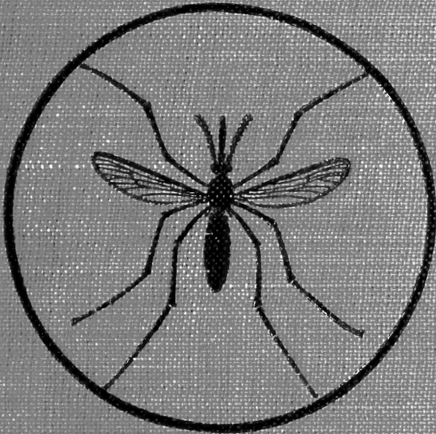
Mosquito Life



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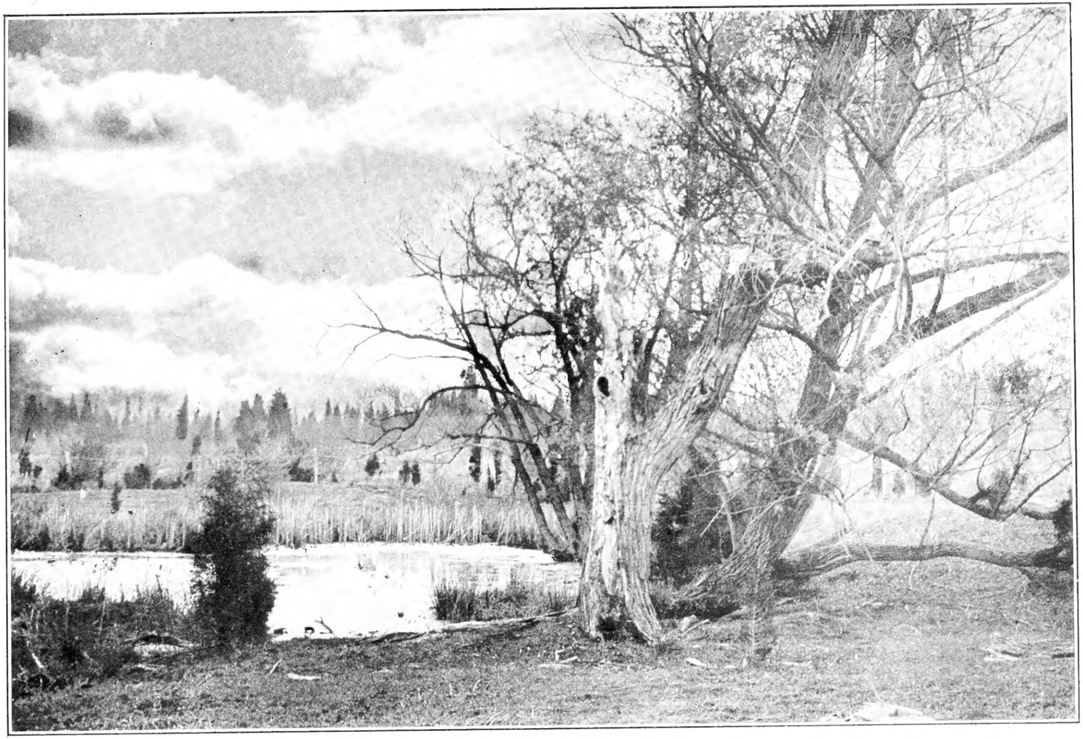

Photograph by H. R. Terhune.

A Mosquito-Breeding Pool.

MOSQUITO LIFE

THE HABITS AND LIFE CYCLES OF THE KNOWN MOSQUITOES OF THE UNITED STATES; METHODS FOR THEIR CONTROL; AND KEYS FOR EASY IDENTIFICATION OF THE SPECIES IN THEIR VARIOUS STAGES. AN ACCOUNT BASED ON THE INVESTIGATIONS OF THE LATE JAMES WILLIAM DUPREE, M.D., SURGEON-GENERAL OF LOUISIANA, AND UPON ORIGINAL OBSERVATIONS BY THE WRITER.

BY

EVELYN GROESBEECK MITCHELL, A.B., M.S.

ILLUSTRATED

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IN MEMORY OF

JAMES WILLIAM DUPREE, M.D.

PREFACE

WITHIN recent years, so much has been written about mosquitoes, and scattered through such a vast number of books and periodicals, that the average student now sorely feels the need of a single work, containing, in a condensed form, the essential facts so far made known in regard to the different phases of this important and highly interesting subject. It was to meet the demands of the constantly increasing army of both professional and lay workers that the present volume was designed. While aiming to keep it within reasonable bounds, that it might be easily used alike in the field and in the laboratory, still it is believed that no portion of the work has been slighted, or fundamental information omitted, in the endeavour to carry this desire into effect.

It has been the constant aim of the author to give, in as succinct a form as possible, both what has been set forth by others and what new facts have been ascertained by Dr. Dupree and herself regarding the lives of these pestiferous creatures in this country—how and where they breed, how they bite, how they transmit disease, how long and on what they live, how they may be identified in their various stages, and finally, but not the least important how they may be locally controlled. The author has endeavoured to present this matter in terms intelligible to the average reader, omitting technical expressions, as far as possible, and explaining them fully where their use becomes necessary.

The illustrations are chiefly from original drawings by the author, made for Dr. Dupree: a few exceptions are noted in their proper place. The drawings of the larval mouth parts are from cast skins, the dissections being also by the author. Particular care has been taken in the mapping of the larval hairs, as much use is here made of these in identification.

I here take pleasure in expressing, both in my own name and that of Dr. Dupree, my appreciation of the kindness of all those who have in any way aided me to bring out this work. Especially do I wish to thank Dr. John B. Smith, State Entomologist of New Jersey, and Dr. E. P. Felt, State Entomologist of New York, for permission to revise my tables from their very comprehensive collections of mosquitoes, for valuable criticism and suggestions, and for the loan of photographs. Also I may here properly extend my thanks to Mr. D. W. Coquillett, of the United States Department of Agriculture, for many helpful hints and bits of information given me at the time when I was engaged in preparing my thesis; and to Professor H. A. Morgan, State Entomologist of Tennessee, for timely advice in regard to my manuscript.

E. G. M.

WASHINGTON, D. C., 1907.

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INTRODUCTION

A WORD of explanation in regard to the composing of this book is necessary. In January, 1904, Dr. J. W. Dupree, Surgeon-General of Louisiana, and Professor H. A. Morgan, at that time Professor of Zoölogy in the Louisiana State University, now State Entomologist of Tennessee, asked Professor J. H. Comstock, of Cornell University, to send them an artist entomologist. Thus I chanced to have the great good fortune of acting as artist and assistant to Dr. Dupree for the space of six months, and to him owe the initial impulse to the study of mosquitoes. It did not take me many hours to see that Dr. Dupree had attacked the problem of life histories of mosquitoes as no one else had done, and in the most logical and scientific way—not by merely collecting larvæ, but by obtaining living adults, inducing them to oviposit, and raising the larvæ. He knew more about mosquito eggs and the peculiar habits of the larvæ than any one else I ever met or heard of, he could tell many of the larvæ by their general appearance and actions without the aid of a magnifying glass, and I never saw any one else who knew so many without bringing to his aid a compound microscope.

When in Baton Rouge I felt the need of a field key for the adults,—one based on colour which would run directly to generic and specific name together, and which could be used with a hand lens. Not finding any such, I proceeded to make one, of which the Doctor approved, and which he advised me to publish. Next I started a larva key, planned to reach the name as quickly as possible, regardless of the genus, by first taking out the larvæ having the most prominent characters. I also made an egg and a pupa key. After going to Washington I kept on collecting and experimenting, finally producing a series of keys which correspond in general to those in this book, except that the former contain extralimital forms, and those keys (from which the present ones are abridged and entirely worked over from new sets of specimens) were accepted as a thesis, in part satisfaction for the degree of M.S., at George Washington University.[1] I have especially planned the adult key for the general, non-technical worker, and as a quick name-finder I think it will be useful to others. The generic key for larvæ is simply to show relationships, as the generic names are also in the general larva key.

After this, I planned to write a book around the keys, one dealing with habits, etc., for popular use. Dr. Dupree, in accord with his broad belief that no true scientist selfishly considers any field pre-eminently his own, but, labouring for the spreading of truth and not for his own personal aggrandisement, is ever ready to aid and to share his results with others, offered me any aid he could give, including his notes, knowing that he need not worry about receiving proper credit. Then we began to plan that I

[1] The Dean requests that this fact be stated in publication.

J. W. Dupree, M.D.

(In his uniform as member of the Staff of the Governor of Louisiana.)

should go there to help him with a book, but that was not to be. After his death, in April, 1906, Mrs. Dupree and Col. T. F. Boyd, President of the Louisiana State University, with the approval of Professor Morgan, who had assisted Dr. Dupree for a couple of years and to whom the bringing out of the notes properly belonged, did me the honour to place these notes in my hands, to be incorporated in my volume. Wherever possible I have reproduced the observations as he wrote them, otherwise only a resumé is given of the results of long series of experiments, which furnish us with many hitherto unknown facts. All the drawings made for him are not shown here for lack of room, but most were copied by me for the forthcoming Carnegie monograph on the subject, when dissecting and drawing larval mouth parts for that work.

In a letter to me, written after Dr. Dupree's death, Colonel Boyd said, alluding to the Doctor's service to science: "Dr. Dupree did the work of several men—was a tireless worker, and a man of far greater worth and ability than he ever received credit for." I agree with him, and think it fitting that a word should here be said of the Doctor and his work. But though I can briefly sketch his life, and set forth a few of his many labours, no words of mine can adequately convey the strength and sweetness of that character which commanded the respect and love of all who knew the man himself.

Dr. James William Dupree was born June 4, 1842, at Jackson, Louisiana, being a descendant of an old Huguenot family. His classical education was obtained at Centenary College, Jackson, and his M. D. was taken at the New Orleans School of Medicine in 1861. In November of 1862 he received an appointment as assistant surgeon under General Bragg in the provisional army, being assigned to duty in the artillery corps of Tennessee. Having served a short time in that capacity, he was invited to appear before the Army Medical Examining Board at Macon, Mississippi. This examination resulted in his being made a surgeon at the early age of twenty-one. Later he was made Chief Surgeon of the Army of Western Tennessee, serving honourably until the close of the war. He then returned to the parish of Point Coupée, to take charge of his mother's large plantation.

In 1867, however, the Doctor moved to Baton Rouge, where he built up a great practice. He told me that in the early days he often rode as much as sixty miles in a day, using relays of horses, and was sometimes so tired that he would sleep on his horse, which would stop when it came to a house and so wake him. He was for a long time often the only available physician for miles around, and for some thirty years he did the greater part of the surgery in this section of Louisiana. Rich and poor he treated alike, and multitudes can testify that he tended them without hope of remuneration; not only this, but he sometimes aided the patient from his own pocket.

During the yellow-fever epidemic of 1878, in which he himself was stricken with the fever, he was health officer of Baton Rouge, and to his efforts the founding of the National Board of Health is largely due.

In 1879 his interest in the State medical problems, as shown by his labours as Chairman on Health and Quarantine of the General Assembly of the State of Louisiana, caused his election as vice-president of the Louisiana Medical Society, and later as a president of that distinguished body. He was a member of the American Medical Association and was honoured by an election as one of the vice-presidents of the Ninth International Medical Congress, in Washington. For many years he was the Surgeon General of the State of Louisiana, as well as president of the Board of Health of Baton Rouge ever since the war, and of the Medical Examining Board for the Pension Bureau at Baton Rouge. He was also for over twenty years the medical officer of the Louisiana State University and the Agricultural and Medical College. From 1878 he filled the chair of anatomy, physiology, and hygiene at that institution. Not only this, but for four terms he was appointed to the State Legislature.

As a bacteriologist he was an expert, owning one of the best laboratories in the State. He used, with great amusement, to tell me about how, when he first took up the work with bacteria, no other doctor in that region would accept the theories at all, but scoffed openly and dubbed him "Microbe Jimmy." He did much bacteriological research, including comparative experiments with Sternberg's Bacillus and Sanarelli's *Bacillus icteroides*. As a yellow-fever expert, indeed, he bore an international reputation, spending much time on the study of the transmission of the disease. He also originated the theory that fleas transmit leprosy.

The New Orleans *Times-Democrat* pertinently stated that "he was remarkable for the unostentatiousness of his bearing, and lived wholly for the sake of his deep scientific knowledge and researches." Nothing can be truer. He was body and soul in his work, often forgetting to eat and even to sleep, never seeming to rest nor take thought for himself, yet always with the tenderest and most chivalric consideration of others. I never knew any one who disliked him. He may have had faults, but, after six months' residence in his home, I can truthfully say I don't know what they were. He was unqualifiedly the most unselfish man I ever saw, both at home and abroad, and, withal, so modest that he could with difficulty be induced to speak of what he had done; so indifferent to personal fame that he never published one tenth of what he might have. Nor, unfortunately, did he note down all he observed. Many a time have I said as he recounted to me some experiment or result, "Doctor, write it down," and with a smile he would say, "It will go in my book," then tuck it away in that wonderful memory of his—and now it will never go into a book!

Thus it has fallen to me to do, in a poor, fragmentary way, what he would have done so well; and may he, knowing the difficulties that have lain in the way, forgive the imperfection of the work, and, remembering only that I have done my best to make it as nearly as possible what I think he would have wished, approve of the result.

Mosquito Life

Mosquito Life

CHAPTER I

SYSTEMATIC POSITION AND STRUCTURE

WE have all read in the Old Testament how, when King Saul was hunting through the wilderness after David to slay him, the monarch, weary, slumbered through the night in a cave, and how David, creeping boldly into the place, secured the king's spear and a bit of his robe. That story is also in the Talmud, with additions. According to this version, it seems that Abner, like a faithful captain, had stretched himself across the door of the cave to sleep. David, in order to enter, found it necessary to creep over him. As David was coming away, Abner tossed restlessly, throwing his leg across the ankle of the intruder. Here, then, was a pretty predicament. If David stirred, Abner would wake and seize him; if he stayed quiet, the day might break ere Abner moved, and death be no less sure. Therefore, says the narrator, was David greatly perplexed. But the Lord, seeing the trouble of His servant, sent a mosquito, which bit Abner violently on the leg, causing him to move the limb in question. Then David went freely forth, rendering praise to God who, by one of His weakest creatures, had saved the life of His servant.

Perhaps this is the only instance on record where thankfulness existed for the presence of the insect now regarded as an unmitigated pest and never thought of as a saver of life. Indeed, many men, both professional and amateur, in many lands, have set themselves to study in what ways the mosquito pest may best be brought under control and the spread of deadly disease thus checked.

To all who are studying the mosquito question the first thing needful is to be able to distinguish the different species; and to make this distinction is equally necessary whether investigators are merely studying for the love of the subject, or are participants in the mosquito war now so actively in progress in many parts of the country—indeed, all over the world. In the case of being engaged in the extermination of the insects, much of the worker's success depends on his knowledge of the species and of its habits. There is no use in going half a mile to oil a puddly meadow for *Anopheles* when the offender is *Stegomyia calopus* (formerly called *fasciata*) multiplying on the premises; nor in hunting vainly about the vicinity for possible breeding places, when the pests have come from some distant salt meadow. To name the specimen correctly, however, it is absolutely essential that the student shall possess some knowledge of the general anatomy of all the forms assumed during the life of the insect.

Systematic Position.—The mosquitoes belong to the family Culicidæ, under the order of Diptera, which includes all flies and gnats. The family is characterised by the possession of a single pair of membranous wings, the hinder pair being represented by two little, stemmed knobs called the halteres or balancers; by a suctorial mouth and many-jointed antennæ. The word "mosquito" comes from the Spanish "mosco," meaning a fly.

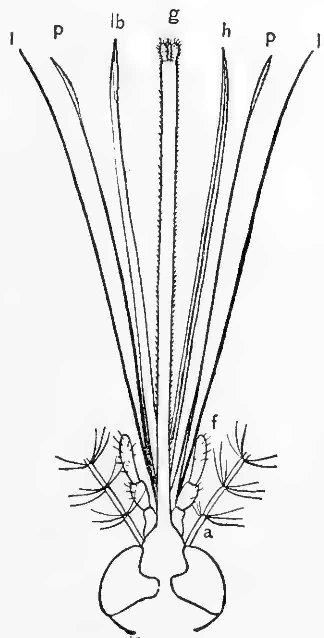


FIG. 1.—Diagram of mouth parts of adult female, from below, greatly enlarged; *l*, lacinia; *p*, palpifer; *lb*, labium; *g*, galea; *h*, hypopharynx; *a*, part of antenna; *f*, palpus. (Adapted from Smith.)

Anatomy of the Adults. — All mosquitoes do not, by any means, look alike. They vary exceedingly, both in colour and in size. Some are plain brown, some black and white, others yellow or iridescent,—gorgeous fellows some of them, spotted and streaked in all sorts of combinations. The legs of certain of them remind one of a visit to Sing-

Sing. As for the sizes, they run from the tiny chaps an eighth of an inch long, up to the giants of the tribe which can proudly boast of half an inch.

The body of the adult consists of head, thorax, and abdomen. The head in great part is made up of the immense oval or reniform compound eyes. The beak in the female and the antennæ in the male are the most conspicuous structures of the head. The construction of the beak is adapted to piercing or sucking (Fig. 1, page 3). It consists of seven parts;[1] the galea, two palpifers, two laciniæ, a hypopharynx, and a labium. The mandibles and labrum are absent in both sexes (Smith). The galea (Fig. 1) forms a sheath for the puncturing and sucking structures which lie within it. When these are separated they are seen to be five, more or less flattened, rods, and an upper, grooved organ.

The laciniæ in the female are strong lancets, fitted for cutting, and bear recurved teeth on the outer side near the enlarged apex. The palpifers are flattened and may or may not bear teeth. The male has no laciniæ (Thompson). It would be interesting to note the construction of the mouth-parts of those species where the males are said to bite. The laciniæ

[1] The names of these organs are as determined by Dr. J. B. Smith after a thorough study and comparison of dissections and cross sections of the mouth-parts of a large number of different kinds of insects belonging to all of the orders. Since he places a different interpretation upon the various organs than what had been done previously, it may be well to give the equivalents of the two systems. Thus, the galea of Smith is the labium of previous authors; the palpifers equal the maxillæ; laciniæ, the mandibles; and labium, the labrum-epipharynx. The hypopharynx is the same in both systems.

PLATE I.

a.

b

c.

Wing Scales (greatly enlarged).

a. Culex territans, lateral scales on veins narrow, median ones broad.
b. Mansonia titillans, broad scales.
c. Tæniorhynchus perturbans, broad scales.

(Courtesy of Dr. E. P. Felt.)

and palpifers have to do with piercing only. Sucking and the injection of saliva are performed by means of the labium and hypopharynx. The labium lies above the hypopharynx and is usually pressed against it. On the mid-ventral line of the labium is a deep gutter, which, together with the salivary gutter on the dorsal side of the hypopharynx, forms a tube through which the blood is sucked. When the insect makes an attack, the entire cluster of lancets is inserted *en masse*, the galea, or sheath, being shoved back in a bow. Immediately a drop of saliva is injected by means of the salivary gutter, which lies on the mid-dorsal line of the hypopharynx. The fluid is secreted by salivary glands situated immediately back of the insertion of the neck in the thorax, a set on each side. From each of these sets comes a duct, the two joining and continuing as one to the base of the hypopharynx. Here the duct opens into the "salivary pump," which forces the saliva along the gutter into the wound. The sets of glands consist of three lobes each. The lateral lobes secrete saliva, the central lobe was supposed by Macloskie to secrete the poison, but Smith considers it a reservoir for the secretion produced by the lateral lobes. As to the question of poison being actually produced by any of the lobes, Miall does not consider it positively demonstrated. The action of the saliva, according to Macloskie, appears to prevent the coagulation of the proteids in the blood and thus facilitates the sucking process. If the insect is allowed to take its fill, it will draw back the injected saliva and, so far as the author's experience goes, there is then, as a rule, no after-effect save a small red spot, but if the insect is killed or driven away, the itching is intense. The sharpness of the bite and the effect of the poison appear to vary with different species of mosquitoes as well as with different victims.

Dr. Dupree speaks in his notes of Schaudinn's demonstration of the existence of bacteria or molds in mosquito ova. Indeed, the latter claims that these fungi, belonging to the Mycetæ, and possibly nearly allied to Entomophracæ, can be found, in all stages of proliferation, in every phase of the insect's existence, eggs included. Immediately after feeding but few of the organisms are present in the diverticulæ, together with traces of blood and bubbles of carbonic acid gas. During the digestive process, however, they increase immensely, while the augmented gas production distends the gut to such an extent as to give the mosquito the appearance of suffering from some digestive affection. Schaudinn questions the dictum which has for so long a time dominated both professional and lay belief, viz.: that the local reaction consequent upon the mosquito's puncture is due to the poisonous saliva injected, affirming that it is the direct result of the initial action of an enzyme elaborated by these commensal bacteria, which are always present in greater or less quantity. In proof of this, he asserts that subcutaneous inoculation with solutions of comminuted mosquito diverticulæ and their bacterial contents (the carbon dioxide having been previously expelled by pressure), is followed by the characteristic effects of a veritable mosquito bite, an occurrence which he says does not take place when saliva alone is introduced, in like manner, into the tissues of a human being. He also denies to saliva the anti-bloodclotting function with which it has already been credited, attributing whatever non-coagulability exists in the fluid at the site of puncture to the action of the carbon dioxide expelled from the diverticulæ, during the act of biting. He says, in substance, that the molds, together with the gas bubbles and saliva infused, may be withdrawn almost completely by the capillary attraction of the epipharynx, aided by the state of negative pressure which exists in the cavity of the proboscis at the end of the abdominal contraction (which forces out the saliva), thence the aforesaid mixture of molds, etc., may be sent by the conjoint action of esophageal peristalsis (contractions of the esophagus) and the abdominal action, into the mid-gut (stomach) where they thrive and multiply. This statement furnishes a scientific basis for the widespread belief that no ill effects ensue from a bite, provided the mosquito is allowed to finish its meal.

On each side of the base of the beak are placed the palpi. These are jointed structures, generally long in the males, extending to or beyond the tip of the beak and thickened at their outer ends. They are, as a rule, short in the females.

The antennæ are elongated, jointed appendages, situated just above the beak, which is usually longer than these organs. The first joint is socket like, the other joints are, in the female, cylindrical and whorled with a few long hairs; in the male they are mostly cup-shaped, with many long hairs around the rim of the cup, and the last segment long and slender. Some of these hairs are for auditory purposes, as Mayer proved by experiment. He also ascertained that the intensity of their vibration is greatest when the sound is directly ahead, and that in this way the song of the female serves as a guide to the male. It is well known that sustained notes of a certain pitch will attract mosquitoes even from some distance.

In this connection the experience of Sir Hiram Maxim is well worth relating. While engaged in constructing an electric-light apparatus, he noticed that one of the lamps gave out a constant musical note. One evening he discovered that everything near the box below this light was covered with mosquitoes, all males, notwithstanding the fact that the females preponderated in numbers in the vicinity. He found that when the lamps were set in action all male mosquitoes at once faced in the direction of the lamp which gave forth the musical note, and flew straight at it. The buzz of the lamp was practically identical in tone with that of the female mosquito. Sir Maxim says: "If you obtain a tuning-fork which emits a note as near to that of a female mosquito as possible, and strike this fork within twenty feet of a male mosquito, he will at once turn about, face the music, and erect the two little feathers of his head, something after the manner of a cockatoo."

Mr. F. K. Pearse remarks that persons are more likely to be bitten when engaged in conversation

PLATE II.

a

b.

c.

Wing Scales and Claspers (greatly enlarged).

a. Portion of wing of *Culex pipiens*, showing marginal fringe.
b. Claspers of male *Ochlerotatus canadensis*.
c. Narrow wing scales of *Ochlerotatus cinereoborealis*.

(Courtesy of Dr. E. P. Felt.)

than when silent. I have noticed that the women on a porch generally begin to complain about the mosquitoes first—of course the men *may* have been smoking. Mr. Pearse further states that a stringed instrument is a great attraction for the insects.

Proceeding now to the thorax, we find it to be covered with fine scales, variously coloured, often arranged in brilliant lines or distinct spots. Frequently there are long, stout bristles mixed with the scales. There are usually lengthy bunches of hair on the scutellum (the hind part of the thorax). To the thorax are attached the wings and legs.

The two long, narrow wings are clear, as a rule, transparent, and exquisitely iridescent, owing to the presence of many minute spines. The veins of the wings bear scales, whose free ends are directed toward the wing-tips. The scales may be linear or broad (Plates I., II.), and both kinds may occur on the same wing. They may be of one or more colours and at times form dark or light spots on the wings, thus becoming of use in classification. Along the lower edge of the wings is a fringe of linear scales (Plate II., Fig. *a*, p. 8).

The legs consist of a number of joints covered with scales, generally appressed, but sometimes more or less erect. First comes the coxa, a short joint which attaches the next, the femur, to the body. The femur widens towards its apex, to which is fastened another long joint, the tibia, which sometimes is banded or spotted. Then follows the tarsus, composed of five joints, each of which is shorter than the preceding one. The tarsi of the hind legs are longer than those of the two other pairs. On the front and middle legs they are about equal. The tarsal joints are often banded with white, generally at the base, frequently at the tips. Sometimes the bands are both basal and apical, and occasionally one or more of the tarsal joints are ringed in the middle, or are wholly white. The last joint bears a pair of claws which Arribalzaga ('91) and Coquillett ('95) found to be of great importance in classification, accordingly as they are toothed or not toothed in one or both sexes of a species. The claws may also differ in this respect on the different pairs of feet in the same species.

The abdomen consists of eight distinct joints. The last joint in the male bears the harpes and claspers (Plate II., Fig. *b*, p. 8), in the female it bears the ovipositor. The male genitalia sometimes possess distinct specific characters. The fifth and sixth joints of the abdomen are usually the longest, the seventh being decidedly narrower than the sixth, and the eighth is often obscure. The first is frequently very short. The joints may possess basal or apical colour-bands, one or both, formed by scales; may have lateral spots, or a stripe down the middle. They are generally lighter beneath. The chitin is covered with appressed scales, which are often mixed with slender hairs.

Eggs.—The eggs of mosquitoes possess specific differences, just as do the larvæ and pupæ, except, apparently, in the case of the raft eggs. We have examined the just hardened eggs of nearly half the species of this country, and although the characters are difficult to describe, yet most of the eggs are easily distinguishable when you have the right light on them. (For illustrations see Plates V. to VIII.) I know of nothing harder to observe properly under the microscope. The egg must not be too wet or the sculpture is invisible, nor too dry or, in many cases, the shell will shrivel; if the light is not exactly right, you see nothing but a black speck; if it is good, only a little patch of the pattern is visible at a time. Alcoholic specimens are absolutely useless, the membrane sticking so close to the egg as to obscure all markings. Formalin specimens are not very bad.

The eggs are of a more or less oval shape, with a hard, almost black, chitinous shell. Over this lies a delicate,—*filmily* delicate,—white, transparent membrane, which, in the eggs laid singly, is sculptured in more or less hexagonal figures. Most of the mosquitoes, contrary to the popular impression, lay their eggs singly, instead of in a raft which floats upon the surface. The single eggs, except those of *Anopheles*, which have the membrane puffed out at the sides to form a float, sink and hatch at the bottom. Often there are small puffs inside the hexagons, or there are spine-like processes of the membrane. The raft eggs have the membrane so tightly spread over the surface of the chitin that it is almost impossible to ascertain whether or not there is a sculpture, but the writer has seen very minute knobs and also hexagons on some. The smaller ends of these eggs generally possess a button of chitin, covered by a small puff of the membrane, and a rosette of the latter is on the larger end. One may often, under the most favourable of conditions, work for hours before the pattern can be determined. The membrane is commonly supposed to be filled with air, but I rather suspect that it contains gelatin, that it is a relic of the highly developed gelatinous envelope found among the eggs of many of the other gnats, notably the Chironomidæ. In fact, if it were air, it is scarcely probable that the single eggs would sink as easily as they do. The *Anopheles* eggs, which are single and float, have considerably more of the membrane proportionately, and those Chironomid egg masses which are surrounded with large masses of gelatin do not easily sink.

This seems also to be the view of Dr. Goeldi, who, in his splendid work, *Os Mosquitos no Para*, speaks of the minute globule at the pointed end of the egg of *C. fatigans* (a raft layer) as containing a gelatinous or mucilaginous substance, and of the base being also covered by a layer of this. He thinks that the gelatine both serves as a float and, possibly, as the first meal of the newly hatched larvæ.

Larvæ.—The larva, or "wiggler," consists of head, thorax, and nine abdominal segments, with their appendages (Plate III, opp. page 16). The head is flattened, usually wider than the joints of the abdomen, and covered with heavy chitin, varying from black to light yellow in colour, sometimes more or less spotted. At the sides are the eyes, which seem to be transitional between the simple and the compound eyes. They are black, and generally of a crescentic form. They alter somewhat during the different moults. In front of the eyes are the antennæ. These differ widely in the various forms, and are of specific importance at least. They may be stubby, straight, and smooth, with but a few hairs, or only a single hair to represent the tufts; they may be covered with spinules; bear a long bunch of many hairs, set in a notch, or not so set; they may carry on their tips long or short spines; may be curved in a crescentic or even sigmoid form; may taper gradually from base to tip or narrow abruptly above the notch.

Beyond the front of the head, when viewed from above, may be seen projecting the mouth brushes.

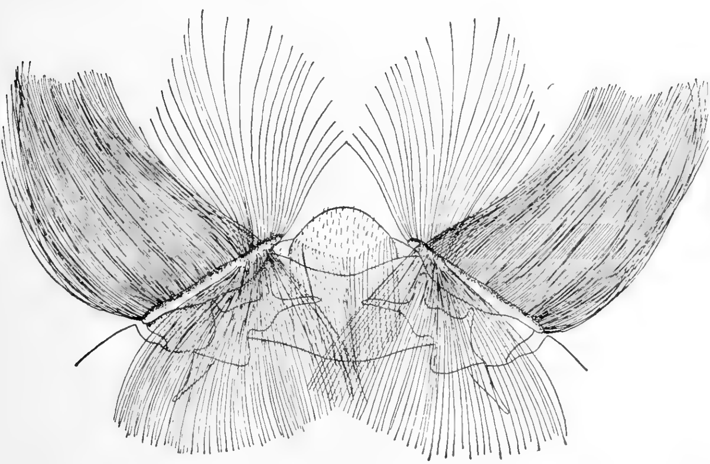


FIG. 2.—Mouth brushes of the larva of *Culex territans*, very greatly enlarged.

On the under side, just outside of the brushes, are the mandibles, and above these the maxillæ with the subtriangular labium between them (see Fig. 3, p. 15).

This labium is of heavy chitin and is toothed, the number of teeth being constant (within a variation of at most two teeth) for many species, but widely variable in a few. A fuller discussion of the mouth-parts will be given in the section relating to larval habits.

On the back of the head, at the roots of the antennæ, are, except in the genera *Anopheles*, *Psorophora* and *Megarhinus*, bunches of hairs, usually eight or ten hairs in each group. Nearer the centre of the head are four tufts, generally with from one to about eight hairs, and, in the great majority of species, the number of hairs in these tufts is constant in at least the last stage of the larvæ, and forms a good specific character. In one genus (*Uranotænia*), these tufts are represented by four spines. The tuft at the base of the antennæ, the antennal tuft, when having more than three or four hairs, and often the other two sets of tufts, are finely plumose, evidently sensory. There is a short bunch near the eye, and often one or two more, of from one to three hairs, on the head.

The thorax is not so heavily chitinised as the head. In reality it consists of three segments, but these are not easily recognised from the contour. They are marked, however, by three rows of long hairs, which extend, one across the anterior margin of the thorax, one a little in front of the middle, and one some distance from the posterior margin. Some of these hairs are single, some form tufts. All arise from more or less conspicuous tubercles, more strongly chitinised than the rest of the thorax. The large tufts are decidedly plumose (very short plumules); the smaller tufts or those with few hairs are simple or have minute plumules, while the long bristles on the same tubercles with the large tufts are frequently smooth. The hairs in the row nearest the head (described in the table of larvæ on a later page as "thoracic row 1") often serve as specific characters. Occasionally the thorax or the whole body may be covered with a growth of minute hairs.

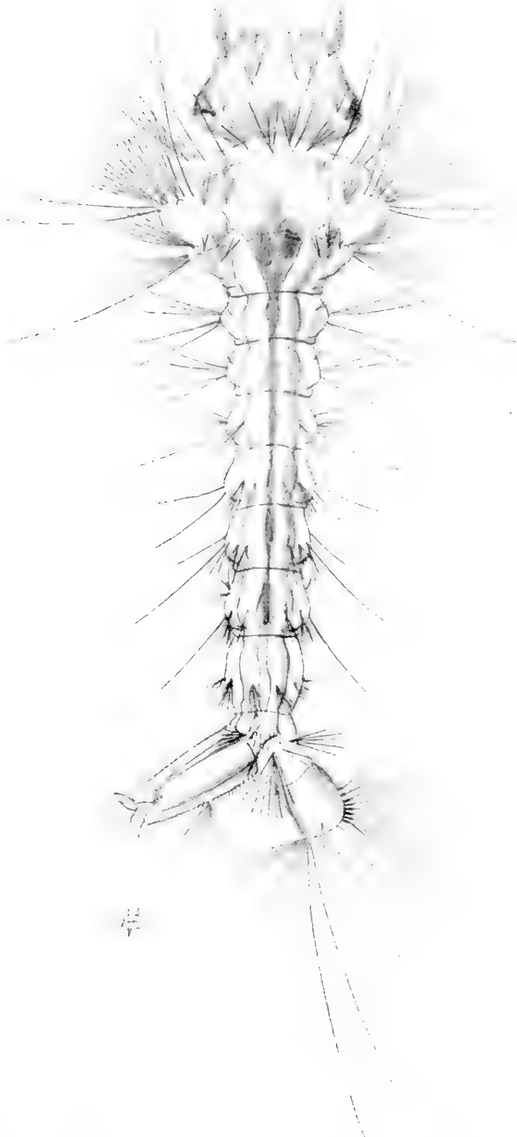
The abdominal segments are, as a rule, fairly soft,

FIG. 3.—*mn*, mandible; *l*, labium; *mx*, maxilla of larva of *Culex restuans*, dorsal view, greatly enlarged.

never very stiff. The first seven are usually much alike, except for the fact that the lateral tufts grow shorter in length as the joints approach the seventh. In many species these segments are much the same, but in others the general aspect of the abdomen is very distinctive by virtue of the great length or number of the hairs, the presence of stellate tufts of hairs, of palmate tufts, or of stiff bristles. On each side of the eighth segment is a patch of scales, varying from one row of four to eight scales to four or five rows of as many as sixty-five scales. The number of scales in the single-rowed species can be used as specific characters, as they do not vary over two at the most, but in the many-rowed species they will sometimes vary as many as twenty, and cannot therefore be depended upon in a table of species, as the two species falling in the same couplet will not infrequently have, the one 20 to 35 scales, the other 30 to 50 scales, or the like.

On the eighth segment is the breathing tube, often referred to as the "anal tube" or "siphon"—why the latter it is hard to imagine, as it is a siphon in no sense of the word. It is very variable in length and form in the different species, but, as a rule, the relation of width to length is not a good character upon which to depend in a key for the identification of the species, especially when skins are to be named or used as a basis for differentiation, as the cover glass on the slide on which the skins are mounted flattens the tube, making the relation quite different in the exuviæ from what it is in a whole larva. When it comes down to employing such a slight

PLATE III.



Larva of *Ochlerotatus bimaculatus* (greatly enlarged).
(Originally published in *Boys and Girls*.)

difference as "tube twice as long as wide" as against "tube three times as long as wide," the distinction is far too small to be certainly accurate; besides, there are always better characters, so that this never need be used as a primary one, unless measurements varying as much as "one by two" as against "one by six," or something like this can be taken. Of course there are some species whose breathing tubes are so distinctive in shape that they can be recognised at a glance, but the number and position of the tufts and hairs on the tube and the situation of the teeth in the pecten—a double row of spines on the lower part of the tube,—sometimes also the shape and number of the pecten teeth, are a far more reliable index. In the tube can be seen two large tracheæ, opening a short distance below the tip, which is closed by a sort of chitinous valve. The tube is of heavy chitin, like the head, and not very movable, although it may be brought up at right angles, or slanted well toward the tail. It is generally held almost perpendicularly to the eighth segment, with a slight backward inclination.

The ninth segment is the smallest. It is very movable, is generally saddled and frequently ringed with chitin, and bears a set of four tracheal anal gills. These are in many species distinctive in appearance, although their length is usually somewhat variable within specific limits. They may be short and bud-like, or longer than the ninth segment, and even over twice as long as the breathing tube. There are generally at least rudiments of tracheæ to be found in the gills; sometimes the tracheæ are large and branched, or with many tracheoles. The gills may be blunt or pointed; sometimes they are spotted. As this maculation is a structural character, which can be brought out by alcohol or formalin in dead specimens not showing spots when alive, the patches being apparently formed of large granular cells, it is not a trustworthy character for classification unless the specimens are identified alive. Sometimes the gills have two or more constrictions. The lower pair of gills often differs greatly from the upper in size, especially so in the case of the pitcher-plant larva. On the ninth segment, below the gills, is usually a series of long tufts on stems arising from a barred area. This series is sometimes wanting, in which case there are more hairs around the termination of the segment. Above the gills are a pair of long tufts and a pair of long, usually single, hairs or bristles.

Pupæ.—The pupa is the form intermediate between the larva and the adult. Unlike most pupæ, those of the mosquito are very active, but, like other pupæ, they do not eat. They are about the shape of fat commas (Fig. 4, page 19), floating quietly at the surface or bobbing crazily downward at the least alarm, to hide at the bottom, propelled by backward flips of the abdomen. On close inspection the head and thorax will be seen to be all together. Through the chitin the head of the adult may be distinguished, with its mouth-parts and eyes, the legs neatly doubled up under the head, the wings folded in their cases — even the veinings distinguishable beneath the delicate coverings. The creature no longer breathes through a single tube on the eighth segment, but by means of a pair of tubes on the back of the thorax. These air pipes are somewhat variable in length and shape and can, in some cases, especially in conjunction with other parts, be depended upon as specific characters. The cephalo-thorax and abdomen are heavily chitinised, the mobility of the latter being due to the soft accommodation membranes between the segments. On the first abdominal segment is a pair of large, thickly branched, circular tufts on short stems. The function of these is apparently to

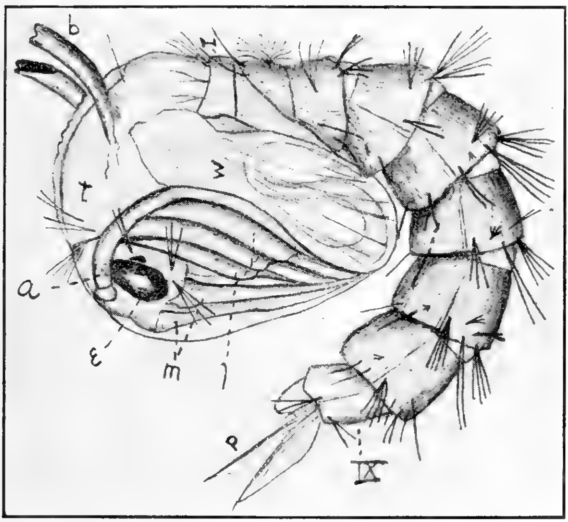


FIG. 4.—Pupa of *Culex pipiens* (greatly enlarged); *e*, eye; *a*, antennna case; *m*, mouth parts; *l*, leg cases; *w*, wing case; *t*, thorax; *b*, breathing tubes; *p*, paddles; I to IX, abdominal segments.

catch in the surface film[1] and, in conjunction with the breathing tubes, which project through the film, to preserve the balance of the top-heavy pupa. On the various abdominal segments are numerous hairs and tufts, the length, number, and position of which can be utilised as specific characters in conjunction with the tufts on the cephalo-thorax. It is true that they can be seen only with the aid of a compound microscope, nevertheless they are present and constant, and it is sometimes better to identify by difficult and minute characteristics than not to distinguish at all. The abdomen ends in two dorso-ventrally flattened paddles, which serve as propellers.

[1] By surface film is meant, not scum, but the film formed by the tension of the water at the point of contact with the air.

CHAPTER II

SOME HABITS OF THE ADULTS

THE study of the ways of the different species in their various stages offers an intensely interesting and almost inexhaustible field of research. Especially to those workers concerned with the extermination of the pests is the knowledge of the habits of the common forms of the utmost importance.

Mosquitoes do not appear to be fond of strong sunlight. Even the yellow-fever mosquito—the "day mosquito," as it has been termed—does not care to fly or bite in the sun at mid-day. During the bright part of the day mosquitoes generally hide in dark, preferably cool, damp places, under leaves, bark, in grass, in cellars, wells, cisterns, lofts and barns, and in the darkest corners of rooms. However, although the malaria carriers, *Anopheles*, are commonly believed to bite only at night, yet I have observed *A. punctipennis* biting on a sunny day, about three P. M., in a dry wood on a hill-top above a brook, the ground covered with dry leaves and the trees (except the maples) not yet blossoming; this was on March 8th, at Washington, D. C. Mosquitoes in the house are apt to take refuge behind pictures or cunningly to settle on dark wood rather than on light, where they would be more conspicuous.

They conceal themselves in closets, back of the head of the bed or the bureau, and under the furniture. The author has frequently chased them from behind and beneath the bed when they could be found nowhere else in the room. Speaking of their preferring to sit on dark wood, Dr. Smith records that *sollicitans* appears to be attracted to black clothing rather than to gray or light brown. We have noted this also with other species. Pearse says that mosquitoes much prefer dark blue and violet to yellow and red. The underside of the foliage of vines or broad-leaved plants affords a cool refuge. Mr. Pergande finds that they hide and breed in the sewer traps. Lieutenant-Colonel Giles speaks of *Anopheles* as having a particular fondness for suspending themselves on the lower side of tables and as preferring this face of any horizontal object. All mosquitoes like dark, poorly aired rooms, viaducts, stone archways, box privies, stables, and damp, bad-smelling places in general.

Some mosquitoes will be found only near dwellings, others in bush or meadow, others in salt marsh or swamp, still others dwell in the woods. *Anopheles* seems to be the most cosmopolitan in selection of habitat.

"Gnats" and mosquitoes are often confused, but the distinction is easily made, as the gnats have not a conspicuous proboscis like the mosquitoes. Moreover, the latter have a habit of sitting with the hind legs held in the air. This custom is evidently for protection—any object approaching from behind will be felt, probably before it actually touches the legs, and the insect will thus have a chance to escape.

The Chironomids, on the contrary, raise the forelegs, and some, at least, of the fungus gnats elevate the middle ones.

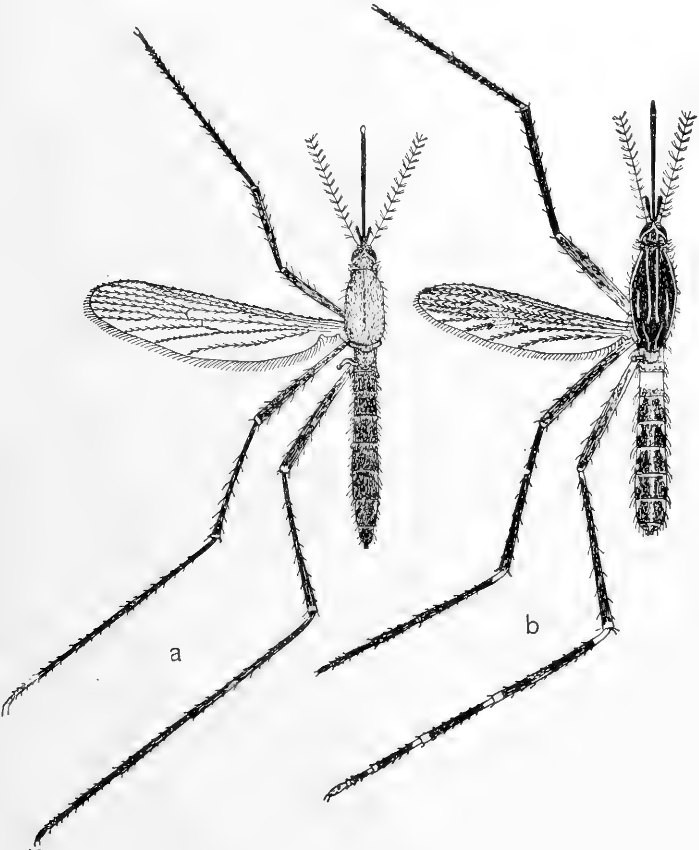


FIG. 5.—*a*, *Melanoconion atratus*, female; *b*, *Pneumaculex signifer*, female (greatly enlarged).

Though the insects appear so frail they can evidently survive a good deal of trouble. I have seen one of Dr. Dupree's *Culex pipiens*, which had but three legs left, bite as hard as if she had a dozen; she afterward laid a batch of eggs, although for lack of her hind legs she could not stick the raft together.

Egg Laying.—It is a popular supposition that all mosquitoes lay their eggs in the form of a raft. As a matter of fact, Dr. Dupree found that only seven species out of thirty-two formed boats, the rest all depositing their eggs singly. He has secured specimens of the eggs of all the species occurring in the State of Louisiana except one or two; inducing the insects to lay by dint of the most marvellous patience and skill. Only a few eggs have ever been taken by others in this or any other country, and he was the first to have had figured the eggs of such a large number of different species. Of the rest of the forms known in this country, it is altogether probable, from general larval and adult characters, that they lay single eggs. Mr. Coquillett has restricted the genus *Culex* to some of the raft layers, as these possess not only generically distinctive larvæ but also adult characters peculiar to themselves. Naturally, the difference in the eggs would indicate an ovarian structure in this genus somewhat different from that of the single-egged genera.

Dr. Dupree roughly divides the mosquitoes into two groups: (1) those whose eggs are provided with a special apparatus for flotation which so perfectly accomplishes its purpose that these eggs cannot be completely and permanently submerged by any manipulation which will not destroy it; and (2) those whose eggs are not thus equipped but which will remain upon the surface of tranquil water by virtue of the air entangled in the reticulated membrane enveloping the individual eggs or which adheres to the spines that in many cases project from it. I think the tension of the surface film, as well as the gelatin between the membrane and the chitin, also helps flotation. The eggs of the first group are deposited in boat-shaped masses, and Dr. Dupree finds these to be intolerant of any lengthy desiccation, refusing to hatch after seven hours of drying, often after as few as four. He has had the eggs of *Anopheles* develop after as many as ten hours out of water, this, however, being exceptional. *Anopheles* eggs often remain for several weeks on the surface without hatching; in one instance they were observed to lie thus dormant for forty-one days. As a rule, however, the floating eggs must soon produce larvæ or perish; hence it was the Doctor's belief that the species possessing such ova must perpetuate themselves by hibernation as adults, or, in some cases, as larvæ. The eggs of group 2 are laid singly, and withstand indefinite drying or submergence.

He further says it is not true that, as has been asserted, neither the entire egg mass nor a single egg of a broken mass can be sunken, no matter how much they may be shaken about in the water on which they were deposited, for, when separated, a slight agitation causes the individual ova to sink to the bottom, where the wigglers emerge. Why is it that these single eggs of a disintegrated boat will produce larvæ and yet, if the whole unbroken mass be secured under water, no larvæ will emerge?

Many people imagine that mosquitoes are in the habit of breeding in wet grass, from the frequency with which adults are found there, but this notion is erroneous. The ova, so far as Dr. Dupree and the writer have observed, are always deposited in water, although accurate observers have seen eggs of the salt-marsh species commonly laid in wet mud, and there is no doubt that, among the species whose eggs resist drying, this habit is variable. Since rafts will not survive over four hours' desiccation, according to Dr. Dupree's experiments, the writer does not believe these are ever placed elsewhere than on water. Mr. F. Knab[1] says that he has found the boats of *territans* above the water level in a barrel, and also under a tussock. The observation is no doubt accurate, but the position of the rafts may be accounted for by removal of water and film tension.

The time for oviposition is, as a rule, late at night or early in the morning. We have seen *S. calopus* and *C. restuans* laying late in the afternoon of a dark day. The insect may sit upon the water or at its edge. Single eggs, except those of *Anopheles*, soon sink, as a rule. Dr. Dupree found agitation to be a great factor in the hatching of this form of ova. The eggs, lying at rest on the bottom, develop the embryos rapidly, usually (in warm weather) in from twenty-four to forty-eight hours. If left undisturbed, they may remain unhatched for over a year, as with *S. calopus* and *J. posticata*. But he found that after

[1] *Journ. N. Y. Ent. Soc.*, vol. xii., no. 4, Dec., 1904.

twenty-four to forty-eight hours, according to the species, if the ova be stirred up in some way, as by a rain or an animal stepping into the pool, stones dropped in, etc., hatching occurs, often in less than half an hour. The larvæ of the same batch will not come out at once, some will keep on emerging, a few at a time, for several hours or days; others will remain quiescent until a second or third stirring up. As the single eggs will resist drying almost indefinitely, Dr. Dupree logically concluded that this accounts for the appearance of larvæ in a pool freshly formed by a rain where there had not been any water for weeks before. The eggs, laid in a former pool on the spot, have been left on the ground as the evaporation took place. The rain makes a new puddle, the eggs are washed about and shaken up, and, often in two or three hours, before there has been any time for oviposition, laying, and hatching, the pool swarms with tiny larvæ. The majority, if not all, of the single-egg-layers winter over as eggs, at least in the North; the early spring rains, as soon as warm enough, bring out the wigglers. The fall batches are those which hibernate. In the laboratory it was possible to keep, as it were, larvæ "on tap"; agitation of the jar in which the eggs lay being sufficient to produce larvæ in a short time, sometimes while still shaking. A weak solution of formalin will hasten hatching, but, naturally, is not healthy for the wigglers. The methods of egg-laying will be discussed under the separate species.

Dr. Dupree finds that eggs will, if left to themselves, hatch in any time from sixteen hours to at least fourteen months. Temperature, evaporation, agitation, all these affect period of incubation. In the case of raft and *Anopheles* eggs, emergence was usually in twenty-four hours, sixteen under favourable conditions. This rapid development lessens the danger which these forms incur from drying. As to the temperature at which development will take place, it varies much with the species. In the case of *O. canadensis*, according to Dr. Smith, the larvæ will issue early in February, when the water is just above the freezing point.

