCHUYLKILL.

24TH, 27TH AND 34TH WARDS.

	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY
Rain Fall - INCHES	0.475	6.640	1.875	2.380	5.530	2.900	4.105	5.360	3.750	2.470
Typhoid Fever	11 Cases	14	7	10	16	22	17	35	21	24



FRANKFORD DISTRICT. DELAWARE WATER.

23RD, 25TH, 35TH AND PART OF 19TH AND 33RD WARDS.

	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY
Rain Fall	7.12 Inches	1.63	3.04	5.78	2.56	4.96	4.50	3.62	1.88
Typhoid Fever	19 Cases	13	24	35	36	29	44	19	23

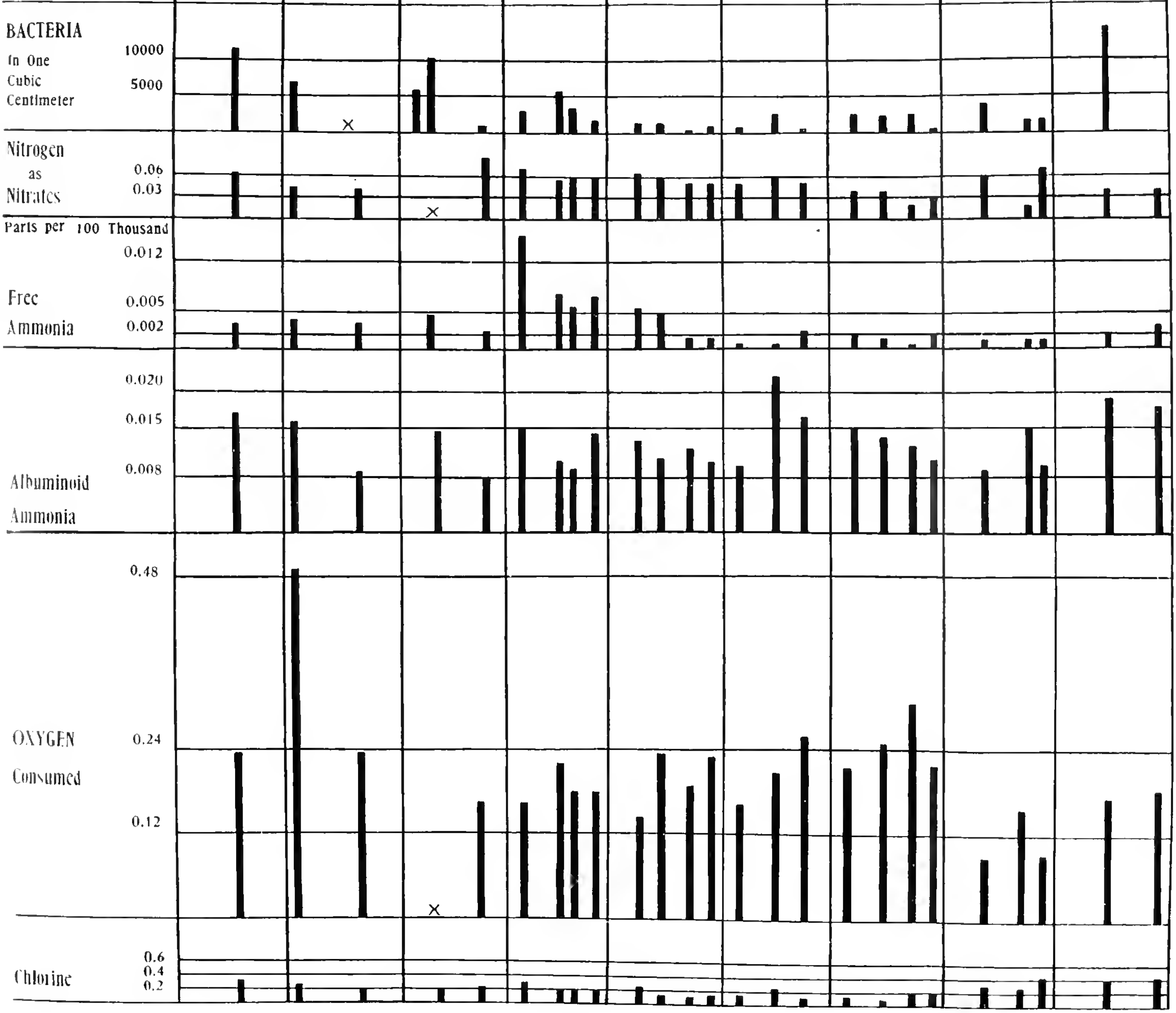
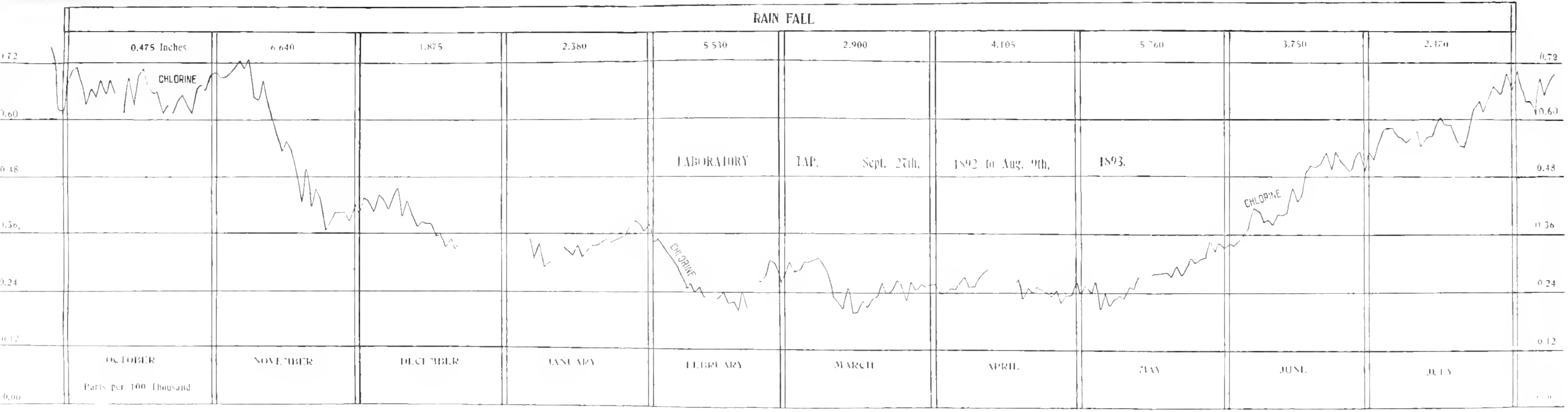


DIAGRAM 7


RAIN FALL
0.475 Inches
6.640
1.875
2.380
5.530
2.900
4.105
3.750
2.370
CHLORINE
LABORATORY TAP. Sept. 27th, 1892 to Aug. 9th, 1893.
0.72
0.60
0.48
0.36
0.24
0.12
0.00
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
Parts per 100 Thousand

2792