

(NEW SERIES.)

No. 25.

SCIENTIFIC MEMOIRS
BY
OFFICERS OF THE MEDICAL AND SANITARY DEPARTMENTS
OF THE
GOVERNMENT OF INDIA.

ON THE IMPORTANCE OF LARVAL CHARACTERS
IN THE CLASSIFICATION OF MOSQUITOES.

BY
CAPTAIN S. R. CHRISTOPHERS, M.B., I.M.S.

ISSUED UNDER THE AUTHORITY OF THE GOVERNMENT OF INDIA
BY THE SANITARY COMMISSIONER WITH THE GOVERNMENT
OF INDIA, SIMLA.



CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.

1906.

ON THE IMPORTANCE OF LARVAL CHARACTERS IN THE CLASSIFICATION OF MOSQUITOES.

IN collaboration with Stephens, I described, in a previous publication,¹ the ovum and larva of most of the common *Anopheles* mosquitoes of India. We gave at that time a division of *Anopheles* into natural groups, largely based upon variations in the immature stages. The groups noted by us, so far as the species investigated were concerned, were practically identical with the genera which Theobald instituted later upon variations in the scale structure of the adult insects; but greater prominence was given to some of these genera, by a consideration of the immature stages, than was apparent from the scale structure of the adults alone.

Of the immature stages of mosquitoes other than *Anopheles*, we unfortunately know very little. The larva of *Anopheles* and that of *Culex* were described by Meinert in 1886.¹ Howard's² description of the larva of *C. pungens* is accurate and detailed. James³ has described and figured the larva of *Stegomyia*, and was the first to draw attention to the occurrence of cannibal larvæ.⁴ The larvæ of species of *Megarhinus*, *Toxorhynchites*, *Desvoidea*, *Theobaldia*, *Melanoconion*, *Grabhamia*, *Acartomyia*, and *Deinocerites* have been to some extent described by Theobald,⁵ who also figures parts of *C. fatigans*, *C. tigripes*, and *C. mimeticus*. In very few of these descriptions, unfortunately, have the points which appear to be of most use in classification been noted. In many cases, indeed, only characters common to nearly all mosquito larvæ have been given.

Before proceeding to describe what has been determined regarding the larval characters of a number of genera of culicidæ other than *Anopheles*, it will be well to briefly mention features which appear to be common to all larvæ, and to single out those which, in my researches, I have found to vary in the different genera or species.

I.

All mosquito larvæ possess a head, an enlarged thorax, and nine abdominal segments.

The Head.—The size and shape of the head vary in the different genera. It is large in *Culex* and *Melanoconion*, smaller in *Anopheles*, *Stegomyia*, and *Tanichtrynchus*.

NOTE.—Mr. Theobald has kindly identified the species of mosquitoes mentioned in this paper from specimens of the adults which I have sent to him.

The upper surface is smooth and convex and carries certain hairs, which are usually six in number. Anteriorly the head forms a rather prominent rounded mass (the clypeus). In some cases the clypeus carries small hairs (clypeal hairs) as in *Anopheles* and *Stegomyia*. As a rule it carries only two thorn-like spines. When present, the clypeal hairs are of specific importance. The clypeus, instead of projecting, may be concave and form a cup-like hollow (cannibal larvæ). In old larvæ of certain species a sharp beak-like process covered with hairs or spines may project from below the clypeus. At the side of the head are the large compound eyes, and immediately behind these are the ocelli of the simple eyes.

The lower surface of the head is smooth and convex and is marked by two grooves which pass from the outer angles of the mental plate backwards. About the middle of the lower surface of the head is a small, dark triangular plate—the *mental plate* or lower lip (Meinert). The mental plate forms a hard and sharp lower lip to the mouth. The upper lip is formed by the prominence already mentioned (clypeus). Arising on each side of the under surface of the clypeus are the *feeding brushes*. These consist, except in cannibal larvæ, of numerous fine curved hairs arranged so as to look very like a shaving brush. In cannibal species these are much modified, each consisting of a series of stout, curved chitinous bars, and are used as a *clasp ing organ* for seizing their prey. The mouth is closed in beneath by two plate-like structures,—*the maxillæ*, which can be opened to expose the buccal cavity, or approximated to almost meet in the middle line. Each maxilla carries on its outer edge a stout, more or less conical, *maxillary palp*. Some variations occur in the maxillæ and palps of different genera; for example, both are very small in *Mucidus* (Pl. III, fig. 14). Lying just behind the maxillæ are two very stout and large plates of chitin—*the mandibles*. On the inner side of each of these there is a variable number of large, strongly chitinised teeth, which meet together, when approximated, in the neighbourhood of the mental plate. Each mandibular plate also has, arising from its anterior edge, a variable number of long processes which are used in combing the feeding brushes and which vary in size and number in different genera.