Freshly laid eggs are white unless, as shown by Dr. Smith, the deposition has occasionally been retarded and the eggs gone on developing and darkened in the ovaries. They will darken, and the shell harden, in an hour or so, after being extruded. So far as the writer has been able to note, ova that dry before they darken will collapse and will not hatch when replaced in water, even if they are the single forms.

The Blood-Sucking Habit.—Another popular superstition is that a mosquito takes but one meal and then dies, and the author has heard people declare that they knew the insects will sometimes drink until they burst. But after long experience in feeding mosquitoes, we must give them credit for never being quite so greedy or foolish as that. As for their making only a single repast, it is far from the truth. Most of the species experimented with by Dr. Dupree would bite *at least* two or three times, and would lay on an average two or three batches of eggs. This will be discussed in detail farther on under the various species. The performances of some of the insects led the Doctor to remark in his notes: "I suspect that Colonel Giles, should he hear of our statement, will repeat with emphasis his remarks concerning Celli's assertions: 'I fancy this conveys rather too high an idea of the gastronomic and reproductive capacity of individual insects.'"

Dr. Dupree found that a mosquito will lay in from twenty-four hours to fourteen days after the first meal of blood, usually in from three to ten days. The one which oviposited fourteen days after feeding was *C. salinarius*, which ate nothing, unless water, during the fourteen days. Of course many mosquitoes never taste human blood, but they bite other animals, including snakes, frogs, turtles, and lizards,[1] and also other insects in the larval and pupal forms of the latter.[2] *C. ciliaris* is recorded as sucking the juices of small diptera.[3] Mosquitoes are a great nuisance to birds, and fanciers say that they often cause the death of caged pigeons, canaries, and others, so that it is well to cover the cages of pets with a net.

It has been supposed that mosquitoes will not attack a dead body. However, the author has seen the pests alight about the open thorax of a freshly killed cat under dissection and drink themselves full. They were *C. pipiens*. There were males as well as females among the feasters, and they all gorged themselves if undisturbed. A most interesting case, in which the insects were actually observed biting a

[1] Mr. J. T. Brakeley. [2] Dr. L. O. Howard. [3] Mr. Theobald.

corpse, is reported by Dr. Cuthbert Christy as follows:

"On one occasion in Nigeria I proceeded to a hut in order to make a post-mortem examination upon the body of a white, non-commissioned officer who had died from black-water fever three and one-half hours previously. On lifting the corner of a mackintosh sheet which had been laid over the body, I was surprised to see a cloud of mosquitoes issue from beneath it. The sheet was replaced, leaving the shoulder and neck slightly uncovered as before, and in a few minutes a number of large brown *Anopheles* were probing the corpse in their characteristic attitudes."

This being the case, any one can easily see that there is no telling how much harm might be done by permitting mosquitoes free access to corpses, especially those dying of fevers the method of transmission of which is unknown.

Do Males Bite?—The only reason that a male mosquito does not bite is not that he does not want to, but that he cannot. The majority will drink fresh blood if it is offered to them, but in most species the mouth-parts are not sufficiently developed to pierce the skin. There are, however, a few recorded instances where they have really probed to blood, although most people believe that they do not do so, and the question has been much discussed. Dr. Stiles, of the U. S. Marine Hospital Service, told me that he was, while out in a row-boat at Leipsic, actually bitten by a male of *C. nemoralis*. The males of *C. salinus*[1] as well as those of certain species (not given) of *Stego-*

[1] Ficalbi.

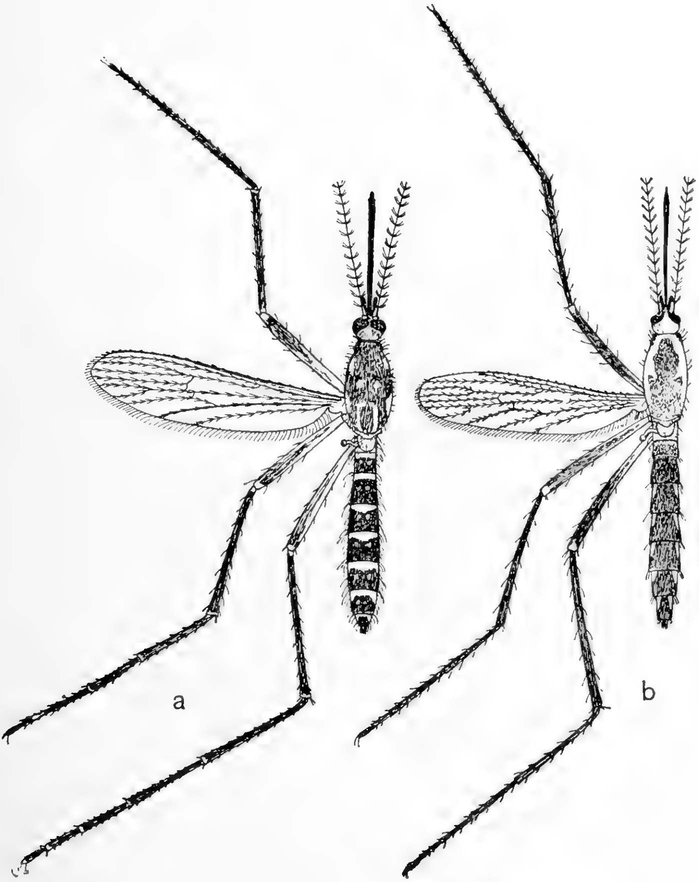


FIG. 6.—*a*, *Culex restuans*, female; *b*, *Ochlerotatus triseriatus*, female, (greatly enlarged).

myia[1] are said to have the blood habit. The author's experience in the case of *S. calopus* agrees exactly with that of Lieutenant-Colonel Giles, who says that the males of some Indian species, especially those of *S. calopus*, undoubtedly often settle on one and place themselves in the attitude of attack, but he has never seen one go as far as to obtain blood. One of the commonest of the Indian species has the reputation of possessing biting males. Giles believes, however, that there is no doubt that the males of some species do bite, although he regards it only as an occasional indulgence. On waking early in the morning in Baton Rouge, shoving aside the mosquito bar and lying still I would, in warm weather particularly, note the males come flying with the females to settle on my hands, where they would go prodding about, evidently very thirsty and wishing I were not so pachydermatous. Although the males will drink perspiration, they were not in this case doing so, I made sure of that. An Egyptian species is said to have blood-sucking males, as are also two Italian and two Madagascan species.[2]

Diet of Males and Females Compared.—Dr. Dupree kept both males and females in captivity on dried dates and water. They are also fond of bananas and other fruits. We have frequently found them sipping at half-rotten and fermenting pears, strong drink being apparently an attraction to the wee roysterers. The females have popularly been supposed to abstain from intoxicating bever-

[1] Stephens and Christophers.

[2] Mr. Austen, quoted by Giles.

ages, but Dr. Schwarz accuses them of drinking lager beer. Mosquitoes also like fresh manure, not being any more fastidious than are the house flies. I have often noticed both sexes in the day-lilies; they may have gone in for nectar, or simply to hide. Dr. Smith records what was probably *O. sollicitans*, both males and females, digging into wild-cherry blossoms.

Dr. Goeldi speaks of the males, indoors, helping themselves to coffee, tea, wine, and broth from the teacups, saucers, and plates on the tables, but, as a rule, abstaining from blood-sucking. The females also have these habits to a certain degree.

He then made some experiments to illustrate the differing tastes of the sexes. Out of thirty-seven mosquitoes captured in a sugar bowl there were one female and one male of *S. calopus*, two females and thirty-three males of *C. fatigans*. On the contrary, in the bedroom, along in the night, he noticed a great number of mosquitoes dancing up and down outside of the mosquito bar, close to his face, trying to find a way in. Suddenly slapping, he crushed a number against the wall. They proved to be twenty-three *Culex* females.

Dr. Goeldi puts forth an interesting hypothesis as to how the blood-sucking habit is formed and why it is restricted almost entirely to the females. He calls attention to the fact that any cuts or wounds, especially in the tropics, are often seen to be attacked by small flies and like insects, which sip the serum, —a slightly sweet substance. Also, the corners of animals' eyes in warm seasons are attacked by "similar impertinent diptera," which are attracted by the eye water. All these small flies, as well as other larger ones, are on the way to blood-sucking. The Culicids, at first suckers of plant juices, learned the taste of animal blood by means of the bloody serum from wounds, and the males content themselves with this, but the females formed the habit of puncturing the skin in order to obtain the desired liquid. Having a better biting equipment than the males and utilising the blood as nutriment for the forming of eggs, the taste easily became an indispensable necessity—another example of the fitting of the body of the female first of all to the necessities of reproduction. Thus the blood-sucking habit, accidentally acquired, becomes an essential factor in the maturing of the sexual products of the female; to-day these insects demand blood as a necessity for the propagation of their species.

Referring particularly to *C. fatigans* as a basis for observation, he states that fertilization seems to stimulate the desire for blood, and, as far as known, it is principally the fecund female which bites. She selects a place near a blood-vessel. "Untroubled, lifting the hind legs, rubbing and moving them back and forth, in visible satisfaction, she fills herself full, literally to the point of intoxication," when she "finally flutters drunkenly to the wall," so full that she is "transformed into a deformed tube" so transparent that the red fluid may be seen through the body wall. There she sits digesting quietly. In about twenty-four hours there is a visible diminution of the abdominal contents, marked by repeated defecation, and, by the next night, she is ready to bite again.

Drs. Dupree and Goeldi both note that with a number of species the female will bite before mating.

The latter further observes that while blood accelerates oviposition, honey and other sweet vegetable diet has an opposite or, at least, a neutral influence upon reproduction. He and Dr. Dupree have both observed that, with some mosquitoes in captivity, deposition of ova may be accelerated or suppressed, and life thus prolonged, by giving or denying blood as food. But while Goeldi's conclusion from this observation, that blood is an indispensable factor for the production of fertile eggs, may be true for many species, it does not hold true with all, for at Baton Rouge *M. atratus* and *C. territans* could never be induced to bite, and I can find no record that any one else has ever observed them to do so. Both males and females of these two species when captured were often full of a clear, greenish fluid, and some of these females laid productive eggs. But Dr. Dupree never had any other species deposit either fertile or unfertile ova without biting at least once.

Parthenogenesis.—There are few observations on this point. Unfertilised females of *S. calopus* have at times been known to oviposit, [1 and 2] this being also the case with *C. pipiens*.[1] The eggs, however, were never fertile.

Poisoning from Bites.—Some people appear to be less attacked by mosquitoes than are others.

[1] Dupree. [2] Goeldi.

Curiously enough, different species sometimes appear to have preferences. *O. triseriatus* would not bite Dr. Dupree without the greatest coaxing, but set to work on me at once; another, I forget which, he used to laugh about as having a great distaste for me and being ready to eat him up. Possibly the acidity of the perspiration makes a difference. The effect of the bite of some species is much more painful than that of others, this also, however, varying more or less with the individual person. The results of the poisoning are, at times, extremely painful. This may be judged by the following, related by Dr. Christy, that in Parana he was bitten by clouds of small, brown mosquitoes from a tall umbelliferous plant. They

"made a gory mess of hands and face. Their bite seemed to cause very little pain or inconvenience at the time; twelve hours afterward, however, I was in bed with a temperature of 102°, vowing vengeance on all mosquitoes, with my eyes closed by œdematous eyelids and with my lips, fingers, and ears double their normal size. A splitting headache and attacks of vomiting completed my discomfort. But no malaria followed. Before leaving the country I saw other cases of similar acute poisoning from mosquito bites, but without the accompaniment of malarial fever."

The author does not feel the bite of *Anopheles* either at the time of puncture or afterward. *O. sollicitans*, although its bite pricks like a pin, leaves no irritation even when disturbed. *J. posticata* bites hard and causes a furious itching, while *C. restuans* and *C. pipiens* are hardly noticeable when piercing,

FIG. 7.—*Megarhinus septentrionalis*, male. (Proboscis normally curved down, here shown straightened, greatly enlarged.)

and never leave much irritation if driven away. *S. calopus* is not noticed at the time of attack, but the spot becomes extremely painful afterward and shows a white lump.

Hibernation.—The places in which the adult mosquitoes pass the winter are various. It seems that only the females hibernate, as a rule, and that these are impregnated in the fall. Usually not until after the first biting in the spring are the eggs deposited. The insects seek safe hiding-places in cellars, hollow trees, under loose bark on dead trees, under weather-boarding—any situation where they are protected, are in the dark and will not desiccate. Dryness is extremely fatal to them. If the breeding cages or jars are dry, or if one attempts to transport them for any distance in a dry tube plugged with dry cotton, they will die. But if there is water in the cage, or if the cotton plug is damp, they will live for days, even in a tube, providing that it is not in the sun or in a warm place. They are truly not the children of light. Dr. Berkeley mentions their fondness for hanging on cobwebs in dark corners of clothes closets, and their resorting to greenhouses, during the winter.

The author has found them, especially *Anopheles*, multiplying in winter in the tanks and water barrels in the Botanical Gardens of Washington, D. C. As an odd instance of tenacity the following is an example:

Having read the descriptions of *W. smithii*, it did not seem logical for that species to have but two anal gills, when all other mosquito larvæ had four or the rudiments of them. Having examined alcoholic specimens to see if at least traces of the other gills were not present, I failed to find any. The specimens being in poor condition, however, I was not satisfied, but desired to examine live specimens. On inquiry it was ascertained that there are no wild pitcher-plants in the District of Columbia, that a number were brought from South Carolina several years ago, and are now in the greenhouses in the Botanical Gardens. On a forlorn hope, I searched these plants and was delighted to find, on June 16th, a larva of the second stage, and, on July 8th, three more. Examining these living specimens, there were seen, not rudiments, but two well-developed gills, pointed, about one-third the length of the two large inflated ones, and situated above them. The published descriptions had probably been made from alcoholic specimens, where the gills are extremely hard to find, even when known to be present, as they shrink between the larger two and it is necessary to remove one of the latter in order to see the smaller gills plainly. But the point, from which I have somewhat digressed, is that *W. smithii* larvæ must have been brought all the way from South Carolina in the pitcher plant leaves, and the species had established itself and gone on breeding in the conservatory, for it is not likely that one or two adults should find their way from some distant point in Maryland or Virginia, to the middle of the District, into a greenhouse in the midst of the city.

It seems wonderful that, fragile as they are, mosquitoes should be able to survive the cold of the Arctic region, but it is well known that they are there met with in almost incredible numbers. Dr. Dall tells a story which proves that in that region, at least, they are not an unmitigated curse, despite their abundance and fierce appetites. It seems that, in the river districts of Alaska, when the ice breaks up and melts in the spring, the hunting of game over the soggy ground and through the melting snow is impossible, while the ice-cakes in the flooded rivers effectually prohibit any fishing. At about this time the stock of food laid in for the winter by the Indians has run low, and matters would sometimes be rather serious for the tribes did not the mosquitoes fly to the rescue. At this season these insects appear in countless hordes, clouds upon clouds, all ravenous for their first spring meal. Falling upon the deer and even the bears, they so torment the poor animals that they rush to the rivers to rid themselves of the bloodthirsty enemy; thus falling an easy prey to the watching Indians. At times the eyes of the bears, which are by far the easiest points of attack for the mosquitoes, are so swollen that bruin can no longer see, and thus starves or is captured by some hungry hunter, four-footed or otherwise.

How Long Do Mosquitoes Live?—With our present knowledge, the answer to this question must needs be "Indefinite." For we know that adults of some species live all winter and a part of the preceding fall and succeeding spring. We know that the *Anopheles* must live long enough to digest at least two feeds of blood, the malaria-receiving and the distributing meal; and that the development of the plasmodium must take place between these two meals. We also know that the *Stegomyia* cannot transmit yellow fever until twelve days after it has bitten a yellow-fever patient. In one instance it did so fifty-nine days after the last feed. I have kept *S. calopus* sixty-one days in captivity, or during the most of June, July, and August; we know that they live for months during the dry season. This does not answer the question as respects other species under normal outdoor conditions.[1]

Buzzing.—Even more aggravating than the bite, although far less serious in its effect (unless influence on nerves, language and feelings, be taken into consideration) is the buzz. There is, to the writer, nothing on earth so irritating as the shrill piping and shrieking right in one's ear just as one is comfortably drifting off into peaceful slumber. It rouses one up like a fire alarm. The victim snatches wildly at the air, thinking unutterableness, with the general result of a self-inflicted thumped head and the escape of the tiny offender. The buzzing is produced by the vibrations of a thin shred of chitin in the large air tubes just behind the openings in the thorax which admit the air. The pitch varies with different species as well as with the sexes. *Stegomyia* is almost a silent mosquito; being a day flier it would not be good policy for it to attract too much attention. *Anopheles* will sing at night, but I have never heard it do so in the daytime. As Dr. Howard has stated, the chant of the female *Anopheles* is of a decidedly lower pitch than that of the other genera, so that the "villain" is

[1] Dupree.

easily distinguishable by its bass voice. Dr. Goeldi says that the amount of distension of the abdomen by food or eggs, influences the pitch. Apart from recognising the use of the hum of the female in guiding the male, I feel somewhat as did a small girl who remarked to me: "I don't see why they screech so. If they don't like how I taste it 's awful impolite of them to holler about it so loud."

CHAPTER III

HOW FAR MOSQUITOES FLY

BECAUSE of the existence of an almost universal belief in the migratory propensities of mosquitoes in general, the question propounded in the heading of this section becomes one of the greatest importance. The application of remedial measures will not receive the hearty approval and co-operation absolutely essential to the attainment of the maximum of efficiency, unless it can be demonstrated that the majority of the species under consideration do not normally wing themselves for any considerable distance. The belief that they do so is so deeply rooted in the public mind, that its eradication will require plentiful testimony to the contrary.

The mass of evidence by experts is to the effect that the greater number of species are not in the habit of flying more than from two hundred yards to a quarter of a mile, and that most places, not situated near a salt marsh, will be found to be locally infested. If there is water available for the laying of the eggs near the place of emergence, and especially if there are warm-blooded animals near by, there is no incentive for migration. Their home-staying propensities are illustrated by the fact that ships moored perhaps a quarter of a mile from the shore are practically untroubled, while those along the wharves may often be invaded by hungry hordes which render life a miserable burden to the occupants of the vessels. If mosquitoes, not the marsh species, are plentiful in a city, the chances are that the breeding place is near by. It is apt to be well concealed and easily overlooked, but a careful search will often locate it in what might have been considered a quite impossible place.

When the wind is brisk, the insects will crawl into crannies or beneath leaves and twigs.

Dr. Smith says that, not only will most species not rise or take flight in a strong breeze, even in the evening, but even a light wind will keep them from the second stories of houses, the insects at this time preferring low and sheltered places. The actual powers of flight, according to Dr. Smith, differ not only in the species but also in the sexes. The flight of the male is mainly a hovering in the evening, although the males of *cantator* accompany the females for some distance inland; much farther than males of *sollicitans* travel. He has watched *sollicitans* carefully on many occasions and finds that it flies quite readily against even a brisk wind, making good progress. Several times, stationing himself in an alley in the direct line of the wind, he has watched the insect come sailing against the breeze without hesitation or apparent effort. He has driven at quite a rapid pace over infested roads and found that the specimens hovering over the horse and above the carriage had no difficulty in keeping up. He also observed a steam launch on which he was, being followed by a mosquito swarm for more than five miles across an open stretch of water. The specimens were not in the launch much of the time, because every effort was made to drive them out and keep them on the wing, which, as the boat was small, was an easy matter. Five or six miles an hour against an ordinary wind, or nearly double that when with a mild wind, he considers quite within the range of *sollicitans* or *cantator*.

Any one may observe for himself how the insects will swarm about and follow a walking person, or a moving vehicle. The slight draught occasioned by the movement of the object followed no doubt often somewhat helps the insects along, but when the breeze is at all strong this would, of course, count for nothing. I have seen a swarm follow a launch from one side of the Mississippi to the other at Baton Rouge, with the wind blowing down the river. The notion that mosquitoes are carried and distributed by air currents is a most popular and convenient excuse for not searching for a near-by and concealed breeding-place. I have been assured that the mosquitoes troubling a city house were brought by the wind from a marshy field about a mile away, whereas the fact was, that they were breeding in an old derby hat and a couple of tin cans lodged between two outbuildings not two hundred feet away. On the removal of the rubbish the trouble ceased.

Dr. Stiles, who has a summer cottage on the Jersey coast, is inclined to the view that a steady "land breeze" will spread mosquitoes seaward, as they appear after, and only after, several days of such breeze. His cottage is so situated that the "land breeze" is really a salt-marsh breeze, for the

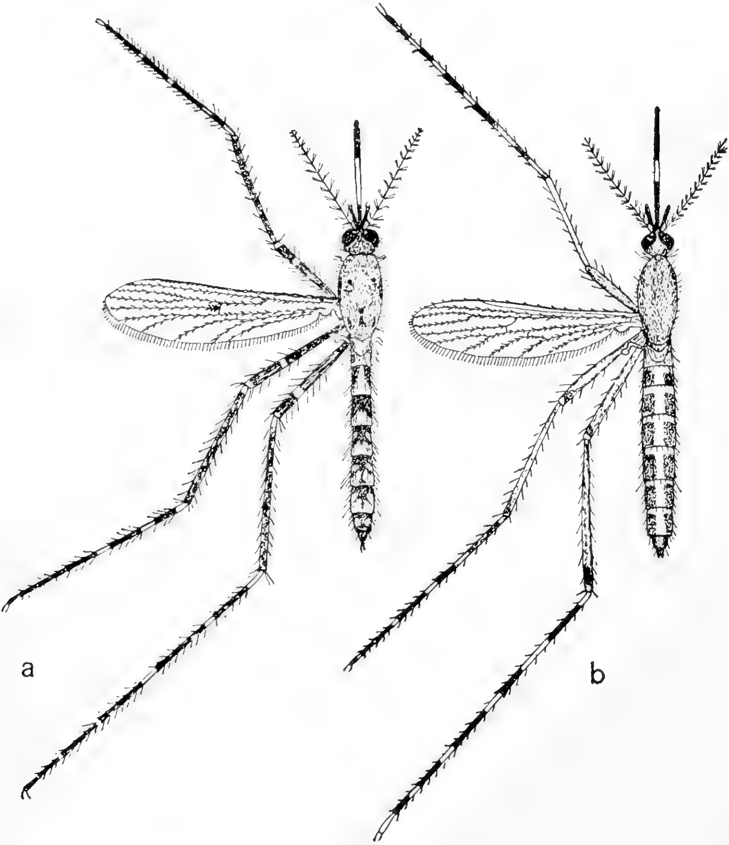


FIG. 8.—*a*, *Grabhamia jamaicensis*, female; *b*. *Ochlerotatus sollicitans*, female (greatly enlarged).

salt marsh there is really inland in relation to his cottage. In East Orange, N. J., I have noted that swarms of the marsh mosquitoes will appear after several days of a light, steady, east wind, practically a sea-breeze. Mrs. C. B. Aaron believes that, during the stiff sea-breezes, the insects hide in the thick grass or wind-flattened tree-tops of the sand dunes, and that during the lull, when the wind veers, they come out. This is why they present themselves at such an extremely short interval after the cessation of the sea-breeze, and such appearance would be impossible if all the mosquitoes were blown far inland. In this case the houses are but a few rods away, not, as in the case of Dr. Stiles's cottage, one-third of a mile from the woods.

As to the height to which the insect will go, Mr. C. A. Sperry, of Chicago, says that they are seldom, if ever, seen as high as the third floor in the city. Dr. Smith, on the contrary, states that he has actually seen them coming in at the fourth- and fifth-story windows in cities. The writer has noted that when mosquitoes were biting on the first and second floors there were none on the fourth; this was during a very light breeze. A fair breeze kept them from the second-floor gallery when they were biting maliciously on the first. In an article by Mr. Knab he quotes Swinton, in 1766, as speaking of six columns of "gnats" "ascending from the tops of six boughs of an apple tree . . . to the height of at least fifty or sixty feet," and also speaks of a swarm which was observed around the cross on the steeple of St. Mary's Church, in Neubrandenburg, at a height of three hundred feet, on the afternoon of August 20, 1859.

The belief from the time Dr. Howard's book was published until about 1902 was, that only rarely and under peculiar circumstances, did the adults fly to any considerable distance from the place where they attained maturity. The consequence was, especially in New Jersey, that a sort of every-community-for-itself sentiment prevailed in regard to the problems of extermination. The apparent uselessness of these attempts in many cases produced great merriment among the sceptics. The magnificent series of experiments and investigations conducted by Dr. Smith and his assistants, however, established conclusively the fact that the mosquitoes, in these cases, were not a home product, and although the majority of species breed within six hundred yards of where they are found, yet the three salt-marsh species, *O. sollicitans*, *O. cantator*, and *O. tæniorhynchus*, have a well-established migratory habit. These adults, day by day, were traced from the marsh, advancing until they were found miles inland, "infernal nuisances, where locals were almost entirely absent." To quote Dr. Smith:

"The observations made during the early season of 1904, with fuller knowledge of the factors, were equally conclusive. The development of the broods on the Newark and Raritan marshes was watched almost from day to day. Before the larvæ matured, careful search was made for several miles back and along the first ridge of the Orange Mountains to make certain of what was developing there. The appearance of the adults was noted on the meadows before a single specimen was seen in Newark. They were watched for a day or two slowly advancing until, a favourable night happening, the ever-increasing swarm arose and next morning had settled along the first ridge of the mountains. The second brood, maturing during the last days of June, was watched in the same way and the early days of July, 1903, brought inland the greatest swarm of mosquitoes I have ever seen. They reached New Brunswick July 2d, and included the three species, *sollicitans*, *cantator*, and *tæniorhynchus*. Meanwhile Mr. Viereck was observing at Cape May and watched the peninsula filling with *sollicitans*, bred at the shore; not a larva of which could he find where the adults swarmed. He noted that after a continuous south wind the marshes became practically free from mosquitoes, and he noted further that a few days later blood-filled specimens with developing or developed ovaries returned to them from the upland. This seemed to him in the nature of a return migration for oviposition, as all specimens were worn and battered."

The insects, in gradually lessening swarms, were traced to Paterson, Morristown, and Summit. At Great Bay, at the mouth of the Mullica River, Dr. Nelson observed the adults emerging on July 21st and 22d, the males the first day. On the 23d they were mating in clouds at from sixteen to twenty feet up, filling the air with a "peculiar humming noise." Next day the females were biting furiously. For four days afterward they kept in hiding from cold mist and north winds, but on the 28th the wind changed south, remaining so that night and all day on the 29th. During the 28th and 29th the mosquitoes departed from the marshes, and Mr. Brakeley reported their arrival, on the day immediately following, over thirty miles away, in the pine region where none breed locally.

In the spring of 1904 the ditching of the Shrewsbury River marshes minimised the surrounding territory for *cantator*, while in the unditched Newark marshes the brood developed and went to Bernardsville, where ordinarily mosquitoes are unknown.

Dr. Smith has observed that in the salt-marsh migration the females almost invariably have undeveloped ovaries. He has examined great numbers of specimens from the same swarm for a period of over a month, so that the eggs would have had plenty of time to develop. He attributes the migration to a restlessness due to the inability to reproduce. This may be a desire to suck blood, since in this species, as in many others, blood seems to be necessary to the development of the eggs. He thinks it probable that these specimens had not yet bitten, those which had done so would, at least in all probability, attempt to return to the marsh and would not be likely to be caught.

Dr. L. O. Howard in his admirable book, *Mosquitoes*, quotes a letter from the Hon. J. D. Mitchell of Victoria, Texas, in which two most remarkable migrations of mosquitoes are described. The first migration, which occurred in October, 1879, was from east to west, in a line about three miles wide, about fifty feet high, coming from a marsh about thirty-five miles distant, during a fairly strong easterly wind which had been blowing for about three days prior to the time when the insects arrived. The passage occupied about five days, enough mosquitoes remaining on the ground "to make everything uncomfortable for about two weeks." The second migration occurred in October, 1886, this swarm not crossing Carancahua Bay on the east, as did the other, but confining itself to the Matagorda Bay shore line on the west, reaching about half a mile inland, but in no less numbers than in the former and wider line. This time there was a light wind from the south that did not hinder the western flight of the swarm, which proceeded at a height of about twelve feet. The enormous numbers may be imagined from Mr. Mitchell's description: "They clouded the sky, bent down the grass with their weight, and made all driftwood and ground the same color." The swarm took about three days to pass and the total distance traversed was between fifty and sixty miles.

Although swarms have been reported as far as fifteen miles out at sea, these flights are not normal, the chilly air at the water-line usually inducing the insects to settle; also the normal flight is always inland when there is either no wind or a favourable one, seaward flights being only forced upon the insects by a high temperature and a stiff land breeze.[1]

The subject of migration and flight should not be closed without reference to the spreading of mosquitoes by cars, steamers, and other artificial means. Until Dr. Howard directed public attention to the dissemination of the pests in this manner, such methods of dispersal had probably been overlooked, although a matter of common observation to every

[1] Smith.

traveller. There is no doubt that the trains are an important means of carrying the coast mosquitoes inland. I have seen freight cars on the sidings at Roseville, N. J., wherein large numbers of marsh mosquitoes had taken refuge, and doubtless many of these were carried on up the line. Thus the pests have in many cases been established at points where, before the railroads came through, they were unknown.

A mosquito in Winchester, Va., was as rare as a horse in Venice, so says the Mayor of the city, until a night train of parlour cars was started on the Baltimore and Ohio Railroad to run from Camden Station, Baltimore, during the summer. A few years later the insects had become a positive annoyance.

As many as two hundred *Anopheles* were counted in a coach by Grassi during a two-hour drive through the plain of Capaccio, Italy, so one may imagine what a freight car may carry after a night on a meadow siding. The distance to which the pests may be transported by artificial means is probably unlimited. They are spread from port to port by ships, especially in the tropics. It is asserted that sailing vessels from our own country, having bred the insects in their water barrels, are responsible for their present abundance in Havana, where formerly they were unknown. Taken by the railroads throughout the country and flying from the cars at the different stops, they breed in the railroad ditches or any convenient pool, thoroughly establishing themselves in a short time. The ditches along railroad beds are prolific and needless sources of the nuisance. With a little forethought in the first place on the part of the engineer, advantage of the natural drainage could

FIG. 9.—*a*, *Psorophora ciliata*, male; *b*, *P. howardii*, female (greatly enlarged).

generally be taken, and breeding places in the ditches made impossible.

The spots available for multiplication of the insects may be numbered *ad infinitum.* I have found *Psorophora* and *O. triseriatus* in hollow trees, *Psorophora* also in pools, *atropalpus* in potholes in the rocks along the Potomac and in hollows in the rocks in swampy places, while in the swamp pools about the rocks *territans* and *Anopheles* were breeding by millions. It was noticeable that while there were *territans* larvæ in the rock cavities nibbling over the dead leaves with the *atropalpus*, there were no *atropalpus* larvæ in the ground puddles. In short it may be said that mosquitoes will breed in any accidental and transient water, in permanent pools, and in slow-flowing streams where the banks are marshy, irregular, and grassy, but not in swift streams or permanent pools having clear-cut banks, especially if inhabited by fish.

CHAPTER IV

MATING

THE mating of the various species seems to differ almost as much as do their other habits. Little observation seems to have been made on the subject, except with a few common species. It appears that, although the copulation of mosquitoes was noted by Diego Reviglias in 1728 (in a non-swarming species), and Swinton noted swarming on August 20, 1766, in a garden at Oxford, the purpose of gathering for copulation was not recognised until Gilbert White recorded it in 1802.

The general impression seems to be that the pairing takes place toward evening, the males assembling and dancing in large groups, the female flying into the swarm where she is seized by a male, after which the two fly for a short distance together. While this is in a general way true, it is not the universal rule. For instance, *P. howardii* would mate in Dr. Dupree's laboratory at any time of day, and did not fly during the act, which lasted for some minutes. The female would stand, quietly as a rule, on the floor of the breeding jar, the male beneath and clinging with body parallel to hers.

The mating of *C. consobrinus* when in confinement is radically different, and was twice observed by Dr.

Dupree and the writer. The insects were first noticed at about 9 A. M., on the vertical side of the jar, the female walking up the side, dragging after her the male, whose tarsi hardly touched the sides of the receptacle, his forefeet being almost constantly in the air. When the female reached the netting on top of the jar, she walked on this with the male hanging downward, his feet in the air and wide spread, his body almost at right angles to hers. The pair moved about frequently. When they took to the air they faced in opposite directions, both using their wings. The female walked and flew about for upwards of two and one-half hours *in copula*. In another case the mating had lasted at least *five hours*, when Dr. Dupree and I left the laboratory. Both of these females bit later and laid fertile eggs within thirty-six hours after their meal.

We also noted solitary pairs of *J. posticata* flying *in copula* through the woods about twilight, but never saw swarms of them.

Dr. Goeldi's account of the swarming and mating of *C. fatigans* is so vividly picturesque that I cannot refrain from translating a part of it:

"They swarm through our windows at nightfall, filling our barracks with an evil humming, to celebrate their bacchanalian orgies. They are chiefly males, coming in swarms of from fifty to one hundred or so. They unite into a dense cloud, coming into the house to find the females already there. An infernal music from numberless dancers fills our ears, at the same time one or another continually dashes against our faces, with hateful impudence and palpable provocation. Striking a light, we see round about us the unholy gang; they are in clouds, each cloud composed of individuals of a single sex, fluttering and describing fantastic evolutions, executing, by the sound produced by the vibration of their wings and halteres, an orchestration or recitative chorus, ruled by the baton of Eros."

This depressing music may be resolved into two tones, one higher, made by the males, the other lower, made by the females. The pitch of the whole sound is different with different species also, the chant of *C. fatigans* differing from that of *S. calopus*, and that of *Tæniorhynchus* being unlike that of *Anopheles*.

The sexes recognise each other at some distance by the song. "There is," says Dr. Goeldi,

"nothing more unceremonious than the union of the sexes; one female suddenly leaves her companions and approaches the dancing cloud of males. Immediately she is seized by a male and, united, they leave the wild multitude with a hum. Rarely they show the faintest care, giddily they dash against everything, even rolling on the ground. Sometimes one female will be seized by two males at once and all three will tumble about together in a frenzy."

Dr. Dupree speaks of the female *calopus* as a veritable Messalina, always ready to receive the approaches of her consort with unresisting submission, however frequent they may be, retiring exhausted but not satisfied. The male is none the less amorous, being ever ready to renew his attentions whenever the whereabouts of the female is located, which is accomplished by means of the long, sensitive hairs of his antennæ. Any disturbance that will cause the female to leave her resting place on the side of the cage in which she is confined will result in her immediate seizure by the male, and the two fly off *in copula*. Nor is the process arrested at once should they be precipitated into water, which occasionally occurs from sudden and unexpected contact with the walls of the cage, but the act is carried to a finish. The performance will be repeated every hour or two if encouraged by a tap on the cage. In one instance it was repeated many times daily for more than a month—a refutation of the statement, so often made, that the male dies soon after the sexual act is completed. Nor, in several other species as well as in this, is it true that the female dies as soon as her eggs are deposited, for the insect sometimes lives two or three days after laying the last batch, the ovaries being found empty after death. This is one of the evidences of the unwisdom of premature generalisation.

These creatures most thoroughly illustrate the rule, so general with insects as to have almost the force of a law, that the first and main business of life is the perpetuation of the species. On one occasion the Doctor employed successfully the inordinate erotism as a means of differentiation of the species. Four females of relatively large size, reared from pupæ of excessive dimensions and peculiar appearance, obtained from most foul water, all of which rendered their identity questionable, were placed in a cage with a male *Stegomyia calopus*, of

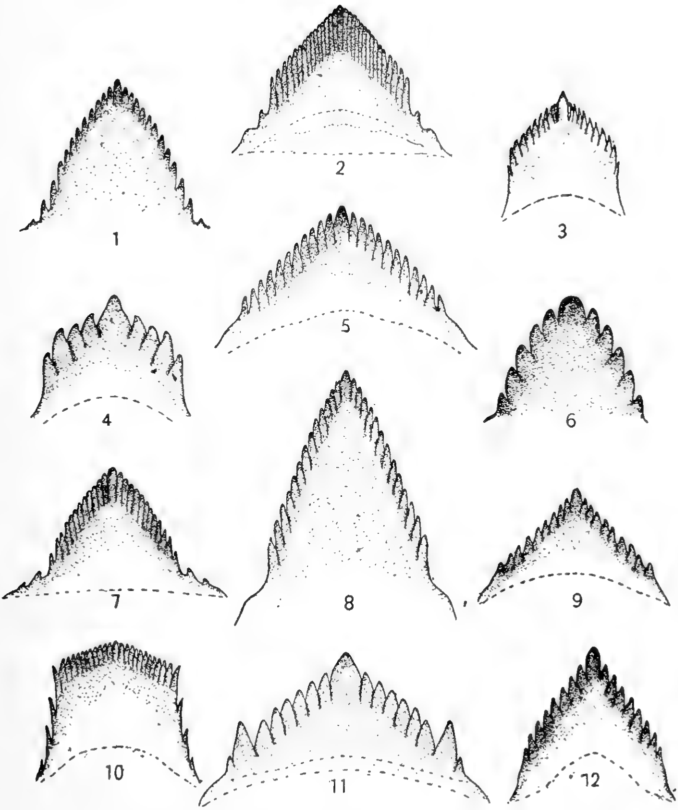


FIG. 10.—Labial plates (greatly enlarged): *1*, *Aëdes fuscus; 2*, *Ochlerotatus bimaculatus; 3*, *Culex pipiens; 4*, *Melanoconion atratus; 5*, *O. sollicitans; 6*, *Uranotænia lowii; 7*, *O. sylvestris; 8*, *Grabhamia jamaicensis; 9*, *O. triseriatus; 10*, *C. restuans; 11*, *Psorophora howardii; 12*, *G. discolor.*

ascertained validity but less than one-third their size. They were promptly seized in turn. Incidentally it may be mentioned that two of the four females escaped the following morning, the male died the seventh day after being caged, and the two remaining females deposited, the one four, the other five batches of fertile eggs, having fed upon blood every two days. These observations establish the fact that a single fertilisation suffices for at least five batches of eggs. Such gastronomic and reproductive powers are noteworthy, especially in view of the fact that Col. Giles, a recognised authority, reviewing Celli's statement that adult *Anopheles* will bite every two days and ovulate several times, says that "generally they take some four days to renew their appetites after a full feed, and the laying of a couple of batches of eggs is about the limit of the reproductive capability of the most of them."

Professor Boyer, of Tulane University, in recording experiments with eighteen *Anopheles* and two *Stegomyia*, states that an *Anopheles* capped the climax by not only living nearly fifteen days, but also by laying a second batch of eggs on the seventh day after her first oviposition.

Dr. Goeldi notes that the males of *S. calopus*, although they may congregate in small groups of from fifteen to twenty over some article of furniture, while the females are hovering about the room, do not form large swarms. The sexes tend to separate into distinct groups, the males going up higher in the bed net than the females and chasing any of the latter which come near. The mating is brief, the male pouncing on some female winging toward him, uniting on the under side, and permitting himself to be carried by her in a slow flight for a few seconds, then separating. One male will mate with several females in succession when thus unconfined. I have noted that, early in the morning, these insects had a habit of coming in pairs when they alighted upon me.

The mating of the marsh species evidently takes place during the evening swarmings, when little or no wind is blowing. The act in these forms, from accounts given, apparently lasts but a short time.

As for *pipiens*' mating, I have noticed them in swarms about sundown in the autumn, from five to eight feet from the ground, the female flying into the swarm, which was composed of males, leaving at once, united with a male, flying with him for a short distance, then abandoning him and seeking a shelter. Mr. Knab gives a good and detailed account of the swarming and mating of *pipiens* observed by him on the evenings of October 15 to 18, 1904, at Urbana, Ill. The first three evenings were warm, with no perceptible breeze, but the drift of smoke showed a light air current. The insects, at about 5 o'clock, were found dancing in swarms composed entirely of males, above all the corn-stooks in a field near a stream, and over trees, shrubbery, etc., all facing in the direction of the air current, and being on the opposite side of the corn-stook to that from which the breeze came.

On the fourth evening a breeze induced the swarms to form to leeward of projecting objects, causing more or less confusion. It was noted that the male and female face in opposite directions, with their bodies in a horizontal plane, the female dragging the male. The pairs flew upward for a while,

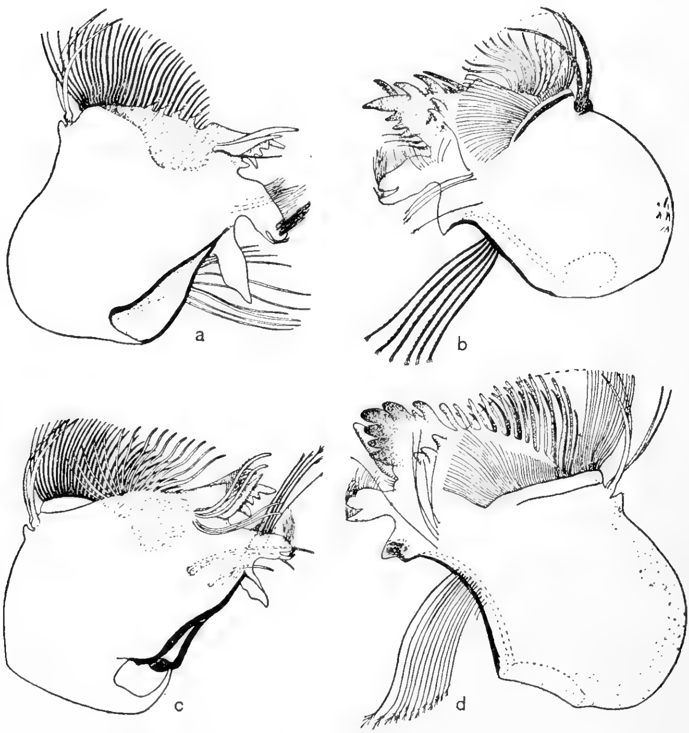


FIG. 11.—Mandibles of non-insectivorous larvæ (greatly enlarged): *a*, *Grabhamia discolor* (dorsal side); *b*, *Ochlerotatus sollicitans* (ventral side); *c*, *O. serratus* (dorsal side); *d*, *Culiseta consobrinus* (ventral side).

then slowly drifted groundward. A pair plunging accidentally into a group, threw this into wildest confusion; but the couple hastily extricated them selves. The swarms grew more restless as darkness gathered, two or three males pouncing simultaneously on one female, all falling together to the ground and there separating. When females ceased coming, the males flew upward and away.

Swarms of mosquitoes often consist of countless myriads. I have been told by a newspaper man who was in Alaska that, at times, he has seen the mosquitoes rise in such droves from low areas that one might easily believe the grass was afire. Something like these must be the swarms at Lake Nyassa, Africa, where, Livingston says, the natives gather the insects into bags, dry them, and press them into a sort of mosquito cake.

Mr. Knab quotes a number of early records of great assemblings of the insects about church steeples, noted as far back as 1813. Three such are recorded by Boll. One of these, around the steeple of the Nicolai Church in Hamburg, took place on a June evening at 9 o'clock. The fire department was called to the spot before the truth was ascertained, and great merriment was thereby aroused in the concourse of spectators. Such false alarms appear not to have been uncommon.

CHAPTER V

LARVÆ AND PUPÆ

THE larvæ are found only in water, never in wet grass, being anatomically fitted for an aquatic life only. A great quantity of water is unnecessary, nor, in many cases, need it be very clean. A canful will sometimes be densely crowded with thriving larvæ. I have never found a larva that would live much over an hour even on damp (not thoroughly soaked, but merely damp) mud. An almost solid group of larvæ are sometimes found in a nearly dry pool, retreating to the deepest part *en masse*. There is no doubt that they will die if they become entirely dried. I have tried this again and again with *pipiens*, *sollicitans*, and *calopus*, which last I believe to be as resistant as any species can possibly be, unless it is a *Psorophora*.

Nor, according to Dr. Dupree, is too much water a good thing for the larvæ, as most species, if forcibly submerged, will drown in one or two hours when full grown, and in four or five hours when very young. It may be conjectured that the young ones take longer to drown because their skin is thinner.

Slow, mud-bottomed meadow streams with grassy banks are apt to breed mosquitoes; clear rock or gravel-bottomed streams, inhabited by aquatic insects and fish, and with no hiding places for the larvæ, are almost sure to be entirely mosquito free. Shallow, stagnant water, especially if in a deep hollow, or among bushes or trees, is an ideal breeding place. The pools covered with "green scum," at which the unsophisticated point with a shudder as "dreadful malaria holes," as a matter of fact, are generally nothing of the sort. "Green scum," if *Spirogyra*, entangles the wigglers and drowns them; duck weed often covers the surface so densely as to choke them; and *Euglena*, a favourite protozoan food, may grow, at least in very small pools, so thick at certain times of the year as to swarm at the surface in such numbers that it forms an impenetrable film. In such pools, too, many of the aquatic insects love to hide, and soon reduce the surplus mosquito population.

Cisterns and old wells are often breeding places, also the bases of flower-pots, vases where flowers have stood for several days, potholes in the rocks, tin cans, or almost any other receptacle that will hold water. Some species, as *territans*, will breed almost anywhere; others, as *A. barberi*, must have a certain sort of locality, in this case a hollow tree. *Anopheles* will breed in clear water or in sewage ditches.

Internal Anatomy.—In the brief general description of the larvæ, given on previous pages, no mention was made of the internal anatomy, and but brief notice was given to the mouth-parts.

The musculature of the larvæ is too complicated to be here described, as is also the minute anatomy; but after one has studied the intricate muscle system he does not wonder that the little wretches can wiggle so fast. The alimentary canal begins with the esophagus, a short, straight tube extending from the mouth to the stomach. The latter is a dilated, straight pipe in the median line, varying in appearance according to its contents. It begins in the upper part of the thorax, and extends to the sixth abdominal segment, where it narrows and continues as the rectum. In the living larva there will be perceived in the thorax four pairs of dark spots, more or less variable. These, at first, may appear like pigmentation, but on inspection will be found to be within the skin. They are glandular sacs, probably having the function of the "liver," and are connected by ducts with the upper end of the stomach. At the beginning of the rectum are the five Malpighian tubes. Above the stomach, one on each side of the middle line, will be seen the great tracheæ, which expand more or less in the thoracic portion and in the breathing tube, and are easily distinguished by their walls of spirally coiled threads of chitin. From these main tracheæ small branches extend to the different organs of the body. The blood, which flows freely about in the body cavity, is clear, colourless, and has no oxygen-carrying cells, but is more in the nature of lymph. It is kept in circulation by the "heart," a dorsal tube, open at

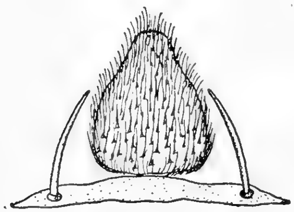


FIG. 12.—Labrum of *Ochlerotatus sollicitans* larva, dorsal side, greatly enlarged.

both ends and extending from the head to the last segment. This tube is so transparent that it can be detected only by its motion, which churns the blood about. The nervous system is a double chain of ganglia on the under side, too transparent to be seen in the living larva. There are two "salivary glands" lying close to the esophagus in the head. The eyes are simple, with no lenses, being a sort of transitional stage between simple and compound eyes.

Mouth-Parts and Food-Habits.—The mouth-parts are very complicated arrangements. They consist of the rotary brushes, labrum, mandibles, maxillæ, and labial plate. As might be expected, these follow the usual rule of nature, that a difference in the structure of the mouth-parts is correlated with a corresponding difference in the food-habits. This fact first forced itself upon the writer's attention when studying the habits of the Louisiana species, and was later confirmed when making dissections and drawings of larvæ of additional species for the forthcoming Carnegie monograph on mosquitoes.

The larvæ fall into the two following categories: (1) Insectivorous, which, like *Megarhinus* and *Psorophora*, normally prey upon small aquatic larvæ of other species of diptera, of other mosquitoes, and, when hard pressed for food, even upon individuals of their own species. (2) Non-insectivorous, which feed on *Euglena* and other protozoa, bacteria, diatoms, slimes, algæ, and other vegetable matter, also at times upon minute crustacea, such as the water-fleas. The members of this class seem to have a habit of swallowing grains of sand, and some of

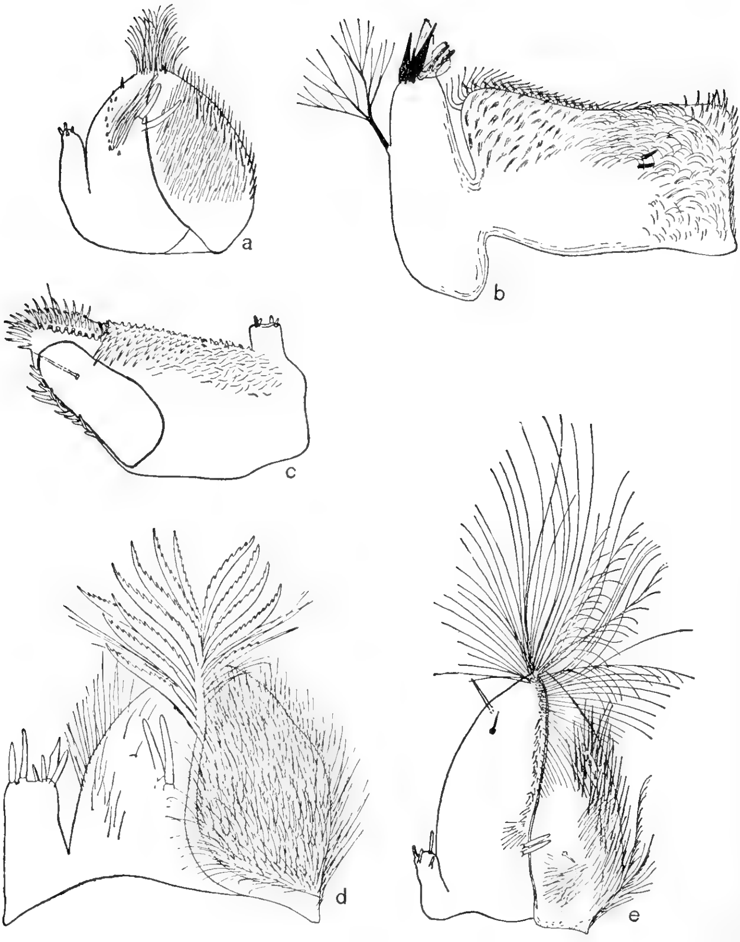


FIG. 13.—Maxillæ of larvæ (ventral view, greatly enlarged): *a*, *Ochlerotatus triseriatus*; *b*, *Anopheles maculipennis*; *c*, *Psorophora ciliata*; *d*, *Uranotænia sapphirina*; *e*, *Culex salinarius*.

them will eat their cast skins, as will also all of those outside of this class. Between the two groups are two others, somewhat intermediate—viz., the *Uranotænia* and the *Anopheles* groups. That the differences in habits are correlated with marked differences in the structure of the mouth-parts will be seen by the following comparison.[1]

In the insectivorous group the mouth-parts are eminently fitted to the diet. The "brushes" are here a few stiff grappling hooks; the mandibles possess long, heavy, curved spines for seizing, and great pointed teeth for tearing (Fig. 14, *a*, page 73); the maxillæ are squared, heavy, and fitted with many stiff, usually curved spines, evidently adapted for retaining a struggling victim (Fig. 13, *c*, page 68).

In the non-insectivores, whose food is usually microscopic, the "brushes" are often of marvellously delicate hairs, very numerous and fitted to form a current which will draw small particles into the mouth. The hairs and spines on the mandibles are movable and not so heavy as in the former group; they are evidently sieves or tactile, or are used to comb off the brushes, which are frequently drawn through them (Fig. 14, *d*, page 73). The biting part is small, with rather blunt, crushing teeth. The maxillæ are conical, with long brushes atop, to thrust food down the gullet, and fine hair sieves on their sides (Fig. 13, *a*, *e*, page 68).

Anopheles and *Uranotænia* seem to correspond

[1] For more detailed comparison in tabulated form see the author's article, "Mouth-Parts of Mosquito Larvæ as Indicative of Habits," *Psyche*, Feb., 1906, pp. 11 to 21.

exactly with neither of the foregoing groups, and their mouth-parts, as well as other parts, are transitional (Figs. 13, *b*, *d*, page 68; Figs. 14, *b*, *c*, page 73). *Anopheles* larvæ will bite each other viciously, tearing off hairs, devouring skins, occasionally killing other larvæ or smaller *Anopheles* larvæ, and always eating any which die. They snap at any floating object as well as at their brethren, differing greatly in this respect from the milder-mannered non-insectivores, which may often be seen combing carefully over one another, or mutually cleaning mouth-brushes. We found the principal food of *Anopheles* to be *Euglena*, protozoa, diatoms, spores, etc., but they will also take in any floating object that is small enough, and a good many which are not, rejecting the latter, after a spiteful chewing, with a vicious flip of the head and a snap of the whole body highly expressive of disgust. *Uranotænia* has much the same habits as *Anopheles*, without the temper. But whereas *Anopheles* turns his head around a half circle and skims the surface, *Uranotænia* feeds just below the film. From the shape of the latter's mouth-parts, I judge it would devour minute crustacea and vegetables.

Among the non-insectivores are also two distinct types of mandibles and maxillæ. The facts on hand suggest that these are associated with two types of breathing tubes and antennæ, as well as with different habits of feeding. The author hopes that this point will some time be worked out more fully. It is intensely interesting, and the observer will feel himself repaid for patient watching. It seems as if there were too much pinning and labelling nowadays, to the neglect of the observation of the wonderful living creature and its individuality—for even these little fellows have individualities, specific at least.

The group of larvæ with long breathing tubes, *M. atratus*, *C. pipiens*, *C. territans*, *C. restuans*, *C. salinarius*, eats with the tubes almost continually at the surface and their heads below the film. They navigate about by the movement of the mouth-brushes, leaving the surface only when disturbed. Their food evidently drifts freely, being drawn in by currents set up by the brushes. In these five species the antennæ have long terminal spines and very large and beautiful plumose tufts set in a notch, the hairs standing out like great aigrettes and being probably tactile, possibly olfactory. The larvæ of this group usually hang with bodies almost parallel to the surface and heads depressed at a sharp angle. They frequently flex the head backward and skim the surface for a moment. Other forms usually hang at a much greater angle, with the head nearly in line with the body, so far as I have observed. The maxillæ here have longer hairs and are fitted to catch floating particles (Fig. 13, *e*, page 68) as opposed to the other group, in which they are used more for grubbing and for brushing over solid objects (Fig. 13, *a*, page 68).

G. discolor forms an apparent exception, having the "floating type" of maxilla and of mandible, but when one considers that, although he feeds at the bottom, he lies on his back most of the time, thus obtaining floating matter, he therefore but proves the rule.

The bottom feeders go rooting in the mud and debris at the bottom, or nibbling over the sides of a tank, or of half submerged objects—grasses, *Spirogyra*, etc. These forms have rather stubby hairs on the maxillæ. The antennæ are stumpy and straight, with small tufts and terminal spines; long ones would be in the way in grubbing. *O. dupreci*, with its very short antennæ and bottom feeding, is a good example; also *O. triseriatus*, which eats at the bottoms of tree hollows. There are maxillæ (never mandibles) which seem transitional, as in *O. atropalpus;* in these forms the larvæ brush submerged objects for protococci and take in considerable floating matter, rather than dig. As to whether larvæ aid much in purifying water is very uncertain.

Other Structures and their Uses.—It might be interesting here to note some of the different adaptations and modifications of other larval structures. The hairs on the head and body are sense organs of some sort; I think that the unfringed ones are tactile; the fringed hairs perceive direction and vibration (are practically auditory). Perhaps the tufts on the sides of the thorax in the forms which feed below the surface are also a help in balancing. On the thorax of *Megarhinus* many of the tufts are converted into large stiff spines with spinules; these may be more or less of a protection. The stellate hairs in *Anopheles* undoubtedly catch in the surface film, thus supporting the larva in the horizontal position which is necessary for its custom of skimming the surface. The breathing tube of *Anopheles* is well adapted to this habit, being prac-

FIG. 14.—Mandibles of larvæ (ventral view, greatly enlarged): *a*, *Psorophora ciliata*; *b*, *Anopheles maculipennis*; *c*, *Uranotænia sapphirina*; *d*, *Ochlerotatus triseriatus*.

tically atrophied. It will readily be seen that a long breathing tube would here be much in the way. The surface feeding will account also for the very slight development of the anal gills. The larva, having its tube continually in contact with the air, has no need for tracheal gills, therefore economical nature does away with them. On the contrary, those forms which remain much under the water have greatly developed gills with many tracheæ. In *O. dupreei* and *G. discolor* especially, the gills are enormously long and well tracheated. *G. discolor* often remains below for hours, and *O. dupreei* only comes to the surface to pupate. There are all sorts of transitions between these extremes in the gills. In *W. smithii*, which stays most of the time at the bottom, the gills, although not long, have one pair very wide, and full of tracheæ. The breathing tube is closed at the top by a chitinous valve, and, when the larva is in the habit of staying long at the bottom, there will occasionally escape from the tube a bubble of air. From the dorsal end of the ninth segment some long hairs project backward, generally farther than the anal gills, probably acting as feelers to prevent a rear attack. The anal brush on the lower side of the ninth segment is evidently used as a propeller and rudder.

It may not be amiss to say a few words here as to the relation of the larval structure to habits of ovulation. The larvæ of those species making rafts evidently form a natural group and possess structural characters peculiar to themselves. Some of the single-egg depositors may have one of these characters (given in the tables), but none has the whole combination of characters. This natural grouping is further emphasised by the fact that the enveloping membrane of the single ova is structurally very different from that of the massed eggs, being much more elaborate. Also, as pointed out by Mr. Coquillett (*Science*, Feb. 23, 1906), all single-egg layers have toothed claws in the adult form so far as known, with the exception of the genus *Grabhamia*, while, except in this genus, all mosquitoes having simple claws form rafts.

Resistance of Larvæ to Cold.—Although so marvellously delicate in appearance some of the larvæ are apparently able to resist much steady cold, alternating low and high temperatures being fatal. Some species hibernate in the larval stage. *O. canadensis* escapes actual freezing, it is said, by burrowing into the mud if he happens to hatch during a thaw, and becomes nipped by the cold later on. *W. smithii*, however, which lives in the leaves of the pitcher-plants, can, as observed by Mr. Brakeley, be frozen up solidly in the ice without coming to harm, and melts out as good as ever. *M. melanurus* also lives through the winter as a half grown larva, probably hiding in the leaves and mud. Dr. M. J. Wright (*British Medical Journal*, 1901, pp. 882–883) reports that he saw active *Culex* larvæ in a pool covered with a thin layer of ice. One of the larvæ, upon coming to the surface to breathe, was frozen stiff, but on being removed to a warmer atmosphere it revived and was soon wriggling merrily. Then the Doctor began experimenting. He placed some *Culex* and *Anopheles* larvæ in a cup of water. Then he gradually froze the water by putting the cup in a mixture of ice and salt. The wrigglers remained active so long as any of the water remained liquid. Some larvæ, kept with the water partially solidified about them, were alive at the end of the fourth day, but were killed that night when all of the water congealed. On February 9th, Dr. Wright removed the snow and ice which for two weeks had covered a pool to a depth of from eighteen inches to two feet; in the water he found active *Culex*, *Anopheles*, *Dixa*, dragon flies, and other insects, but no culicid pupæ. Larvæ which pupated in November, December, and January died before completing their changes, being unable to resist the low temperature as did the other, younger larvæ. It is probable that mosquitoes do not winter in the pupa stage.

Sight of Larvæ.—I have no reason to think that the sight of larvæ is well developed. It is true that they distinguish between light and darkness, a sudden shadow often sending them wriggling wildly away, but from the character of their movements when any small water dweller, such as a water-flea, approaches, the probability is that they do not see it, but sense it with their feathered hairs when it is close enough. It seldom comes near enough to touch the hairs, however. They can evidently smell in some manner, as they will gather around some large piece of food, a dead larva for instance.

Moulting.—The larva sheds his skin three times before pupation, the exuviæ cast when the pupa emerges being sometimes referred to as the fourth moult. The first stages often differ much from the last. Before the primary moult the head is larger in

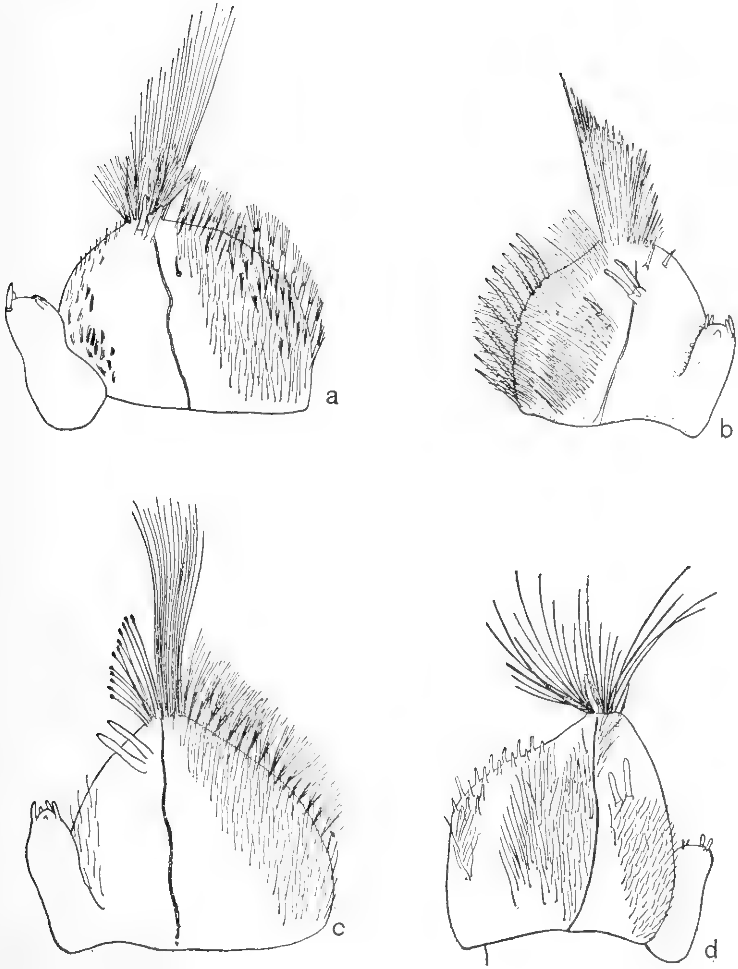


FIG. 15.—Maxillæ of non-insectivorous larvæ (ventral view, greatly enlarged): *a*, *Ochlerotatus infirmatus*; *b*, *O. serratus*; *c* *O. bimaculatus*; *d*, *O. tæniorhynchus*.

proportion to the body, the hairs proportionately longer and usually fewer; and the larva is more transparent and colourless than in the later stages. Young larvæ seem to be attracted to light in the first day or so, massing on the side of the jar next the window. Later many species avoid the light. When moulting, the skin splits on the back of the larva's thorax. The whole lining of the tracheæ and intestine is shed also. It sounds uncomfortable and dangerous, yet few larvæ die in the process. Before a larva moults, he stops feeding for a time and keeps quiet. Sometimes he lies on the bottom as if dead. Then he generally comes up and begins to jerk viciously every little while, snapping his head from side to side. The contortions increase in frequency and force until the skin splits and the larva shakes himself out of his old suit and swims away. After this he usually appears to be furiously hungry, and falls to as if he were just over an attack of typhoid, but he never seems to die of indigestion or overeating.

I closely watched the emergence of a pupa of *W. smithii* from the larval skin and took the following notes. The larva, when first observed, was thought to be dead, but under the microscope was seen to be twitching the muscles of the breathing tube, no other motion being apparent. The breathing tubes of the pupa were plainly visible through the chitin of the neck of the larva, the pupal head being forming in the lower part of the larval head. When placed in a deep cell the larva lay perfectly quiet, the head, thorax, eighth and ninth abdominal segments, and the tube being bent downward. The position slowly warped—there is no other expression, for there was no visible movement—during almost two hours, to an arc of a circle. By this time the jerking of the muscles in the tube had ceased and the tail of the pupa had shrunk from the ninth segment into the eighth of the larval skin, in front of the tube. The head of the pupa was now a complete cephalo-thorax and lay entirely in the thorax of the larval skin, the pupal breathing tubes plainly visible. The curved position meanwhile changed to one almost parallel with the bottom of the dish, the thorax being the resting point and the abdomen slightly elevated, with a twist to the right. The time was now 11:30 A. M.

At 11:48 the head of the pupa had shrunk clear away from the sides of the larval thorax and the tail was well into the eighth larval segment, almost at its forward margin. There still seemed to be tracheæ connected with the anal gills. The tubes of the pupa were folded toward the head, the lateral and dorsal hairs toward the middle of the back. The pupa was gradually darkening by irregular pigment (?) spots.

By 2 P. M. the pupa occupied about three-quarters of the middle of the larval thorax and did not extend to the larval neck. The tail was at the hind border of the seventh larval segment. At 2:30 the wings were developing rapidly and showing at the sides of the pupal thorax, not yet bent much downward. The larval abdomen was not now bent at all to the right, but the last three segments of the pupa were curved upward. The tracheæ still led to the gills.

At 2:50 the wings were perceptibly widened and grown longer. The lower part of the thorax of the pupa and the first and second abdominal segments were not nearly as dark as the rest, the remainder of the abdomen in particular being quite well and evenly chitinised. At this time the tracheæ to the gills had broken and a few moments (less than five minutes) afterward the pupa shook itself free from the larval skin, the wing cases folding into their usual position just after the pupa emerged, which it did rather quickly, popping up at once when placed in deep water.

Pupæ.—There is practically nothing to be said about the habits of the pupæ. They are, on the whole, a rather uninteresting set. They look like a lot of overgrown commas bobbing about in the water. Being of less specific gravity than the water, they float at the surface film, supported by the two tubes and the tuft on the first abdominal segment, until a shadow or a motion affrights them, when they dive downward with mad jerks. Then, the panic over, they resume their natural curled up attitude, and float calmly to the top again. They never go about with their tails sticking straight out, as most of the pictures show them; some of the dead ones look that way, but live ones only straighten out when about to emerge.

Pupæ, when first formed, are generally more or less transparent and of a pale colour, darkening as they grow older, the deepened tint being mostly due to the development, on the included imago, of the scales on the back and wings, which are visible through the thin chitin of the pupa skin. There is no use in trying, in a drawing of a pupa, to show the colour markings, for they vary from hour to hour. When the included adult has nearly reached its full development, the pupa is not quite so lively. It abandons its curved posture

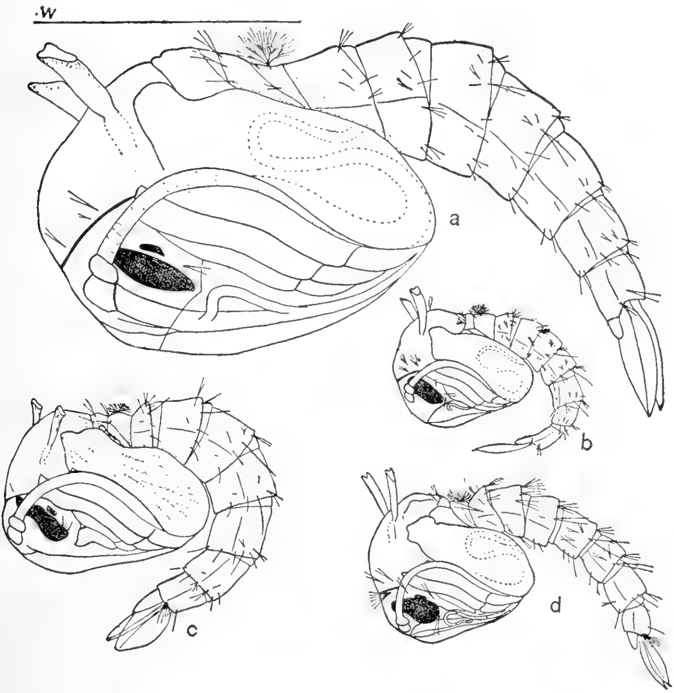


FIG. 16.—Pupæ of: *a*, *Psorophora howardii*; *b*, *Ochlerotatus dupreei*; *c*, *O. triseriatus*; *d*, *Culex restuans*; *w*, water line. (Drawn to scale, greatly enlarged.)

and becomes almost straight. At times it jerks violently. Finally the skin of the cephalo-thorax bursts open, the head of the imago appears, and the insect, gradually, without visible effort, rises out of the pupa skin, which floats on the water like a ghostly craft. The weird rising continues until the wings are free, the legs all this while being stiff, straight, and slanted backward close to the body, which emerges at an angle of 50° or so from the skin. The fore legs are then drawn out and rest on the water, then the other legs. The mosquito during this performance, and in fact until the wings are dry, is in imminent danger of being upset by the ripples, or a puff of wind, or of seizure by some aquatic or aërial enemy. For a moment's space the creature stands upon the surface of the water, then the rainbow wings stiffen and the insect lightly sails away to buzz, suck nectar, or stab a victim.

This slow emergence is in great contrast to the sudden bursting forth of many of the Chironomidæ, which flash forth from the pupa skin with almost incredible rapidity, literally leaping from the pupa case into instantaneous flight. This is necessary, particularly in the case of those living in running water, which would inevitably upset and drown an emerging mosquito.

CHAPTER VI

MALARIA

IT is sad to relate that, in spite of all that has been said and published on the subject of the transmission of malaria by mosquitoes, there still remains a deep-rooted prejudice in the minds of the populace against "night air." The tenacity of that idea amounts to superstition. There are some people who apparently cannot possibly apprehend the fact that, as long as they screen off the mosquitoes, they may sit on a porch or leave the window open all night with impunity.

History of the Malaria Theory.—The connection of mosquitoes and malaria, however, is not a modern theory. Nuttall says that those learned old Romans, Vitruvius, Columella, and Varro, mentioned this connection nearly two thousand years ago. Dr. H. A. Veazie goes farther back than that. He states that he once read somewhere that some ancient Egyptian physician named Mah said that "malaria was a disease produced by a parasite in the blood, but the organism was so small that the human eye was unable to see it." How Mah, without a microscope, could evolve that notion is a mystery, and the tale smacks somewhat of the Sunday papers. However, Dr. Goeldi tells us that the Egyptians used bed nets, at any rate, and these were called "Konopeion." Perchance the expression "What under the canopy?" dates back to a mosquito-plagued Pharaoh.

To come down to more certain and recent times. In 1833 Dr. A. F. A. King discussed at length the etiological relationship of mosquitoes to malaria. Michel in 1847 described the ovoid bodies and the pigment, as did also Prof. J. Jones a few years later. In 1848 Dr. J. E. Nott published his opinion that the mosquitoes transmit this disease. Laveran, a French physician, in 1880 finally and conclusively proved the cause of malaria to be the parasite. Flugge, Welch, Ross, Manson, Pfeiffer, Bignani, Thayer, Grassi, Celli, Koch, Dionisi, and scores of others have toiled with infinite pains over the various phases of the problem.

In 1894 Manson took up the theory, and from this time may be said to date the present scientific interest in the subject. He supposed that man took in the parasites from water and dust, that the mosquitoes took theirs from man, that the flagellated forms developed in the stomach of the insect, that finally the flagellæ broke loose and, after penetrating the tissues of the insect, proceeded with their extra-corporeal development and reproduction, being returned to the dust and water.

Surgeon-Major Ross, I. M. S., during his experiments on the hypotheses of Laurens and Manson in 1895, in India, proved that the parasites taken by the mosquitoes from infected patients developed in the stomach of the insect to the flagellated forms. In 1897 he finally discovered the parasite in the tissues of an *Anopheles*. In 1898, after experimenting with the "bird malaria," due to proteosoma, he found that a thread-like spore developed and made its way to the salivary glands of the mosquito, and demonstrated the whole life history of the bird malaria, even to the transmission of infection by bites of *Culex*. In 1898 also, Bignani, Bastinelli, and Grassi, of Rome, for the first time succeeded in producing malaria experimentally in man by bites of mosquitoes. Dr. Grassi, applying Dr. Ross's theories, also traced out the full cycle of the human malaria parasite. Ross's researches were confirmed and amplified by Koch and Daniels, in 1898 and 1899; also by Zieman, Christophers, Stephens, Manson, Van der Scheer, Van Berkelon, Nuttall, Ruge, Annett, James, and others. Since then many have worked with the disease and have thoroughly established the fact that malaria is due to a parasite taken from an infected patient by a mosquito, and that that mosquito must be an *Anopheles*. With the proteosoma of birds, as well as with estivo-autumnal and tertian fever in man, every step in the chain of development has been demonstrated. Many attempts have been made to transmit malaria by subcutaneous injection of dew and water from malarial regions, by infection through breathing the ground air, or by drinking the water from those regions, and have failed.

The experiments of Dr. Patrick Manson in London, in 1900, served to confirm the theory. For these tests Dr. T. Manson and Dr. R. Warren offered themselves as subjects. They permitted themselves to be bitten by *Anopheles* infected in Italy, and in eighteen days both developed the fever, tertian parasites being found in their blood by experts.

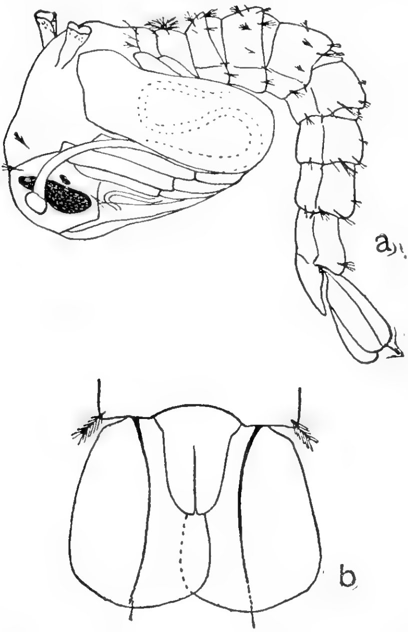


FIG. 17.—*a*, Pupa of *Anopheles crucians*; *b*, front view of paddles. Both greatly enlarged.

In the same way Drs. Low, Sambon, and two others spent the fever season in Ostia, Central Italy, right in the midst of the dreaded Roman Campagna. No quinine or other drugs were used, but the men were careful to retire into a well screened hut an hour before sunset, going freely about all day. Not one of them contracted malaria.

In North America *Anopheles maculipennis*, as well as *punctipennis* and *crucians*, according to Dr. Dupree, transmits malaria.

Protozoa in General.—The cause of malaria, as stated above, is a protozoan. Now a protozoan is decidedly not a bacterian. It is an animal, a unicellular animal. Perhaps it will be well to briefly discuss protozoa in general. They are microscopic in nearly all cases, but are sometimes two or three inches in diameter or length. They consist of a single, nucleated cell. They are found almost everywhere, mostly in water, especially when it is stagnant, but a certain number, comparatively few, however, exist as parasites. In spite of their minuteness, these latter little creatures are far more to be feared than wolves or tigers, for they not only have caused terrific epidemics among fish, birds, silkworms, domestic and other animals, but have also slain their tens of thousands among the human race.

The life of the individual protozoan is but a few hours, yet these organisms are commonly said to be immortal, although some time ago I saw an account of an ameba which disintegrated. Perhaps it was attacked by bacteria, although this is merely a guess. However, the protozoan, at the end of some hours, or possibly one or two days, divides into two or more distinct animals. It has not died, but as an individual it has disappeared. This process of reproduction is varied occasionally by conjugation of two of the creatures which come together, exchange half their nuclei, then separate, and go on dividing again. Conjugation, as has been proved by experiment, is necessary to the rejuvenescence and immortal life of the protozoan. Division cannot be continued indefinitely without an occasional interchanging of nuclear substance.

The malaria protozoan belongs to the group of spore producers, or sporozoa, and depends on a host for the life cycle. Without a host the sporozoa will die—this not being the case with bacteria, which, with few exceptions, can be reared on nutrient media such as bouillon or gelatin. The protozoa can get out of the body of an animal, human or otherwise, in only one way, by the aid of the mosquito. Within this insect they complete their life cycle and by its aid they are again transmitted to the proper host. In the case of bird malaria the carrier is a *Culex;* in the case of human malaria, an *Anopheles.* No protozoan parasite can possibly pass from host to host of one species without the intervention of an animal of another species. In the case of sporozoa passing through a stage between hosts in the free air, this stage is as an encysted spore; all the growing is done in one host or the other. The malaria parasite does not encyst nor resist drying.

Transmission of Malaria.—We make a great fuss about mosquitoes giving us malaria, but as a matter of fact it is the mosquito that has the malaria, and that is the "primary host," in which the spore matures, conjugates, and produces the stage when it may be passed on to man; therefore we are the pests who give malaria to the mosquitoes.

In from seven to fourteen days after the poor, unsuspecting creature has bitten a human being with blood full of crescents or pigmented spheres, it is able to retaliate, having a salivary gland full of parasites, so that the person bitten by that mosquito will develop his case of chills in anywhere from two days to three weeks, according to the dose of parasites received, their kind, and perhaps also the patient's natural resistance or vitality, as different people are more or less immune.

Development of the Malaria Parasite.—It is a most wonderful and complicated thing, this de-

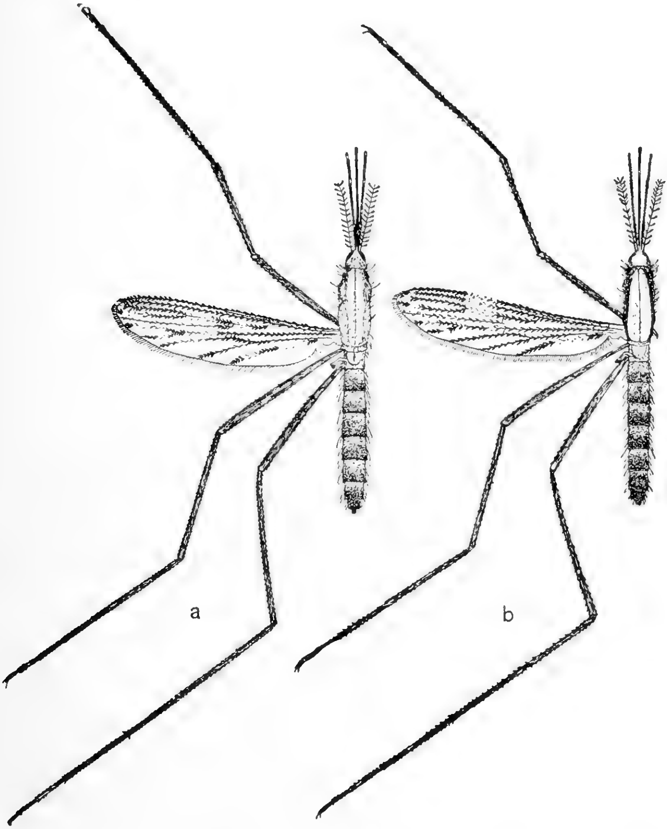


FIG. 18.—*a*, *Anopheles crucians*, female ; *b*, *A. punctipennis*, female (greatly enlarged).

velopment of the tiny parasite which does so much mischief and is such a curse to our Southern States.

It is really very beautiful, too, but it is doubtful if it is one of the things whose beauty will ever be appreciated. When your teeth are chattering, and all your bones are filled with a thousand aches, and your head feels like an over-ripe pumpkin in the sun, it is small comfort to meditate on the marvellous transformations going on within your blood. You are n't grateful for being selected as the vehicle for such miracles of nature—not a bit.

The best place at which to start in following the life of the parasite is at the "amebula" or "plasmodium" stage (Fig. 19, page 92). At this period the animal is a single cell, a shapeless, jelly-like lump appearing as a spot inside a red blood corpuscle, where it moves, or rather flows about, with the streaming motion of an ameba, feeding on the corpuscle and destroying its red colouring matter (hemoglobin), until the corpuscle is all eaten up except its wall. When this has come to pass, the parasite, having literally eaten itself out of house and home, finds it high time to be moving. It has devoured all there is to devour. The next stage is a non-sexual reproduction. First, the nucleus of the cell splits into several daughter nuclei. (A nucleus is a sort of lump of specialised, dense protoplasm within the cell protoplasm, or jelly, and on it evidently depends the life of the cell.) Each of the daughter nuclei proceeds to take its equal share of the property—that is to say, the protoplasm of the mother cell. This done, they burst out through the membrane of the used-up corpuscle and go house-hunting, each locating in a new corpuscle. There is probably a certain amount of poison set free from the broken corpuscle when the young amebulæ, now called spores when outside the corpuscle, break loose; the amebula being supposed to produce a toxin while eating the contents of the corpuscle, this poison consisting of the waste products of the amebula's digestion. This toxin, when set free in the blood, affects the temperature, the result being a chill. Now is the time for quinine. There is no corpuscle wall to protect the spores, they are free in the blood serum, and thus the drug has the best effect.

If no medicine is given, the spores simply go on invading more corpuscles, developing into amebulæ and again sporulating, the victim meanwhile becoming worse. But the process of reproduction by spores cannot go on indefinitely. After a time some of the amebulæ take on another form, that of the "crescent" or "gamete," very marked in the estivo-autumnal malaria. This process is thought to commence in the bone-marrow and internal organs.

Some of these gametes, somewhat larger than the rest, develop small threadlike bodies, which break loose and swarm freely through the blood. These are the male elements, or microgametes. Wriggling through the serum, these come into contact and unite with other gametes (macrogametes), the female elements, which have produced no flagellæ. This conjunction is fertilisation. But the union never takes place while the blood is within the human body, only after it has been removed. Otherwise the gametes may persist indefinitely in an inert form in the

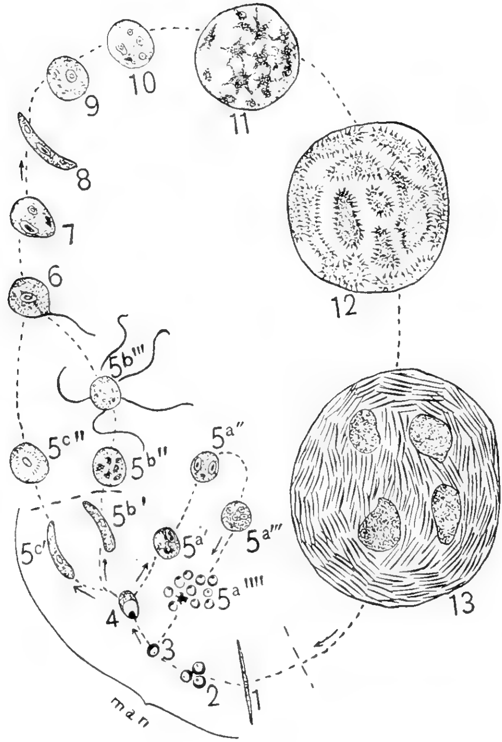


FIG. 19.—Development of malaria parasite, showing some of the stages, greatly enlarged: *1*, sporozoit; *2* to *4*, amebulæ; $5^{a'}$ to $5^{a''''}$, asexual reproduction in human blood; $5^{c'}$, $5^{b'}$, crescents; $5^{c''}$, macrogamete; $5^{b''}$, $5^{b'''}$, male gametocyte forming microgametes; *6*, conjugation; *8*, vermicule; *9 to 12*, amphiont developing to, *13*, last stage where it is filled with sporozoits. Stages *1* to $5^{b'}$ and $5^{c'}$ in human body; others in mosquito. (Adapted from Grassi.)

blood. If the removal has been by the bite of any insect whatever, the conjugation of the micro- and macrogametes will occur, but unless the blood has entered the stomach of an *Anopheles* mosquito, the development will cease here.

Supposing the *Anopheles* has been the biter, the result of the union is the vermicule (oökinet), a worm-like thing which penetrates into the wall of the mosquito's stomach—no doubt a most uncomfortable process for the insect. Under the thin outer muscular layer of the stomach these vermicules locate and grow at a rapid rate, distending the peritoneal (outer) surface of the stomach as they increase in size, soon becoming plainly visible under the microscope. The nucleus of the amphiont, as the body is now called, next begins to divide and, as occurred in the division of the nucleus of the amebula, each nucleus takes for its portion a mass of protoplasm, stellate this time, and goes on splitting up until the final result is a great mass of nuclei (each nucleus the centre of a rod-shaped body, the sporozoit), which lies in bundles in the amphiont. Then the capsule of the amphiont ruptures and the sporozoits, 10,000 or more, escape into the body cavity of the infested insect and make their way to the cells of the salivary glands. Thence they go with the saliva into the first person whom Madame *Anopheles* bites, and, unless the victim has a good resistance, they seek for a blood corpuscle, seize upon it and recommence the life cycle as amebulæ, just the same as did the spores. There is a certain amount of evidence to indicate that a gamete in the blood may retrograde and give rise directly to young parasites. If this is the case, it will explain the supposed power of crescents to produce relapses.

Not everybody who has malaria can have the fun of retaliating on a mosquito. Unless the insect bites after the macro- and microgametes are developed, there would be no infection of the mosquito. Also the patient must have enough gametes in his blood for them to be found in the capillary circulation, where the insect can reach them. Dr. Johnson says that the malaria parasites have their winter quarters in the human body, because the female mosquitoes do not make a meal just before hibernation. But, as Dr. Smith remarks, they may bite during the winter in a warm house. Also, as he further states, there is good evidence that the parasites may remain inert for a long time in a person, manifesting activity when, in some way, the physical force of their host is weakened. Thus the gametes lying dormant in the blood of an apparently healthy person who has come to a non-malarial locality may be taken by an *Anopheles* and start an epidemic.[1]

Malaria may be roughly divided into benign and malignant infections. Many authorities refuse to recognise the existence of more than one species or variety of malaria parasite. We have described five —two of benign and three of malignant infection. That there are others may be confidently postulated, for we have a number of imperfectly classed forms of fever, characterized by clinical symptoms so different

[1] The observations in the remainder of the chapter are from Dr. Dupree's notes.

from those of the fevers here mentioned that they cannot usually be recognized as the product of any one of the malaria parasites with which we are familiar. They also differ from one another so markedly in their clinical manifestations that they may be regarded as entities.

Benign malaria has two species of parasites: tertian and quartan; in the former the fever recurs every two days, in the latter every three days. If the chills come every day it signifies that in a tertian case there has been a reinfection on an alternate day. As the parasites develop at a constant rate, the two sets sporulate twenty-four hours apart, the liberation of the spores and toxins into the blood causing the chill. It is during the chill that the action of quinine is most effective, the organisms being unprotected by the walls of the corpuscles.

Malignant malaria (estivo-autumnal fever, hemorrhagica, tropical malaria, congestive malaria, etc.) has three species of parasites: pigmented quotidian, unpigmented quotidian, and sub-tertian. In congestive malaria the fact that the organisms throng the kidneys, liver, brain, and spleen, while in the other forms the parasites live in the red blood corpuscles, would, in itself, indicate that these were a different species from the protozoa of the benign infections.

Relation of Parasite to Intermediate Host.—Dr. Miajiama, of Tokio, seems to have shown that there are certain species of mosquitoes capable of conveying only one species of malaria parasite. In Japan proper, he declares, only one kind of malaria (tertian) and only one species of *Anopheles* (*sinensis*) occur, while in Formosa three well developed kinds of malaria and at least six different species of *Anopheles*

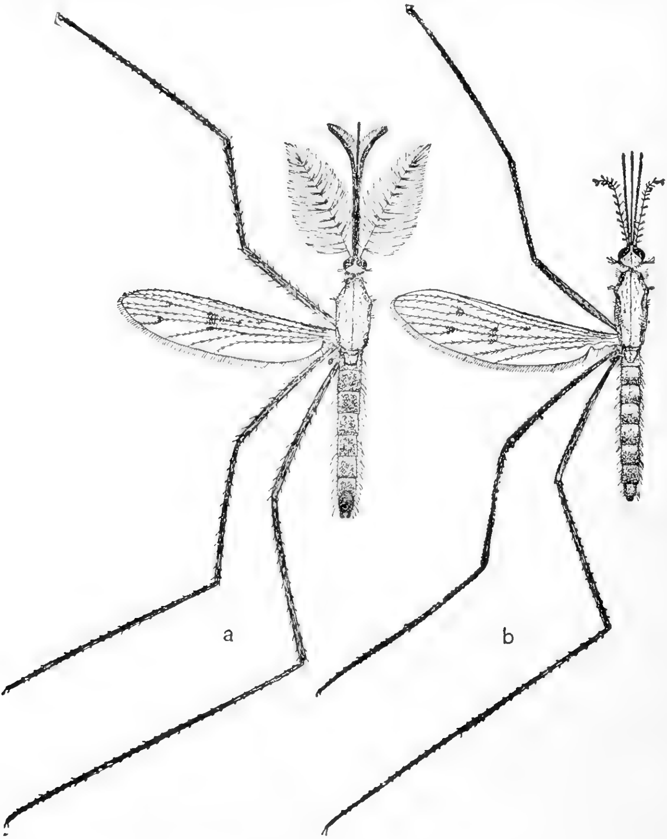


FIG. 20.—*Anopheles maculipennis* (greatly enlarged): *a*, male; *b*, female.

are found. It would seem also that the intermediate host may impress on the parasite special properties and biological characters.

The tertian parasite consists of a small pale speck on or in the red blood cell, exhibiting almost incessant ameboid activity, which persists during growth and the acquisition of pigment, diminishing as colour increases; its pigment granules are relatively fine and are in active and constant motion; the corpuscle invaded by it is much enlarged and often discoloured, and the hemoglobin of the former, when subjected to Rornanski's stain, shows chromophile particles. The spores of this form of parasite, fifteen to twenty in number, are small, smooth, and round, arranged irregularly, with one or more masses of pigment. Its gamete is a spherical body. The cycle is twenty-four hours, causing a fever that recurs every two days. It occurs alike in temperate and tropical latitudes, and is often encountered as a double infection, giving rise to quotidian as well as tertian ague.

The quartan parasite in its epicorpuscular and unpigmented intracorpuscular life, like the tertian, appears as a small rounded clear speck, its ameboid movements, however, are feeble as contrasted with those of the tertian, and cease entirely on becoming pigmented. Its pigment is larger in amount and coarser in grain, sometimes forming short rods; its spores, numbering from eight to ten, are placed symmetrically around one or two massive blocks of black pigment, daisy-fashion. Its gametes, like those of the tertian, are spherical pigmented bodies, but are smaller. It does not cause enlargement of the invaded corpuscle, as does the tertian, but fills it entirely when mature. It is more often found in peripheral blood than are the other sorts of parasites.

Its fever recurs every three days. It is relatively much more common in temperate latitudes than in the tropics. The entire intracorpuscular cycle is completed in the peripheral blood, and here its sporulating form is also more often seen than is the corresponding phase of the other malaria parasites. There are more parasites, and therefore it is more liable to recur, than the others.

The pigmented parasite of quotidian malignant infection gives rise to a fever of irregular duration. Its gamete is a crescent. The unpigmented parasite of quotidian malignant infection resembles it very closely. Both these have a cycle of approximately twenty-four hours; both exhibit very active ameboid movements when growing, and tend to assume the ring form. They are much smaller than either of the benign parasites, occupying from one-fifth to one-third of the corpuscle only. They both form little heaps of from six to eight very minute spores. In the unpigmented parasite, pigment is never present except in the crescent phase, when it is never absent. The fevers to which both give rise usually run an irregular course with dynamic tendencies, great proneness to relapses, rapid destruction of blood corpuscles, and the production of cachexia.

The sub-tertian is the usual parasite of malignant infection, resembling in many respects the tertian of benign infection, but is much smaller, occupying when mature only from one-half to two-thirds of the corpuscle, which it alters in colour, sometimes causing it to shrink, shrivel, or double up. Its spores, usually ten or twelve in number, are arranged, along with the clump or clumps of pigment, in an irregular heap; its gamete, like that of the pigmented and unpigmented parasites of malignant quotidian infection, is a crescent. The fever is irregular, rigour is not as prominent; pyrexia is more prolonged, often exceeding twenty-four hours, and the incursive paroxysms tend to overlap.

Hemoglobinuris has symptoms, distinctive and alarming, so that it should be regarded as having an etiology distinct from that of ordinary malaria. Although all known varieties of human malaria parasites have been found in the blood and organs of hemoglobinures, such findings in a population so unusually affected with malaria as were the inhabitants of the lowlands of Louisiana between Baton Rouge and New Orleans, when these lands were practically a rice field, do not establish a chronological relation of a cause and effect, their presence being simply a matter of coincidence. Nor is there any warrant for the often repeated assertions that the present almost complete exemption from this disease in this region and the comparative freedom from all forms of malaria are due to a more universal and a more liberal use of quinine, for exactly the reverse is the case. Then the vast majority of practitioners combated both these ailments with enormous doses of this alkaloid; now most physicians terminate ordinary malarial fevers with relatively small quantities of quinine, and eschew its use entirely in the treatment of hemoglobinurinic fever, believing its action harmful rather than helpful; in this opinion they are sustained by high authority.

Clinical observation has established for malarial parasites a latent phase of existence; concurrently with the subsidence of acute symptoms they may disappear from the peripheral circulation. This takes place sometimes spontaneously, but generally by the

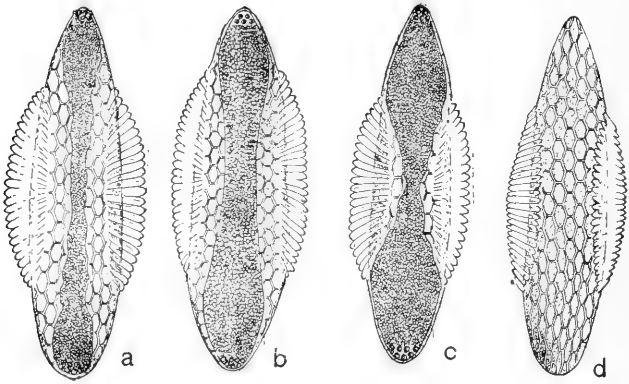


FIG. 21.—Eggs, top views: *a*, *Anopheles crucians*; *b*, *A. punctipennis*; *c*, *A. maculipennis*; *d*, lower side, *A. maculipennis* (same scale as Plates VI to VIII).

use of quinine. This vanishing is not permanent, for in the course of weeks or months they reappear in the general circulation simultaneously with a renewal of clinical phenomena. As to the particular organs or tissues in which they return, or as to their morphology and histology during latency, we know nothing definite, nor are we better informed as to the conditions which cause them to assume active, propagating, circulating existence. We do know that any and all agents that lower physiological resistance in their host tend to bring about conditions which break up, and that quinine and vital vigour make for conditions that form latency.

The foregoing account, so far as it relates to the clinical manifestations, applies only to uncomplicated typical infections. Since there may be, and frequently is, an infinite variety as regards the number of parasites present, different degrees of individual susceptibility, a concurrence of several species, or a number of generations of the same species maturing at different times, there may be a corresponding variety of clinical manifestations, a detailed description of which, did space permit, would be, as Manson has truly said, but an uninteresting and unprofitable ringing of the changes on rigour, pyrexia, gastritis, bone-ache, prostration, and other morbid phenomena. The picture would be further confused by the fact that the natural progress of the disease is generally broken by the patient's use of quinine.

Malaria and Anopheles.—Wherever the seasonal prevalence of mosquitoes has been made the subject of careful investigation, the period of greatest intensity of malaria has been found to coincide with that of the greatest prevalence of mosquitoes of the genus *Anopheles*. It is not a disease necessarily concomitant with a tropical climate.

CHAPTER VII

YELLOW FEVER AND OTHER DISEASES

Is Yellow Fever a Protozoan Disease?—Although the parasite of yellow fever has never been found, the chances are that, like malaria, it is a protozoan. There are striking resemblances between the two diseases. Both occur in low areas and are commonest in the situations where, and seasons when, mosquitoes are most abundant, disappearing after the severe frosts, which drive the insects into hibernation. Direct inoculation of the blood of a patient will convey either disease. To quote from Dr. Calkins's paper, read at the meeting of the American Association for the Advancement of Science in New Orleans:—

"The asexual protozoan organisms are transferred from the warm blood of birds, or mammals, or man, to the cold environment of the insects' digestive tract. This is accomplished in the case of malaria by mosquitoes belonging to the genus *Anopheles*; in the case of bird malaria, by *Culex*; in the case of sleeping sickness, by the tsetse fly; in the case of Texas fever among cattle, by ticks belonging to the genus *Boöphilus*. Where the full life history has been made out, it has been found that conjugation takes place within the body of the insect, and here, therefore, vitality of the parasite is restored. What is known to take place in some of these well authenticated cases is presumably true in the case of yellow fever."

He then goes on to tell how, in various protozoa, the vitality decreases with repeated division until reproduction by division will no longer take place. The vitality can be stimulated to a new cycle by artificial means, but, after a time, this too fails and only conjugation will prevent the death of the protoplasm.

He says :—

"Such artificial stimulation suggests the possibility that in certain human disease, such as malaria, the organisms may become exhausted so far as the division energy is concerned, but may remain quiescent in the system, hibernating, as it were, in some organ until, owing to some change in the chemical composition of the blood, an artificial stimulus renews the division energy and a recurrence follows.

Turning now to the data that have accumulated in regard to the organism of yellow fever, we must note that the rapid development in the blood indicates that the organisms have been killed off through excess of their own toxins, or by accumulations and actions of the autobodies. The long period of incubation in the mosquitoes indicates that processes are taking place in the development of the germs which can be explained only on the supposition that conjugation phenomena, analogous to those in the malaria mosquito, are taking place, and this supports the view that in the human blood the organisms are endowed with a high potential of vitality. Again, the filtration experiments, in which it has been demonstrated that the organisms may pass through the finest filters known to us, indicate that the organism is among the smallest of living beings, and belongs to that group which is rapidly becoming more than hypothetical—the ultra-microscopic forms. The small size may be a result of rapid multiplication, and it is not improbable that, after the incubation period, larger forms will be recognised in the digestive tract of the mosquito and in the salivary glands. . . .

A single genus of protozoa is known at the present time that fulfils all the conditions of the yellow-fever organisms; amongst its species are some that are at times ultra-microscopic, that have a characteristic change of hosts from warm-blooded forms to mosquitoes, and that are characterised by remarkable virulence. This is the genus *Spirochæta*, and in it alone at the present time do we find the type that satisfies all the conditions known of the organism of yellow fever."

Dr. Carroll also puts the argument for the theory of a protozoan strongly:

"It seems quite rational to exclude it from the bacteria, because: (1) It has never been cultivated nor stained by any of our known methods. (2) The work of Marchoux, Salimbeni, and Simond has shown that the blood of a patient after its withdrawal loses its power to infect within two days, if kept exposed to the air, and within five days if air be excluded. (3) The disease has been shown to be absolutely non-contagious in regions where *Stegomyia fasciata* (*calopus*) is not present, *i. e.* in Petropolis, near Rio Janeiro. (4) We know no bacteria that live in the tissues of animals as the yellow-fever organism does in the mosquito, for months, as a harmless parasite. The logical conclusion, therefore, would seem to be that the parasite of yellow fever belongs to the animal kingdom, because: (1) It is absolutely necessary for its continued existence that it pass alternately through man and the mosquito, and the parasitic existence in those hosts is obligatory. (2) The fact that a period of about two weeks or more must elapse before the contaminated mosquito is capable of infecting, points to a definite cycle of development in that insect. (3) The limitation of its developmental cycle to mosquitoes of a single genus, and to a single vertebrate, conforms to a natural zoölogical law, and does not agree with our present knowledge of the life history of bacteria. (4) The effects of climate and temperature upon *Stegomyia*, and upon the rate of development of the yellow-fever parasite within the body of that insect, are exactly the same as the effects of the same conditions upon the *Anopheles* mosquito and the malarial parasite."

Infection.—The shortest period of incubation within the insect is twelve days. The invalid usually manifests the first symptoms within five days after having been bitten, and the germ is accessible to new mosquitoes only during the first three days of the fever. To be on the safe side, however, the physicians hold the patient as possibly infectious for four days, and the mosquito so on the tenth. The shortest term in which the disease can be transmitted from one patient to another is the sum of the two periods of incubation, that of the insect and of the human—fifteen days in all.

Yet, in spite of all the experiments of Reed, Carroll, Lazear and Agramonte in Cuba (described at length in Dr. Howard's *Mosquitoes* and in other publications), which clearly demonstrated that supposedly infected clothing, bedding, or other articles can not possibly convey the disease, that only the bite of an infected mosquito or the subcutaneous injection of blood taken from the general circulation during the first and second days of the fever can possibly transmit the infection and in the face of recent demonstrations of the fact in New Orleans and elsewhere, there actually remain physicians who still cling tenaciously to the notion—I almost said *superstition*—that the disease may be carried otherwise than by the mosquito. Not long ago I talked with one who still insists, though he admits the mosquito theory, that it may also be conveyed after the manner of typhoid. He is a fine physician, but he never studied zoölogy. In the light of recent scientific developments, it seems to me that a short course in invertebrate zoölogy, with particular reference to parasitic forms, is an essential to the making of an up-to-date doctor.

Yellow fever has never been contracted, so far as experiment goes, from air, soil, water, or any other infected media, nor even from dead bodies. This all agrees with the protozoan theory, and it is conclusively proved that yellow fever is not contagious.

The work of the French Commission at Petropolis, a town at an elevation of three thousand feet at a distance of twenty-five miles from Rio de Janeiro, is a good illustration of the case. Nobody can find *Stegomyia* in Petropolis, and nobody ever developed yellow fever there spontaneously. The French Commission produced it there, however, by the bites of infected insects brought from Rio. There is yellow fever continually in Rio, and also plenty of the mosquitoes. Non-immunes with business in Rio make it a habit to sleep at Petropolis, and thereby escape.

The authorities at Rio are perfectly convinced of the truth of the mosquito theory. Dr. Oswaldo Cruz, Director of Public Health, conducted a most vigorous campaign against the insects in the year 1903, spending over $65,000 per month from April to December on the work of the sanitary brigade of about two thousand men, which thoroughly and systematically went over the city, isolating and screening patients, destroying insects in the infected houses, wiping out breeding places, moving patients to hospital, and even fumigating the main sewers.

FIG. 22.—*Stegomyia calopus*, female (greatly enlarged).

From vessels entering the harbors any patients are at once removed and secluded, the vessel rid of mosquitoes and their breeding places, and all passengers landing given a health certificate and kept under medical supervision for twelve days. Then the vessel is permitted to have free intercourse, and admits a health inspector on board, who will accompany the vessel to its last Brazilian port, and examine daily, with care, all the passengers and the crew, and isolate with netting any who show symptoms of fever. If mosquitoes be present, their immediate destruction is ordered at once.[1]

The New Orleans Epidemic of 1905.—The recent epidemic in New Orleans might have been easily prevented had the inhabitants listened a couple of years ago to the warnings, and followed the advice, of Dr. Kohnke. He was unfortunate enough to be ahead of his time and to have to deal with a large number of illiterate foreigners as well as with an unscientific and somewhat careless better class. Dr. Kohnke prophesied — and had the reward of a prophet. He explained, he lectured, he tried to have the cisterns screened, he did everything that he could; some laughed openly, some listened and did not understand, others deliberately turned their backs. Most went on carelessly, thinking that there were a great many more vital questions than that of mosquitoes. Then they woke up — after they had it. But, when they awakened, they fought, and the result was as great a victory as that won by any general or admiral of modern times.

It was a terrific contest, conducted under the most adverse conditions. When it began there were hun-

[1] Otto and Neuman.

dreds of cases. It was hot weather — late July. The part of the city first and worst infected was thronged with an unsanitary, ignorant, superstitious class, fearful alike of police and physicians, drawing their water from open cisterns, or, generally, from open barrels in which the river water is allowed to stand and settle. The inhabitants of this section resented and feared inspection. They systematically hid fever cases and could not be made to see the danger from mosquitoes. Had it not been for the intelligent coöperation of the clergy, the task in this quarter would have been appalling. It is a pity that mosquito breeding in New Orleans is not subject to a fine, as it was in Havana, especially as 75 % of New Orleans was non-immune, against 90 % of immunes in Havana.

The regular city organisation, with its central headquarters and eighteen ward headquarters, each in command of a medical officer with one to six medical assistants, inspectors, fumigators, screeners, and supplies, all under Dr. J. H. White, worked side by side with the Citizens Volunteer Ward Organisation, which screened and oiled cisterns, oiled and salted gutters and pools (950 miles of gutters were salted), and sometimes fumigated houses — this last, on account of the indifference or opposition of the inhabitants, being very difficult. Systematic house to house inspection was begun in the infected district and kept up until about October. More or less of such inspection was carried on all over the city. When a case was reported, warning was at once given to the ward headquarters. The patient was at once removed to the emergency hospital if willing, if not he was screened, removed to another room if not too ill, and his room fumigated, then returned and the rest of the house — including the chimneys—submitted to a thorough fumigation and cleaning, repeated before twelve days had elapsed, to make sure that no infected insects remained. Cars and freights were disinfected, this being mostly unnecessary but done to satisfy the popular demands. In proof of his view that most of the car disinfection and relaying was superfluous, Dr. White states that on the Louisville and Nashville coaches, which ran without relay or disinfection from New Orleans 116 miles to the Alabama State line, where they were relayed, several score of quarantine guards, who travelled in the cars with the passengers in all hours and weather for the entire time of the epidemic, were not stricken with any kind of fever whatsoever, nor were any of the train crews taken ill, notwithstanding the fact that the trains passed through the most infected district in the city. Dr. White does not believe that the *Stegomyia* often travels far from its birthplace, citing that, in all cases where a town had been infected and the disease traced, it has been found to be due to some virulent person coming there during the incubation period of the fever.

This would hold true on a ship; the mosquitoes would probably not fly out to a ship in the harbour, but if there were mosquitoes breeding on the ship, carried there by launches, or when the ship was in the dock, etc., and an infected person, after boarding the ship, was bitten, of course infection of the mosquitoes on board would follow. Dr. White says that there is no more rationalism in quarantining yellow fever than there would be in quarantining typhoid—indeed there is less, because it may be stated as an absolute and invariable law that a case of yellow fever known in the first two or three days of its existence, and to which proper measures can be applied, presents absolutely no menace to the community, not even to the family resident in the house with it. But, of course, quarantine of the city is necessary so long as the people persist in concealing cases and will not take proper sanitary precautions.

They made a good fight in New Orleans, unselfish, patient, sensible, systematic, scientific—and they won. Those who have never been long in the city, especially in the infected districts, can never appreciate just what it was with which that gallant band of citizens and officers had to contend. All praise to them—the loyal workers and the level-headed, wise directors. The fever was extirpated, but New Orleans is not yet immune, nor will she be until, like the cities of the north, she posseses city waterworks, underground sewerage and drainage, and stone pavements. They will be the best investment she can make.

The *Matin* reports that Drs. Marchoux and Simond who, under Dr. Roux, Chief of the Pasteurian School, have studied the disease at Rio for the last five years, entirely reject the hypothesis that the yellow fever of Panama can possibly differ from that of Havana or Rio. In fact their results confirmed those of Finlay, that *S. calopus* is tne only agent transmitting the disease.

Strangely, and, what is more, dangerously, the French Commission reports that there is no danger of an infected mosquito biting in the day, and that *Stegomyia* attacks thus only in the first week and a half of its life, after that feeding only at night. This last is certainly not the case in Baton Rouge and New Orleans, as the insect may bite there at any time of day, if it be not too sunny, and there is no reason to think that a free, infected mosquito would do any differently from those fed on ordinary blood; these last certainly make subsequent meals during the daylight hours. Therefore, notwithstanding the French to the contrary, gloves and veils are not to be despised as a means of protection during an epidemic, in this country at least. Nevertheless the prophylactic measures adopted by the French at Rio have lowered the mortality, from 2500 to 2000 annually, to 45.

But if the French Commission firmly believes that *S. calopus* is the only agent of transmission, it also holds that, during the first three days of the disease, the mosquito can be infected otherwise than by biting a patient with characteristic yellow fever.

It, as well as others, has admitted the fact that there is always a latent source of danger in the weakened yellow fevers unrecognised by the physicians, which, nevertheless, furnish the elements of infection to the mosquitoes. Among these weakened yellow fevers MM. Marchoux and Simond quote particularly those of very young children, who oppose to the virus a remarkable resistance, thus concealing its character and preventing the taking of isolative measures, as well as the presence of such fevers among the immunes by habitat. The physicians of New Orleans used to believe that, as although Creole children had what was called the "prevailing fever," yet did not have characteristic yellow fever, therefore the two fevers were not the same. This old belief in the immunity of native-born children was exploded by the Yellow Fever Commission of 1897. Since then we have known that the almost complete exemption enjoyed by children in practically endemic areas during years gone by was not due to inherent vital resistance, but rather to immunity acquired by an attack of the disease in infancy, when the resistance is high and the disease therefore mild and thus unrecognised.

Can Yellow Fever be Transmitted through the Egg?—If, indeed, yellow fever is due to a protozoan, it is quite within the range of possibility that the organism might pass into the eggs of the infected mosquito and thus infect the second generation of insects without their ever coming into contact with a yellow-fever patient, just as the Texas cattle fever is transmitted from the tick to its eggs. Though the experiments along this line have, for the most part, been negative in result, still they have not been altogether so. It is true that Reed and his associates in Havana found that the bites of fourteen mosquitoes, hatched from the ova of an *S. calopus* which had already shown itself capable of conveying the disease, did not transmit the infection. But Simond and Marchoux did actually transmit yellow fever to a voluntary patient with the aid of a mosquito produced from an egg laid by a virulent mosquito. They say that the mosquitoes can thus be infected at birth, and the germ passes through the different stages of the insect's life cycle in a virulent condition if the egg is laid by a mosquito which, after having been infected, but before ovipositing, goes through the twelve days necessary for the proper incubation of the fever organism.

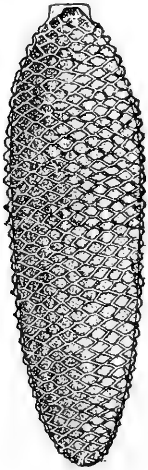


FIG. 23.—Egg of *Stegomyia calopus*, (enlarged about 114 times). Originally published in *Boys and Girls*.

The French doctors do not fail to make about this very important experiment the reservation that it is the only one, and, in consequence, cannot be considered as definitely demonstrative. But even if such infection happened only rarely, the knowledge of its possible occurrence is nevertheless important as explaining the sudden epidemics of yellow fever which break out mysteriously with no imaginable importation of cases or of infected mosquitoes. While an isolated test, made in an infected locality, does not absolutely satisfy the very exacting demands of science, the known ability of the scientists, the high character of their previous work, and the caution with which the experiment was conducted, all go to support the belief that egg infection is within the range of biologic possibility.

"If," says Dr. Dupree, "we admit contagious transference from mosquito to mosquito through the egg, two questions present themselves: First, What proportion of the eggs are thus endowed? secondly, How long can the hibernating or dormant egg retain the infection in a virulent condition? It is possible that the infection will lose its virulence in wintering over; it is also possible that it will not lose it at all, or may do so partially, and thus produce mild, unrecognised cases which, in their turn, may produce virulent ones. In the present state of our knowledge, data for answer to these queries are extremely meagre. Parker, Beyer, and Porthier report that in mosquitoes contaminated by feeding on a yellow-fever patient the ova primarily take on a hypertrophy, but subsequently begin to degenerate until there is practically nothing left but fibrous tissue. Were this true in every instance, the possibility of ova infection as a means of propagating yellow-fever would receive a most positive and absolute denial. While we do not question the accuracy of this observation, we must, after the experiments of the American and French Commissions, regard such degeneracy as exceptional."

To establish the connection between the so-called *Myxococcidium stegomyiæ*, by some suspected of being the "yellow-fever germ," Dr. Carroll made some experiments. He found fusiform yeast cells in the diverticula of a very few males of *S. calopus* in alcohol, received from the Department of Agriculture. An ellipsoidal wild yeast was then isolated from an old banana, and insects were subsequently fed on the fermenting fruit, to which the yeast, in pure culture, had been added. As a result, bodies identical in appearance with the fusiform stage of the so-called *Myxococcidium stegomyiæ* were found in nearly fifty insects that had never been in contact with a case of yellow fever. There were obtained, in one instance, as the result of feeding a male insect on wild yeast and banana, sections which show these organisms among the muscular tissues of the thorax, many of them lying in close proximity to the salivary glands. This organism appeared to be not a protozoan, as classed by Parker, Beyer, and Porthier, but a wild yeast.

Just here I may be permitted to remark that the mosquitoes and eggs furnished to Dr. Carroll by Dr. Howard were reared in the laboratory at Baton Rouge, where the fungi had already been observed in non-infected Stegomyias fed on rotten fruit, a fact that Dr. Carroll does not fail to mention. Whether these bodies belong to the vegetable or to the animal kingdom, the fact remains that they were found in the mosquito's esophageal diverticula, the thoracic muscles, and also in the salivary glands, from which they may be injected along with the saliva while the insect is feeding. According to Dr. Carroll, the researches of Robinovitch show that the ellipsoidal wild yeast may be pathogenic for the lower animals. Similar forms have been isolated from the broken-down nodules of spurious glanders. Among the multitudes of blastomycetes so universally disseminated in nature, it would not be a matter of great surprise if some should prove to be pathogenic for man.

Christophers and Stephens have noted the occurrence of sporozoa in the ova of certain species of *Anopheles*, also the presence of the gregarines in the

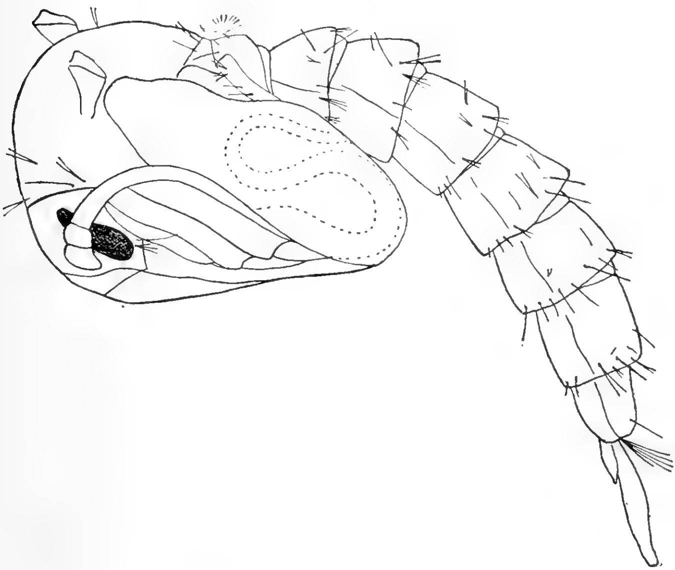


FIG. 24.—Pupa of *Stegomyia calopus* (greatly enlarged).

gut of mosquito larvæ. Referring to the parasites found by American authors in the diverticula of *S. calopus* these observers remark that they are quite common in other species of the genus, and regard them as belonging to the genus *Nosema*.

Grassi describes sporozoa and other similar objects in the body cavity of mosquitoes. Johnson, in Massachusetts, describes the finding of gregarines in *A. maculipennis*. They were on the outer surface of the stomach, on the Malpighian tubes, and in the salivary glands. They resemble malarial oöcysts in appearance.

Filariasis.—*Filaria*, the cause in the Orient of elephantiasis, is by no means unknown in this country. There is one case of several years' standing in Washington, D. C. In this individual, a drop of his blood, taken after 8 or 9 P. M., will show several active worm-like embryos. During the day, as is always the case with this disease, the embryos retire to the capillaries of the lungs. The adult *Filaria* lives in the lymphatics, especially in the glands. Here the female gives birth to a vast number of capsulated embryos, which often choke up the lymph vessels. The result is that the connective areolar tissues fill up with lymph and the parts swell to enormous size. The embryos swim about in the lymph and thence make their way into the blood. Dr. Manson, connecting the nocturnal appearance of the parasites in the peripheral circulation with the night-feeding habits of mosquitoes, began a series of observations which proved his suspicion to be true. The intermediary host in this case is apparently not confined to a single genus, but several species of both *Culex* and *Anopheles* may carry the parasite, which is somewhat unusual. The embryos lose their capsules and work through the stomach wall of the mosquito into the thoracic muscles, where, for a period of from fourteen to twenty days, they remain quiescent, growing and developing into larvæ. They then become active and make their way through the cavity of the body to the connective tissue in the forward part of the thorax in front of the muscles. By the twentieth day these larvæ have gone into the head and beak, by which route they are transferred to the human subject, in whose lymph glands they become adult and probably pair. A patient with *Filaria* should certainly not be allowed to run at large without any precautions, especially as the common house mosquito is supposed to be one of the intermediary hosts, and it may be that other insects than mosquitoes are able to transmit the disease, though from the laws of parasites this is very improbable.

Other Diseases.—Mosquitoes also come under the accusation of conveying that most loathsome disease, leprosy. As leprosy is due to bacteria it follows that any mosquito might carry the infection under the proper conditions. Other biting insects, as fleas and bedbugs, also fall under a ban in this respect. (See the Appendix, p. 267).

In the U. S. Marine Hospital Service laboratory experiments were conducted with a view to ascertaining whether or not mosquitoes can convey a bacterial disease from infected to healthy animals. The experiments were conducted with anthrax, very virulent pneumonia coccus, and *Bacillus icteroides*. *Culex pipiens* or *S. calopus* was used. The experiments resulted negatively, except in two instances where, after several weeks' exposure to the mosquitoes, two white mice died of anthrax.

CHAPTER VIII

MOSQUITO REMEDIES AND ENEMIES

REMEDIES may be treated under two heads: local, when in reference to a single house or a small number of dwellings; and general, when in reference to a very large area. Dr. Howard and Dr. Smith have gone thoroughly into this subject, and it is from the latter that many of the observations in this section are taken.

Local Remedies.—If your house is infested, the best thing to do is to find out what sort of mosquitoes they are, then you will know where they are apt to be breeding. Next, if they are from a distant salt marsh, you will have to screen. If not, find their breeding place. If it is water standing in a receptacle that can be dumped, dump it; if it is a puddle that can be filled by a few barrels or even a cart-load of earth, fill it; if that chances to be impossible, oil it. An ounce of cheap kerosene or fuel oil, applied carefully with a spray or otherwise, will cover fifteen square feet of surface, and, if not in a place exposed to currents of wind, will last for several days, trapping the adults that come to deposit, as well as suffocating the larvæ and pupæ by entering their breathing tubes when they rise to the surface. All bodies of standing water which cannot be drained, filled, or screened should be oiled at least once in three weeks.

Dr. Smith suggests keeping a half tub with about six inches of water in the bottom for the purpose of attracting stray insects to deposit eggs therein, and emptying it every day or so. This, during early spring, catches the species which hibernate in or around the house. It is an excellent way in which to control the breeding about a house, but needs careful attention. Cellars should be fumigated, especially to kill hibernating specimens in the fall. Cisterns or rain barrels should be screened or, if this is not possible, oiled. Oil also keeps the dust out. The tap should be near the bottom of the receptacle. If oiling is distasteful, however, a few "killies" may be introduced to devour the larvæ. All cesspool covers should be tight and their ventilators screened. Manure pits should be covered or oiled with fuel oil—not with a germicide. Water in chicken coops, etc., should be changed regularly; fire-buckets, gutters, etc., should be systematically inspected at intervals of from three to five days. Plumbing and pipes should be kept in order. Near-by vacant lots should be visited, and cans and other collectors of water emptied and smashed or buried. The neighbours ought to be induced to feel responsible for such places. Greenhouse tanks are a prolific source of mosquitoes; sticklebacks or oil will remedy this. *Anopheles* is apt to breed in the overflow of clear springs; this should be watched for and the overflow led in a clear drain. Post-holes, cow-tracks, and other small holes should be filled in with earth and ashes.

Lily ponds or watering troughs, where oil is undesirable, should be stocked with small fish, and as the larvæ congregate and eggs accumulate around the margins of such places, the edges of the water must be deep enough to permit the fish to work. Long grass and weeds, unnecessary vines and bushes where the adults may hide, should be cleaned up, lawns cut, vacant lots kept clear of growth, and tree holes filled. Sewer catch-basins should be oiled two or three days after each heavy rain, and about every ten days thereafter. If it rains heavily about the end of the ten days they are safe for a few days more. But it should be remembered that a very little rain will wash the oil down the sewer, and it takes a fairly heavy downpour, as a rule, to wash out the eggs and larvæ.

Chemical Destroyers.—If one does not object to the odour, kerosene or fuel oil are cheap and sufficient remedies, especially for sewer catch-basins. Soluble crude petroleum, Phinotas oil, or chloronaptholeum may be used. The last is quite expensive, but, as it poisons the water thoroughly and becomes mixed through it, it continues effective against the larvæ for some time, even when considerably diluted. It does not, however, kill the pupæ, nor does it act well in water containing more than a trace of salt. This preparation, sold by the West Disinfecting Co., of New York, costs $1.00 per gallon, and should be used at the rate of 1 part to 50 parts of water. It is a disinfectant as well as a larvicide, and is good to use in places where oil would be found objectionable.

Phinotas oil is the most effective of all larvicides, both suffocating by film and poisoning the larvæ. It kills larvæ and pupæ in a very short time but, as it also kills everything else, it is useful only for lot pools, cesspools, sewers, and the like. It is made by the Phinotas Chemical Co., New York, and costs about forty cents per gallon. It is of no value in salt water. Two ounces suffice for the ordinary sewer catch-basin. It should be sprayed through a fine rose nozzle, with a gardener's syringe, as should the other destructives, or by a sprayer in large areas. This method insures the best distribution and most economical use of the oil. As a very little goes a great way, it is really not particularly expensive.

Phinotas oil and soluble crude oil are theoretically the best larvicides, but they are dirty and also too destructive to aquatic life, beside not disinfecting as well as some of the Cresol preparations for gutters, etc. A soluble crude oil, prepared by a Baltimore firm, destroys larvæ and pupæ, but the infested area in this case soon becomes reinfested, and as the other water insects are killed at the same time, the last condition is worse than the first.

Kerosene has been used as a larvicide as far back as 1845, by Delboeuf; and in 1812 it was suggested in a work by Robert Southey (published anonymously) and entitled "*Omniana* or *Horæ Otiosiores*," that pouring oil on water at the seasons when they emerge and when they deposit their eggs might lessen the number of mosquitoes. Kerosene does not harm fish, or aquatic insects that do not breathe at the surface. It acts well in salt water, the chief trouble being that the wind drives off the film. This oil is not disinfecting, and, after a few days, may impart a slight taste to water in cisterns or barrels, unless the film is very thin. The cost is thirteen cents per gallon or less; an ounce, sprayed on, covers fifteen square feet, and it kills not only larvæ and pupæ but catches the adults; it is, therefore, by virtue of its simplicity, cheapness, and efficiency, the best larvicide for many purposes, where the odour is not offensive nor disinfection desirable. The effectiveness of a film of kerosene will last one or two weeks with no rain, according to temperature and amount of shade. Calculating on the average growth of a larva, oiling with fuel oil once in fifteen to twenty days will be absolutely safe. Crude petroleum, having a tendency to form masses rather than films, is not as satisfactory.

The "Bordeaux Mixture" of lime and copper sulphate, and the last in simple solution have popularly been supposed to be good larvicides; but Mr. Dickerson's experiments prove them to be unreliable as such. As, however, they kill out the algæ and microscopic forms in a pool, thus destroying hiding places and food of the larvæ, there is undoubtedly a great diminution of larvæ on that account. It might be worth trying, where there are no fish, but as copper sulphate is fatal to many of the finny tribe and harmless to most larvæ, its use in fish ponds is not to be recommended.

While salt prevents many mosquitoes from ovipositing, yet it does not, in many cases, kill larvæ already in the water, but simply hastens maturity. It does kill the newly hatched larvæ of some species, and it is my impression that *Stegomyia* is one of these, but I cannot find the notes on this point. Salting the gutters would kill much of the food of the larvæ—thus, to some degree, reducing them by starvation.

Lime in large quantities keeps the nuisances out of buckets, pools, etc., and is to be recommended for barnyards and muddy pools, as the results last for a long time. Much must be used, and it is ineffective when there is much addition of water. Chloride of lime, as ordinarily applied for disinfecting purposes, is a good larvicide for gutters and drains.

As for permanganate of potash, it is of no use whatsoever.

Repellents for Adults.—Dr. Smith says that for years he used a repellent consisting of a mixture of oil of tar, oil of pennyroyal, and olive oil. It is not to be wondered at that any respectable mosquito would flee from such a concoction. He also states that oil of citronella, which has an odour not unpleasant to most people, is thoroughly protective, and, when there is little perspiration, lasts for an hour or more. It stings if it gets into the eyes.

Fish oil, with a little crude carbolic acid, will keep the mosquitoes from horses and cattle. As Dr. Smith remarks, the actual monetary loss resulting to dairymen from the lessened flow of milk, consequent to continual fighting of mosquitoes, would go far toward eradicating the dangerous breeding areas.

The following mixture is, I believe, the best: Cedar oil, one ounce; oil of citronella, two ounces; spirits camphor, two ounces. A few drops of this on a

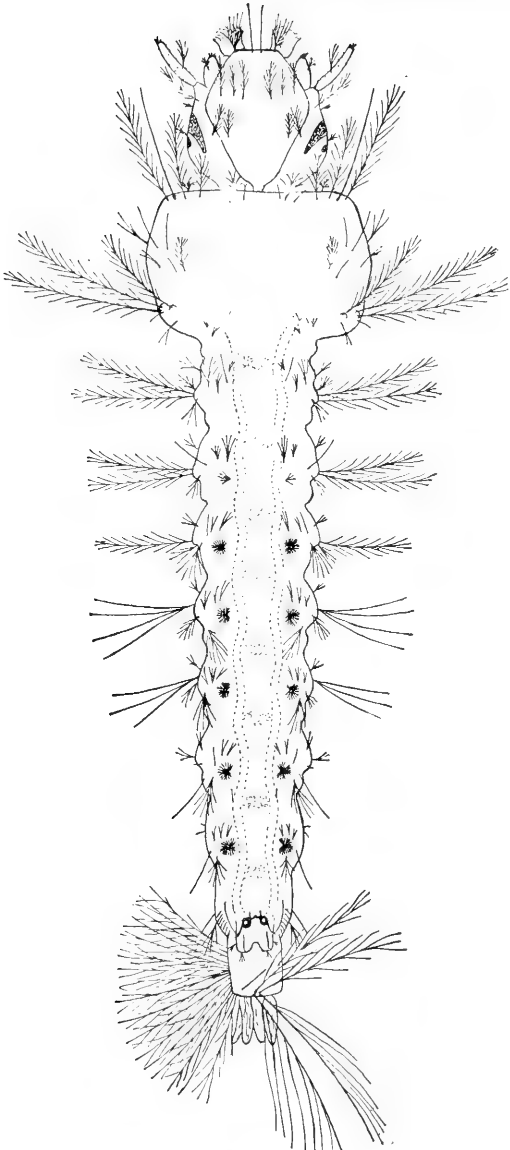


Fig. 25.—*Anopheles maculipennis* larva, dorsal view (greatly enlarged).

cloth hung on the bed will keep mosquitoes at a distance, and the efficiency continues for a long time.

Tobacco and punk sticks do very well in a general way, but do not prevent the ankles being bitten. Mosquitoes do not appear to like moth balls, or naphthaline, and I have successfully used these, powdered, in low shoes. Most of the mosquito cones on the market contain naphthaline and pyrethrum.

General Remedies.—It is better to permanently eradicate the breeding places than to be continually treating them; over large areas constant oiling is almost impossible, and, even if feasible, is more expensive in the long run. In the case of troublesome marshes, the destruction of breeding places is the only possible course. Dr. Smith says that ditches from two to two and one-half feet deep, and six inches wide, at intervals of from sixty to one hundred feet, are best for an ordinary marsh. About eighty per cent. of marsh land can thus be treated. Where the marshes are too soft for the narrow ditches to hold, wider ones must be dug. The object is to prevent the formation of pools by rains or tides, and all surface water should be removed by proper drainage within forty-eight hours. Large holes in the marshes should be filled unless big enough so that fish can dwell there, but over large marsh areas ditches are all that is necessary. Just enough drainage to remove all surface water in forty-eight hours is necessary; it need not be such as to fit the land for agricultural or other purposes. A hole twelve inches or so in depth will collect water drained from the surrounding soil, and, especially if close to high tide, dry so slowly as to give ample time for development. A large, single, depressed area in an otherwise safe space is best converted into a permanent pool at least two and one-half feet deep, stocked with killies. A shallow pool would soon fill up with vegetation, becoming a good breeding place. Sods should never be left where they can fall in the ditches, but are useful in filling up holes. If a marsh can be burnt over, it seems to drive the mosquitoes off the next season, and also to promote the levelling and drying of the land.

Ditching may be accomplished by hand or by a machine. In extensive work, machine ditching, which should cost little over one cent per running foot, or perhaps one and one-half if sods are to be removed and holes filled in, is cheapest. Hand ditching costs one and three-quarter cents at the highest. On the Newark meadows the "True ditcher" is used, cutting from 3000 to 4000 feet of ditch two feet deep and from six to twelve inches wide per day. Long, narrow steel spades are used in hand ditching; square-edged, to cut the sides; curved, and a little grooved, to level the bottom. Ditch bottoms should be level and outlets wide.

Where there is much sand, ditching is ineffective; in such places and in swamps with no outlets, situated among sandhills, filling is the only remedy. The large areas must be filled by hydraulic dredges, which process costs fifteen cents per cubic yard—an expensive method.

Woodland swamps are best drained, unless densely overgrown with tall vegetation. The open areas harbour danger, if partly filled with reeds, lilies, and such plants, because fish cannot well go through such spots. If these places cannot be drained, they should be cleared of vegetation, the edges depressed, and fish introduced. The material removed may be used for filling. Oils do not readily spread among the grasses, and are ineffective in such places, while the chemicals supposed to mix with water cannot, as a rule, be used in sufficient quantity.

Anopheles frequently breeds in the grasses along the edges of slow streams, or in overflow pools on their margins. Such streams should be cleaned, or the bed deepened and the edges filled. Oil is quickly carried away, even in a sluggish stream.

Old mill-ponds, or pools with boggy margins, are also menaces. Around the margins of these the imprints of cattle hoofs remain, collecting enough water to breed many mosquitoes, especially *Anopheles*. Such ponds should be drained, or the margins cleaned and deepened to at least eighteen inches and a stock of fish put in.

Graders frequently dig up the sides of roads to mend the centres, thus producing places for puddles. When a soft spot exists in the road it is often a good plan to give it a chance to harden by throwing upon it grass and weeds cut from the roadside.

Mosquito Enemies.—Dr. Dupree writes on this subject as follows :—

"Most if not all insects have their natural enemies, a fact the early recognition of which is evidenced by these well-known lines of Swift:

> 'So naturalists observe, a flea
> Has smaller that upon him prey;
> And these have smaller still to bite 'em,
> And so proceed *ad infinitum.*'

Of which a more popular alliterative and generalised version is:

> 'Big bugs have little bugs
> Upon their backs to bite 'em;
> And little bugs have lesser bugs
> And so *ad infinitum.*'

"Mosquitoes are not exempt, but, like the rest of the insect world, must needs fight for their lives.

"Among the most important enemies with which the mosquito must contend are the following, named in the order of their importance: fishes, birds, predaceous insects (including certain mosquito larvæ), reptiles, crustaceans, and certain lower forms of animal and plant life, as hydra, infusoria, and fungi. Many species of fish devour mosquitoes in the egg, larval, pupal, and adult stages (in the last stage just as the adult emerges, or during the oviposition period). This gustatory election is not common to all species of fish, which accounts for the apparent contradictions that appear in communications from different observers in various parts of the world respecting their mosquito-destroying efficiency. Capt. James asserts that he found fish constantly in company with culicid larvæ in the rice fields of southern India. Col. Giles, on the other hand, declares that in northern India he never met with fish and larvæ of Culicidæ in company. Nuttall, in England, claims to have found *Culex* and *Anopheles* larvæ ten times in company with fish; while Mr. Aitken reports that he never found larvæ and fish in the same pool, adding that of all larvicides the most effectual in the case of *Anopheles* are little fishes. These discrepancies in no wise discredit the accuracy of the observations they record, but clearly show that the tastes of different species of fish differ like those of other orders of animals. Impressed with the economic importance of fish as factors in the destruction of gnats, a number of observations have been made by us with a view of determining the larva-feeding capacity of the various species that inhabit our local waters, from which we have reached the conclusion that for the maximum of efficiency no species so nearly suffices as does top minnows (*Gambusia affinis*). It is true that they are omnivorous and soft-rayed (objections urged against their general employment as mosquito exterminators, and in favour of wholly carnivorous and spine-rayed species), but we are persuaded that their diminutive size, extreme vitality, restless activity, exceptional reproductive capability, and surface feeding habit will more than counterbalance the advantages claimed for those species of wholly carnivorous appetite and with greater freedom from molestation by larger fishes. In fact we have long since learned the utter futility of searching for culicid larvæ in pools that harbour top minnows. The presence of minnows is to us sufficient guarantee of the absence of mosquito larvæ. Observations during the summer of 1902 fully justify the latter statement. In a low-lying wooded area near a public road not far from the city of Baton Rouge there exist two depressions, one in either bed of the branches of a small stream that divides a short distance above the depressions. These depressions are similar in contour formation and alike in all respects save that one is somewhat the deeper in the most dependent part, and contains more or less water, stocked with minnows the year round. In the latter part of September both depressions were filled to about the same level by an unusually hard rain that succeeded a drought of sixty or more days. Exactly four days after this rain the fishless pool contained the larvæ of *G. jamaicensis* and *Janthinosoma posticata* in abundance, and a few larvæ of *O. bimaculatus*. *Psorophora ciliata* and *howardii* were full grown, or nearly so, as was shown by the pupation of many of them the following day; while a prolonged and most diligent search failed to reveal the presence of a single larva of any species in the pool that sheltered the minnows. From a third pool much smaller and about two hundred yards above, that was conspicuous for the absence of minnows, were also taken a large number of *J. posticata* and a few of both species of *Psorophora*. Again, during the summer just passed repeated examinations were made of the rice fields below Baton Rouge while they were flooded, with the invariable result of our failure to find mosquito larvæ; but minnows were everywhere in evidence and in enormous numbers. Two weeks or more after the water had been withdrawn (and presumably the minnows with it, since they usually swim with the current), leaving many pools and puddles in natural depressions and imperfectly graded ditches, whose continuity was maintained by frequently recurring showers of rain, we found mosquito larvæ in plenty, and during the early morning and late evening mosquitoes in such quantities that we dare not venture a story of our experiences or an estimate of the numbers of insects, lest it should be regarded as extremely 'fishy,' although the large fish were all dead, a fact forcibly impressed upon our olfactories at previous visits by the stench that arose from their decomposing bodies. We will leave its description to our farmer colleagues who own a plantation."

Pollywogs do not eat larvæ, though the fishes are so fond of the latter. Both the salt- and fresh-water killies, top feeders, devour them voraciously. These fish will live in cisterns and rain-water barrels, though in the latter, at least, they do not breed. The fresh-water killie is apt to eat the eggs of more valuable species, according to Mr. Seal, but, where there are none such, may be very useful. Mr. Viereck has determined its value as a devourer of larvæ so that, as it is, according to Dr. Bean, "one of the best of its family for aquarium purposes, as it thrives and breeds in captivity," it would be, as Dr. Smith suggests, worth experimenting with in cisterns. The top minnow was one of the first enemies of the mosquito to be pressed into service. As a surface feeder, an active species, fond of frequenting masses of vegetation and borders of ponds, and as a rapid breeder, it is the most efficient of all, being able to live in fresh or brackish water and in restricted areas.

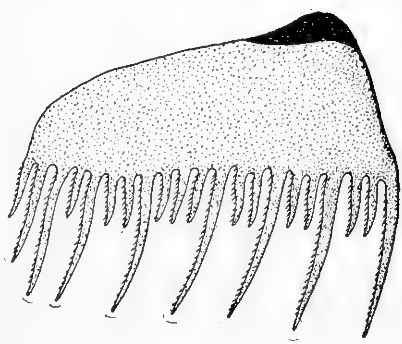


FIG. 26.—Comb of larva of *Anopheles maculipennis* (greatly enlarged).

The roach in ponds; the goldfish in fountains, small ponds, and quarry holes; sunfish in ponds; sticklebacks, which are bottom feeders, for ditches and pools, are also useful. Top minnows and sticklebacks are a good combination, making a division of labour.

Libellula larvæ, water beetles (except hydrophillids), *Corixa*, and *Nepa* are enemies. Larvæ of *Psorophora* and *Megarhinus* mosquitoes, being cannibals, are useful in that stage. Water "scorpions," isopods or "shrimps," *Corethra* larvæ, water striders, "water tigers" (the larvæ of *Dytiscus* beetles), and, in shallow ponds, dragon-fly larvæ, are great aids in controlling the mosquito pest. Dr. Smith says that the larvæ of dragon-flies are as little entitled to credit for effective work as the adults. They are bottom feeders as a rule, and usually far below the range of even *Culex*, while *Anopheles* is in no danger from them whatever. However, in the shallow pool on the Louisiana State University campus, Dr. Dupree and I have watched the larvæ do some very effective work on *Culex*, and have seen the adults snatch mosquitoes as they were issuing from the pupa skins.

The adult mosquitoes also have enemies in the shape of a mite or tick, about .5 mm. long, which fastens upon them, sucking the fluids from the body; also a tiny fly, about .2 mm. long. After the mosquito has had a full meal, and the abdomen is distended, both fly and tick will sometimes manage to penetrate to the stomach with their beaks and suck a meal of blood—decidedly a case of thief rob thief.

At times the mosquitoes are attacked by a parasitic round-worm, *Agamomermis culicis*. It is found in the abdominal cavity of all the stages, and therefore must attack the mosquito while in one of its aquatic forms. I have seen as many as three of these worms in a larva, filling up the greater part of the body cavity. This parasite was described by Dr. Stiles. There are other parasitic forms found preying on the Culicidæ. Indian larvæ are attacked by an intestinal gregarine [1]; *Anopheles* in Italy is harassed by a filamentous phytoparasite [2]; in Spain a pathogenic yeast has been found in the abdominal cavity of *A. maculipennis* and Acarines externally on Culicidæ [3]; while the adult female of *A. maculipennis* has also an intestinal infection of a parasitic flagellate [4]; *Anopheles* seems, by most poetic justice, to come under a special ban, for it is also afflicted by sporozoa [5]; and a small trematode [6]; sporozoa are found in *Culex* as well. [7] Dr. Smith considers that the parasitic worms of *C. sollicitans* form a very material check to its propagation, since where the parasites are present the ovaries do not develop, and large numbers of the females are often so infested. Infection, however, does not prevent migration nor biting.

[1] Ross. [2] Perroncito. [3] Laveran. [4] Leger. [5] Jonnson. [6] Martirano. [7] Mueller.

CHAPTER IX

NOTES ON THE COMMONER SPECIES[1]

Group I. Mosquitoes Known to Spread Disease

Anopheles.—The genus *Anopheles*, as the carrier of malaria, which kills 5,000,000 human beings a year in India alone, may fitly take precedence of the others. *A. maculipennis* (Fig. 20, page 96) is the worst of the three common species in this country, but the other two, *punctipennis* and *crucians* (Fig. 18, page 89) are also malaria carriers. Dr. Dupree showed me the parasites in the salivary glands of all three species. When he had any patient with malaria, he did not take a sample of the blood but let several mosquitoes, often different species, bite the patient, put them by to incubate, and at the proper time looked for the parasites. It used to be a joke among students at the college that, if you became ill, the Doctor would have you eaten up by his "pets."

Of the three species of *Anopheles* found at Baton Rouge, *A. crucians* is the most common during January and February in that locality, but the adults of

[1] Observations in this chapter, unless otherwise credited, belong to Dr. Dupree, except those made outside of the laboratory, which, with the exception of dates of capture, are chiefly supplied from my note-book.—E. G. M.

all three species are quite frequently met with out-of-doors during fall and winter, and will bite on warm days. The young larvæ were found as early as the

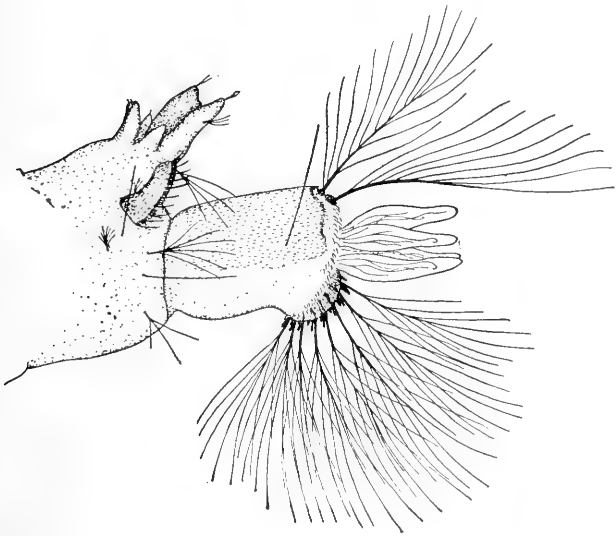


FIG. 27.—Air tube and ninth segment of *Anopheles crucians* larva, side view, greatly enlarged, showing only the branched hairs of the near half.

24th of February, but they cannot stand freezing, as do those of some other genera. A number of young *Anopheles* larvæ in jars in the laboratory were caused, by a temperature of 32° F., to fall to the bottom of the receptacles, where most of them died. A few, however, revived upon being warmed by the fire, having remained in a cold and torpid condition under water for many hours.

The members of this genus hibernate in the adult state, either out-of-doors under bark or in hollow trees or caves, or, which they greatly prefer, indoors, particularly in cellars and privies. They seek winter quarters at the first chill, and as, in the North, they frequently do not reappear until late May, the life of the adult is often eight or nine months. The males do not hibernate, the mating being in the fall. Dr. Smith says that the females do not feed before retiring, but are fat, the adipose tissue disappearing as the spring approaches, evidently going to develop the ovaries. Usually they stay in one spot all winter, hugging the wall closer as the weather is colder, extending the legs as it grows warmer, and not until summer weather has fully set in is there any attempt at flight (Smith). However, if it is a warm and open winter they may fly and bite, both outdoors and in; they will do it indoors anyway if the house temperature is high enough.

The attitude during hibernation is rather different from that assumed in warm weather, the hind legs being drawn in and the body brought close to the wall. In summer, as Cuthbert Clensby remarks, *Anopheles* looks like a thorn sticking in the wall, the hind end of the body being well elevated, at almost 90° to the wall, the proboscis in line with the body and the hind legs extended (but *not curved*) upward, waving about as feelers, to prevent a rear attack. Mosquitoes of other genera usually sit with the body parallel to the wall; they occasionally assume an *Anopheles*-like position, but in these cases, so far as the writer has observed, the hind legs are not straight but curved upward. The posture, the usually spotted wings, and the long black legs of *Anopheles* enable any one to distinguish them at a glance.

Many specimens die during hibernation, especially if the temperature fluctuates frequently.

The three malaria-carrying species of *Anopheles* are prolific breeders and greedy feeders, often voiding blood while sucking. Nevertheless, blood is not necessary for either mating or laying. A male and a female *crucians*, reared from larvæ collected by Dr. Dupree, were placed, on emergence April 21st, in a large cage with dried figs and a shallow saucer of water. On the 28th there were a number of eggs, but there is no record of their hatching.

Crucians is not recorded as depositing more than one batch, but *punctipennis* and *maculipennis* will ovulate several times. The following is the record of a specimen of *A. punctipennis*, which was kept for 19 days in the laboratory:

Fed blood, March 28.
Eggs, April 2 (302); hatched, 10th; pupa, 28th; adult, 30th.
Fed, April 7.
Eggs, " 7 (341); preserved.
Eggs, " 10 (263); hatched, 13th; pupa, May 4th; adult, 6th.
Fed, April 10.
Eggs, " 13 (272); hatched, 17th; pupa, May 5th; adult, 7th.
Fed, April 13.
Eggs, " 18 (257); hatched, 21st; (upset).
Fed, " 18 (has lost two legs).
Eggs, " 22 (134); (upset).
Died, " 22.

1569 total eggs.

Punctipennis may deposit more than 2000 eggs during a single breeding season, with but a single fertilisation, when supplied with blood.

From other experiments it seems that *A. punctipennis* at midwinter in Louisiana will lay eggs indoors in 3 to 7 days after feeding, that the eggs will hatch in the laboratory in 8 to 10 days, and that 6 or 7 batches are most frequent, but as many as 9 have been deposited. One fed January 26 laid between this time and February 20, 6 batches of eggs, the first ovulation occurring 4 days after the first repast, and the others from 3 to 5 days after each successive feed, one meal to a batch. She fed the same day she laid, immediately after oviposition if she had a chance, and escaped after her seventh meal. Another laid 8 batches at intervals of 4 to 7 days, feeding about the same way except that, having deposited eggs and been fed February 24, she laid her fifth and sixth batches February 28 and March 6 without a meal between them. Her last batch was February 10, and she fed immediately after.

The winter period of incubation was found to be from 2 to 58 days, generally (in the laboratory) 10 to 18. The winter pupæ came 18 to 25 days after hatching, the pupa stage lasting from 2 to 4 days. The time between a meal and laying is 3 to 6 days; *punctipennis* generally takes 4 days, sometimes 5. One of this species, captured December 12, not fed but put in a bottle with water, was active on the 19th, laid on the 20th, and died on the 21st. The eggs hatched February 6 to 8. In summer the cycle may be completed in 16 days, possibly less.

The adults are not very delicate, females of *A. maculipennis* having lived in the laboratory for as long as 7 days on dried figs, with no water. One *punctipennis*, captured and given blood December 12, lived nearly 7 days without any other food, even water.

The eggs resist drying fairly well. Some ova of *A. crucians* laid on the morning of March 7 were dried until the 17th. They were then floated on water, and on the morning of the 19th larvæ were found. The pupæ appeared on the 9th of April, the adults issued the 13th.

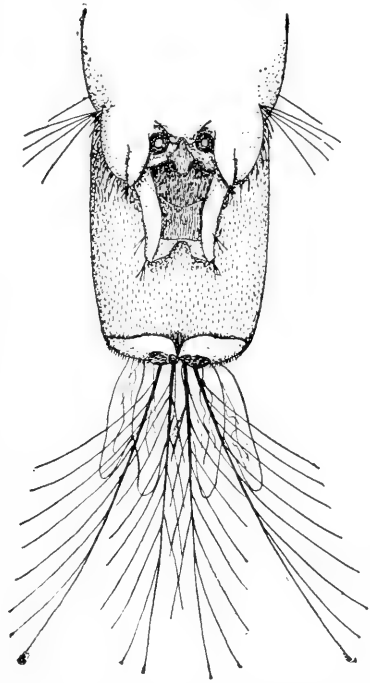


FIG. 28.—Air tube and ninth segment of *Anopheles crucians* larva, top view (greatly enlarged).

The ova of the three common species are easily distinguishable, as the writer found while drawing them for Dr. Dupree. The differences may best be told by the illustrations. We also managed to distinguish the larvæ of the three species, checking up our characters by identifying collected live wigglers and breeding the adults. The characters, though minute, are quite usable after a little practice. To procure absolutely perfect specimens we isolated the larvæ, to prevent their biting each other.

How far *Anopheles* can fly is uncertain. I am sure that they will go at least half a mile, and Dr. Smith says that he has reason to believe they will travel a mile or more, but do not do so habitually, the local confinement of malaria epidemics to the vicinity of breeding places and the practical exemption of large portions of even small towns where the fever breaks out every year, all indicating that the *Anopheles* are preferably home bodies. If there is need for a long journey to oviposit or bite, they attempt to make it.

The length of life in summer is estimated by Dr. Smith at a month. Since, as he remarks, *crucians* bites in the daytime, from sunrise to 11 A. M., and from 3 P. M. until after dark, the mere going early indoors is not a positive protection against malaria. In the South I have frequently been attacked by *punctipennis* at one or two o'clock on a bright afternoon, but when resting in a shady place. *Maculipennis* does not seem normally to feed during the day, though with some coaxing it may be induced to do so in the laboratory. Most *Anopheles* feasting, however, seems to begin about dusk, when they hold high carnival and raise their ribald drinking song, whose unwelcome sound I do not recollect hearing in the middle of the day.

There has been some discussion as to the attitude assumed by *Anopheles* while biting. To settle the point definitely, the author allowed *punctipennis* to bite her, and saw that the feeding posture was exactly like that assumed on a wall — the insect "stood on its head."

Anopheles evidently prefers houses to out-of-doors. Mr. Berkeley states that he has captured it in the open air in the latitude of New York only once in two years. However, the writer has caught *punctipennis* in the open in the lower part of the city of Ithaca near the marsh, and also along the Erie Canal, near Cohoes.

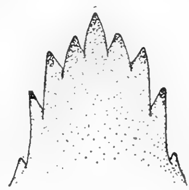


Fig. 29. — Labial plate of *Anopheles punctipennis* larva (greatly enlarged).

With the exception of *A. barberi*, which breeds in tree holes, is not known to carry malaria, and has not spotted wings like the others, the *Anopheles* multiply anywhere, in any water, even on salt marshes. The larvæ seem to like filthy water. Their colour, which varies much with age, food, and amount of light, and their habit of floating flat to the surface film, make them resemble bits of debris, rendering them inconspicuous. As from their manner of drifting the merest film of water gives them enough room, they find safe refuge in the film over lilypads and leaves and among the grass stems, grassy pools being almost invariably inhabited by the pernicious mites.

The larvæ have the odd habit of twisting the head around so that the under side of the head is upward, and they can skim the floating particles from the surface. It requires a distinct effort on their part to jerk away from the surface film, so well are they supported by the entanglement with it of the breathing tube and of the palmate tufts on their backs.

A. maculipennis is found all along the eastern coast, more abundantly northward, being found from Florida to Canada. *A. punctipennis* seems to have a general range throughout the country. *A. crucians*, while found in New York State, is most abundant in the South, being plentiful along the southern Mississippi.

Stegomyia calopus.—Convicted by a competent jury of scientists, upon the testimony of trained experts, of transmitting that most dread disease, yellow fever; suspected of further mischief of a kindred nature, and, by common consent, admitted to be the most pestiferous member of the whole family of Culicidæ, in the South at least, an effort to rob *S. calopus* of the only decent characteristic with which it is popularly credited would seem to be a matter of persecution. The larvæ, however, are frequently found in company with the typically foul water *C. fatigans*, in sewage polluted water. The larval stage of their existence is *much* shortened in the germ-laden fluid. In a saturated solution of fecal matter, this portion of its life cycle is but four days, as against a minimum of six in any other media with which Dr. Dupree experimented, the imagos from batches in this solution coming out in six days, while all in gutter water died in two days, and those placed in Mississippi River water survived but six days. These experiments were made in August and September.

Dr. Agramonte asserts that the eggs of *calopus* hatch sooner in lye of wood ash than in the dirty water of overflows or gutters, the larvæ emerging in from fifteen hours to three days.

S. calopus (Fig. 22, page 107) is pre-eminently a bacteria-eating wiggler—indeed, says Dr. Dupree, as a sewage devourer it is to be commended. This explains the lack of agreement in the past of the New Orleans observers as to whether or not it is a cistern breeder. If the cistern water abounds in live creatures, the larvæ will thrive, reaching the adult stage rapidly. If aquatic organisms are scarce, most of the wigglers will perish. Some, however, after a prolonged existence, will reach maturity but will be small in size. The Doctor reared them in jars of Baton Rouge hydrant water, which is practically pure, the larvæ apparently subsisting chiefly on what fell in from the air. Most of these larvæ did not live to pupate. When found dead in such vessels or in cisterns, it is not from drowning, but from sheer starvation.

Young, newly hatched *S. calopus* larvæ are remarkably tenacious under water. They were found to tolerate, with apparent comfort, three hours of continuous submergence and can be resuscitated after as much as five hours under water. The full-grown larvæ were found to be able to survive these conditions for one and a half hours without visible effect, and can be revived after two hours. Dr. Agramonte speaks of the *old* larvæ remaining under water for as long as four or five hours, but Dr. Dupree's invariably died after any such lengthy

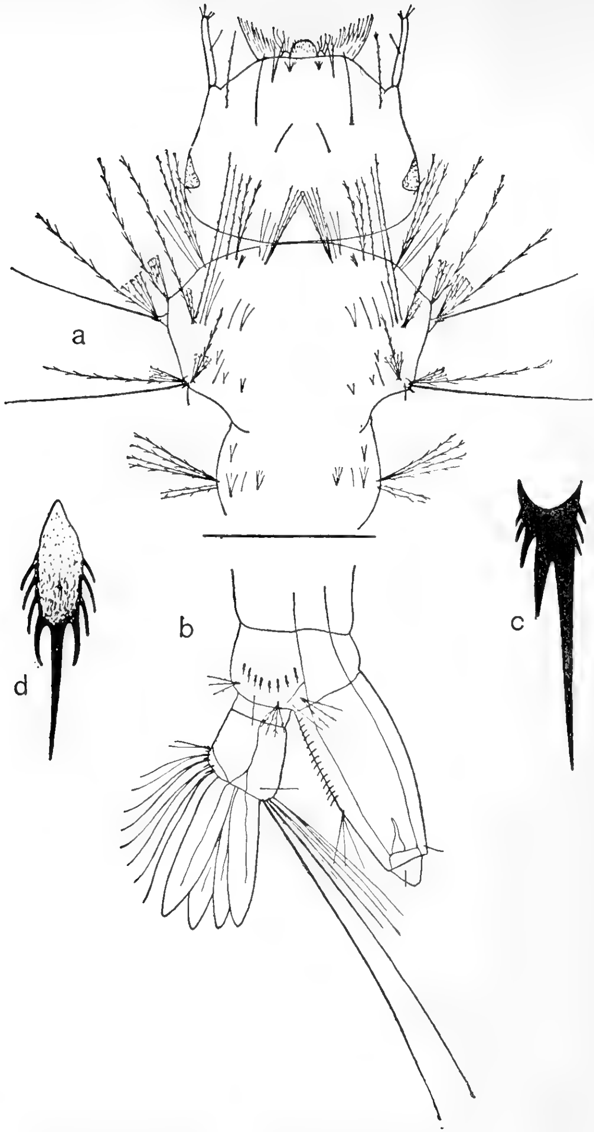


FIG. 30.—Portions of larva of *Stegomyia calopus* (greatly enlarged) : *a*, head, thorax, and first abdominal segment, dorsal view ; *b*, eighth and ninth segments, lateral view; *c*, spine from tube ; *d*, spine from eighth segment.

immersion. These data do not by any means apply to all the other Culicid larvæ, most of which are far less resistant.

Some *calopus* larvæ four hours old were alive after four hours of compulsory subaqueous existence, but were apparently dead after four and a half hours. They revived, however, on being placed in shallow water; so did also a pupa, after eighty minutes. A full-grown larva, re-animated after two hours under water, pupated during the night, and the imago issued about twenty-six hours later.

This ability to stay under water for so long a time will enable the larvæ to nibble on the bottoms of cisterns of the usual water depth in general use. Dr. Dupree examined a number of cisterns, finding the larvæ feeding thus in many instances. I cannot speak for New Orleans, but in Baton Rouge *Stegomyia* is principally a cistern, tank, bucket and tub breeder, and will also propagate in the house, lay eggs in your water pitcher overnight, and produce lusty crops of wigglers in flower vases or flower-pot saucers if water be left long in them.

The larvæ were sometimes observed feeding, of their own volition, at the bottom and at the sides of the vessel in which they were reared in the laboratory, for as much as two hours consecutively. This applies more especially to very young larvæ, whether they "flood their air chambers," or whether their anal gills sustain respiration while they are engaged thus in diving, the Doctor would not venture an opinion. Possibly the thinness of the skin at this stage aids in breathing. Full-grown larvæ never remained under water so long.

S. calopus adults were found out-of-doors in Baton Rouge from March 25 to November, and in the house in November. Larvæ were found out-of-doors November 15. Larvæ taken November 3 were imagos November 9; temperature, 56° F.; 50° numbed them, and they refuse to bite at that temperature, but can stand it as low as 34°. Larvæ will live in water of 50°, and pupate at 53°. Two individuals which imaginated November 3, lived to January 9. On that night the cold stiffened them, but one revived and fed. *C. restuans* in the same cage were not affected by the cold. *S. calopus* will mate and at times lay without feeding, but they generally bite two or three times before depositing the first batch, which is laid from six to fifteen days after the first meal. They average two or three batches, but will lay nine. There are from twenty-seven to ninety-seven eggs in a batch, extruded singly. They hatch in from six days to nine months after laying. The larval life is from eight to thirteen days in fairly warm weather, the pupal one to five. The adult can survive for six days with neither food nor water; females have lived sixty-one days on dates and water, males sixty-eight days. They generally bite three days after emergence, but may feed in twenty-four hours. They often mate five minutes after oviposition.

The following is a typical record. This female made a meal July 30 and mated the same day. She subsequently fed after each oviposition, immediately after leaving the water, except on August 16. She did not eat then nor until after laying, on the 17th. This female issued from a captured pupa July 29, mated in captivity with a male from the same batch; the male died on August 7, and the female laid eggs as follows:

August 5, 8 A. M. (66.)
" 10. Hatched 4 P.M., August 12.
" 12, presumably the night of the 11th. Hatched 10 A.M. of the 14th.
" 14, (49), 10 A.M. A few hatched in 24 hours.
" 16. Hatched August 18, 10 A.M.
" 17, 10 A.M. Hatched August 19, at 3 P.M.
" 19, (50), 10 A.M.
" 20, (45), 10 A.M.

The following is the record of hatching of the eggs laid on August 5; the jar was not shaken at any time during the incubation (unless on the 7th), and the larvæ were removed shortly after emerging:

Time of Hatching.			No. of Larvæ.
August	7,	8 A.M.	6
"	"	12 M.	2
"	"	1 P.M.	1
"	"	2 "	2
"	"	4 "	2
"	"	5 "	1
"	"	6 "	1
"	9,	9 A.M.	16
"	"	10 "	2
"	"	11 "	5
"	"	11:30 A.M.	2
"	"	12 M.	1
Carried Forward,			41

Time of Hatching.			No of Larvæ.
		Brought Forward,	41
August	9,	12:30 P.M.	1
"	"	1 P.M.	1
"	"	4 "	1
"	"	5 "	4
"	"	5:10 P.M.	4
"	"	5:12 "	4
"	10,	11 A.M.	4
"	"	3 P.M.	3
		Total	63

Three of the eggs did not hatch.

In Dr. Berkeley's *Laboratory Work on Mosquitoes*, Dr. Agramonte gives a number of interesting notes on *Stegomyia*. He speaks of never having found them in the open fields or in the woods. He notes that the larvæ are killed both by cold and drying. The adult, he says, may bite at any time, but does so chiefly in the late afternoon. In Baton Rouge I was troubled most before 9 A. M. in warm weather, and in the evening they were often troublesome beside a lighted lamp, though they could be escaped by sitting on the upper gallery. They used sometimes to attack us on the lower gallery on warm, bright, moonlight nights. In Para, says Dr. Goeldi, people are punctured from fifty to a hundred times a day, the insects being abundant in the houses and hovering in groups of from four to ten over each person—a pleasant state of affairs, indeed. Dr. Agramonte's specimens rarely fed before the fourth day, and oviposited at about this time. They could be kept seventy-six days in his laboratory and would infect fifty-seven days after biting. Not all which bite a fever patient at the same time are infected and allow the parasite to develop, the same being true with *Anopheles*. There is reason to believe, says Dr. Agramonte, that an infected mosquito can transmit the virus all the rest of its life; if this is so, one mosquito might be responsible for at least six cases of fever. He also makes an interesting statement to the effect that, especially in Cuba, ants will attack the adults, hanging viciously to their legs.

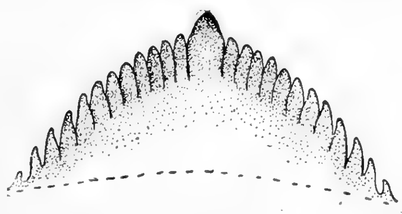


FIG. 31.—Labial plate of *Stegomyia calopus* larva (greatly enlarged).

I have taken the liberty of copying Dr. Agramonte's fine description of *Stegomyia*'s method of oviposition:

"The mosquito alighted upon the water, which was in a small beaker inside the jar, with legs spread wide apart. The abdominal segments being bent forward and downward, she dipped her whole body until the last segment touched the surface of the water; then she rose, walked a few steps and dipped again. This she would do repeatedly (fourteen to twenty-two times), when she would remain for a slightly longer time, with the last abdominal segment touching the water, and would allow a minute white egg to issue forth upon the surface. In this way she laid at the rate of three eggs per minute, resting quietly after every sixth or eighth egg for about thirty seconds, when she would resume the process."

Dr. Goeldi's experiments with about two hundred and twenty adults of *S. calopus*, as well as with two hundred and sixty *C. fatigans*, to discover the relation of repasts of blood to egg-laying and mating, are most interesting. He used both bred and captured specimens. He seems to consider blood necessary to the development of fertile eggs, in contrast to Dr. Dupree's tests, which show that it is not always so. His other conclusions, applicable particularly to *S. calopus*, are briefly as follows:

1. Both male and female eat honey, which prolongs life in captivity.

2. The female greedily seeks vertebrate blood; sucking it shortens her life by facilitating egg production.

3. Sucked blood favours and hastens egg-laying, the effect on the female being accentuated and immediately perceptible.

4. Honey has a retarding or neutral effect, as have other liquids.

5. With certain captive mosquitoes blood withheld or given will lengthen life, while retarding oviposition, or cause prompt oviposition at will of the experimenter.

6. In fertilised *S. calopus* the power to lay fertile eggs may be latent from twenty-three days to one hundred and two days, and awakened by a meal of blood.

7. A honey diet favours the individual life, but is disadvantageous to the species by retarding reproduction; blood diet is reverse in effect.

8. Bred, unfertilised females suck blood.

9. These females may lay eggs which are unfertile and do not hatch.

10. Oviposition finished, the female dies, generally at once; she may, of course, lay several batches before completing her task.

11. To deposit all her eggs *S. calopus* must feed on blood at least two or three times.

12. The time between eating and laying for *S. calopus*, on the average, is 88.8 hours.

13. The time from laying to hatching averages 4.5 days.

Dr. Goeldi blames steamers for the spread of *S. calopus*, which, with the spread of steam navigation up the Amazon, has gradually appeared and spread the fever through that valley. The males he speaks of as trying to bite, and thinks that they irritate the skin. He remarks that the adult *Stegomyia* in cages dance and hum when the late afternoon sun strikes in, the male humming above treble clef, 880 vibrations to the second; the female, at C in the treble clef, 480 vibrations. He seems to think there is also an obscuring octave overtone. *S. calopus* would not accept reptilian blood; would bite guinea-pigs, but decidedly preferred man. It did not, as do other mosquitoes, seem to object to draughts, nor even to an electric fan.

Stegomyia is of general distribution through the south, and has been reported as far north as New York, where it was brought by steamers, but it will not winter in so cold a climate. In dry seasons, with this, as with many other species, the adults will be dwarfed, so that they can come crawling through the nets. It is an essentially domesticated species. Its black-and-white dress renders it very conspicuous, so that it is often referred to as the "calico mosquito," and its day habits render its feeding much more unsafe than that of the noisy revelers who attack in the night.

Group II. The Salt-Marsh Mosquitoes

The three great nuisances of the salt marsh are *C. salinarius*, *O. sollicitans*, and *O. cantator*. The last two migrate in numbers for long distances, and thus, bringing trouble into a locality far from their breeding place, are a state or county rather than a city problem.

O. tæniorhynchus is also an inhabitant of salt marshes.

Culex Salinarius.—This species does not migrate very far. It is also the only one of the four which lays rafts of eggs, and which hibernates in the adult form. In Baton Rouge there are, of course, no salt marshes, but this insect breeds there abundantly in the swampy places. It evidently prefers clean water, and did not do well in fecal matter. Swarms rise quickly from the swampy land around the bayou early in the evening, attacking furiously when they have a chance, and frequently entering houses. Like *pipiens*, *salinarius* is a great singer as well as a hard biter. It so resembles *pipiens* that it is very difficult to distinguish the adults, though the larvæ are easily separable.

In the North this species breeds from about April to October, when the females retire for the winter; in Baton Rouge the adults are hard to find in December and January, but the larvæ are obtained as early as February 21 and as late as the last part of November, though I do not think these late batches often come to maturity.

The female does not wait to mate before she bites, and is ready for a meal within 12 hours after emergence. Often she feeds twice and lays 2 rafts of from 50 to 55 eggs anywhere from 2 to 10 days after her meal. The eggs hatch in from 2 to 4 days, the larval period is 18 to 24 days, and the pupal stage lasts normally 2 or 3 days, but may be extended by cold to 16. This insect the Doctor found to live for 17 days in captivity after emergence, and for 14 days without food.

Dr. Smith remarks that the egg boats of this species go to pieces rapidly and are difficult to discover, the larvæ occurring, as a rule, more abundantly near the highland than the shore, preferring rain pools or those formed by springs, but living both in fresh and in salt water throughout the marsh. Unlike the other marsh species, it is also found in the more permanent pools. He states that it is fond of hiding in cellars, great numbers being found in the basements of factories near the salt meadows.

This species is distributed along the eastern half of the United States.

Ochlerotatus sollicitans.—This marsh dweller, which enjoys the unenviable reputation of being the pest of New Jersey, breeds there only upon the salt marshes, though it also multiplies abundantly at Baton Rouge (Fig. 8, *b*, page 46). It is the commonest species along the eastern coast, and, from its numbers and blood-thirstiness, while not known to be a disease carrier, is yet of the greatest economic importance along the eastern shore, where, especially in New Jersey and Long Island, extensive and organised efforts have been made to reduce its myriads. Its golden-brown, white-sided thorax and the yellowish-white stripe down the centre of the abdomen, crossing the basal abdominal bands of the same colour, together with the broad, white, tarsal bands, render the adult easily recognisable.

They inhabit the salt marshes in hordes, hiding during the day in the grass or shrubs, whence they rise in great clouds at the least disturbance, and then—woe to the intruder! For the winged torments say little but proceed to work, frequently making the place utterly untenable. I have been simply routed by them in the meadows near Staten Island Sound. Never shall I forget several maddening hours in an open trolley car, stalled one night on the meadows between Newark and Jersey City. The insects came down like Morgan's raiders, out for blood and gore, piercing every bit of exposed skin and frequently biting through the clothing. Our ankles—a favourite point of attack with this species—were one furious itch. Finally, the men built a smudge, which gave some relief. It is said that people have been driven temporarily insane by the bites, and it is not hard to believe. Along the the Jersey coast *sollicitans* and *cantator* make life a song that is anything but sweet, especially to persons not fortunate enough to possess screened porches, though, luckily, they do not much care to enter the houses. Some of the streets in summer resorts smell like joss houses with the burning of punk.

This species mates readily in captivity. Dr. Dupree made a number of breeding experiments with laboratory-reared specimens. He found that the insects would live from twenty-five to thirty-five days. They generally feed twice before the first ovulation, which may occur eight days after emergence, the eggs being deposited singly on top of the water. In the laboratory we could induce them to lay nowhere save on water, though Mr. Viereck induced them to oviposit on moist material but not on water, dry sand, nor lint; and Dr. Smith finds that in New Jersey the eggs are laid all over the marsh mud and not on water, remaining on the mud or the roots of the grass tussocks until hatched by an inrush of water of the proper temperature. Thus it is seen that what may be true of a species in one place may not be so in another. Dr. Smith kept ova indoors, and exposed to the air of the room; they collapsed, as did also some in a closet when on lint or garden soil, but not those kept on the mould of black grass marsh. Dr. Dupree finds both in this and other species that if the eggs are dried before they darken, they collapse and will not hatch. It was noted by Dr. Smith that during a long, dry season the females would retain the eggs, which would develop so far as to blacken in the ovaries before oviposition took place, but normally eggs are white when extruded.

The experiments at Baton Rouge demonstrated that the first batch is generally extruded from eight to ten days after the first food has been taken, and that the average number of batches is three, of from fourteen to one hundred and fifteen eggs each, but often there are as many as seven batches, with sometimes some containing up to one hundred and thirty ova. One individual is able to lay as many as six hundred and fourteen eggs altogether in seven batches, over a period of thirty-five days, feeding nine times. The interval between the ovulations is four to seven days, with an average of five. Unlike the Jersey form, which is said by Dr. Smith to require drying, or at least twenty-four hours without being water-covered, as a prerequisite to hatching, the Southern form, even if under water from the first, would hatch if agitated after a few days. All the larvæ do not emerge at once, nor is agitation necessary, for if left to themselves they will come out after one hundred and fifteen to one hundred and forty-five days, the time of hatching extending over several days. The larval stage is about eight days, the pupal three to six. The adults at Baton Rouge were found from March 2 to December 3; in New Jersey, from late April or early May until late October.

When the tides or rains cover the eggs, the larvæ come in an incredibly short time, though all the larvæ of the same batch do not appear at the first wetting, a good thing for the preservation of the species in case the first overflow does not last long enough to permit maturity. Dr. Smith states that the wigglers thrive either in fresh or in salt water at the edge of

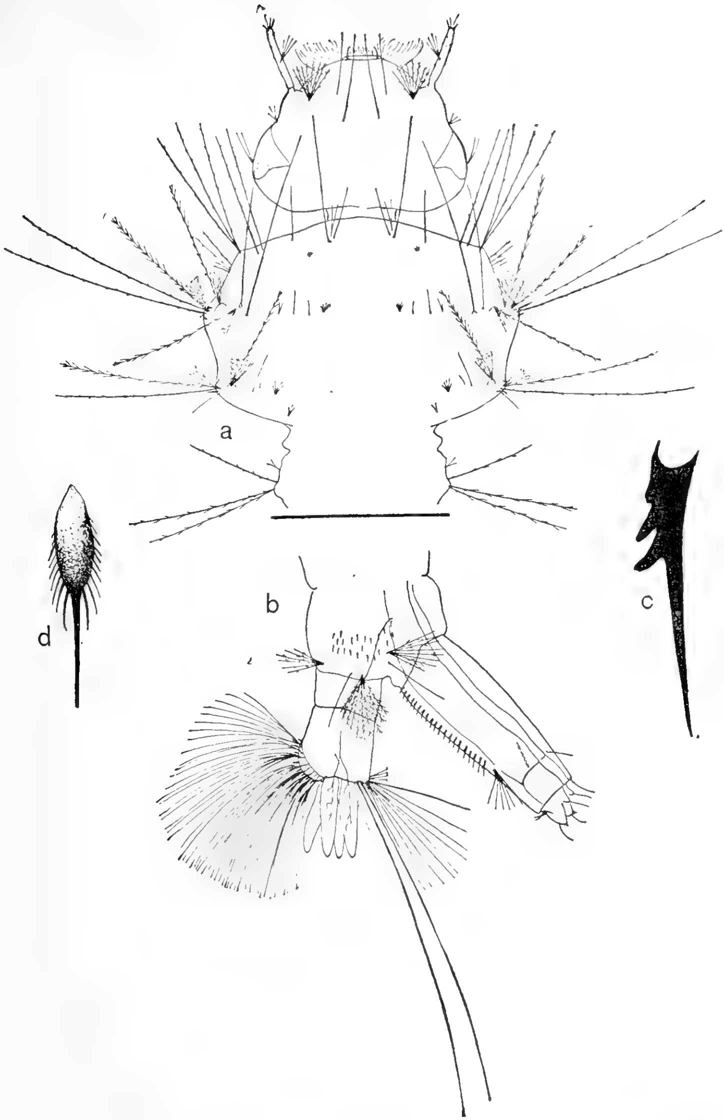


FIG. 32.—Portions of larva of *Ochlerotatus sollicitans* (greatly enlarged): *a*, head, thorax, and first abdominal segment, dorsal view; *b*, eighth and ninth segments, lateral view; *c*, spine from tube; *d*, spine from eighth segment.

the salt marsh, being found on the marsh, in the salt-hay zone along shore, and in grassy depressions among the sand hills where there was just a scum of the organic mud on the surface, sometimes in foul pools, preferably in clear ones, but never in clear, sandy-bottomed pools, or off of the marshes. He finds the larvæ to be quite tenacious, being able to live in soft mud for several hours, and complete their transformation if again flooded. Fish are fatal to the breeding of this species.

Ochlerotatus cantator.—This, the third of the marsh pests, commonly called the brown salt-marsh mosquito, is found in the north-eastern part of the United States, breeding in great swarms in the New Jersey and Long Island marshes and, like *sollicitans*, migrating inland in hordes. They have been traced from the coast as far as Morristown. Dr. Smith observes that *O. cantator* differs from the other migratory forms in that the sexes fly for some distance together, the males being able to stand a journey of a few miles, and also in that occasional females with developed ovaries are found far from any possible breeding place during the earlier part of the stay of an invading swarm, disappearing later. The insects bite hard, flying and feeding by day as well as in the evening, but sing little, and will enter houses, but do not crawl through nets. The eggs are laid after the fashion of *sollicitans*, but are larger and more numerous. The larvæ are found nearer the upland, but rarely on it, either in fresh or in salt pools, but preferably the former. The number of broods depends on the weather, but in midsummer, when the eggs are all over the marsh, each heavy rain or extra tide means a fresh batch of larvæ. The early brood hatches in March, the adults beginning to emerge early in April, finishing in May. A second brood is found about June, and breeding thereafter goes on all summer.

Ochlerotatus tæniorhynchus.—This is also one of the inhabitants of the salt marsh, though not found in such abundance as *sollicitans*. It breeds in fresh water at Baton Rouge swamp, and occurs along the coast from Louisiana to New York, more abundantly south. By day it often hides in the grass or shrubs, or in swampy woods, and will bite in the daytime during warm weather. Dr. Smith says that it migrates in small numbers, but not so far as do *sollicitans* and *cantator*.

The adults were taken at Baton Rouge from May 25 to September 5. They generally made a single meal, laying one set of eggs, much like those of *sollicitans*, but one specimen bit four times and laid two batches. They will feed both before and after mating. There are from sixty-one to seventy-one ova in a clutch, which is laid three to six days after biting. They hatch in from one to twenty-two days. The larval stage lasts four to seven days, the pupal twenty-four to thirty-eight hours. The adults lived in captivity twenty-five days, biting the second day after emergence. In habits the larvæ are much like *sollicitans* and *cantator*.

Group III.—Other Swamp Forms

Culiseta consobrinus.—This species is, in Louisiana, what might be called a midwinter form. Dr. Dupree remarks that it is taken from October 11 to April 4. It mates readily in confinement, and will do so in a space one and one-half by two inches. The act lasts from ten minutes to five hours. The female bites from one to four times before laying the mass of eggs, which will hatch even if the raft be broken up. There is generally one batch, but may be as many as six. On blotting-paper the eggs shrivel but swell again when placed on water; if dried more than a few hours they will not hatch. When separated they sink, but will come to maturity when submerged without being shaken. If they are put in formalin while white they will not darken. Larvæ will emerge at 50° F. The first eggs are laid from four and one-half to eleven days after the first meal, hatching in one to ten days; in three days at 70° F., and in eight at 52° F. The larval life is from ten to twenty-seven days, the pupal two and one-half to four. Sometimes it is as long, however, as fifty-one days from ovum to adult. The larvæ, when very young, show a tendency to gather in bunches near the surface. The female dies soon after depositing. They will live 38 days on dried figs with no water. They are very abundant in the shrubs on the Louisiana State University campus, also in the swamp. The species seems to be somewhat generally distributed over the United States.

Ochlerotatus sylvestris.—*O. sylvestris*, commonly called the swamp mosquito, is found where its name would indicate, in swamps and also in woods, lot pools and ditches, being apparently rather adaptable. It will not multiply in foul water, and Dr. Smith does not find it in salt marshes. It will breed successfully in hydrant water. The species enjoys a general distribution over the Eastern United States. It does not migrate in swarms, but Dr. Smith says that it can fly perhaps five miles, and will gradually, during a season, increase in numbers in a place by individual migration, being a considerable nuisance in some localities. We found the insects to be somewhat of a pest outside the house in Baton Rouge; but few came in, though the house was not screened. It seemed to be worst in the fall, and was troublesome in some parts of the city about the end of July. The adults were taken plentifully out-of-doors all the year, but hibernation in the egg stage is the rule farther north. There is laid one batch of single eggs deposited on top of the water, where, in the laboratory, they sometimes floated for a month or so. As a rule, however, they soon sink to the bottom, where they will lie for from four days to a year before hatching. They will emerge without agitation, but this accelerates matters. A few larvæ appear at a time, the process extending over a number of days. The insect bites once, rarely twice, before laying, the oviposition occurring from two to twelve days after the meal, the average being eight days, but on one occasion in the spring it was as long as twenty-six days after feeding. The larval period is from six to nine days, the pupal two to six days. In warm weather, out-of-doors, the whole cycle may be completed in five and one-half days. The larvæ were found out-doors in Baton Rouge from February 22

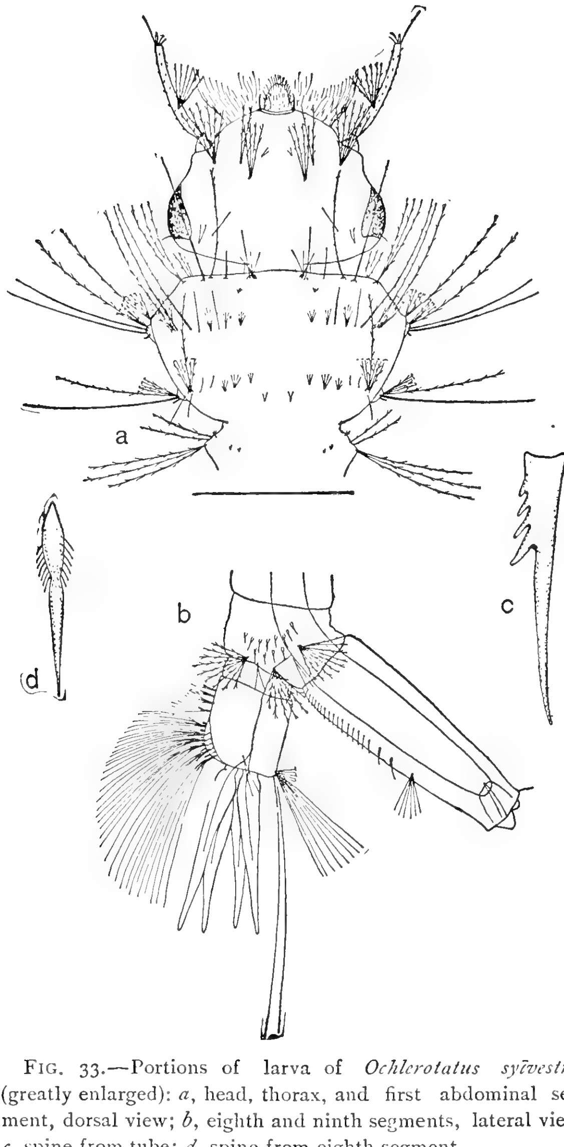


FIG. 33.—Portions of larva of *Ochlerotatus sylvestris* (greatly enlarged): *a*, head, thorax, and first abdominal segment, dorsal view; *b*, eighth and ninth segments, lateral view; *c*, spine from tube; *d*, spine from eighth segment.

to November 13; in New Jersey from early May to October. There are several broods in a season.

Ochlerotatus canadensis.—This species breeds in the larger pools and bodies of water in the wood-surrounded bogs of the eastern half of the United States. We found it at Baton Rouge in the willow pool on the campus, along the edges of the bayou, in woodland pools and in springs. It does not like foul water. Specimens in the adult stage were taken at Baton Rouge from April 18 to June 4; Dr. Smith took them from April 27 to as late as September 21, the greatest abundance being in May; and new larvæ in February and in November. The species hibernates in the egg stage. Dr. Smith states that the eggs will hatch in water just above the freezing point, and during a spring freeze the larvæ will hide in the mud. They never seemed to come into the city in Baton Rouge, but did plenty of biting along the bayou, though the porches of a house not far away were practically free from them. They fed once and laid one batch of from thirty to seventy-five single eggs from four to seven days later. The ova usually hatched in about twenty days, but some, deposited in April, lay under water until the 20th of the following March before hatching, when agitation caused the larvæ to appear. The larval life is about seven days, the pupal two. Adults did not survive over eight days in captivity.

Melanoconion melanurus.—This form occurs only in New Jersey and northward, where it is found in swamps, woodlands, and springs, in clean water.

Mr. Brakeley has found that the larvæ winter over in a half-grown condition under the ice. They are, he says, slow-moving creatures and feed at the bottom. From their anatomy I imagine they lie on their backs, or, at least, do not grub in the mud. The adults do not seem to bite and are not, therefore, of much economic importance.

Wyeomyia smithii.—A curious little swamp dweller is *W. smithii*, the pitcher-plant mosquito, found breeding in the leaves of these plants from Canada southward to Florida and as far west as Illinois. We did not have it in Baton Rouge. The larvæ grub about in the debris at the bottoms of the pitcher-plant leaves, and occasionally feed, head upward, at the surface. They seem to breathe at the top but rarely. They will eat dead gnat larvæ. This species does not like foul water, and is not injured in the early stages by cold. Mr. Brakeley records that they freeze up solidly in the pitcher-plant leaves during the winter, thawing out in the spring, and the larval stage may last as long as ten months, including the entire summer. The egg-laying seems to be done at night, and the ova may be deposited in perfectly dry, usually new, leaves, according to Mr. Brakeley, singly, in groups fastened to the sides or, if water is present, floating. The eggs may be from twenty to one hundred in a leaf, and are comparatively large. The adults appear in May in New Jersey. I never could coax those I raised in Washington to bite. They lived about a week and drank water; there is no evidence that they are addicted to blood. The position they assume while at rest is very odd, the hind legs being curled far over toward the head, which is ducked down between the fore legs.

Group IV.—The Domesticated Mosquitoes

Probably the most domesticated species is *S. calopus*, but this has already been under discussion in connection with disease-spreading. The general household pest of this country, however, is *Culex pipiens.*

Culex pipiens.—This piper, with the sober suit of brown, breeds in and about the houses in Louisiana during the winter; in colder sections it hibernates within doors and the larvæ may be found from about May until frost. In Dr. Dupree's laboratory, in winter, its rafts hatched in two or three days, the larval stage being about twenty-four days, the pupal two or three. Larvæ were captured out-of-doors in January, and the first general appearance of the adults out-of-doors was noted March 24. Not many were found in the open after November 3. In the north the eggs are laid about May, in any standing water, the adults retreating to winter quarters about September. The species does not migrate, and, as a rule, breeds near its victims. It prefers indoors to out, crawling in through the nets. It is an evil biter, and a most persistent and annoying cantatrice, especially at night. The adults will survive seven days without water; they lived in the laboratory on dried dates or blood for eighty-three days. They generally bit twice, and laid two rafts, each about eight days after a meal, the rafts hatching in from one to three days. The rafts will be deposited and the larvæ thrive in a saturated solution of fecal matter. Drying for over six and one-half hours, or before they darken, effectually kills the eggs, which resist desiccation better if the raft is broken up, just as they will hatch if broken apart and submerged, but will not do so if the whole raft is sunk. When the dark rafts are dried, the eggs cave in somewhat, but swell again if placed on water before they are dead. The adults bite twelve hours after emergence, and will sometimes feed twice after emptying the ovaries. Bred specimens which were never allowed to make a meal of blood, mated and laid fertile eggs. The larval life is from six to ten days, the pupal one to three. The larvæ are found in any ditch, vacant lot pool, sewer trap or cesspool, or any other place near town, indoors or out. When there is not enough food, or the weather is cold, the larval period is prolonged and the adult dwarfed, says Dr. Smith. Insufficiency of food produces small imagos of any species; moreover these starved adults are dark and not well marked. Drying up the water causes a hurried maturation, with the same effect. On the western coast, *pipiens*, while present, is largely replaced as the great domestic pest by *Theobaldia incidens*, which, although not resembling *pipiens*, breeds there just as does the latter in the east.

Culex restuans.—Close to *pipiens* in habits and appearance is *Culex restuans*, distinguished in perfect specimens by the two or four small, light spots on the thorax (Fig. 6, *a*, page 31). It is generally a trifle smaller than and not so lean as the former. It multiplies in barrels,

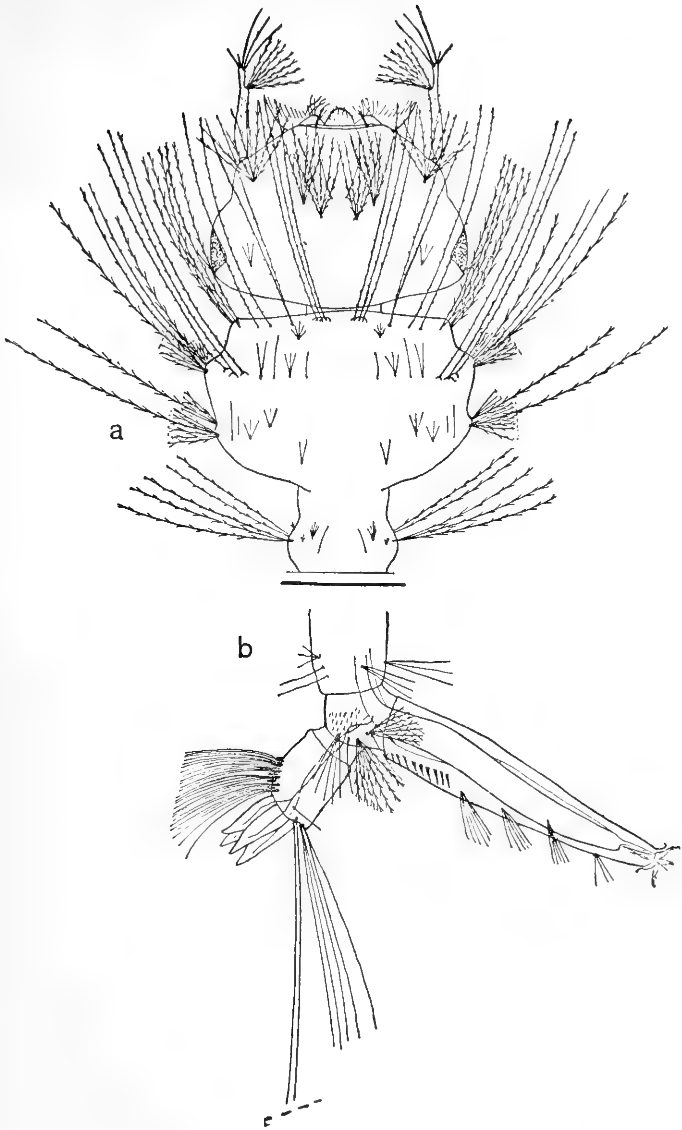


FIG. 34.—Portions of larva of *Culex pipiens* (greatly enlarged). *a*, head, thorax, and first abdominal segment, dorsal view; *b*, eighth and ninth segments, lateral view (tube somewhat distorted).

springs, rain puddles, and everywhere that *pipiens* does except in filthy water, and, like it, hibernates. It seems to be confined to the eastern half of the United States. The adults were found in Baton Rouge from early April to December 19. Like *pipiens*, they bit twelve hours after emergence, sometimes feeding twice and living several days after they had emptied the ovaries. They generally lay one raft, but sometimes two, in from four to ten days after the first meal. The eggs hatch in from one to three days, and will not resist over six hours' drying. The larvæ are found from February 22 to October 23, and at the same time as *pipiens* at the north. They are readily distinguished from those of the latter species by having the antennal tuft decidedly below the middle of the antenna, while in *pipiens* it is at the outer two-thirds. Both species, as larvæ, feed almost constantly, sailing about with the tube at the surface, the body slanting downward and the head sharply depressed.

Melanoconion atratus.—Although this is not strictly a domesticated species, yet we used to find the rafts in the brick drains around the campus of the Louisiana State University. The adults (Fig. 5, *a*, page 23) were taken from June 20 to September 4. They did not bite but sometimes were filled with some clear fluid. But if they did not make a meal it was not from lack of coaxing, for Dr. Dupree offered a wonderful jack-knife to any one who could induce them to feed on blood, and several of the students, as well as the Doctor and myself, spent much time upon them. He even went to the length of turning some of them loose in my bed net nights, his last resort when, as sometimes happened, a species could not be induced to take nourishment during the day. He used to victimise himself also, but had an unfortunate habit of smashing them in his sleep and lamenting greatly thereat in the morning. The eggs were deposited in long rafts, easily distinguishable at a glance. They did not have five or six rows curving up at the ends, like other rafts, but were in a double or sometimes partly triple row, and, what is more, the rows were zigzagged (see Plate V. op. page 194).

Group V.—Breeders in Streams and Ponds

Culex territans.—This species, so closely related to the three foregoing forms, seems logically to come next in discussion. It is distributed over the greater part of the United States but is not known to bite, which is fortunate, as, though it seldom comes into the house, it is very plentiful locally, not being a migrant. In Baton Rouge the adults were taken out-of-doors between February 29 and May 1, occasionally also in the hospital. During the hibernating season we never saw any. The females were often fat, full of a clear, greenish liquid. They refused blood and existed on dry figs for sixty days. The ova are about 240 in number, laid in rafts which hatch in two days and will not resist drying. The larvæ hang from the surface film at a wide angle, sailing peacefully about, propelled by the mouth brushes. They much resemble *pipiens* larvæ. The larval life is thirteen days, the pupal two or three days. They propagate in clear ditches or puddles. I never found them in foul water. I have taken them abundantly, the last week in March, in pools formed in the ditches along the park roads in Washington, D. C., the snow still lingering in the woods. They breed in the marshy ground between the canal and the Potomac, in the rock pools, in springs, and in the grassy edges of the lily-and-flag-grown fish ponds. Dr. Smith says they like quiet side pools of streams. I have discovered the larvæ out-of-doors in Washington as late as December. They hibernate either as adults or as larvæ, probably as the former.

Grabhamia discolor.—This rather small, mottled mosquito is taken from New York to Texas. In the north it appears to be rare, as well as in the south except from June 26 to July 17, when we found it near the ponds which were the breeding places. Larvæ were taken as late as October 24. Twenty-four hours after emergence the insect requires no coaxing to induce it to partake of a meal. She settles down to business at once, gorging herself almost to the bursting point, which performance she will probably repeat in twenty-four hours. She will bite once or twice. The eggs are single, one or two batches, laid from four to seven days after the first meal, and hatching in about eight days. The larval stage lasts ten days, the pupal one day. The life of the adult is from seven to fifteen days. The larvæ remain at the bottom of the vessel, not caring to come to the surface. They lie on their backs, with thorax and tube touching the bottom, and move about only when disturbed. When they rise to the top to pupate, air is disengaged from the breathing tube. They ascend a short time before pupation and then keep the tube at the surface, with the body nearly parallel to the latter, in marked contrast to the feeding posture. They are noticeable for their enormous, S-shaped antennæ.

Grabhamia jamaicensis.—This, too, is a breeder in pools in the open, from which it never flies far (Fig. 8, *a*, page 46). It is found from New Jersey to Louisiana. This species does not enter the house. It seems to prefer the pools just at the edge of the woods, but used to get into the tubs on the campus with *restuans* and *pipiens*, and also in wood pools with *sylvestris*, *posticata*, and *varipes*. It also propagated in the drains on the campus, and not always in the cleanest of water, though I never found the larvæ in positively foul fluid. The wigglers keep the body almost, not quite, parallel to the surface while feeding, but it forms a downward curve in the middle, like a slack rope. They go sailing about, frequently backward, by means of the mouth brushes. Adults were taken from June 7 to September 30; in the north they are most abundant in midsummer. The insect bit from once to three times, often twice, before laying the first batch of single eggs, which is deposited from four to eight days after the first meal. There are from one to five batches, generally three, with forty-one to eighty-one ova in a clutch. Dr. Smith and Prof. Herrick think the eggs are deposited in moist mud; we could induce oviposition on nothing but water. The eggs will resist drying, and doubtless hibernate. They hatch in from two to seven days. The larval life is about ten days, the pupal one to three days, longest in early spring. The adults survived from fifteen to thirty-two days. They are not of great importance but may be temporarily a local nuisance, as, at times, they are voracious biters late in the afternoon and early in the morning, especially on a rather damp day.

Ochlerotatus infirmatus.—This species appears to be southern in range, abundant only locally and for very short seasons. I do not believe that they migrate or even fly very far from the pools at the edge of the woods where they breed. They do not l.ke foul water. The adults are ordinarily taken at Baton Rouge from April 25 to July 26; after that but few were seen. They seem to bite but once and lay a batch of single ova four to six days afterward, this hatching in from fourteen to thirty-four days, except when it winters over. In warm weather the larval stage is seven or eight days, the pupal from one to three. One adult, captured December 12 and fed, laid three eggs on the 20th, but died before completing oviposition. The three eggs, however, were fertile, and their imagos were out February 7. The adult will mate in captivity but will not live in confinement over four or five days.

Uranotænia sapphirina.—This dainty little sapphire-gemmed insect bred plentifully in pits and hollows on the University grounds, as well as among the plants in lily and fish ponds and where *Spirogyra* is abundant. Adults are taken from July to September 3, and in the north it seems also to be found only after midsummer. It is confined to the eastern United States. The females bit but once and laid one raft, averaging forty-one eggs, the mass floating with the middle partly under water. The boat hatches in a day and will not stand drying, hence the species probably winters as adults. The larval stage lasts from nine to twelve days. The larvæ feed at the top, sometimes partly rotating the head to skim the surface but generally doubling backward to do so. They move slowly and intermittently by a jerk of the tail (not of the whole body), being apparently sluggish in disposition and not easily frightened. The body is generally held nearly parallel with the surface of the water—they might perhaps be taken for *Anopheles* were it not for the breathing tube. The adults will live sixteen days. They have a habit of standing with the body held high from the surface, the hind legs, which are very long, bent obliquely over the back. Two other species of the genus, *socialis* and *lowii*, are also found at Baton Rouge. These appear to be entirely southern in range, while *sapphirina* is found in New York State. In life history and habits they seem to be like *sapphirina.*

Psorophora ciliata and howardii.—These are giants among mosquitoes (Fig. 9, page 53), being from 8 to 10 mm. in length, and are able to puncture clothing to an alarming degree—through coat, vest, and two shirts, as Dr. Smith says. He further states that they do not attack in swarms in New Jersey, but once I met a swarm in a cane-field. They bit furiously right through my coat, and I was glad to get

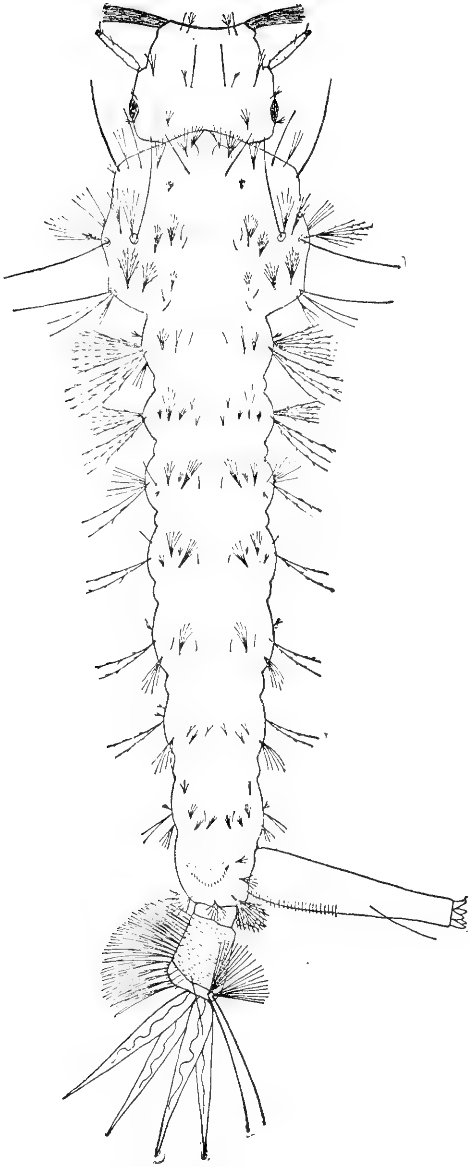


FIG. 35.—Larva of *Psorophora howardii*, dorsal view (greatly enlarged).

away. I think only *howardii* were in the gathering. A mixed swarm once attacked the horse while the Doctor and I were collecting in the woods, so that Sallie, almost frantic, started for home, and we came near having to take a tramp of several miles. The bites do not swell much, as far as my experience goes, but the puncture feels like a pin-prick.

P. howardii is southern in range, from south of the Potomac to Texas, while *ciliata* is found as far north as New York. In Baton Rouge the former is the common species, though we usually took the larvæ in conjunction with those of *ciliata*. The adults of both species are generally located in the woods, and I do not know that they fly far as a rule. Still, I have seen as many as thirty *howardii* in a drug store in the evening, evidently attracted by the syrup spilled on the soda counter, as they greedily sucked this whenever the opportunity offered, and the attendant said that at this time of year (July) they were a nuisance, always coming about the stand. They seldom attacked him and would not feed on me in the store, though they did so readily enough in the laboratory.

The *Psorophora* larvæ are immense for wigglers, and their size renders them readily recognisable. They are predaceous, and also cannibalistic. Those with which the Doctor first experimented were taken from a small body of water about ten by four feet and three inches deep in the middle, located in a depressed portion of the bed of the ditch in the botanical garden of the Louisiana State University. On September 3 it rained, forming this pool; on the 8th it held full-grown larvæ, pupæ, and emerging imagos. The captured larvæ devoured greedily the larvæ of a *Culex* and *C. consobrinus* taken from the same pool. The drain had been dry as a bone for more than a month previous to this rain. Dr. Dupree watched his captives, he says, with a view to determining their manner of attacking their prey, and was unable to confirm Dr. Howard's observation that they grasp it just below the tube, to choke it, and, when the struggles cease, devour it to the head. They seem to have no choice as to the part seized, frequently catching the prey by or near the head, and not choking it. I watched to see how many *Culex* larvæ they would eat, and found that the average was about three an hour, one occasionally being killed between meals and dropped whole on the bottom of the dish. They are evidently of some use as exterminators, and not, as a rule, a nuisance, though the occasional onsets of even one, on the horse, made things lively at times. The eggs of *Psorophora* are very large, ovate, and coarsely sculptured. They are extremely resistant to drying, and well fitted for over-wintering.

From a long series of experiments with *howardii* the following facts have been gathered. It seems to be found a few days earlier than *P. ciliata*. The first larvæ are recorded April 30, one hour after a rain. The eggs had evidently lain all winter and hatched on being stirred up by this spring rain. They are frequently thus found in newly formed pools immediately after a downpour. They will breed in drains, though not in foul water. The first adult specimens of the year were taken May 8, the last November 13.

They mate but once. They bite from two to four times before the first oviposition, at intervals of from two to four days, and once, twice, or even three times, for every batch after that. They will usually feed once before mating; will make a meal the day after emergence and also immediately after laying. Generally they lay two or three batches, but may deposit as many as nine. The first ovulation is from eight to ten days after the first meal, the others two days after a repast. There are from twelve to sixty-five eggs in a batch, the average being thirty-two, usually about two hundred eggs in all. The ova may hatch in the next rain, or even one hundred and sixty-two days after. The larval life is five or six days, the pupal twenty-eight to thirty hours. The larvæ will not subsist on vegetable diet, but will eat protozoa. The males issue from one hour to twenty-four hours ahead of the females. These insects will copulate in ten minutes after emergence. The females live from fourteen to twenty-seven days, the males ten to fifteen; the latter can survive seven days without food or water.

Psorophora ciliata seems to feed almost always three times before laying, generally at intervals of three days. It usually deposits two batches of from fifteen to thirty eggs, but sometimes four batches; and there have been as many as sixty-three, and as few as five, eggs in a clutch. The first laying is always the smallest, which is not usually the case among mosquitoes. This species, as a rule, seems to feed between depositions but once. Ovulation occurs at intervals of from two to four days. It will make a meal two days after emerging and before mating, which latter act it readily performs in captivity. It mates but once. The adults were found from April to November 17, the length of life being about that of *P. howardii*, as is the larval stage. The pupal stage lasts from forty-nine to fifty-four hours, in a temperature of about 60° F.

Ochlerotatus bimaculatus.—Rarely found was this southern species. It bred in the pool under the willows on the campus, the imagos emerging in October; larvæ were found in the pool. The pupal stage lasted from one to three days. Judging from the eggs, they must winter in that form.

The other mosquitoes breeding in the open, to which I refer under this group, were not experimented with at Baton Rouge.

Ochlerotatus atropalpus and varipalpus.—*O. atropalpus*, the rock-pool mosquito, is reported from Maine, New Hampshire, and the Potomac River, at which last place it is very common. The adults frequently make the life of the canoeist and camper unhappy, while the larvæ swarm in the pot-holes in the rocks when the river is low. They are not only in the boulders in the river bed, but also in any hollowed stone holding rain water on the flats along the river, where this species is associated with gnat larvæ and *territans*, but they are never found in ground pools. They nibble over the leaves at the bottoms of the cavities, seldom rising to the top. They do not seem to breed in foul or even in muddy water. The eggs are single, with distinct sculpture; this is evidently the hibernating stage. I have found this species in pot-holes in a creek near Voorheesville, N. Y. I do not think it flies far. An allied form, found only in the western United States, is *varipalpus*, distinguished by the curious spotted anal gills.

Aëdes fuscus, etc.—*Aëdes fuscus* is found in New Jersey; we also secured adults in Louisiana, but never obtained larvæ. It is not known whether the insect will bite. Dr. Smith believes that it is only a local breeder, which winters in the egg stage. Mr. Brakeley found the larvæ early in April, and they have been taken in pools dry through the winter, and only filled by spring rains. They seem to be recorded only in April and May.

O. nivitarsis also appears to be a local species, reported from New Jersey as a propagator in rocky pools on the Garrett mountain.

O. dyari is found in New Hampshire and British Columbia, multiplying in cold, permanent springs and slow streams in the woods; it is not common.

Theobaldia annulatus should be noted as of general distribution, not only in the south-west but also in Europe; as, however, it does not seem to bite, it is of little importance.

Group VI.—The Woodland Breeders

Janthinosoma posticata.—This species was very thick on the edges of the woods about Baton Rouge. One could not sit down in the shade for a moment, but that their white hind feet were seen bobbing through the air at one. They bit like fiends, and frequently drove us to rest in the sun, or under some

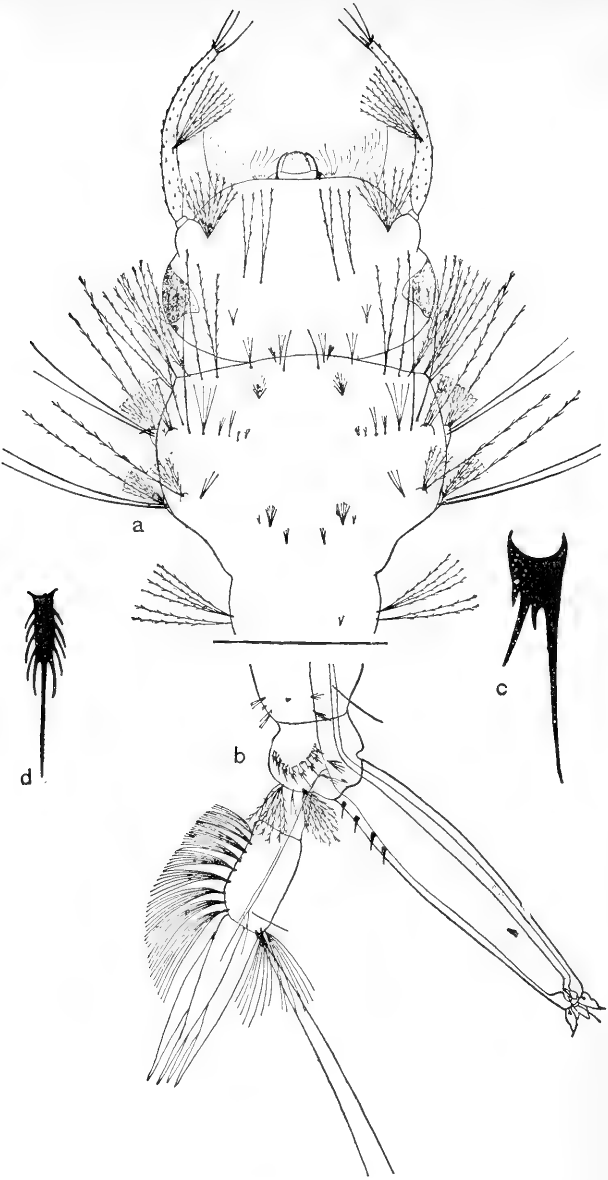


Fig. 36.—Portions of larva of *Janthinosoma posticata* (greatly enlarged); *a*, head, thorax, and first abdominal segment, dorsal view; *b*, eighth and ninth segments, lateral view; *c*, spine from tube; *d*, spine from eighth segment.

isolated tree a few yards from the edge of the wood. They did not like to come out into the hot sunshine, but would follow into the open for some distance, as the shadows began to lengthen, seldom, however, going beyond them. Farther north they do not seem to mind the sun. Sometimes we met them, about sundown, in the middle of an open swamp surrounded by woods, but we never discovered them in houses, and there seem to be no records of any one else finding them indoors. They are remarkably persistent, returning with indefatigable obstinacy to the attack, and are very easy to catch. The bites hurt at the time, and swell afterward, though after feeding a number this effect disappeared—in fact we became almost perfectly immune to the punctures of any species. The adults of *posticata* were first found out-of-doors March 14, the latest October 18. June 30 to September 9 appears to be the New Jersey period. They seldom bite more than once before laying, and very few laid two batches. The interval between their first meal and oviposition is generally five days, it may be two. There are usually about 139 eggs in a batch, but when there are two sets there may be as few as forty in one. The female sits on the water, with legs wide spread, lays a few eggs, flies off, then lights and lays some more. The one described was observed by Dr. Dupree to be ovipositing at 10 A.M., and was still thus engaged at 1 P.M., the first eggs blackening within an hour. The life of the adult raised in captivity has been fifteen days. The larval life is about seven days, the pupal two. The hatching occurs with or without agitation in from fourteen to one hundred and ninety-four days after laying, and the eggs will resist drying. The period of hatching of the ova of the same batch may extend over forty days. This species evidently winters in the egg stage. The larvæ devour Euglena, also young Spirogyra. They have a habit of sailing about by means of the mouth brushes, from the surface to the bottom, proceeding from the top at an angle of about 45° or so. When they reach the bottom they will seize a large bunch of Spirogyra and again float upward, shaking the bunch and breaking it to bits. Unless disturbed they do not jerk about. They stay below for long periods, sometimes for an hour. This species cannot be considered as a city nuisance, but in the woods, in the south at least, it is certainly very troublesome. It ranges from New York to the Gulf, and westward to Indiana, being also a common South American form.

Janthinosoma varipes.—This is another inhabitant of clear wood pools and appears to be southern in range. We occasionally found them, though not abundantly, in the willow pool on the campus. They are sometimes locally plentiful for a short time, but cannot be considered a nuisance. The adults were taken between April 18 and October 18. They bite sometimes twice, usually once, before laying the first batch. They generally deposit one or two batches, averaging about 60 eggs each. One specimen made a record, laying eight batches of from 51 to 104 ova, 578 altogether, biting nine times. The first clutch is laid three to eight days after the first feed, generally three or four days. In captivity the adult lived from eleven to twenty-eight days. The eggs are single, hatching in twenty-eight days. The larval life is about five days, the pupal life two. Hibernation is doubtless in the egg stage.

Ochlerotatus serratus.—This species bred in the swampy wood near the bayou, and required considerable patience to catch, as it was not, as a rule, bloodthirsty. We never found them indoors. In Baton Rouge the adults were found from May 12 until September 1. They bit once, laying one batch of eggs three to five days later. Hatching took place in ten days in warm weather if agitated, but ova have kept under water from one July to the next before the larvæ emerged. The larval life is about ten days, the pupal two. Larvæ were taken as late as September 22, but hibernation is doubtless in the egg stage. The ova resist drying well. The adult lives but a few days in captivity.

Ochlerotatus dupreei (Fig. 37, page 186).—This small species ranges from New York to Louisiana, where it was originally taken by Dr. Dupree. It seldom bites, but our bred specimens did so the third or fourth day after emerging, before mating, but not more than one meal would be accepted. They did not lay, but, judging from dissection of the ovaries, they do not form a raft. The species is not abundant south, being found from June 29 to August 25, and has been taken, but rarely, north to New Jersey. The larvæ are found in pools of clear water in the woods, where they nibble over the leaves and grub in the debris on the bottom. The only time they come to the top is when they pupate. The anal gills are

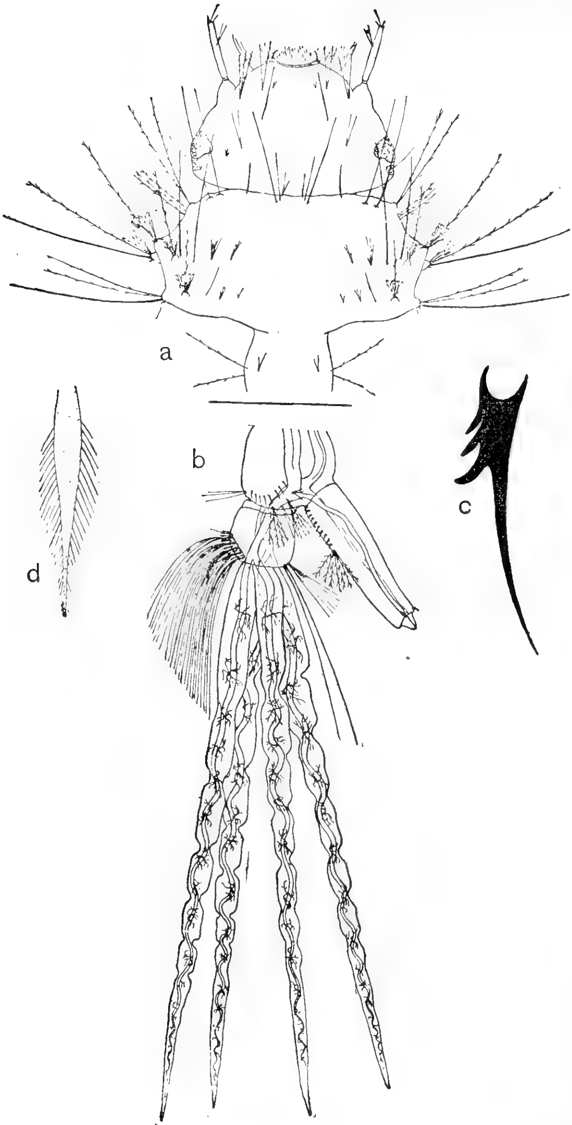


FIG. 37.—Portions of larva of *Ochlerotatus dupreei* (greatly enlarged): *a*, head, thorax, and first abdominal segement, dorsal view; *b*, eighth and ninth segments, lateral view; *c*, spine from tube; *d*, spine from eighth segment.

enormously developed, being about half the length of the larva itself, and are well tracheated, obviating any necessity for surface breathing. The insects apparently dislike to rise from the bottom, and if chased up, dive down as soon as possible. They avoid the light, hiding among the debris. The pupa stage is less than twenty-four hours. The adult lives twelve days, and can exist for eight days on water alone.

Ochlerotatus triseriatus.—This species has the curious habit of breeding in tree holes (Fig. 6, *b*, page 31). It ranges from New York to Louisiana, and while a hard biter, and by no means rare, can scarcely be classed as a nuisance. It is not found in the houses, though sometimes it comes on sheltered porches of homes in groves or near woods, but it does not fly far. The time of day does not seem to affect its biting if it is hungry. Its bites used to raise white lumps on me, not painful, however, after I had become immune to most of the rest, but on Dr. Dupree it never seemed to have any effect. We generally caught the adults about half an hour before sundown, captures being made from March 21 to October 11—earlier, though not later, than in New Jersey. They fed once to four times before, and sometimes once after, laying, but usually died immediately after oviposition. One batch seemed to be the rule. In New Jersey the eggs have frequently been collected in tree stump holes, Mr. Brakeley finding them also in an iron kettle, at the sides and above the then surface. The ova were deposited in the laboratory from three to twelve days after feeding, and are evidently the hibernating form. Hatching took place in from ten to thirty-one days, the larval period extending over about eleven days. The larvæ were frequently found in tree holes, usually accompanied by *Psorophora*. I have found them thus also at Washington. They are bottom feeders, grubbing about voraciously. The pupal stage is two or three days. The life of the adult in captivity is about fourteen days. They seem to breed all summer around Washington, but cannot be considered troublesome.

Ochlerotatus pretans.—This species we found but once in Baton Rouge. A few were taken near the wood, February 13. Eggs laid that day hatched, and the pupa emerged fourteen days after. The pupal stage lasted two or three days. The male imagoes, as is often the case, issued the day before the females. The females fed the fourth day and again on the tenth. Judging from the eggs, this species, in the more northern part of the country, must winter in that stage. It is found in the north-eastern part of the country. Although a biter, it is sufficiently rare not to be classed as a nuisance. It breeds in rather out-of-the-way woodland pools.

Ochlerotatus subcantans.—This form, commonly called the brown woods mosquito, is found from Canada to the Gulf of Mexico. It also has a general distribution in the west. It was taken in Baton Rouge in the woods, along with *canadensis*, as early as April 22, but did not seem to occur after May, which is also the case in New Jersey. There appears to be but one brood, the species hibernating in the egg form. The adults bite once before oviposition, depositing a batch of from thirty to forty-five single eggs four or five days later, which hatches in ten days. The life of the larva is about seven days, that of the pupa two. Dr. Smith says that the wigglers prefer the deeper pools, concealing themselves among the leaves at the bottom, not often coming to the top, nor staying there any length of time. The species is not troublesome, although sometimes locally common in the woods for a short time.

Ochlerotatus trivittatus.—This species ranges over the eastern United States, as far as northern New York, but was not taken in Baton Rouge. Dr. Smith says that it is never found in towns or even on porches. The attack of these insects is fierce, but as the objective point is generally below the knees, they are able to do little actual biting. *Trivittatus* breeds in woodland rain-pools. The adults were taken in New Jersey from July 2 to September 3, in the northern part of the State. The larvæ were found from June to August 12, being comparatively rare. It is probable that this species winters in the egg stage.

Pneumaculex signifer.—This mosquito, which bears in the adult form a rather close resemblance to *S. calopus*, ranges from Louisiana and the Mississippi River northward to New York. The adults were taken at Baton Rouge in the wood near the creek, and also once on the campus at the willow pool, but they would not bite. Mr. Seal says that the larvæ were found in company with *C. pipiens* in a tub of

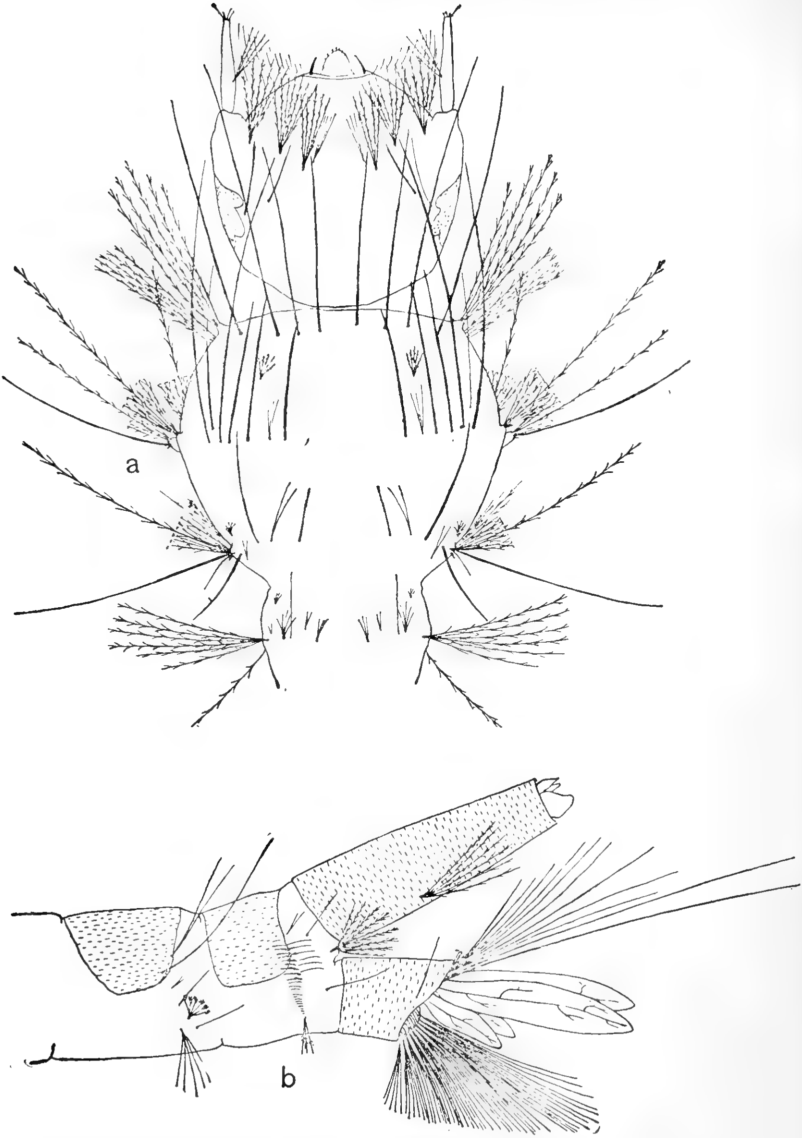


FIG. 38.—Portions of larva of *Pneumaculex signifer* (greatly enlarged). *a*, head, thorax, and first abdominal segment, dorsal view; *b*, seventh, eighth, and ninth segments, lateral view.

rather foul water, under an apple tree in a chicken yard. There were three developments of this species observed by him in the same receptacle, and in no other, although there were over twenty other tubs of water nearby. As his specimens deposited single eggs, the three developments, which were in small numbers, in the one tub, may have all been from the same batch. Mr. H. Marsh found them near Chester, N. J., in a tree hollow, September 5, in company with *triseriatus*, and again October 3. They were fully mature in both cases, and of the September lot some were already in the pupal stage, most of the adults appearing within a week. I captured some in a tree hole near Washington. They were pretty larvæ, having a rosaceous tint of the upper part of the thorax and abdomen, the sides of the thorax and body being a translucent pearl grey. The rosaceous colour is caused by the air gleaming through the dark air tubes, which, in most larvæ, are less heavily chitinised, more transparent, and show silvery. In some lights the tracheæ of this species shine like polished copper. The rosaceous colour deepens toward the tail. The head is dark brown, almost black, while the golden-yellow mouth brushes contrast sharply with it.

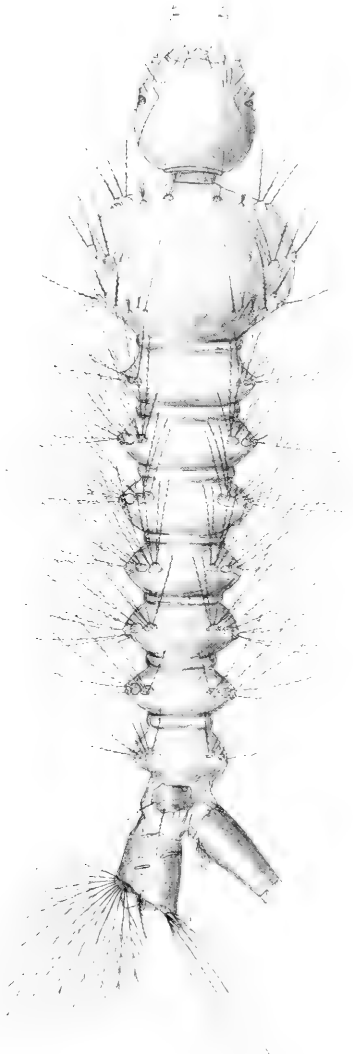
Lepidoplatys sylvicola, etc.—These were taken in Baton Rouge from April 8 to May 7. They bit but once and a few laid one batch of single eggs, about one hundred and forty-six eggs in the clutch. They oviposited in from one to eight days after biting, then died. None of the eggs hatched. They are found in the woods, but rarely. This species is also found in California as well as in New Jersey, and

Dr. Smith thinks the individual life to be about three months. The eggs would indicate that hibernation takes place in that stage. The adults were always found with *canadensis*, they had the same flight habits and bit readily, not, however, being noticeably greedy. They are never found outside of the woods, and the infrequency of their occurrence makes them of little economic importance.

The occurrence of a number of species of which little is known and which are not, as a rule, common or troublesome, is as follows.

In the south we have *Megarhinus rutilus* and *septentrionalis* (Fig. 7, page 37), gigantic and gorgeous mosquitoes, easily distinguished by their size and curved probosces. The latter was taken in Louisiana, near New Orleans, but not at Baton Rouge. *M. rutilus* occurs in Florida, *M. septentrionalis* from Ohio south to the Gulf and westward to Missouri. Other southern forms are *Lepidosia cyanescens*, ranging from southern Alabama to Texas; *O. bracteatus* in the southern portion of the United States east of Texas; *O. mitchellæ* in Florida, where also occurs *Deinocerites cancer*, which has a most curious larva that lives in the crab holes; *Grabhamia signipennis* in Texas. In the north are found *O. spenceri*, north-western United States and Canada; *O. fletcheri*, and *O. vittatus*, generally over the west; *C. tarsalis*, Illinois westward to the Pacific; *O. cinereoborealis*, a wood species, as are also *lazarensis* and *inconspicuus*, the latter being a New Jersey species, the former ranging over the eastern United States. *O. impiger* is found in the eastern United States; *Culicella dyari*, from New

PLATE IV.



Larva of *Megarhinus septentrionalis* (greatly enlarged).

England to New York. *T. perturbans* has a rather general range, being common locally over the country. Adults of this were taken at Baton Rouge. Little is known of this species. It has a most disagreeable buzz, quite audible when the insects are abundant. Mr. Brakeley records that it is a very fierce biter and believes it to be a migratory form.

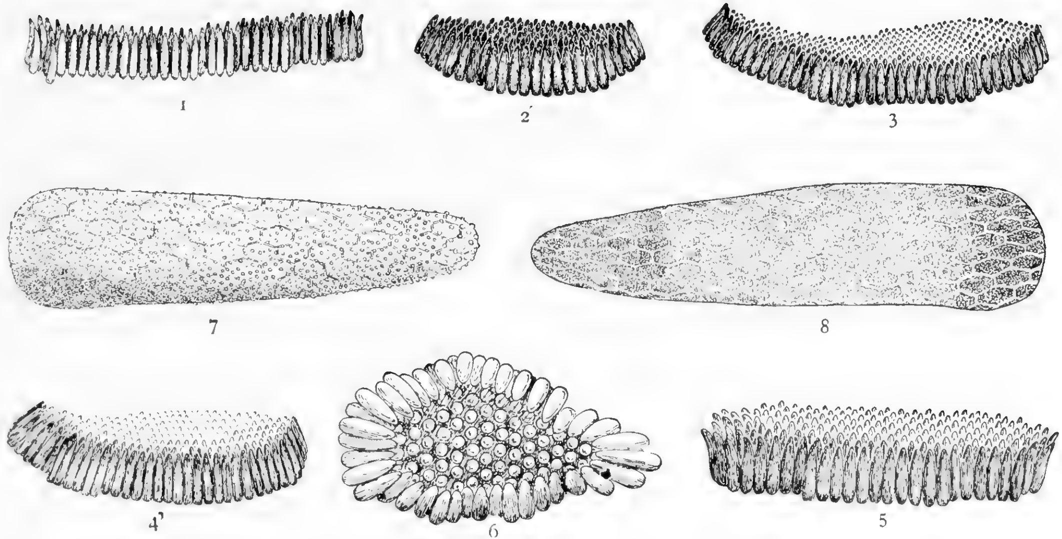
CHAPTER X

COLLECTING AND LABORATORY METHODS

IN concluding, it may be well to touch on a few points concerning the best methods of collecting and preserving specimens of the different stages, and also of collecting and rearing living specimens. Any student who wishes to do extensive work should run a mosquito laboratory; luckily, this is neither difficult nor expensive. Those in charge of mosquito extermination in towns, as well as inspectors of health, should also possess collections of the different stages of the local forms.

To begin with the outdoor collecting. All the apparatus which we used in this was a long-handled tin, or, what was better, an enamelled-ware dipper, some pint jars, a number of homeopathic vials or small test tubes with cotton plugs, and a long, wide-mouthed medicine dropper with a strong bulb. We did not use a net, finding it apt to kill or injure the specimens; however, if the specimens are to be killed, a light net may be used, though it is apt to rub or break them. When we were out for adults, we would go and sit quietly in some locality where it was thought these would be found. They would come, alight on our hands and arms, and bite, then by quietly placing the vial over them they were caught. The vial was plugged with cotton. If

PLATE V.



Raft Eggs (greatly enlarged).

Rafts of: 1, *Melanoconion atratus*; 2, *Culex salinarius*; 3, *Culex pipiens* originally published in *Boys and Girls*; 4, *Culex restuans*; 5, *Culiseta consobrinus* (top view); 6, *Culex territans*. Single egg from rafts of· 7, *Tæniorhynchus perturbans*; 8, *Culiseta consobrinus*.

the insects are to be carried a long distance, or if the weather is hot, it is necessary to slightly dampen the cotton, or the mosquito will dry up and die. In this manner adults can be sent alive in the mail, by placing the vial in a mailing tube. Care must be taken that the cotton is not so wet that the moisture will run down the side of the bottle, as in this case the insect will be caught and probably killed by the water. A horse makes good mosquito bait, and, if it will stand still, may be used to advantage. In catching mosquitoes in the sick-room, a glass or wide-mouthed bottle will do; Dr. Smith says that cotton fastened to the bottom of this and well dosed with chloroform is an aid in capture, stupefying the specimens, but if they are to be kept alive this is not a good method, being likely to kill them or, if they revive, to affect their ovipositing. Also, it is not well to allow mosquitoes in a sick-room to be captured by the method used in the woods.

Adult specimens for preservation may be killed by chloroform or in a cyanide jar. The latter may be easily made from a wide-mouthed bottle. In the bottom of this place a small lump of cyanide of potassium and cover the cyanide with liquid plaster of Paris. When this hardens it will prevent the water which results from the deliquescence of the chemical from escaping and ruining the specimens. It is well, for still further safety in this direction, to place on top of the plaster a disk of blotting-paper. It should be borne in mind that cyanide is one of the most deadly poisons, and that its fumes are very active, a small amount being fatal. The vial should be always kept tightly closed, preferably with a rubber stopper, but a cork stopper without cracks will do. When I use a cork stopper on a cyanide bottle I always try to have it infiltrated with paraffine to stop up the cracks. Adults should not be preserved in liquid, nor should they be mounted on slides. They may be temporarily preserved in pill boxes on cotton, the pill boxes being afterward placed in wooden boxes; they may safely be mailed in this condition. A study collection is best mounted on triangular tags of pasteboard about three-eighths of an inch long and one-eighth inch or less wide at the base. An insect pin is run through the base of the tag, and the tip of the tag touched with white shellac. The mosquito should be fastened to this tip on its right side at a point just back of the wing, or, if preferred, on its breast. This permits of working all around the insect and obtaining a good view of all parts. Put a label on the pin below the triangle, with date, locality, and name of the collector, and below this another label with the name of the insect. There are other methods of mounting, but none so simple or so safe to handle, or permitting the specimen to be worked over with the compound microscope.

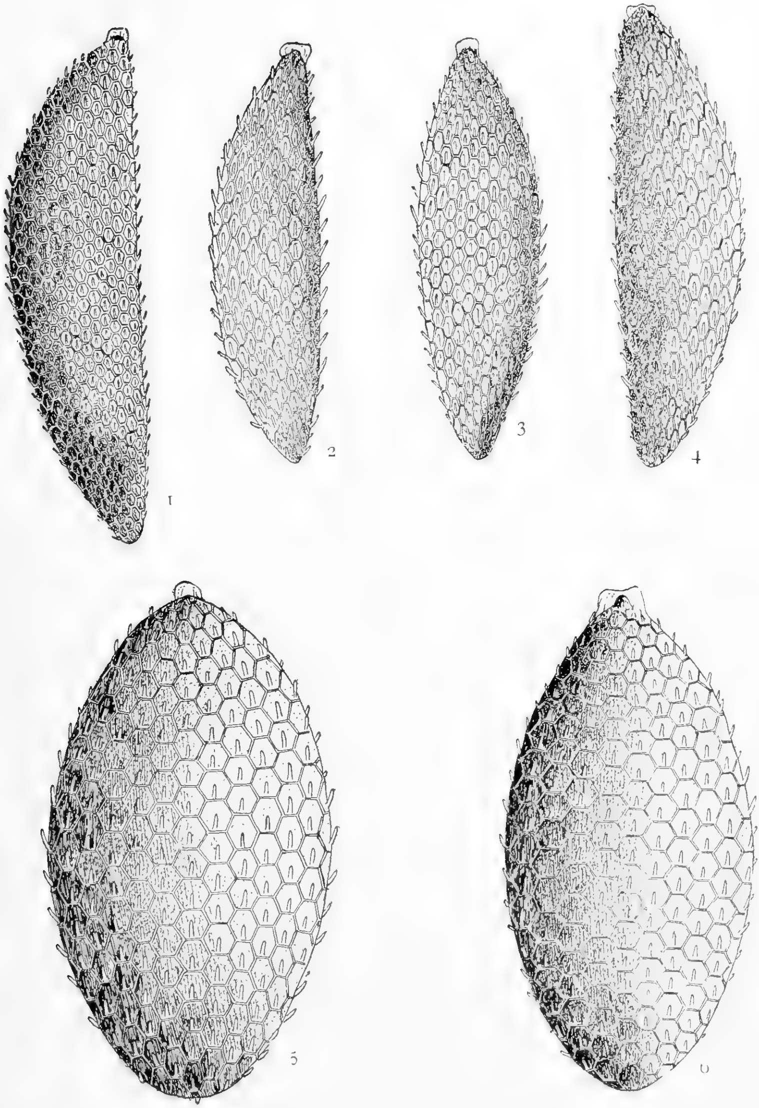
In the laboratory the adults are placed in some sort of breeding jar. A glass cylinder with a cover of cheese-cloth held on with a rubber band is one sort. Or a wire netting may be tacked in an arch, about eight inches high, over a piece of board about a foot long and ten inches wide. At the open ends fasten cheese-cloth, one end flat across, the other left in a bag about six inches long with a hole in the centre, the hole to be held closed by a rubber band. Then when one reaches into the cage the bag may be slipped up over the wrist, and the chance of escape of insects lessened. The breeding jar should contain a dish of water and some fruit. Fresh fruit moulds and is apt to kill the captives; dried dates and figs will not mildew and are quite satisfactory. I suppose any sweet, dried fruit will do. Mosquitoes which are desired to lay should be put singly into any wide-mouthed bottle or an ordinary glass with a little water in the bottom and the top closed with cheese-cloth or a cotton plug.

Parts of adults to be investigated in detail are advantageously mounted on glass slides. Wings are best examined dry, in a ring made with asphaltum on a slide by the aid of a small camel's-hair brush. The wing, or wings, should be placed within the circle and the cover glass placed on when the asphaltum has dried so that it is barely sticky, and will not run. Legs, antennæ, etc., should be immersed for a little while in alcohol, then preferably in carbolic acid for a short time, then mounted in balsam or xylol-balsam. The object may be placed in position on a slide, the liquids applied in succession and absorbed by blotting-paper, and the balsam finally put on without moving the specimen. Adults desired for dissection should preferably be examined fresh; if this is impossible, they should be placed in weak alcohol or ten per cent. formalin ; I prefer the latter, since the parts remain more pliable and shrink less. Some say that formalin specimens are apt to spoil, but none of mine have done so, and I still have some, put up four years ago, on which the liquid has not been renewed. If it irritates the fingers, grease them, or wear thin rubber gloves or tips. If it is necessary to clear a specimen more than the acid will accomplish, place it for a few hours in liquor potassæ.[1] The best method of mounting the head and genitalia is first to dehydrate with absolute alcohol, put on chloroform, then mount in chloroform balsam. Dissecting should be done in a weak salt solution, about .05 per cent. will do. To secure the alimentary canal, the simplest way is to pull off the wings and legs and separate the last two abdominal segments. Then, by holding the base of the forelegs and pulling on the separated segment, the alimentary canal can be drawn out. The ovaries will be found in the posterior part of the abdomen. It is very hard to work out the salivary glands, but they may be obtained by picking off the top of the thorax and gently pulling off the head. The soft parts do not make good permanent mounts.

In collecting larvæ it is best to go two or three days after a rain, as the larvæ from the eggs which were on the ground and hatched by the downpour are now developed far enough to be plainly visible when scooped up in the dipper. If one waits more than four days in hot weather there will be nothing much, in the case of many species, but pupæ and pupa skins. The enamelled-ware dipper shows the larvæ best. When they are scooped up, they will make for the bottom of the dipper, and it may be so

[1] Smith.

PLATE VI.



Eggs of: 1, *Grabhamia jamaicensis*; 2, *Janthinosoma varipes*; 3, *Grabhamia discolor*: 4, *Janthinosoma posticata*; 5, *Psorophora ciliata*; 6, *P. howardii*.
(Plates VI. to VIII. drawn to scale, enlargement about 860 diameters.)

manipulated that they will stay there while all but a very little water is poured off; what remains may, with the larvæ, be poured into one of the collecting jars. If there are many wigglers in the dipper, this is a much quicker method than picking them out and placing them in the jar with the pipette. A stick may be tied to the handle of the dipper if it is not long enough. Some people prefer a coffee strainer, but I think it is harder to remove the larvæ from this than from a common dipper, and they are more likely to be injured. Many species can be carried a long way in the jars, and even several days' journey will not hurt them if the jar is aired occasionally, and they are not shaken about too much. This last may be averted by filling the jar pretty well, but not entirely, with water and putting in Spirogyra or water weed, which not only prevents jarring, but freshens the air somewhat. I have sent the larvæ successfully in this way for short distances by mail.

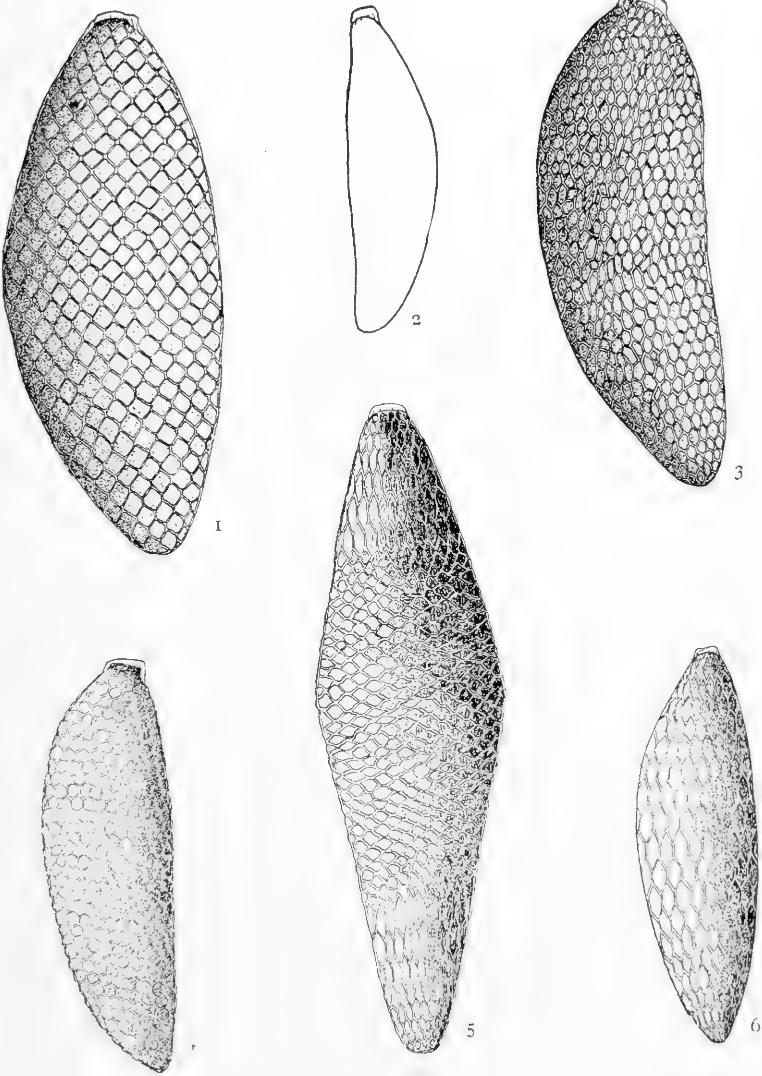
On reaching the laboratory the larvæ should be sorted out and identified alive if possible. Often this may be done with a strong hand lens mounted in a holder, if one has no compound microscope. The larvæ may be examined alive in a hollowed glass slide; they will usually, after the first minute or so, keep fairly quiet, and if they do not, a cover glass on top of them for a few minutes will not hurt them. The chief thing is, not to let them dry. Too much light will make them restless. If a hollowed glass slide cannot be obtained, use a slide ringed with asphaltum, clay or paraffine, or even a wet cotton ring. The larvæ may be bred in jars or shallow dishes with Spirogyra and protozoa to eat. I always keep a big jar with Euglena and other protozoa in it all the time, as a base of supplies. The larvæ should not be set in strong sunlight. They may easily be handled by the pipette, the mouth of which should never have sharp edges. The movements of the bottom feeders may best be observed through the sides of the jar; an ordinary thin tumbler may advantageously be used for this purpose. For the other forms, shallow dishes are better. When the pupæ form, they may be removed by the pipette to wide-mouth bottles; old vaseline bottles are good, with cheese-cloth over the top and about an inch of water in the bottom, no weeds.

Eggs of *Culex* are easily obtained by setting pails in the yard. The rafts may be put in the breeding-jar and the development observed.

Careful records are an absolute necessity. In taking adults, record place and time of capture, date, wind if many captures are being made at the time, temperature, and weather; also, if there is a swarm, and if mating is going on. If the mosquito is fed, record that; date, time of day at which it feeds, how many meals it makes, time of laying eggs, time of hatching, kind and number of eggs, whether they need agitating to hatch, whether they all hatch at once, how many batches are laid, length of larval period, any sudden fluctuation of temperature which may affect this, food and habits of larvæ, length of pupal period, length of life of adults, and habits as far as possible.

The best preservative for larvæ, pupæ, and eggs is

PLATE VII.



Eggs of: 1, *Ochlerotatus impiger*; 2, *O. dupreei*; 3, *O. subcantans*; 4, *O. triseriatus*; 5, *O. serratus*; 6, *O. sylvestris*.

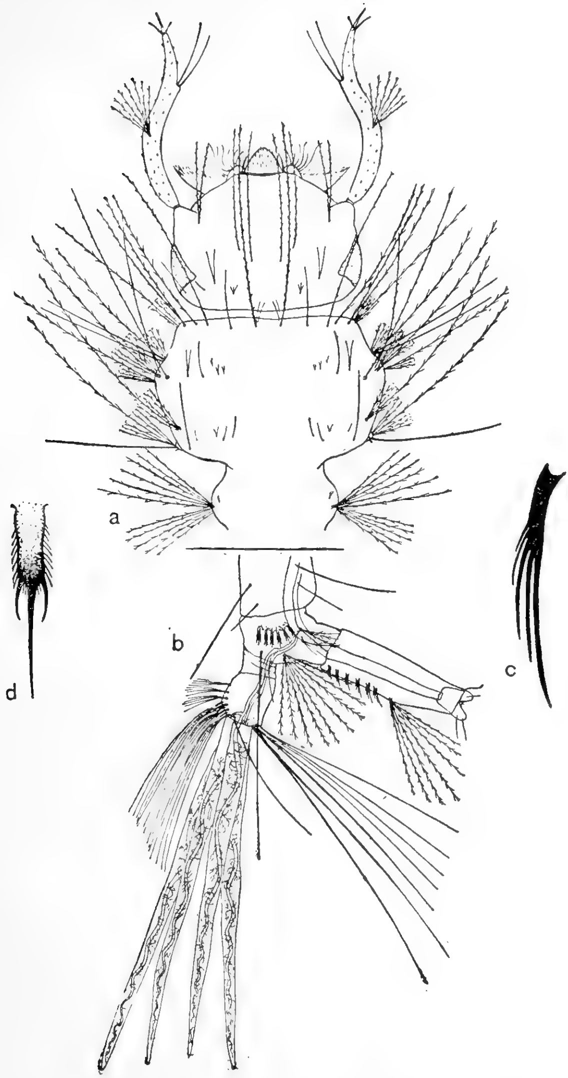
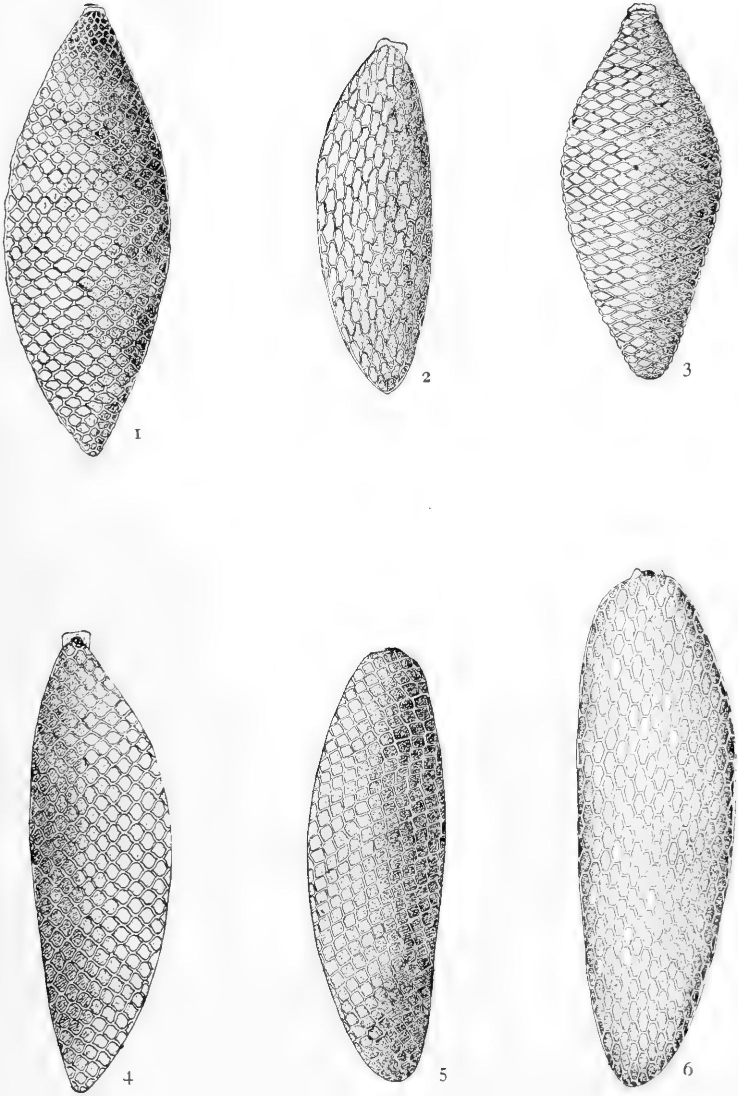


FIG. 39.—Portions of larva of *Grabhamia discolor* (greatly enlarged): *a*, head, thorax, and first abdominal segment, dorsal view; *b*, eighth and ninth segments, lateral view; *c*, spine of tube; *d*, spine from eighth segment.

formalin. Alcohol makes them shrink and grow brittle, the hairs fall off the larvæ, and all sculpture disappears from the eggs, which are thus absolutely spoiled save for general shape and size. No sculpture can be seen on mounted eggs. Formalin, with a few drops of glycerine, will not injure the fingers and will keep the specimens perfect, shapely, and pliable. Dissections of larvæ are best studied fresh, and will not mount so very well, but formalin specimens can be used. Mounted skins are of little use, as the hairs show on both sides apparently; it is almost impossible to tell on which side the hairs are, as such skins curl up and are shapeless. Skins of the different stages should be carefully preserved in formalin, each stage in a separate bottle, and examined in water on a slide. For dissection of the mouth-parts, skins are better than whole larvæ, the parts being far less apt to be broken. Do not put labels *in* the bottles; they ruin the specimens by breaking the hairs, unless the label be fastened to the sides. The label may be pinned on the cork with short insect pins.

PLATE VIII.



Eggs of: *1, Ochlerotatus infirmatus; 2, O. tæniorhynchus; 3, O. pretans; 4, O. sollicitans; 5, O. canadensis; 6, Lepidoplatys sylvicola.*

CHAPTER XI

IDENTIFICATION KEYS AND SYSTEMATIC LIST

TO those not accustomed to using keys of this kind as a short cut to ascertaining the name of the mosquito in hand, a few words of explanation may be in order. First, read the two paragraphs composing the couplet numbered 1, then examine the specimen and see with which of these it agrees, the number at the end of this paragraph is that of the couplet next to be examined. Proceed with the second couplet as with the first and continue in this manner until the agreeing line leads to the name of the insect. For instance, if we have a specimen of a salt-marsh mosquito at hand and wish to know its scientific name, by turning to the Key to the Adults and reading the first paragraph of couplet 1, we find that our specimen has both the proboscis and the tarsi ringed with whitish, therefore agreeing with these lines; this leads to the number 2, indicating that the couplet bearing the same number is the next to be examined. As our specimen has the joints, or segments, of the tarsi white at their bases only, not at their apices also, the agreement is with the second half of couplet 2; this leads to the number 3. The wings of our specimen being unspotted, it agrees with the second line of couplet 3; this leads to the number 5. The abdomen having a median light-coloured stripe throws our specimen in the first part of couplet 5, which refers us to couplet 6; here the agreement is with the first paragraph, correctly referring our specimen to *Ochlerotatus sollicitans*, Walker.

This method may seem a little tiresome at first, but with some practice it becomes comparatively easy, and the time and labour saved are considerable as compared to the tedious plan of reading the descriptions of the many species—all of which are not often accessible—and comparing the specimen with each one of them.

Key to the Adults

1. Proboscis with a median light-coloured band; tarsi also with whitish bands..............2
   Proboscis devoid of such a band, tarsi variable 10

2. Each joint of the tarsi basally and apically banded with white.
   Culex tarsalis, Coquillett.
   Each joint of the tarsi not basally and apically banded with white......................3

3. With more than one dark spot on each wing..4
   With one spot or no spots on wings.........5

4. Spots on wings confined to the front margins.
   Grabhamia signipennis, Coquillett.
   Spots distributed over the wings.
   Grabhamia discolor, Coquillett.

5. Abdomen with a median, light-coloured stripe spreading into a basal band on each segment 6
   Abdomen with no median, light-colored stripe.7

6. First tarsal joint on the middle and hind legs with a light median band. Light and dark scales on the wings. All light scales buff colour. Last tarsal joint usually dark-tipped.
Ochlerotatus sollicitans, Walker.

First tarsal joint with no light median band. Only dark scales on wings. All light scales snow-white. Last tarsal joint white.
Ochlerotatus mitchellæ, Dyar.

7. Whitish bands on abdominal segments basal..8
Whitish bands on abdominal segments apical..9

8. Hind tibia with broad whitish band just beyond middle. Scales of wings broad.
Taeniorhynchus perturbans, Walker.
Hind tibia unbanded. Scales of wings very narrow..*Ochlerotatus tæniorhynchus*, Wiedemann.

9. Basal joint of tarsi with whitish band in middle Tibiæ distinctly spotted with white.
Grabhamia jamaicensis, Theobald.
Basal joint of the tarsi unbanded. Tibiæ not distinctly spotted with white.
Grabhamia pygmæus, Theobald.

10. Tarsi, or at least the hind ones, distinctly bicoloured, blackish, or brown, and white....11
Tarsi unicolorous.........................37

11. First four joints of tarsi both basally and apically banded with white.......................12
First four joints of tarsi not both basally and apically banded with white (sometimes entirely white)...............................18

12. Thorax with both very dark and light scales arranged in distinct stripes.................13
Thorax not distinctly striped, the scales chiefly yellow or brown........................16

13. With basal and apical bands and lateral spots (almost stripes) and white median line on abdominal segments. (Salt water usually.)
Ochlerotatus onondagensis, Felt.[1]
With basal bands only on abdominal segments. 14

14. Stripe on thorax black, placed in the middle.
Ochlerotatus atropalpus, Coquillett.
Stripes on thorax white 15

15. Silvery white lines on thorax, irregularly expanding into spots, one of the lines median.
Ochlerotatus varipalpus, Coquillett.
Silvery white lines on thorax all narrow and sharply marked, no white median line, remainder of scales dead black with a very few scattered light scales of brown.
Pneumaculex signifer, Coquillett.

16. Scales of abdomen black except at the bases of the segments 17
Scales of abdomen yellow and with a pair of black spots of scales on all but first and last segments. (Fresh water.)
Ochlerotatus curriei, Coquillett.

17. Wings with two large black spots on each. Light-coloured basal bands of abdominal segments very distinct... *Theobaldia incidens*, Thomson.
Wings unspotted. Light-coloured basal bands of abdomen not very distinct. Last joint of hind tarsi white.
Ochlerotatus canadensis, Theobald.

18. Proboscis strongly curved downward 19
Proboscis not strongly curved downward 20

[1] The thorax of this species varies.

19. Front feet wholly black. (Male.)
Megarhinus septentrionalis, Dyar and Knab.
Front feet with a white band on each.
Both sexes of *Megarhinus rutilus*, Coquillett, and female of *Megarhinus septentrionalis*, Dyar and Knab.

20. Legs with fuzzy appearance, caused by nearly erect scales...... *Psorophora ciliata*, Fabricius.
Legs not fuzzy in appearance, scales nearly flat 21

21. Front and middle tarsi unicolorous..........22
Front or middle tarsi distinctly bicolorous...26

22. Terminal joint of hind tarsi and apex of preceding joint black........................23
Terminal joint of hind tarsi and preceding joint wholly white 24

23. Scales on upper side of thorax yellow.
Janthinosoma varipes, Coquillett.
Scales yellow and with a median stripe of black.
Janthinosoma discrucians, Walker.

24. With metallic blue scales at side of thorax, base of wings and head.
Uranotænia lowii, Theobald.
Without such blue scales.....................25

25. Stripe of black scales down middle of thorax.
Janthinosoma lutzii, Theobald.
Stripe absent, scales of thorax wholly yellow.
Janthinosoma posticata, Wiedemann.

26. Lyre-shaped white mark on thorax. Last hind tarsal joint wholly white.
Stegomyia calopus, Meigen.
Lyre-shaped white mark absent.............27

27. Wings with distinct black spots. Femora ringed with white beyond the middle.
Theobaldia annulata, Schrank.
Wings unspotted. No rings on femora......28

28. Abdomen and thorax wholly yellow-scaled.
Ochlerotatus fletcheri, Coquillett.
Abdomen with distinct markings............29

29. Scales of wings unusually broad, light and dark. Scales at middle of thorax dark, light at sides..................................30

Scales of wings narrow.....................31

30. With cinereous scales on mesonotum. Tibiæ and femora with many velvety black scales intermixed with white. Beak black. Subapical lobe of genitalia prominent, projecting laterally, distinctly excavated below apex.
Lepidoplatys sylvicola, Grossbeck.

Without cinereous scales on mesonotum. Tibiæ and femora with lighter scales. Beak not black, but brown. Subapical lobe not emarginate below apex.
Lepidoplatys squamiger, Coquillett.

31. Last joint and nearly the whole of the other joints of the hind tarsi white.
Ochlerotatus nivitarsis, Coquillett.
Last joint black, wholly, or except at base...32

32. Thorax with distinct or indistinct *stripes*. First joint of hind tarsi white on basal third....33
Thorax plain except sometimes for faint silvery *lines*. First joint of hind tarsi white on less than basal fourth in the former case, on basal third in the latter.........................35

33. With median dark stripe, which may be very faint on thorax, sides ashy................34
With two whitish stripes on thorax.
Culex vittatus, Theobald.

34. Basal clasp segments of male with conical tuberculate processes thickly set with many stout hairs. Female with reddish-brown stripe bordered with silvery stripes in the centre of the mesonotum........*Ochlerotatus fitchii*, Felt.

Basal clasp segments with no such structure. Thoracic stripe, if present, faintly brown, a faint silvery line on either side of middle of mesonotum.......*Ochlerotatus abfitchii*, Felt, and *Ochlerotatus subcantans*, Felt.

35. First tarsal joint with narrow basal band, hardly covering one-fourth of the joint. No silvery lines on thorax........................36
First tarsal joint with white basal band covering fully one-third of joint. A faint silvery line each side of centre of mesonotum, curving down sides to pleuræ.[1]
Ochlerotatus abfitchii, Felt, and *Ochlerotatus subcantans*, Felt.

36. Seventh abdominal segment chiefly yellow-scaled......*Ochlerotatus cantator*, Coquillett.
Seventh abdominal segment chiefly black-scaled.
Ochlerotatus sylvestris, Theobald.

37. Wings distinctly spotted. Palpi about as long as proboscis in both sexes................38
Wings not distinctly spotted................41

38. With usually four, sometimes five or three, black spots on each wing.
Anopheles maculipennis, Meigen.
With more than five black spots on each wing..39

[1] The thorax in these two species often lacks a median band, so they are inserted in two places in the key.

39. Last vein of wing with three black spots. Thorax not distinctly marked.
Anopheles crucians, Wiedemann.
Last vein of wing with not more than two black spots. Thorax with distinct, broad, light median stripe........................40.

40. Scales at base and tip of last vein black, remainder white...........*Anopheles punctipennis*, Say.
Scales on basal half of last vein white, remainder black.....*Anopheles franciscanus*, McCracken.

41. Tibiæ and distal ends of femora with nearly erect scales, scales of thorax forming a dark stripe, irregular toward hinder end.
Psorophora howardii, Coquillett.
Tibiæ and femora without erect scales.......42

42. Thorax with three lines of metallic violet scales. Scales of wings chiefly broad.............43
Thorax without metallic violet scales........44

43. Median metallic stripe on thorax moderately broad and extending to hinder margin.
Uranotænia sapphirina, Osten Sacken.
Median stripe narrow and extending two-thirds of the way to hinder margin.
Uranotænia socialis, Theobald.

44. Chitin of thorax light yellow and with a black mark on each side of the middle, extending from the posterior margin about half way to the anterior.
Ochlerotatus bimaculatus, Coquillett.
Chitin not so marked......................45

45. Scales of thorax distinctly of two colours or shades, in distinct stripes, patches, or spots..46
Scales of thorax usually of one colour, sometimes of two colours, but never forming distinct stripes or patches 57

46. With apical abdominal bands of cream white over one-third of the otherwise black segment, two creamy spots and two fine creamy lines (not stripes) on the thorax, which is otherwise covered with dark brown and golden scales. (These spots and the apical bands being twice as wide as those of *territans* distinguish this species from the latter.)
Culex saxatilis, Grossbeck.
With basal or no abdominal bands..........47

47. Abdomen with light-coloured basal bands which widen at sides..........................48
Abdomen devoid of light-coloured bands....52

48. Median patch or stripe on thorax of lighter scales than the sides, upper side of thorax deep-brown-scaled and with a large patch of lighter, more golden-brown scales in the middle of the anterior half.
Ochlerotatus bracteatus, Coquillett.
Median patch of thorax darker than sides, median stripe of brown scales, sides with golden-yellow or yellowish-brown scales................49

49. With definite dark and light markings on under side of abdomen, white basal bands widening, their points reaching almost to the apex at the sides of segments, leaving a narrow, dark, apical band on under side with a median brown triangle whose point reaches almost to base of segment; legs very long.
Ochlerotatus auroides, Felt.
With under side of abdomen not distinctly bi-colorous..............................50

50. Under side of abdomen wholly whitish......51
Under side of abdomen in female pale brownish and with scattered white scales, in male whitish and with mixed brown scales.
Ochlerotatus inconspicuus, Grossbeck.

51. Thorax thickly clothed with golden yellow scales, except for the median, narrow, dark line and the semicircular lateral line on the posterior third..........*Ochlerotatus abserratus*, Felt.
Thorax with sides and front end, also back of head, whitish-scaled. Two patches of brown at base of thorax for about half length.
Ochlerotatus pretans, Grossbeck.

52. Middle of thorax light, sides dark...........53
Middle of thorax dark, sides light..........55

53. Light median stripe of thorax extends to scutellum................ 54
Light median stripe confined to anterior two-thirds of thorax.
Ochlerotatus infirmatus, Dyar and Knab.

54. Median light stripe of thorax narrower than lateral dark spaces and distinctly demarcated.
Ochlerotatus serratus, Theobald.
Median light stripe of thorax broader than lateral dark spaces, outlines not distinctly demarcated.
Ochlerotatus dupreei, Coquillett.

55. With black stripe on sides as well as in middle of thorax, the middle stripe parallel-sided.
Ochlerotatus trivittatus, Coquillett.
Without black stripe on sides of thorax, the dark middle mark of irregular outline..........56

56. Sides of thorax white-scaled.
Ochlerotatus triseriatus, Say.
Sides of thorax golden-yellow-scaled.
Ochlerotatus aurifer, Coquillett.

57. First long joint of antennæ over three times as long as any other joint.
Deinocerites cancer, Theobald.
First long joint of antennæ never twice as long as any other joint.....................58

58. Abdomen blue-scaled except on first segment, and with whitish triangular patches of scales at apices of other segments.
Lepidosia cyanescens, Coquillett.
Abdomen without blue scales..............59

59. Bands of light-coloured scales on abdomen..60
Bands of light-coloured scales wanting on abdomen..............................74

60. Segments of abdomen light-banded at apex.
Culex territans, Walker.
Segments of abdomen light-banded at base..61

61. Median light line, as well as basal bands, on abdomen......*Ochlerotatus spenceri*, Theobald.
Median light line wanting.................62

62. Middle of thorax with a narrow, bare stripe on each side, from anterior margin to wings.
Culicella dyari, Coquillett.
Middle of thorax without bare stripes 63

63. Thorax light brown and with two small light spots of scales near middle. Light-coloured bands on basal two-thirds of abdomen of the same width at sides as in middle. Tarsi, for a very short distance each side of sutures, indistinctly light-coloured.[1]
Culex restuans, Theobald.

[1] In case the spots are wanting on the thorax of *restuans* it may *in general*—that is, in a series—be distinguished from *pipiens* thus:

C. pipiens: Petiole of second forked vein about twice as long as that of first, and a little over half the length of the lower branch forming its own cell. Petiole of first forked vein about one-seventh the length of the fork.

C. restuans: Petiole of second forked vein longer than, though not twice as long as, that of first, over two-thirds as long as the lower branch of its own vein, about one-fifth length of first fork.

C. fatigans: Petiole of second forked vein but little longer than that of the first and about as long as the lower fork of its own cell. Petiole of first vein almost one-third (over one-fourth) the length of its fork.

Thorax without such marks. Light-coloured bands of abdomen usually widening or narrowing toward sides 64

64. Light-coloured bands of abdomen never narrowing, usually distinctly widening, toward sides 65

Light-coloured bands of abdomen narrowing toward sides 72

65. Ends of light-coloured bands of abdomen extending over more than two-thirds the length of segment. Front tarsal claws of female not toothed ...... *Culiseta consobrinus*, Desvoidy.

Ends of light-coloured bands of abdominal segments two to five extending at most over only one-half length of the segment 66

66. Bristles of scutellum light-coloured 67

Bristles of scutellum black................ 71

67. Scales of thorax yellowish-white, mostly minute, rather sparse. Chitin of thorax chestnut-brown. Tarsal claws of female simple.

Culiseta absobrinus, Felt.

Scales of thorax deep yellow or golden brown, small and thickly set, covering well the almost black or dark-brown chitin. Tarsal claws of female toothed................ 68

68. Abdominal bands usually decidedly wider at ends 69

Abdominal bands straight................ 70

69. Creamy lines on sides of thorax, sides of mesonotum black and with creamy scales.

Ochlerotatus punctor, Kirby.

Creamy lines absent. (This species sometimes lacks distinct dark lines on thorax, in that case it runs here.)

Ochlerotatus abserratus, Felt.

70\. Bands of abdomen white, not extending over one-third length of segment, no light-coloured scales in dark portions of segments.
Ochlerotatus impiger, Walker.

Bands of abdomen light fawn-colored, extending over one-third (nearly one-half) length of segment; dark portion of segment with a mixture of light scales.
Ochlerotatus lazarensis, Felt and Young.

71\. Thoracic scales deep yellow and rather long.
Ochlerotatus pullatus, Coquillett.
Thoracic scales white, short.
Ochlerotatus cinereoborealis, Felt.

72\. Front tarsal claws of female toothed. Palpi of male less than one-third as long as proboscis. Bright yellow scales on upper side of thorax; abdominal segments black, with basal yellow bands; feet black.
Aëdes fuscus, Osten Sacken.
Front tarsal claws of female not toothed. Palpi of male about as long as proboscis....... 73

73\. Yellowish bands of abdomen conspicuous.
Culex pipiens, Linné.
Yellowish bands of abdomen not very conspicuous[1].......*Culex salinarius*, Coquillett.

74\. Scales in outer half of wing chiefly broad... 75
Scales in lateral rows on veins of entire wing very narrow.......................... 76

75\. Abdominal scales bronze-yellow (Northern).
Melanoconion melanurus, Coquillett.
Abdominal scales black (Southern).
Melanoconion atratus, Theobald.

[1] Above characters not at all dependable, especially in dwarfed specimens of *pipiens*, but *salinarius* is generally smaller and with narrower bands.

76. Thorax densely covered with broad yellow scales. Bristles (4 to 6) on thorax beneath scutellum. Palpi in male and female short.
Wyeomyia smithii, Coquillett.
Thorax devoid of broad scales............. 77

77. Dorsum of thorax greyish-brown, another scaleless, three brown stripes set with black bristles, from anterior margin to middle. Abdomen brown. Legs almost black. Palpi about as long as proboscis.
Anopheles barberi, Coquillett.
Dorsum of thorax covered with pale-brown scales. Legs cream-colour. Abdomen creamy and with metallic silver-grey lustre in life.
Ochlerotatus pallidohirta, Grossbeck.

Key for Eggs

1. Eggs single, floated by lateral membranous puffs................ 2
Eggs in rafts or single, if the latter not with floats. 4

2. Attached edge of membrane on upper surface of egg wavy, the edges near together in the central three-fifths of the egg and not receding far toward the sides at the broad end. Knobs at narrow end arranged: 4 distad, 3 centrad. (Fig. 21, *a*, page 100.)....*Anopheles crucians*.
Attached edge of membrane not wavy and leaving at least one-third of the upper surface at the centre practically black............ 3

3. Membrane receding sharply to sides, from the point of nearest approach at centre of egg to ends of floats, leaving over three-fourths of upper surface practically black. Knobs: 2 distad, 3 centrad, at narrow end. (Fig. 21, *c*, page 100.)..........*Anopheles maculipennis*.

Membrane not sharply receding and not touching side until some distance beyond end of float. Knobs on narrow end: 2 distad, 3 centrad. (Fig. 21, *b*, page 100.). *Anopheles punctipennis.*

4. Eggs in rafts 5
   Eggs single 7

5. Mass in zigzag string, mostly a double, never more than a third row in part. (Plate V., Fig. 1, opp. page 194.)...... *Melanoconion atratus.*
   Mass with 4 or more transverse rows 6

6. Raft resting flat on water, ends not upturned. (Plate V., Fig. 5, opp. page 194). *Culex territans.*
   Raft upturned at ends. (Plate V., Figs. 2, 3, 4, 6, opp. page 194)..*Culex restuans, Culex pipiens, Culex salinarius, Culiseta consobrinus, Theobaldia incidens*, and *Ochlerotatus dupreei.*

7. Spines present 8
   Spines absent 11

8. Egg ovate 9
   Egg not ovate..............................10

9. Width contained in length twice. Distinct knob on small end. (Plate VI., Fig. 6, opp. page 198.) *Psorophora howardii.*
   Width in length one and three-fourth times. Knob minute. (Plate VI., Fig. 5, opp. page 198.) *Psorophora ciliata.*

10. Sculptured cells about as long as wide. Width into length 3.8 times. (Plate VI., Fig. 1, opp. page 198)........... *Grabhamia jamaicensis.*
    Sculptured cells longer than wide. (Plate VI., Figs. 2, 3, 4, opp. page 198.)....*Janthinosoma posticata, Janthinosoma varipes*, and *Grabhamia discolor.*

11. Egg regularly elliptical, membrane showing plainly in many small puffs. Pattern longest transversely, a sort of hexagon with points toward sides. Width into length three and one-half times. (Fig. 23, page 114.)
Stegomyia calopus.

Egg not regularly elliptical, membrane at most but slightly puffed........................12

12. Pattern of ends differing from that of median half, that of ends an angled hexagon longer than wide, that of middle a modified hexagon wider than long. Egg shaped like 2 unequal cones with bluntly rounded ends, placed with the bottoms together. (Plate VII., Fig. 5, opp. page 200.).............*Ochlerotatus serratus.*

Pattern same all over the egg 13

13. Cells wider than long.......................14

Cells not wider than long (both lines of this section refer to cells toward the middle of the egg)..................................15

14. Greatest width of egg not at middle.
Ochlerotatus reptans.

Greatest width of egg at middle. (Plate VIII., Fig. 1, opp. page 202.). *Ochlerotatus infirmatus.*

15. Pattern regular, of practically uniformly-sized figures 17

Pattern irregular, of varying-sized figures....16

16. Cells irregular hexagons. (Plate VII., Fig. 3, opp. page 200.)..........*Ochlerotatus subcantans.*

Cells irregular, longer than wide, not hexagons. (Plate VIII., Fig. 2, opp. page 202.)
Ochlerotatus tæniorhynchus.

17. With cells noticeably longer than wide. (Plate VII., Fig. 6, opp. page 200.)
Ochlerotatus sylvestris.

With cells not noticeably longer than wide...18

18. Cells regular hexagons. (Plate VII., Fig. 4, opp. page 200.) .... *Ochlerotatus triseriatus.*
Cells modified hexagons 19

19. Hexagons with definite straight sides, the lateral sides shorter 20
Hexagons without definite straight sides, lateral side obscure. (Plate VII., Fig. 4, opp. page 200.) .... *Ochlerotatus sollicitans.*

20. Egg broadly ovate, not regular, width in length two and one-half times. (Plate VII., Fig. 1, opp. page 200.) .... *Ochlerotatus impiger.*
Egg roughly ellipsoidal, width in length over three times. (Plate VIII., Fig. 5, opp. page 202.) .... *Ochlerotatus canadensis.*

Generic Key for Larvæ

1. Breathing tube almost wanting, not tubelike. Palmate tufts on abdominal segments three to seven, sometimes a rudiment on the second. Thoracic tufts reduced to single, long-plumose hairs.

SUBFAMILY ANOPHELINÆ.

Anopheles.

Breathing tube well developed, tubelike. Long thoracic tufts present or reduced to stiff spines with spinules. No palmate tufts 2

SUBFAMILY MEGARHININÆ.

2. Comb of eighth segment represented by patch of chitin without scales, or absent. Tube without pecten .... *Megarhinus.*
Comb present. Long thoracic tufts of hairs. No hairs on antennæ between bases and tufts. 3

SUBFAMILY PSOROPHORINÆ.

3. Mouth brushes of a few heavy bristles directed outward at right angles to head, or folded under. Antennæ near middle of side of head. *Psorophora*.

Mouth brushes of thin hairs directed forward. Antennæ situated far forward. Larva not very large............................4

SUBFAMILY CULICINÆ.

4. Having head tufts A[1] and B two-branched. Antennæ longer than head; comb in one row of about eight spines; breathing tube inflated, and with one small or minute tuft above middle; pecten of four to six teeth *Janthinosoma*.

Having no such series of characters..........5

5. Ventral tufts of ninth segment, if present, with the caudal three pairs having three or more branches. Tuft C of two or more hairs....6

Ventral tufts of ninth segment consisting of about five pairs of bifurcate (rarely the caudal pair of trifurcate) hairs. Tufts A, B, and C of single hairs. Antennæ bare and with a single hair in place of the tuft. Comb in one row.............................*Stegomyia*.

6. With the pecten not extending beyond the single tuft. Comb three-rowed. Anal gills shorter than ventral tuft, and about as long as ninth segment, which is not ringed by chitin. Tufts A and B eight-haired ....*Lepidoplatys*.

Without this series of characters............7

[1] See Fig. 40, page 224.

7. Larva with pecten not extending beyond the single tuft, outer two or three spines more widely separated than others. Ventral tufts not on cephalic one-half of ninth segment nor over three-quarters as long as anal gills, which are shorter than tube. Comb two rows, having the secondary teeth on the spines very slender. Tuft A, five; B, six to seven-haired. *Aëdes.*

   Larva without above combination of characters.......................................8

8. Ninth segment with distinct ventral brush....9

   Ninth segment without distinct ventral brush.20

9. Posterior angle of mandible heavily spined and produced so as to be more or less visible at side of head; or with four large stout spines on head; or tube without pecten.........18

   Posterior angle of the mandible never visible from above; without any other of the characters mentioned in the preceding paragraph.10

10. Pecten on breathing tube continued by ten or more bristles. Tuft almost at base of tube..16

    Pecten not so continued....................11

11. With only two tufts on breathing tube, except in one case, where there are, besides the two large tufts on ventral side of pecten, three small tufts laterad of the pecten, and four small tufts on the dorsal side of the tube..12

    With more than two tufts or with four long single hairs and two small tufts on tube. Never tufts laterad of pecten. Antennæ usually with tufts in notch...........................17

12. Spines on breathing tube more than eight...13

    Spines on breathing tube three to six.......14

13. Tuft over one-quarter up the tube *Ochlerotatus.*

    Tuft almost at base of tube, within the pecten. 15

14. Five or six spines in comb, three of the teeth on each spine much larger than the others, the central tooth longest and stoutest, spines in a single row on a sort of thickened, chitinous band[1] . . . . *Grabhamia.*

15. Antennæ sigmoid, tuft far up, in notch, a pair of long spines at three-fourths of distance from notch to tip of antennæ. Ventral tufts of ninth segment extending nearly to the anterior end of the segment . . . . *Culicella.*

16. Tufts D and E two- to three-branched, small. Antennæ if bent backward would not reach hind margin of head. Not more than three tufts in front of barred area . . . . . . *Theobaldia.*
Tufts D and E four- and five-branched, quite large: or two- and three-branched and quite small; if the latter, the antennæ are elongated and if bent backward would reach beyond hind margin of head, and there may be four tufts in front of barred area . . . . *Culiseta.*

17. Comb over two rows, teeth spatulate, fringed at the top. Antennal tuft in notch . . . . . . *Culex.*
Comb one or two rows, teeth lanceolate. *Melanoconion.*

18. Breathing tube without a pecten and having a single tuft. Saddles of chitin on segments seven and eight . . . . *Pneumaculex.*
Breathing tube not as above 19

[1] Paragraphs numbered 14, 15, and 20 seem to be incomplete couplets, but are really portions of the couplets referring to these numbers, and are transferred to their present position in order to show the closest relationship, or systematic position, of the genera as in Mr. Coquillett's classification.

SUBFAMILY DEINOCERITINÆ.

19. Chitin of head produced laterally into a prominent angle caudad of, and extending laterad of, the base of the antennæ. Head at least twice as long as thorax.......... *Deinocerites.*

SUBFAMILY URANOTÆNINÆ.

Chitin of head never produced laterally, with four large, stout spines in place of tufts A and B, antennal tuft represented by a single hair. *Uranotænia.*

SUBFAMILY TRICHOPROSOPONINÆ.

20. Without a conspicuous spine at posterior angle of thorax.[1] .... *Wyeomia.*

Key to Species of Larvæ.[2]

1. Breathing tube almost wanting, not tubelike. Palmate tufts on some of abdominal segments three to seven. Long thoracic tufts reduced to slender, long-plumose hairs.... 2
Breathing tube well developed, tubelike. Long thoracic tufts present, or represented by stiff spines with spinules. No palmate tufts.... 6

2. Plumose lateral hairs on abdominal segments four to six. Spines of comb subequal. Hairs on cephalic margin of head simple. Hair nearest meson of dorsum in the first thoracic row well developed, slightly plumose. Spines of palmate tufts uniformly pale. *Anopheles barberi.*

[1] This character was given it by me in more extended tables ncluding extralimital forms, and separates this genus from that of *Dendromyia*, which possesses a stout, heavily chitinised spine at the posterior angle of the thorax.

[2] For references to tufts in this key see Fig. 40, page 224.

Plumose hairs wanting on abdominal segments four to six. Comb with long and short spines. Forked, much branched hair each side the pair of simple hairs at forward margin of head. Hair nearest meson of dorsum of thorax in the first row minute, one- to four-branched. Spines of palmate tufts almost black at base, or uniformly dark brown........................3

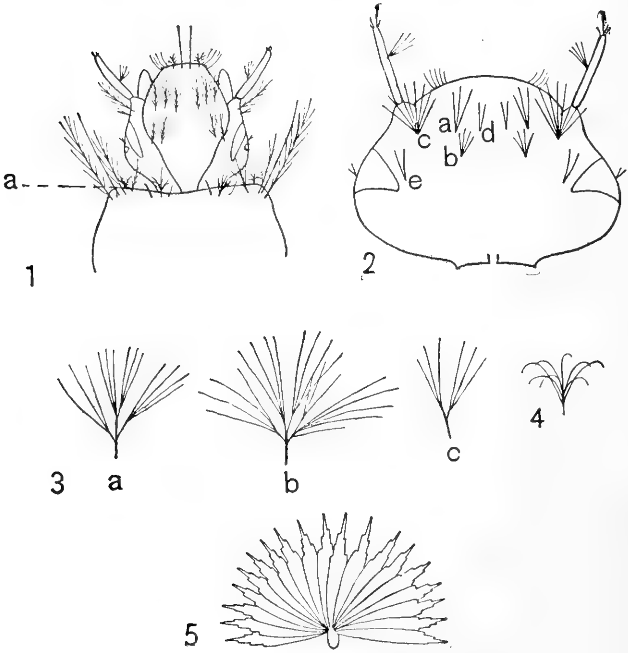


FIG. 40.—Larval tuft characters: *1*, *Anopheles* head and thoracic row 1; *a*, shoulder tuft. *2*, Culicid head, showing tufts as referred to in key. *3*, Shoulder tufts of: *a*, *Anopheles maculipennis; b*, *A. crucians; c*, *A. punctipennis*. *4*, Stellate tuft. *5*, Palmate tuft (all greatly enlarged).

3. Lateral tufts on abdominal segments four to seven, four- to five-branched, about as long as the segment. Hair nearest meson of dorsum in the first thoracic row three- or four-branched, not split to base...... *Anopheles franciscanus.*
Lateral tuft two- to four-branched on abdominal segments four and five (four-branched only on the fourth segment of *A. maculipennis*).....4
4. Hair nearest meson of dorsum in first thoracic row bifid to base. Shoulder tuft small, unbranched. Spinules on large teeth of comb not extending farther up than the level of the tops of the secondary teeth. *Anopheles punctipennis.*
Hair nearest meson of dorsum in first thoracic row not split, or split less than half way. Spinules extending to top of large teeth on comb.................................5
5. Shoulder tuft very large, hairs long. Two or three long single hairs in row 1, ventral aspect. Antennal tuft below middle. Lateral tuft on fourth abdominal segment, two- or three-branched. Hair X[1] simple. *Anopheles crucians.*
Shoulder tuft moderate. Four or more long single hairs in row 1, ventral aspect. Antennal tuft at middle, its hairs reach to tip of antenna. Lateral tuft on fourth abdominal segment four-haired. Hair X four-branched. (Fig. 25, page 126.)........... *Anopheles maculipennis.*
6. Pecten present on the tube.................9
Pecten not present on the tube..............7
Long thoracic tufts represented by stout spines covered with spinules. Comb of eighth segment replaced by a patch of chitin. Tuft of tube situated near its base. Antennæ smooth and with two bristles caudad of tuft.
Megarhinus septentrionalis.
Long thoracic tufts present, comb also present. 8

[1] Hair X is the one nearest meson of dorsum in the first row on the thorax.

8. Saddles of chitin on seventh and eighth segments. Single tuft near middle of tube. (Fig. 38, page 190.)....*Pneumaculex signifer.*
   Saddles of chitin absent. No tuft present on tube, which is sparsely covered with long, single hairs. The two ventral gills spatulate, well developed, the dorsal pair about one-third as long, pointed..........*Wyeomyia smithii.*

9. Chitin of head produced laterally into a prominent angle caudad of and extending laterad of the base of the antennæ, continued ventrad into a sort of trough in which may be seen protruded the outer portion of the mandible, produced, like a glove thumb, and heavily spined. Anal gills very little developed; body transparent, almost white.
   Deinocerites cancer.
   Chitin of head not produced as above; posterior portion of mandible never produced nor visible from above......................10

10. Anal gills three times as long as tube, with six or more constrictions. Bunches of tracheoles in gills. Antennæ shorter than head, straight. Eighth segment comb in one row. (Fig 37, page 186.).............*Ochlerotatus dupreei.*
   Anal gills never three times as long as tube, never with more than four distinct constrictions.................................11

11. Mouth brushes of a few heavy bristles directed outward at right angles to head, or folded under. Antennæ near middle of side of head. Comb scales in a single row; tuft of breathing tube represented by one or two hairs. Larva very large.............................12
   Mouth brushes of slender hairs directed forward. Antennæ situated far forward. Larva small or moderately large.......................13

12. Ninth segment with a single lateral hair. Antennæ sparsely covered with short spines. (Fig. 35, page 176).....*Psorophora howardii.*
Ninth segment with a two- or three-branched tuft. Antennæ also with short spines.
Psorophora ciliata.

13. Tuft single, almost at base of breathing tube, within the pecten........................14
Tufts many, or, if single, on same side with pecten and over one-quarter up tube......17

14. Pecten of tube continued by ten to sixteen hairlike spines...............................15
Pecten of tube without hairlike spines above it. Antennæ sigmoid, tuft far up, in notch, a pair of long spines at three-quarters of distance from notch to tip of antennæ. Ventral tufts of ninth abdominal segment extending nearly to the anterior end of the segment.
Culicella dyari.

15. Tufts D and E four- and five-branched, quite large and conspicuous. (Fig. 41, page 238).
Culiseta consobrinus.
Tufts D and E two- or three-branched, small. 16

16. Comb scales not over forty-six. Not more than three tufts in front of barred area. Spines on tip of antenna one-fifth its length.
Theobaldia incidens.
Comb scales not less than fifty-five. Three or four tufts in front of barred area. The two lower spines on tip of antenna one-fourth its length..................*Culiseta absobrinus.*

17. Breathing tube with either more than two tufts, or with four long single hairs and two small tufts................................ 18
Breathing tube with not more than two tufts. Antennal tuft never in notch............ 25

18. Antennal tuft in notch and having ten to thirty hairs, usually over fifteen. Pecten extending less than half way up breathing tube, not more than two teeth separated.......... 19
Antennal tuft not in notch, of six to eight hairs. Tube with a pair of large tufts about half up on ventral side, mesad of pecten. Pecten runs three-fourths up, last three or four teeth separated. Three small tufts laterad of pecten and four on dorsal side of tube, which is not pubescent. Comb in two rows.
Ochlerotatus cinereoborealis.

19. Body covered with a distinctly noticeable pilosity. Two rows in comb. Five plumose tufts on tube. (Fig. 42, page 239.)
Melanoconion atratus.
Body and head with no noticeable pilosity.. 20

20. Scales of comb in more than two rows. Tufts of tube not plumose.................... 21
Scales of comb in one row. Tufts beginning at end of pecten and extending over five-sixths to top, the tufts of the two sides forming a mesal row of about ten.
Melanoconion melanurus.

21. Group of hairs nearest meson, in row one on dorsum of thorax, with two long hairs and one short tuft. On head one large tuft, other two represented by one to three hairs (usually one). Tube flares at apex, and bears two rows of five tufts each.......*Culex territans.*
Group of hairs nearest meson, in row one on dorsum of thorax, with three or four long hairs and no tuft, or with two long single hairs, or with one long double hair....... 22

22. Antennal tuft below middle. On head three large tufts. Thoracic row one with four long hairs in group nearest meson. Tube with two long hairs in line with pecten and beyond it, and two on the dorsum. (Fig. 43, page 240.) .... *Culex restuans.*
Antennal tuft beyond middle. Tube with tufts 23

23. Group of hairs nearest meson, in thoracic row one, of three long single hairs. Tufts of breathing tube mostly of two to four hairs..... 24
Group nearest meson of thorax, in row one, with two long single hairs and one long double hair.........................*Culex tarsalis.*

24. Tufts on tube, five, the penultimate one more lateral. Terminal spines of antennæ decidedly long, over one-half length of antennæ, heavily chitinised, black. All head tufts decidedly long. Tip of antennæ very heavily chitinised. (Fig. 44, page 241.)........*Culex salinarius.*
Tufts on tube, four, the penultimate one more lateral; tube tapering decidedly on the last half. Terminal spines of antennæ not very long, not over one-half length of antennæ. Head tufts not projecting much, if at all, beyond forward margin of head. Tips of antennæ and spines of but slightly heavier chitin than base of antennæ. (Fig. 34, page 169)........................*Culex pipiens.*

25. Anal gills at least twice as long as breathing tube, tapering to tip, containing bunches of tracheoles. Antennæ longer than head, strongly sigmoid, with two spines in a notch two-thirds from base of antenna. Comb and pecten six-toothed. Tufts A and B single-haired. (Fig. 39, page 201.)
Grabhamia discolor.

Anal gills never twice as long as tube. Antennæ never with spines as above. Gills never as above 26

26. Pecten extending beyond tuft.... 27
Pecten sometimes extending to, but never beyond, tuft. Anal gills never constricted toward tip.............................29

27. Constrictions, one or more, present toward tips of anal gills............................28
Constrictions absent. Gills of almost uniform width to bluntly rounded apex. Antennæ with a few spinules, one or two hairs in tuft. Tufts A and B one-haired.
Ochlerotatus atropalpus.

28. Anal gills with one constriction. Tuft of tube below middle, pecten not extending more than two-thirds up. (Fig. 45 page 242.)
Ochlerotatus bimaculatus.
Anal gills with three constrictions. Tuft of tube above middle. Pecten extending almost to tip of tube. (Fig. 46, page 24 .)
Ochlerotatus serratus.

29. Comb in one row, sometimes irregular......30
Comb in two or more rows..................42

30. Tufts A and B each represented by a large stout spine on which are spinules. Antennæ with a few scattered spines, tuft represented by a single hair. Stellate hairs on thorax and abdomen...............................31
Tufts A and B of one or more hairs. Antennæ either with tufts of more than one hair and with spines, or with a single hair and smooth.33

31. Antennal tuft decidedly over one-third distad, longest terminal spine, if turned backward, reaching below tuft. Scales on eighth segment not fringed on apical one-third (reckoned from centre of base to tip). Central tooth of labial plate bluntly rounded and widely separated from adjacent teeth. (Dyar and Knab renamed this "*continentalis.*")

Uranotænia lowii.

Antennal tuft scarcely, if any, over one-third distad 32

32. Longest terminal spine almost as long as antenna; accessory spine on terminal joint not nearly reaching to tip of joint. Scales of eighth segment not fringed on apical one-half. Central tooth on labial plate bluntly rounded and not widely separated from the adjacent teeth ....*Uranotænia sapphirina.*

Longest terminal spine scarcely two-thirds length of antenna, scarcely reaching tuft; secondary spine on terminal joint reaching nearly to tip of joint. Scales of eighth segment with a fringe of uniform spines extending over apex. Central tooth of labial plate sharp, distinct from the adjacent teeth. (Dyar and Knab renamed this "*coquilletti.*")

Uranotænia socialis.

33. Head tufts A and B with more than three hairs 34

Head tuft A never with more than three hairs . 35

34. Comb an even row of six teeth, secondary spines of scales stout. Spines of tube five or six, regularly placed. Ventral tuft of ninth segment reaching nearly to cephalic margin of chitin. Tuft of tube of five or six comparatively short hairs decidedly above middle; tube not less than three times as long as great-

est width, which is about twice that of apex. (Fig. 47, page 244)... *Grabhamia jamaicensis.*

Comb an irregular row of ten or more teeth, secondary spines of scales very slender. Spines of tube more than ten, the last two or three separated from the rest. (Fig. 48, page 245.) *Aëdes fuscus.*

35. Antennal tuft with at least three more or less plumose hairs; antennæ with spinules. Head tuft B with never more than three hairs; A with one to three hairs..................37

Antennal tuft represented by a single hair, antennæ smooth. Head tufts as above...36

36. Ventral tufts of ninth segment bifurcate, occasionally the caudal pair trifurcate. Tuft C one-haired. Comb scales with apical spine much larger than the others. (Fig. 30, page 146.) *Stegomyia calopus.*

Ventral tufts of last segment of four or five hairs. Tuft C five- or six-haired. Tuft of tube of one or two hairs. (Fig. 49, page 246.) *Ochlerotatus triseriatus.*

37. With fourteen or more spines on tube, the tuft well developed and placed near pecten .. 38

With not more than eight spines on tube...39

38. Comb scales five to seven, arranged in a curved row, scales rather broadly spatulate at base, and with a stout central spine bearing seven or eight very minute teeth.............. *Ochlerotatus abserratus.*

Comb scales twelve to sixteen, and with the upper pair of teeth decidedly heavier than the rest............ *Ochlerotatus auroides.*

39. Having the tube tuft small, sometimes minute, and lateral, far beyond pecten..........40
Having the tuft not small nor lateral, and situated immediately above and in line with pecten, which extends about half-way up the tube, the last being about twice as long as its greatest width. Tufts A and B one-haired. *Ochlerotatus atlanticus.*

40. Tufts A and B two-haired. Antennæ decidedly long and curved. Tube inflated. Pecten extending one-third, or less, up tube 41
Tufts A and B one-haired. Antennæ not unusually long. (Rare species from the extreme south.).... *Grabhamia signipennis.*

41. Spines of tube four or five; one to three or more large and small teeth on one side of them, sometimes one tooth on the other side; tube tuft very small, two-thirds distad, lateral. Antennæ decidedly arcuate. Tube very large. (Fig. 36, page 182.)............... *Janthinosoma posticata.*
Spines of tube four to six, a tooth on each side of the long central spine, the two secondary teeth about equal. Tuft of tube small but not minute, just above middle, not lateral. Antennæ weakly sigmoid. (Fig. 50, page 247). *Janthinosoma varipes.*

42. Tufts A and B both represented by single hairs 43
Tuft A or B represented by two or more hairs.................................50

43. Anal gills at least as long as chitin of ninth segment 44
Anal gills not one-half as long as chitin of ninth segment; tube tuft at middle, comb teeth fringed at apex with spines of uniform size............ *Ochlerotatus onondagensis.*

44. Spines of tube with teeth on one side only. 45
Spines of tube with teeth on back and front. Comb scales with teeth graded from side to apex, but with no strongly differentiated apical tooth. (Fig. 51, page 248)......... *Ochlerotatus tæniorhynchus.*

45. Comb scales with apical tooth decidedly stouter and sometimes longer than secondary teeth 46
Comb scales with apical tooth of nearly equal size to secondary teeth; tufts of tube at its middle............ *Ochlerotatus lazarensis.*

46. Ninth segment ringed with chitin. Comb scales with apical teeth decidedly longer than secondaries. Tube at most two and one-half times as long as broad 47
Ninth segment with saddle of chitin. Comb scales with apical teeth stouter but not longer than secondaries. Tube three and one-half to four times as long as broad............ *Lepidoplatys sylvicola.*

47. Body sparsely covered with minute, simple hairs (visible under a two-thirds objective). Labial plate with thirty-one to thirty-three teeth...............................49
Body without minute hairs................48

48. Breathing tube at least three times as long as wide .... *Ochlerotatus mitchellæ.*[1]
Breathing tube not over twice as long as wide. Body with papillate appearance under a one-sixth objective. Labial plate with at most 25 teeth. (Fig. 32, page 159.) *Ochlerotatus sollicitans.*

[1] This species appears at times to have tuft B two-haired on one side, but as the specimens examined were skins in poor condition, I have not been able to determine whether it is ever two-haired on both sides.

49. Tuft situated slightly above middle of tube. (Fig. 52, page 249).
Ochlerotatus infirmatus

Tuft two-thirds up tube. (Specimen very poor.)
Ochlerotatus trivittatus.

50. Last two or three spines on tube more widely separated than others 51

Last two or three spines on tube not more widely separated than others.............54

51. Comb of two irregular rows, less than fifteen teeth; tuft B three- or four-haired. (Fig. 33, page 164.)
Ochlerotatus sylvestris.

Comb 3-rowed, more than twenty-four teeth, tuft B two- or three- haired..............52

52. With one terminal spine of the antenna well developed, the other spines not over one-half its length, whole antenna rather heavily chitinised, and not as long as the distance between the antennal bases..............53

With three terminal spines of each antenna well developed and subequal, terminal one-fifth of antennæ with very heavy chitin, the rest light, antennæ as long as distance between their bases............*Ochlerotatus aurifer.*

53. First two abdominal segments each bearing two long, single, lateral hairs.
Ochlerotatus vittatus.

First two abdominal segments with one long single and one double lateral hair, or with two long double hairs on first segment.
Ochlerotatus abfitchii.

54. Tufts A and B of five or more plumose hairs. 55

Tufts A and B with less five than hairs each, simple or plumose......................57

55. Central tooth of comb scales scarcely larger than the secondary, the scales usually more than twenty-five. 56

Central tooth of comb scales distinct, about 3 times as long as the secondary teeth, scales less than twenty-five (Louisiana specimens). (Fig. 53, page 250). . . . . *Ochlerotatus impiger.*

56. Ventral tufts of ninth segment generally extending almost to cephalic margin of chitin, always at least half-way 57

Ventral tufts of ninth segment not half-way to cephalic margin of chitin. Antennæ with no small spinules, the tuft represented by a single hair . . . . *Ochlerotatus varipalpus.*

57. Comb in two rows. (Louisiana specimens.) *Ochlerotatus* "*reptans.*"

Comb in three or more irregular rows. 58

58. Spines of the tube, at least those in the outer half of the row, with minute teeth above the largest tooth 60

Spines of tube with no secondary teeth above largest tooth. 59

59. Head tuft A, three-; B, three- or four-haired. Tube scarcely over three by one. . . . . *Ochlerotatus cantator.*

Head tuft A, three-; B, five-haired. (Very rare.) *Ochlerotatus inconspicuus.*

60. Subdorsal tufts on abdominal segments three to six as long as two abdominal segments; long lateral abdominal tufts as long as three segments. Tracheæ angled. Labial plate twenty-one toothed. A, two-, B, three-haired. Pecten continuous. . . . . *Ochlerotatus fitchii.*

Subdorsal tufts on abdominal segments three to six not as long as one segment; long lateral abdominal tufts at most about as long as two segments........................61

61. Scales of comb (twenty-two to thirty in number) with secondary teeth less than one-half as long as the apical tooth. Labial plate having thirty-three to thirty-five teeth. Head unspotted in living specimens.
Ochlerotatus pretans.

Scales of comb with secondary teeth at least three-fourths as long as the apical tooth. Labial plate of twenty-three to twenty-five teeth. Tuft A, one-; B, two- or three-haired.............*Ochlerotatus subcantans.*

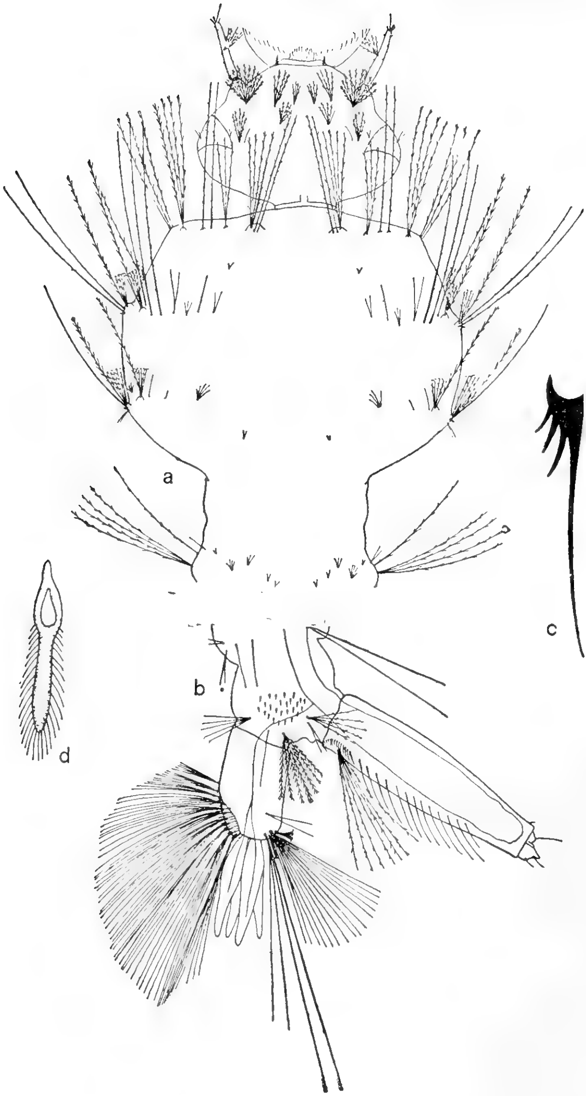


FIG. 41.—Portions of *Culiseta consobrinus* larva (greatly enlarged); *a*, head, thorax and first abdominal segment; *b*, eighth and ninth segments; *c*, spine from tube; *d*, spine from eighth segment.

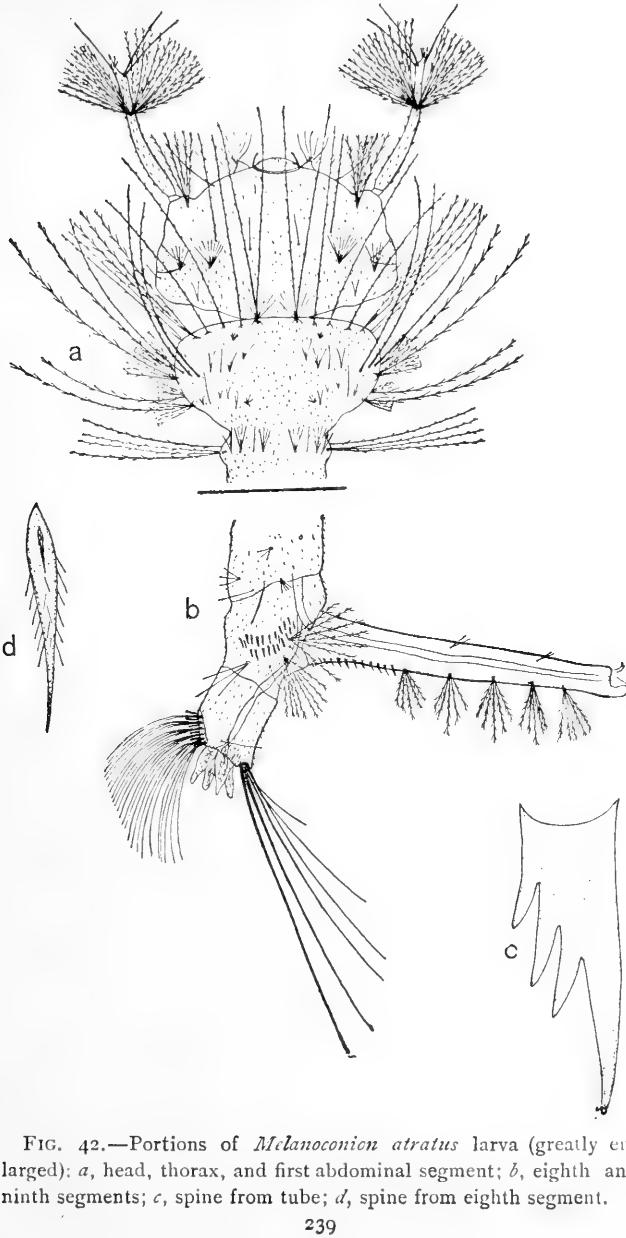


FIG. 42.—Portions of *Melanoconion atratus* larva (greatly enlarged): *a*, head, thorax, and first abdominal segment; *b*, eighth and ninth segments; *c*, spine from tube; *d*, spine from eighth segment.

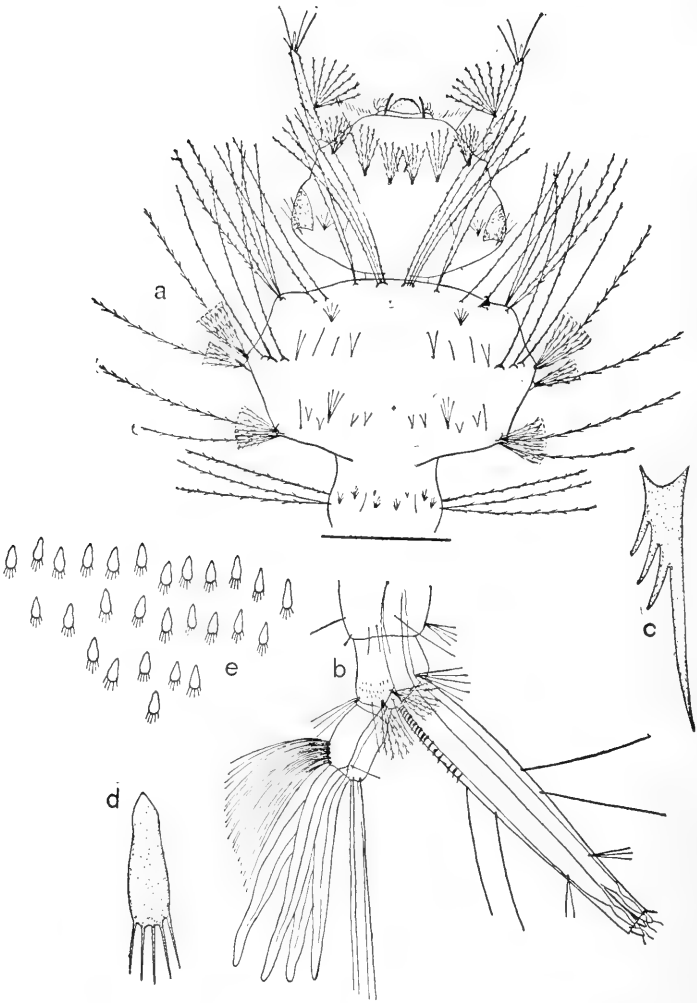


FIG. 43.—Portions of *Culex restuans* larva (greatly enlarged): *a*, head, thorax, and first abdominal segment; *b*, eighth and ninth segments; *c*, spine from tube; *d*. spine from eighth segment; *e*, whole comb of eighth segment.

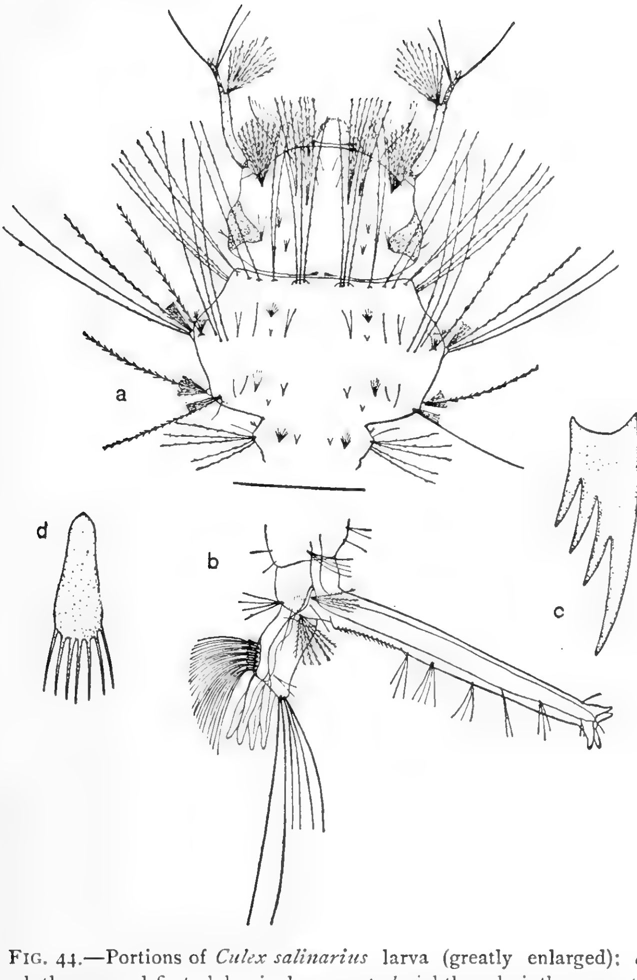


FIG. 44.—Portions of *Culex salinarius* larva (greatly enlarged): *a*, head, thorax, and first abdominal segment; *b*, eighth and ninth segments; *c*, spine from tube; *d*, spine from eighth segment.

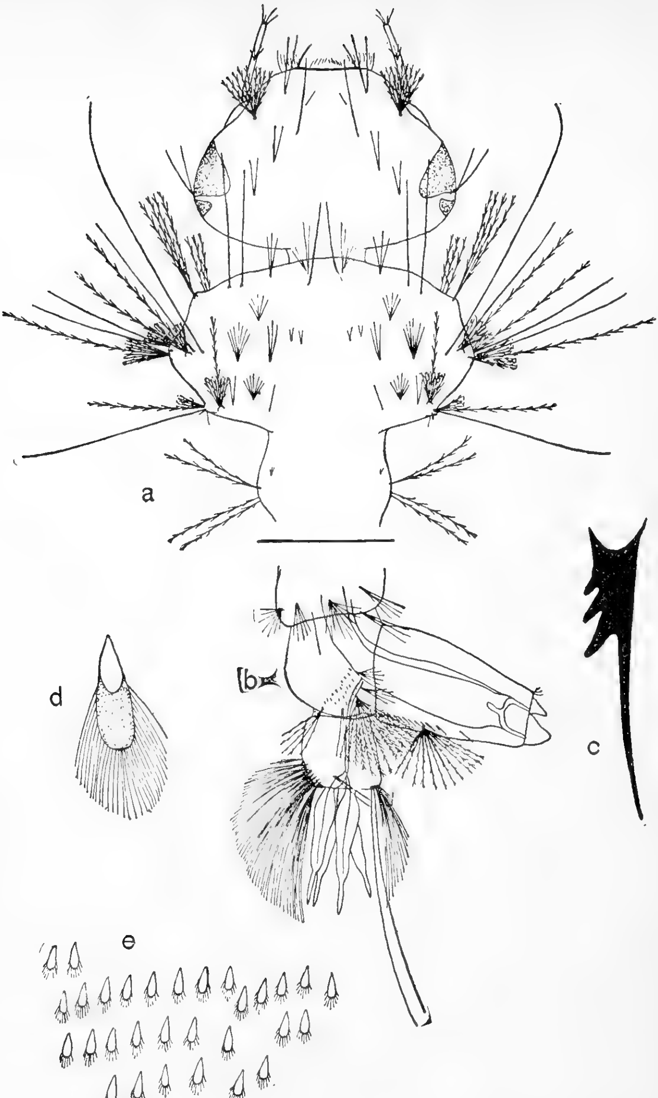


FIG. 45.—Portions of larva of *Ochlerotatus bimaculatus* (greatly enlarged): *a*, head, thorax, and first abdominal segment; *b*, eighth and ninth segments; *c*, spine from tube; *d*, spine from eighth segment; *e*, whole comb.

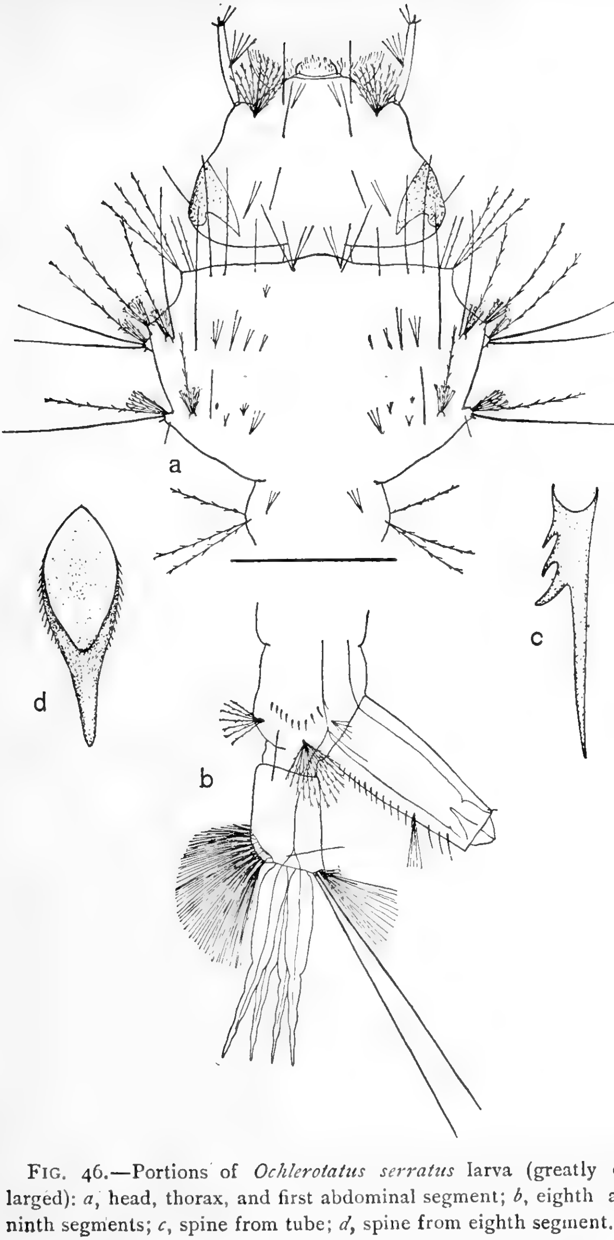


FIG. 46.—Portions of *Ochlerotatus serratus* larva (greatly enlarged): *a*, head, thorax, and first abdominal segment; *b*, eighth and ninth segments; *c*, spine from tube; *d*, spine from eighth segment.

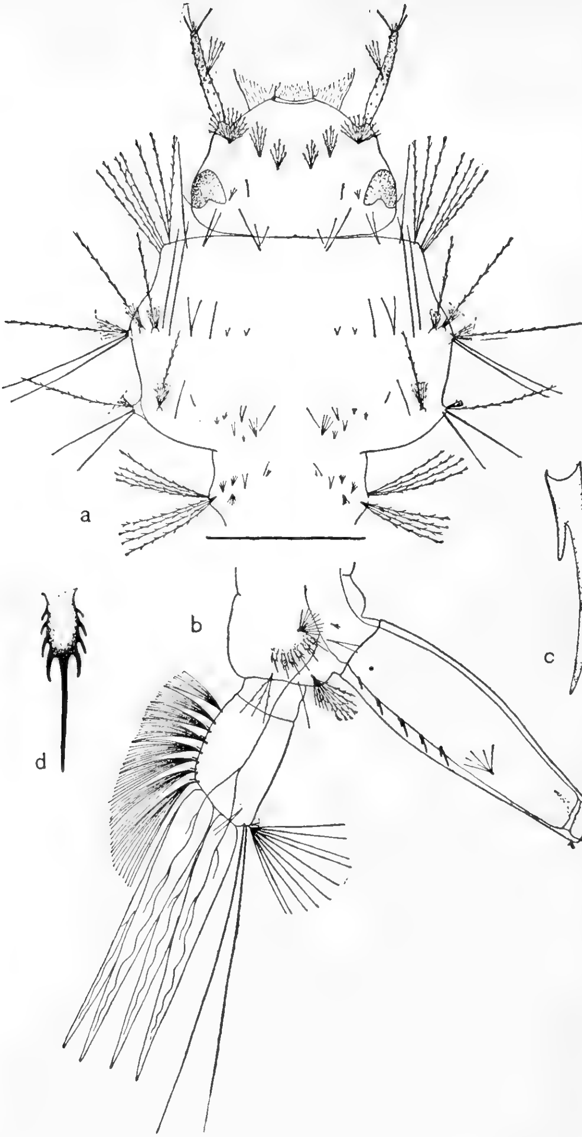


FIG. 47.—Portions of larva of *Grabhamia jamaicensis* (greatly enlarged): *a*, head, thorax, and first abdominal segment; *b*, eighth and ninth segments; *c*, spine from tube; *d*, spine from eighth segment.

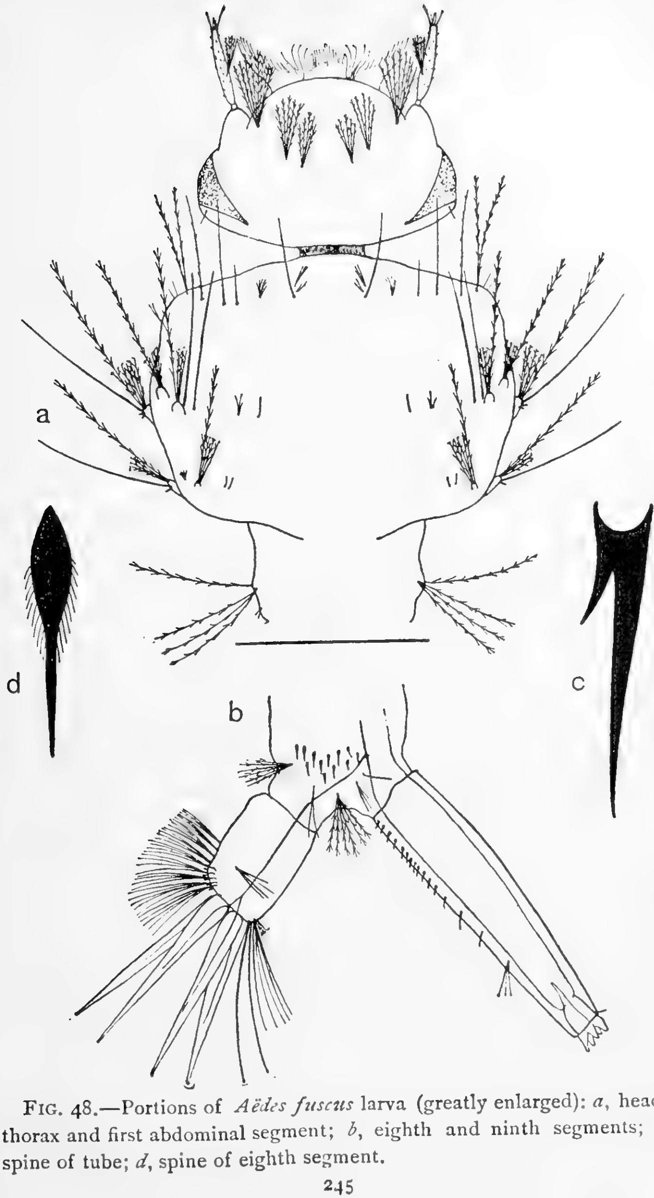


FIG. 48.—Portions of *Aëdes fuscus* larva (greatly enlarged): *a*, head, thorax and first abdominal segment; *b*, eighth and ninth segments; *c*, spine of tube; *d*, spine of eighth segment.

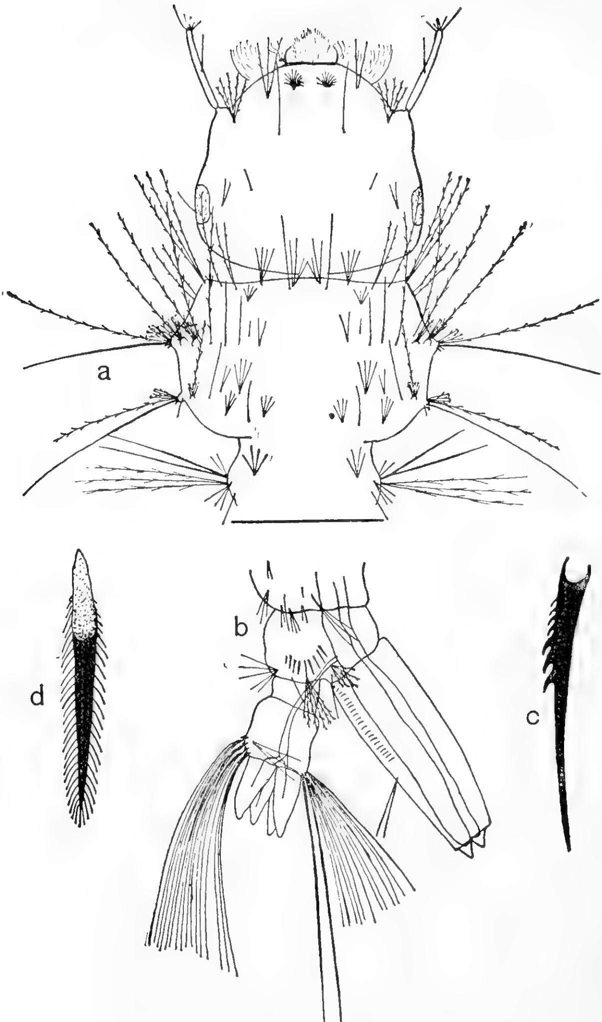


FIG. 49.—Portions of *Ochlerotatus triseriatus* larva (greatly enlarged): *a*, head, thorax and first abdominal segment; *b*, eighth and ninth segments; *c*, spine of tube; *d*, spine of eighth segment.

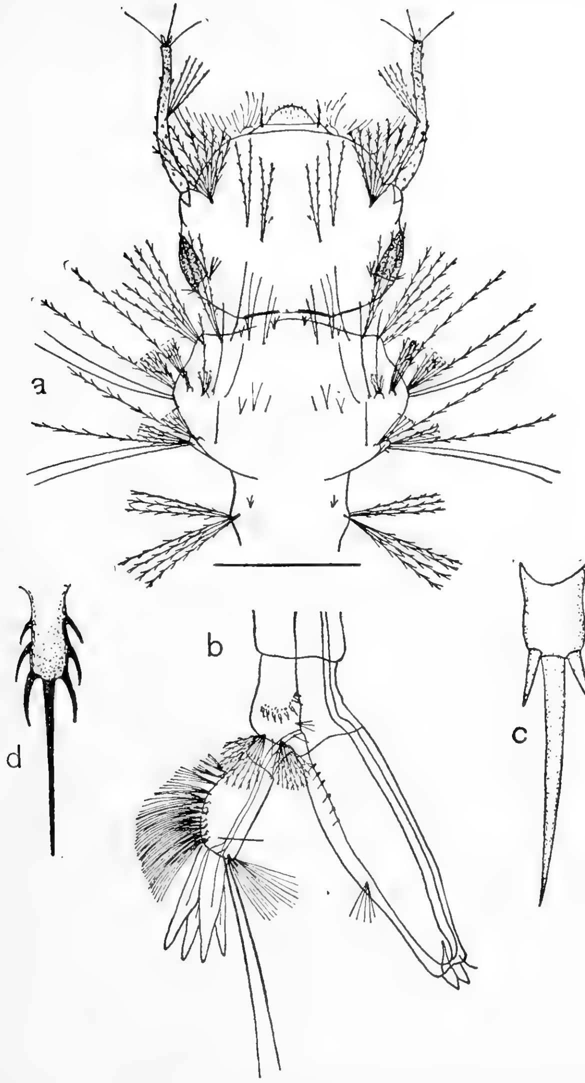


FIG. 50.—Portions of *Janthinosoma varipes* larva (greatly enlarged): *a*, head, thorax and first abdominal segment; *b*, eighth and ninth segments; *c*, spine of tube; *d*, spine of eighth segment.

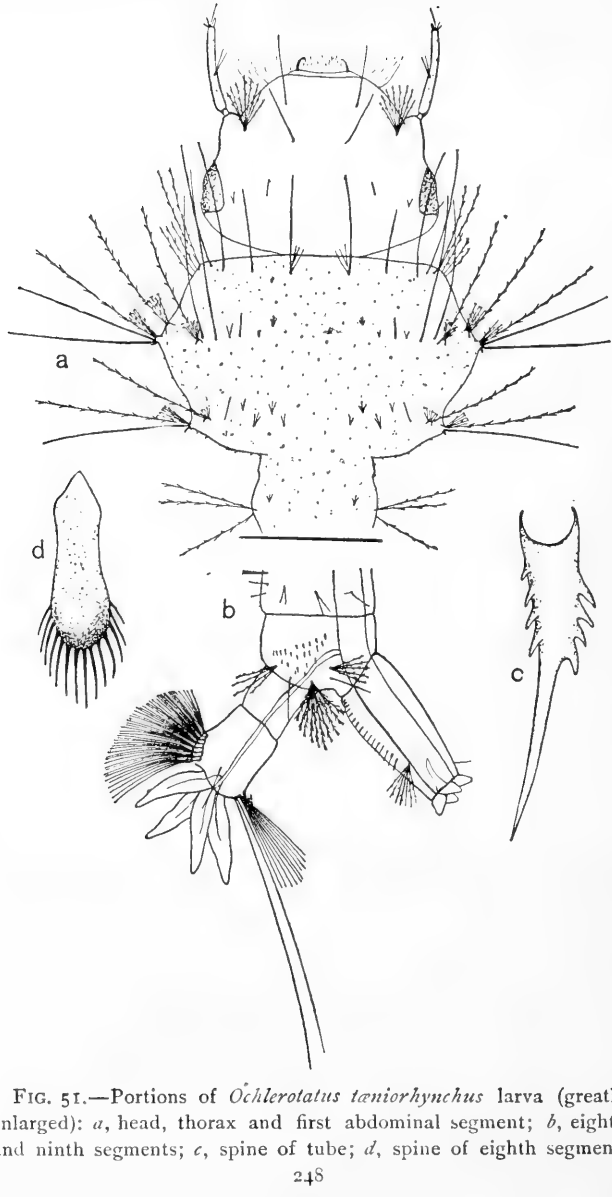


FIG. 51.—Portions of *Ochlerotatus tæniorhynchus* larva (greatly enlarged): *a*, head, thorax and first abdominal segment; *b*, eighth and ninth segments; *c*, spine of tube; *d*, spine of eighth segment.

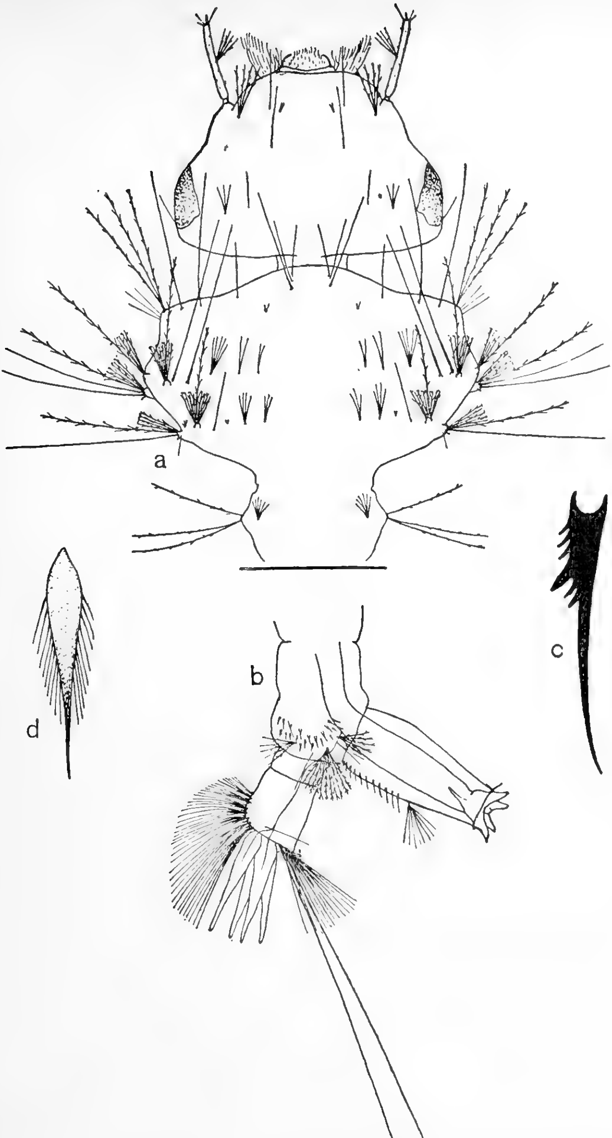


FIG. 52.—Portions of *Ochlerotatus infirmatus* larva (greatly enlarged): *a*, head, thorax and first abdominal segment; *b*, eighth and ninth segments; *c*, spine of tube; *d*, spine of eighth segment.

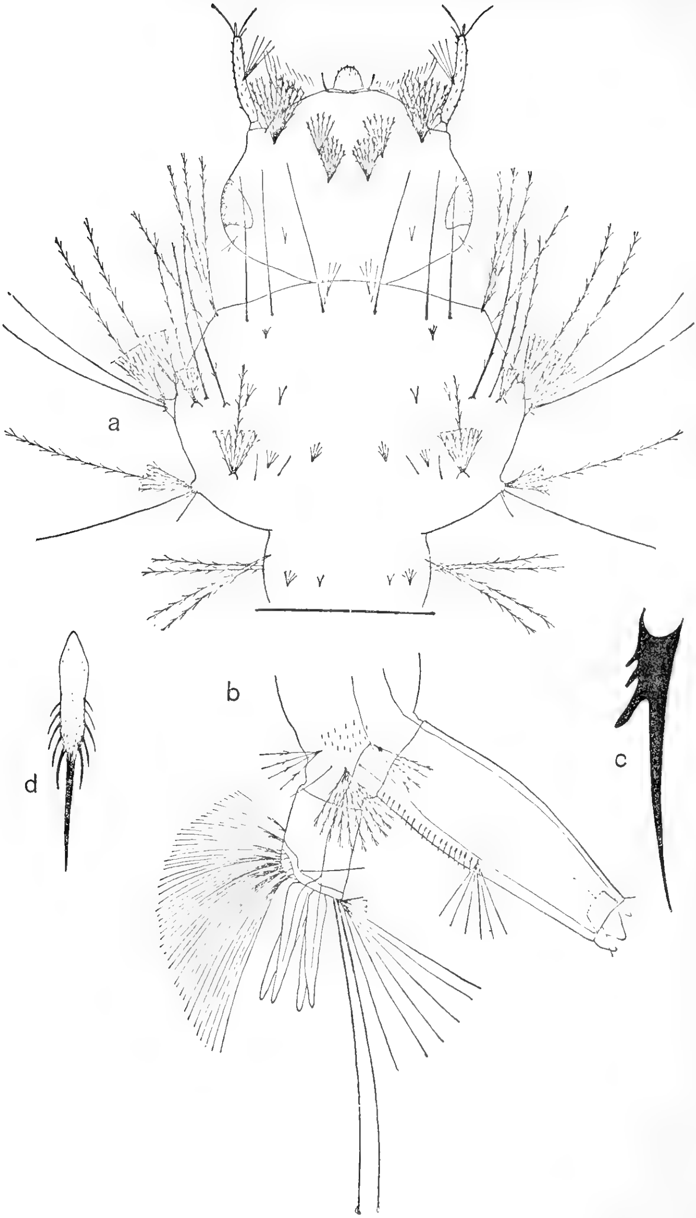


FIG. 53.—Portions of *Ochlerotatus impiger* larva (greatly enlarged): *a*, head, thorax, and first abdominal segment; *b*, eighth and ninth segments; *c*, spine of tube; *d*, spine of eighth segment.

Key to Pupæ.[1]

1. Abdomen with a spine on the caudal margin of the lateral angle of each segment beyond the 3rd. Breathing tubes not over twice as long as greatest width, squarely truncate at top, with sharp notch at inner side.........*Anopheles.*
   Abdomen unspined........................2

2. Paddles diverging widely, scarcely overlapping at base, a fringe of minute spines on inner margin, continued in two or three rows around the tip for a short distance on the outer margin. Breathing tubes about eight times as long as wide, constricted at or near upper fourth, the apex flaring somewhat. Length about 15 mm..........*Megarhinus.*
   Paddles diverging but slightly at most, usually overlapping well at base and inner margin, the terminal hair or tuft present. Breathing tubes never constricted near upper fourth..3

3. Paddles as broad as long. Terminal tuft minute. Pupa generally large (9 to 10 mm.), very heavily chitinised. Hairs of head and thorax minute, never over two in a tuft..........4
   Paddles longer than broad, terminal hair or hairs generally well developed, if not, having the hairs on head and thorax very long, or with at least two well-developed tufts of two or more branches........................5

4. All hairs on dorsal half of segment eight double, two double hairs on dorsum of segment seven. *Psorophora howardii.*
   All hairs but one on dorsal half of segment eight, single, five double hairs on the dorsal half of segment seven..........*Psorophora ciliata.*

[1] For references to hairs, etc., see Fig. 54, page 258.

5. With a double hair on thorax long enough to reach from eye to breathing tubes and bent in two approximately right angles, situated in the dorso-caudal angle between the eye and the antenna case. A large, plumose tuft, longer than the segment, on the lateral caudal angle of the last and penultimate segments.................. *Wyeomyia smithii.*
With no such hair or tufts..................6

6. Breathing tubes very slender, over nine times as long as wide. Stellate tufts of widely diverging hairs on head, thorax and abdominal segments three to five.. *Uranotænia sapphirina.*
Breathing tubes never nine times as long as wide. No stellate tufts, though sometimes a tuft of not more than four widely diverging hairs on some of the abdominal segments..........7

7. With D conspicuously longer (four or five times.) than E or F............*Deinocerites cancer*
With D not conspicuously longer than E or F..8

8. Having M on abdominal segments five and six represented by a single hair.
Grabhamia jamaicensis.
Having M on segments five or six composed of two or more hairs.......................9

9. K, at least on segments five and six, composed of a single hair.........................10
K on segments five and six, of two or more hairs..................................15

10. With K on segments five and six noticeably shorter than the following segments......12
With K on segments five and six about as long as, or longer than, the following segments..11

11. H on segments five to seven single. D, F, and G two-haired. M on segments four to six, two-haired. K on segments five to seven not noticeably longer than the following segments. . . . . *Ochlerotatus triseriatus.*

H on segments five to seven, double. D, F, and G three-haired. M on segments four to six, three- or more haired. K on segments five to seven noticeably longer than the following segments. . . . . *Ochlerotatus dupreei.*

12. Segment eight having H of two or more hairs. 13

Segment eight having H of one hair. 14

13. F double, with a long single hair exceeding it in length just in front of it. H on ninth segment large, composed of about five stiff hairs which are conspicuously plumose at about half their length; on segments five and six double; two tufts on ventral side of segment three. *Stegomyia calopus.*

F double, with no long hair in front of it. H on ninth segment of six or seven small hairs not noticeably plumose; on five to seven single hairs. No tufts, but one hair, on ventral side of segment three. *Ochlerotatus varipalpus.*

14. G three-haired. H on segments four to six, double; on segment eight single, with a hair just ahead. D, E, and F, two-, three-, and two-haired respectively. Breathing tubes five times as long as wide. . . . . *Aëdes fuscus.*

G single. H on segments four to six, single; on segment eight a small double hair, with no hair ahead. D, E, and F, two-, two-, and one-haired respectively. Breathing tubes three times as long as wide. . . . . *Janthinosoma varipes.*

15. H on segments four to seven, four-haired, the hairs long and widely divergent; on segment eight a small tuft with a long one just ahead. K two-haired, long, on segments six and seven; three-haired, short, on segments four and five.................... *Culex tarsalis.*

H never four-haired, at least on segments six and seven, and never with widely divergent hairs.................................. 16

16. K on segments four and five, or five to seven, conspicuously longer than the chitin of the next segment.......................... 17

K never conspicuously longer than the chitin of the following segment.................. 18

17. Breathing tubes over five times as long as wide. Segments five to seven having K at least twice as long as the following segment. *Culex restuans.*

Breathing tubes somewhat over twice as long as wide. Segments five to seven having K not over one and one-half times the length of the following segment. *Ochlerotatus tæniorhynchus.*

18. Terminal tufts on paddles small, four- to six-haired. Many of the body tufts compoundly branched............. *Pneumaculex signifer.*

Terminal tufts on paddles, if minute, not having over two hairs....................... 19

19. With terminal hair on paddle at least one-third the length of the latter................. 20

With the terminal hair never over one-fourth the length of paddle.................... 21

20. Breathing tubes over three and one-half times as long as wide, spines not noticeable. K on segments six and seven, single. Terminal hair about one-half the length of paddle............. *Ochlerotatus atropalpus.*

Breathing tubes twice as long as wide, quite heavily spined. Terminal hair one-third the length of paddle. K on segments five to seven double........*Grabhamia discolor.*

21. Terminal hairs of paddle two, minute.......22
Terminal hair single, not minute...........26

22. Breathing tubes about three times as long as wide.................................. 23
Breathing tubes at least six times as long as wide...................................24

23. H, on eighth segment, four- or five-haired, small, less than half as long as segment; a long, stout, two-haired tuft ahead. G two-haired. K and M, on segment five, of four or more hairs, not as long as the following segment. *Theobaldia incidens.*
H, on eighth segment, four-haired, about half the length of the segment, no tuft ahead. G, four-haired. K and M, on segment five, two-haired, as long as following segment. *Ochlerotatus curriei.*

24. Segment eight with H small, three-haired, a well developed tuft of five somewhat plumose hairs ahead. D, five-haired. M on segments six to eight, of three or more hairs. *Culex salinarius.*
Segment eight with H two- or one-haired, a two-haired tuft ahead........................25

25. The pair of tufts beneath eye each three-haired. M on segments six and seven, having at least three hairs, D and F, three-haired, D cephalad of suture...................*Culex territans.*
The pair of tufts beneath eye each two-haired. M on segments six and seven, two-haired, D and F each two-haired, D not cephalad of suture...............*Janthinosoma posticata.*

26. Tufts K and M on segment five, both with four or more hairs.............................27
Tufts K and M not having four or more hairs each......................................29

27. Seventh and eighth segments having H, four-haired; D, five-haired; G, one-haired. Breathing tubes over six times as long as wide. Segments four and five, with one long tuft above margin. *Culex pipiens.*
Seventh and eighth segments not having H four-haired. Without the other above combination of characters 28

28. Having one or two long, single hairs on the ventral half of segments six to eight. D, three-haired, G, two-haired. Breathing tubes four times as long as wide. Segments four and five each with two tufts, one of them short, just above margin...........*Culiseta consobrinus.*
Having no conspicuous single hairs on ventral half of segments six to eight. Tubes decidedly flaring and truncate. Without above combination of characters....*Melanoconion atratus*

29. With H sub-obsolete on segments four to seven or four to six; if so on four to seven, with four-haired tuft on ventral margin of segment five......................................30
With H well developed on segments four to seven. With at most a two-haired tuft on segment five....................................32

30. Single hair dorsad of H on segment nine. Tufts K and M on segments four to seven, of over two hairs............*Ochlerotatus canadensis.*
Single hair represented by a tuft on segment nine. Tuft M, sometimes K also, on segments four to seven, with three or more hairs..........31

31. F short, two- or three-haired. Segment eight, K three- or four-haired, a longer two-haired tuft between it and H ; I, four-haired, conspicuous; M, five-haired........*Ochlerotatus infirmatus.*
F long, five-haired. Segment eight, K three. haired, no tuft between it and H; I, two-haired; M, two-haired.........*Ochlerotatus serratus.*

32. M, on segments seven and eight, one-haired, short; D, E, F, and G, three-, three-, three-, and one-haired respectively. Breathing tubes three times as long as wide. H, on segment eight, having one small hair, with a longer double hair cephalad.........*Ochlerotatus sylvestris.*
M, on segments seven and eight, two- or more haired, over one-half as long as the following segments..............................33

33. H, on segment nine, a tuft of five or more hairs. 34
H, on segment nine, a single hair: D, E, F, and G, three-, two-, two-, and three-haired respectively. Breathing tubes about five times as long as wide................*Culicella dyari.*

34. D and E each two-haired. M, on segments five to seven, four-haired. H, on segment eight, four-haired, with a longer, two-haired tuft cephalad. Breathing tubes four times as long as wide................*Ochlerotatus abfitchii.*
D and E each with three or more hairs. Following combination of characters not as above. 35

35. K and M, on segment eight, each two-haired. Hair dorsad of H, on segment nine, double. H and the tuft cephalad of it on segment eight, not much different in size................36
K, on segment eight, four-haired, shorter than in preceding group. Hair dorsad of H, on segment nine, single. H on segment eight much shorter than the tuft cephalad. D, E, F,

and G, five-, five-, three-, and three-haired respectively............*Ochlerotatus sollicitans.*

36. K, on segments six and seven, three-haired. M, on segment five, three-haired. H, on segment eight, four-haired, with five somewhat longer hairs in the tuft just cephalad. D, E, F, and G, four-, four-, five-, and four-haired respectively. Breathing tubes over three, but less than four, times as long as wide................*Ochlerotatus mitchellæ.*

K, on segments six and seven, two-haired. M, on segment five, five-haired. H, on segment eight, three-haired, about as long as the tuft of three hairs just cephalad. D, E, F, and G, four-, three-, two-, and four-haired respectively. Breathing tubes five times as long as wide....*Ochlerotatus aurifer.*

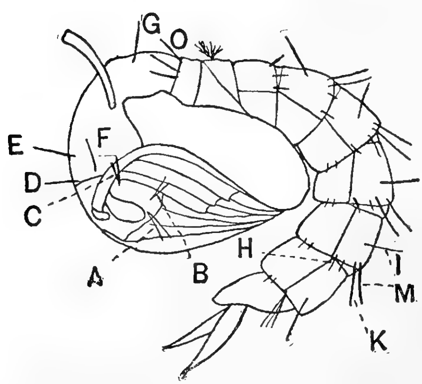


FIG. 54.—Diagram of pupa, showing location of hairs referred to in the key.

LIST OF SUBFAMILIES, GENERA, AND SPECIES.

(*Synonyms are in* plain *type and are indented.*)

Subfamily ANOPHELINÆ, Theobald.

Genus ANOPHELES, Meigen.

SPECIES AND SYNONYMS.

barberi, Coq.
crucians, Wied.
franciscanus, McCracken.
punctipennis, Say.
  hyemalis, Fitch.
maculipennis, Meig.
  annulimanus, Wulp.
  bifurcatus, Meig. (not Linné).
  quadrimaculatus, Say.

UNRECOGNISED SPECIES.

bifurcatus, Linné; *nigripes*, Staeger; *walkeri*, Theob.

Subfamily MEGARHININÆ, Theobald.
Syn. Lynchiellinæ, Lahille.

Genus MEGARHINUS, Desvoidy.
Syn. Lynchiella, Lahille.

SPECIES AND SYNONYMS.

septentrionalis, D. and K.
  ferox, Walk. (not Wied.).
  herrickii, Theob.
  portoricensis (U. S. references).
rutilus, Coq.

Subfamily PSOROPHORINÆ, Mitchell.

Genus PSOROPHORA, Desvoidy.

SPECIES AND SYNONYMS.

ciliata, Fab.
conterrens, Walk.
molestus, Wied.
perterrens, Walk.
rubidus, Desv.

howardii, Coq.

Subfamily CULICINÆ, Theobald.
Syn. Ædeomyinæ, Theobald; Hæmagoginæ, Lutz.

Genus LEPIDOSIA, Coquillett.

SPECIES.

cyanescens Coq.

Genus JANTHINOSOMA, Arribalzaga.
Syn. Conchyliastes, Theobald.

SPECIES AND SYNONYMS.

discrucians, Walk. (not Giles and Theob.).
arribalzagæ, Giles.
lutzii, Theob.
albitarsis, Neveu-Lemaire (not Theob.).
discrucians, Giles and Theob. (not Walk.).

posticata, Wied. (not Theob.).
musica, Say.
sayi, Dyar and Knab.
varipes, Coq.

Genus STEGOMYIA, Theobald.

SPECIES AND SYNONYMS.

calopus, Meig.
annulitarsis, Macq.
bancroftii, Skuse.
elegans, Ficalbi.
exagitans, Walk.
excitans, Walk.
fasciata, Fab.
formosa, Walk.

calopus—(continued)
frater, Desv.
incompatabilis, Walk.
inexorabilis, Walk.
konoupi, Brullé.
luciensis, Theob.
mosquito, Desv.
queenslandensis, Theob.
rossii, Giles.
tæniatus, Wied.
toxorhynchus, Macq.
viridifrons, Walk.
zonatipes, Walk.

Genus Lepidoplatys, Coquillett.

Species and Synonymy.

squamiger, Coq.
deniedmanni, Lud.
sylvicola, Grossb.

Genus Aëdes, Wiedemann.

Species.

fuscus, O. S. (*A. smithii* belongs to *Wyeomyia.*)

Genus Ochlerotatus, Arribalzaga.

Syn. Culicada, Felt; Culicelsa, Felt; Ecculex, Felt; Protoculex, Felt; Pseudoculex, Dyar.

Species and Synonyms.

abfitchii, Felt.
siphonalis, Grossb.
abserratus, F. and Y.
atlanticus, D. and K.
serratus, Smith (not Theob.).
atropalpus, Coq.
aurifer, Coq.
auroides, Felt.
bimaculatus, Coq.
bracteatus, Coq.
cantator, Coq.
canadensis, Theob.
cinereoborealis, F. and Y.
trichurus, Dyar.
curriei, Coq.
lativittatus, Coq.?
onondagensis, Felt?
dupreei, Coq.
fitchii, F. and Y.
fletcheri, Coq.
impiger, Walk.
implacabilis, Walk.
inconspicuus, Grossb.
infirmatus, D. and K.
confirmatus (N. Am. references).
lazarensis, F. and Y.
mitchellæ, Dyar.

nivitarsis, Coq.
onondagensis, Felt.
lativittatus Coq.
(See *curriei*.)
pallidohirta, Grossb.
pretans, Grossb.
pullatus, Coq.
punctor, Kirby.
reptans, Meig.?
serratus, Theob.
mathisi, Nev.-Lem.
tormentor, D. and K.
sollicitans, Walk.
spenceri, Theob.
idahoensis, Theob.
subcantans, Felt.
sylvestris, Theob.
montcalmi, Blanch.
tæniorhynchus, Wied.
damnosus, Say.
triseriatus, Say.
nigra, Lud.
(Finlaya.)
trivittatus, Coq.
varipalpus, Coq.
sierrensis, Lud.

UNRECOGNISED SPECIES.

æstivalis, Dyar; *excrucians*, Walk.; *hirsuteron*, Theob.; *nigromaculis*, Ludlow; *provocans*, Walk.; *stimulans*, Walk.; *testaceus*, van der Wulp.

Genus GRABHAMIA, Theob.
Syn. Feltidia, Dyar.

SPECIES AND SYNONYMS.

discolor, Coq.
jamaicensis, Theob.
confinis (all references in U. S.).
pygmæa, Theob.
antiquæ, Giles.
nana, Coq.
signipennis, Coq.

Genus CULICELLA, Felt.

SPECIES AND SYNONYMY.

dyari, Coq.
brittoni, Felt.

Genus THEOBALDIA, Neveu-Lemaire.

SPECIES AND SYNONYMS.

annulata, Schrank.
affinis, Stephens.
variegata, Schrank.
incidens, Thoms.
particeps, Adams.

Genus CULISETA, Felt.

SPECIES AND SYNONYMS.

absobrinus, Felt.
consobrinus, Desv.
impatiens, Walk.
inornatus, Will.
magnipennis, Felt.
pinguis, Walk.

Genus CULEX, Linné.

Syn. Heteronycha, Arribalzaga; Neoculex, Dyar.

SPECIES AND SYNONYMS.

fatigans, Wied.
pipiens, Linné.
boscii, Desv.
cubensis, Bigot.
ferruginosus, Wied. (Anoph.).
pungens, Wied.
quinquefasciatus, Say.
restuans, Theob.
salinarius, Coq.
nigritulus (N. Am. references).
saxatilis, Grossb.
tarsalis, Coq.
affinis, Adams (not Stephens).
kelloggii, Theob.
peus, Speiser.
willistoni, Giles.
territans, Walk.
apicalis, Adams.

Genus MELANOCONION, Theobald.

SPECIES.

atratus, Theob.
melanurus, Coq.

Genus TÆNIORHYNCHUS, Arribalzaga.

Syn. Coquillettidia, Dyar.

SPECIES.

perturbans, Walk.

UNRECOGNISED SPECIES.

richardi, Ficalbi; a European species reported from Canada by Theobald.

Genus Pneumaculex, Dyar.

Species.

signifer, Coq.

Subfamily DEINOCERITINÆ, Mitchell.

Genus Deinocerites, Theobald.

Syn. Brachiomyia, Theobald.

Species and Synonyms.

cancer, Theob.
magna, Theob.

Subfamily URANOTÆNINÆ, Lahille.

Genus Uranotænia, Arribalzaga.

Species and Synonymy.

lowii, Theob.
continentalis, D. and K.

sapphirina, O. S.

socialis, Theob.
coquilletti, D. and K.

Subfamily TRICHOPROSOPONINÆ, Theobald.

Syn. Dendromyinæ, Lutz ; Hyloconopinæ, Lutz ; Sabettinæ, Blanchard.

Genus Wyeomyia, Theobald.

Species.

smithii, Coq.

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This does not pretend to be a complete bibliography, but merely refers to the most important works. A complete list of all the notes and papers published would take up much space and be of little value to the mass of readers.

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APPENDIX.

MOSQUITOES AND LEPROSY.

IN a most interesting letter from Dr. Dupree to Dr. Albert S. Ashmead, of New York, in reply to inquiries concerning the transmission of leprosy by mosquitoes, are also some statements concerning the possible culpability of the wicked flea. Although these do not properly belong to this work, the correspondence is of so much interest that it seems a pity to lose any of it. I have, therefore, in substance set down practically the whole.

Dr. Ashmead's remarks and queries cover, in brief, the following points: Leprosy never arises *de novo*, but it is supposed that the bacilli, or spores, may remain in the soil, etc. The earth may possibly be also infected by dead insects, or by grubs and earthworms, and human beings be inoculated by one or more species of insects (the disease being bacterial, and not protozoan). Referring to the case of some people who lived, after the death of two lepers, in and very near the homes of the latter, and who took the disease, while the wife and husband of the two original lepers escaped entirely, it is suggested that the infection might have been carried to the latter patients by insects, from the leper's soiled dressings, which were thrown out of the back doors and left on the ground. Leprosy is always carried to a virgin soil by immigrants, or by the effects of lepers. When first introduced into a new country it is endemic (exists only in imported cases), for fifty to one hundred years, when it suddenly becomes epidemic (occurs in people who have never been out of the country). Something appears to have become infected, either insects or food, as in Colombia, S. A., where forty years ago, as U. S. Minister McKinney wrote Dr. Ashmead, there were but 400 lepers, and to-day there are 30,000. In this case, the insects have become infected. Hawaii is another example of infection from abroad; the Kanaka race is now being destroyed by epidemic leprosy. At Molokai there are 700 or 800 dogs, all much infested with fleas. Visitors going there by every boat from Honolulu, carry home infected fleas. This would account for the increasing number of lepers in Honolulu. The mosquitoes would not go far from Molokai and its fish ponds, the fish of which may be contaminated by bacteria from the stomachs of mosquito larvæ bred in the ponds, and, being eaten raw, may spread the disease among the Kanakas; this is also the case with the carp in Japan, where the fish is eaten raw, often, indeed, living. Dr. Sommer, of Buenos Ayres, writes Dr. Ashmead that in Argentina the salt licks of various animals are the breeding places of leprosy. These places are known to be the congregating point, too, of hosts of fleas, as well as being mosquito breeding localities. As fleas show the leper bacillus in their intestinal contents, it is reasonable to assume that it was the flea of swine that propagated leprosy in Brazil. It has been found that the bacillus of leprosy cannot grow in the presence of oxygen. Are, then, mosquitoes and fleas chlorine free? or are mosquitoes acid, like ants? The fact that lesions of leprosy occur always on the exposed parts of the human body would indicate an inoculation by insects, possibly an internal inoculation through the chyle and mesenteric glands from food contaminated by insects, which had sucked the blood or sores of lepers. (Now, fleas are said to like raw meat, and I have seen salt marsh and other mosquitoes sucking at the juices of fish which I had caught and was cleaning there in the boat. Might not these insects thus either inoculate the food with their probosces or by depositing their fæces upon it?)

Dr. Dupree replies in substance as follows: The statement made by Dr. Ashmead that he has shown that those sections of Japan most afflicted by elephantiasis are in exact ratio also scourged by leprosy, seemingly suggests a common carrier for the two viruses. In this case, *C. fatigans*, *microannulatus*, *albopictus*, *pipiens*, and *albimanus; A. rossi* and *nigerrimus*, *Cellia argyrotarsis* and *albimanus*, known to transmit filariasis, may also infect with leprosy. Possibly still other species may be guilty as well.

Leprosy preceding, concurrent with, or sequential to a malarial attack, as is the usual case with Japanese leprosy, may be merely a coincidence, or due to simultaneous infection with malaria protozoa and leper bacilli brought by the same mosquito, which is not at all unlikely.

Whether or not the leper bacillus has a spore stage is in doubt. Bacilli will not be brought up from a deep interment by earthworms, nor can they come to the surface unaided. But internal inoculation of leprosy may occur from eating food contaminated by insects filled with infected secretions. The insects may have come, by flight or otherwise, from some distance. If fish are contaminated by mosquito larvæ, the question is raised as to how these larvæ have received the infection. There are two possible methods. The adult may have laid an infected egg, or the larvæ may have become infected by devouring bacilli liberated in the ponds by disintegrated dead bodies of infected mosquitoes. Leprosy, however, existed in Hawaii before mosquitoes were brought there, which last was accomplished by larvæ breeding in the water tanks of American vessels. Before this introduction leprosy was probably spread by fleas. Unquestionably, bloodsucking or secretion-feeding mosquitoes may become infected with bacteria or their spores. Many of the ingested bacteria may escape destruction and pass out with the fæces in a virulent condition. Probably in some instances the bacteria actually multiply within the bodies of mosquitoes and possibly reach the salivary glands, escaping with the secretion when it is emitted.

Fleas, known to convey plague bacilli from rats, may also deposit fæces infected with leper bacilli on the mangy sores of dogs, where the bacilli may multiply and reinfect other fleas. The bacilli are known to exist in fleas that have bitten leprous persons. Nuttall, however, claims that fleas do not transmit bacteria, but by sucking they remove any that may be present at the point of puncture; further, that inoculations of anthrax-infected organs of fleas into healthy animals always give negative results, while similar experiments with bedbugs are always successful. Carasquilla holds that fleas are responsible for the spread of leprosy, and that it is not contagious. Cases of undoubted transmission of leprosy by means of bedbugs are also recorded, therefore in a leprous country the greatest care should be taken to prevent the bites of insects, as there are apparently numerous possibilities of infection.

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Note:—Figures in italics denote illustrations; black-faced type signifies that the subject is there treated in detail.

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Grabhamia discolor = Psorophora (G.) discolor Coq.
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G. pygmaea = P.(G.) pygmaea Theob.
G. signipennis = P.(G.) signipennis Coq.
Culicella dyari = Culiseta (Culicella) dyari Coq.
Theobaldia annulata = ?
T. incidens = Culiseta (Culiseta) incidens Theob.
Culiseta absobrinus = C.(C.) impatiens Walk. ? (Walk.)
C. consobrinus = C.(C.) inornatus Will. and C.(C.) impatiens
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Anopheles barberi Coq. = A. (Coelodiazesis) barberi Coq.
A. crucians Wied. = A. (A.) crucians Wied. (Theob.)
A. franciscanus Macer. = A. (Proterorhynchys) pseudopunctipennis
A. punctipennis Say = A. (A.) punctipennis Say.
A. maculipennis Say = A. (A.) maculipennis Say and A. (A.)
quadrimaculatus Say. (K.)
Megarhinus septentrionalis D. and K. = M. septentrionalis D. and
M. rutilus Coq. = M. rutila Coq.
Psorophora ciliata Fab. = P. (P.) ciliata Fab.
P. howardii Coq. = P. (P.) howardii Coq. (Coq.)
Lepidosia cyanescens Coq. = Psorophora (Janthinosoma) cyanescens
Janthinosoma discrucians Walk. = Psorophora (J.) discrucians Walk.
J. lutzii = ?
J. posticata = P. (J.) sayi D. and K.
J. varipes Coq. = P. (J.) discrucians Coq.
Stegomyia calopus = Aedes (Stegomyia) aegypti Linn.
Lepidoplatys squamiger = Aedes (Heteronycha) squamiger Coq.
L. sylvatica = Aedes (H.) grossbecki D. and K.
Aedes fuscus = A. (A.) cinereus Meig.
Ochlerotatus abfitchii = Aedes (Heteronycha) excrucians Walk.
O. abserratus = form of A.(H.) punctor Kirby.
O. atlanticus = A.(H.) atlanticus D. and K.
O. atropalpus = A.(Taeniorhynchus) atropalpus Coq.
O. aurifer Coq. = A.(H.) aurifer Coq.
O. auroides = A.(H.) punctor Kirby.
O. bimaculatus Coq. = A.(H.) bimaculatus Coq.
O. bracteata Coq. = ?
O. cantator = A.(H.) cantator Coq.
O. canadensis = A.(H.) canadensis Theob.
O. cinereoborealis F. and Y. = A.(H.) cinereoborealis F. and Y. and
A.(H.) trichurus Dyar.
O. curriei = A.(H.) dorsalis Meig.
O. dupreei = A.(H.) dupreei Coq.
O. fitchii F. and Y. = A.(H.) fitchii F. and Y.
O. fletcheri Coq. = A.(H.) flavescens Müller. (A. punctor K.)
O. impiger = A.(H.) impiger Walk., probably also confused with
O. inconspicuus Grossb. = A.(H.) trivittatus Coq.
O. infirmatus = A.(H.) infirmatus D. and K.
O. lazarensis = A.(H.) lazarensis F. and Y., etc.
O. mitchellae = A.(Taeniorhynchus) mitchellae Dyar.
O. nivitarsis = A.(H.) canadensis Theob.
O. onondagensis = A.(H.) dorsalis Meig.
O. pallidohirta = A.(A.) cinereus Meig.
O. pretans = A.(H.) hirsuteron Theob.
O. pullatus = A.(H.) pullatus Coq.
O. punctor = A.(H.) punctor Kirby, etc.
O. reptans Meig. = ?
O. serratus Theob. = ?
O. tormentor = A.(H.) tormentor D. and K.
O. sollicitans = A.(Taeniorhynchus) sollicitans Walk.
O. spenceri = A.(H.) spencerii Theob. and A.(H.) idahoensis Theob.
O. subcantans Felt = A.(H.) stimulans Walk.
O. sylvestris = A.(Ecculex) vexans Meig.
O. taeniorhynchus = A.(Taeniorhynchus) taeniorhynchus Wied.
O. triseriatus = A.(Finlaya) triseriatus Say.

(over)

+ Add water to a portion of ppt. and boil
+ Add potassium chromate to resulting solution
Add ammonium hydroxide to a portion of ppt.

2. Lead acetate plus hydrogen sulfide
3. Lead acetate plus ammonium hydroxide
4. Lead acetate plus ammonium sulfide
5. Lead acetate plus ammonium carbonate
6. Lead acetate plus acid sodium phosphate
7. Lead acetate plus sodium carbonate
8. Lead acetate plus sulfuric acid
+ 9. Lead acetate plus potassium chromate
10. Lead acetate plus potassium iodide

+ Confirming tests for lead

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Culex tarsalis = C.(C.) tarsalis Coq.
Culex territans = C.(Neoculex) testaceus v.d.Wulp.
Melanoconion atratus = ?
M. melanurus = Culex (Climacura) melanurus Coq. (Walk.)
Taeniorhynchus perturbans = Mansonia (Coquilletidea) perturbans
Pneumaculex signifer = Orthopodomyia signifer Coq.
Deinocerites cancer Theob.
Uranotaenia lowii Theob.
U. sapphirina O.-S.
U. socialis Theob.
Wyeomyia smithii = W.(Dendromyia) smithii Coq.

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