On each side of the head, arising from prominences in front of the eyes, are *the antennæ*. These vary very considerably in different genera, and have already been shown by us to have great significance in the classification of the *anophelina*. Each antenna consists of a basal segment immoveably fixed and more or less blended with the head mass, and a loosely jointed distal segment carrying various spines, hairs, etc.—the antenna proper. When fully developed, three distinct portions, which, however, form a single unjointed piece, may be distinguished in the distal segment, a proximal, a median, and a shorter distal portion, which I have called the *first, second, and third portion* respectively. At the junction

of the first and second portions a large series of long stout hairs arises which I have termed the *basal tuft*. At the junction of the second and third portions there are generally two large and very stout hairs or spines. I have, for descriptive purposes, termed these the *median spines*. From the end of the third portion, one or more spines project. I have called these *terminal spines*. There is also, at the extreme end of the antenna, a papilla, which may be large and conspicuous, possibly a sense organ. I have named it the *terminal papilla* (Pl. II, fig. 16).

The antennæ are often very small and poorly developed. In the case of some species (*Stegomyia*) this appears due to retrograde changes, since most of the above-mentioned structures are represented only by small hairs or spines.

The Thorax.—The thorax is more or less globular in shape, and greater in diameter than the abdominal segments. The exact size and shape depend upon the genus concerned. On each side, arising from papillæ, are three main series of large, stout hairs. The papillæ, from which these arise, may or may not carry a stout spine resembling a thorn. The hairs are of various lengths in different species and may be simple, branched, or feathered. On the whole they do not appear to be very important from the point of view of ascertaining the affinities of different genera. In addition to the above there are usually a few small hairs which arise immediately behind the head and overhang the occiput. In certain species (open water species, e.g., *Melanoconion Taniorhynchus*) these are large and may form very prominent objects in the living larvæ, projecting to a great distance and appearing to act as tactile organs.

The Abdomen.—The first seven abdominal segments do not appear to be of sufficient importance to be described in detail in the present connection. In the *Anophelina* oar-like feathered hairs arise from the first three segments. This sub-family also differs from all other *Culicidae* in having palmate hairs on some or all of the segments. The eighth and ninth segments require separate mention.

The eighth abdominal segment.—This segment is profoundly modified by the presence of the respiratory openings and their armature. In all genera but the *Anophelina* a tube carries the spiracles to a distance from the segment. This tube has usually been called the respiratory *siphon* or *siphon tube*.

The siphon tube consists of an unbroken tubular piece of chitin of varied shape and size in different species. It usually carries a few small branched hairs, and on the posterior aspect, on each side of the median line, there are two rows of conspicuous spines, the number of which is of specific importance. Each of these spines, is a compound one consisting of three or more long tooth-like processes. Their actual shape seems to be much the same, even in widely different genera, but their appearance varies considerably with the different points

of view. In a few cases only (certain cannibal larvæ) a conspicuous series of hairs, forming a rudder-like expansion, springs from the median line posteriorly. On the eighth segment there are, on either side, a number of claw-like spines. Several small branched hairs also rise near the base of the siphon tube. Neither the spines nor the hairs appear to be of much importance in relation to classification, since they do not vary to any extent in the genera examined. The characters of the siphon tube are of importance, since this organ is subject to great variations in different genera and even in different species. The relative shortness or tenuity of the organ is an important character. In descriptions of larvæ the terms employed in describing this tube do not allow of accurate information being conveyed. I have therefore employed what I have termed the siphonic index. This is obtained by dividing the length by the greatest breadth of the tube. I have employed an eyepiece micrometer for the purpose of measurement. The figures given by the different genera have been very constant.

<i>Stegomyia</i>	<i>sugens</i>	.	.	.	.	.	2
„	<i>fasciata</i>	.	.	.	.	.	1.8
„	?	.	.	.	.	.	1.6
<i>Desvoidea</i>	.	.	.	.	.	.	1.7
<i>Culex</i>	<i>fatigans</i>	.	.	.	.	.	4.3
„	?	.	.	.	.	.	4.1
„	<i>impellens</i>	.	.	.	.	.	5
„	?	.	.	.	.	.	5
<i>Melanoconion</i>	.	.	.	.	.	.	7.5
<i>Tæniorhynchus</i>	<i>tenax</i>	.	.	.	.	.	13
„	<i>N. SP.</i>	.	.	.	.	.	13

In describing the siphon tube, it is desirable that a drawing accurately measured should be given, since the siphon tube is subject to the most extraordinary variations in size and shape. In *tæniorhynchus* it is developed into a long and slender tube. In certain species not yet determined, the siphon tube is enormous.

The ninth abdominal segment.—This very much modified segment lies, during life, so as to form an angle with the rest of the abdomen, and when the siphon tube is large has the appearance of an appendage rather than of an abdominal segment. It is cylindrical in shape, and covered dorsally and laterally by a single curved piece of chitin. The ventral surface of the segment is, for the most part, soft and membranous. Posteriorly is the opening of the anus and around this arranged symmetrically are the four *anal papillæ*. In most larvæ these papillæ are of considerable size, reaching to about one-tenth of the body length. In others they are still larger and very conspicuous (*Desvoidea*). In some cases they are very small and rudimentary (cannibal larvæ). The papillæ

appear to be of the nature of gills. In the case of a species of *Stegomyia*, in which these were of very great size, the larvæ habitually remained long periods without rising to the surface. Dorsally, immediately above the anus, four or six long hairs arise from one or two small chitinous plates. Ventrally, a double row of hairs forms a large fan-like expansion. The variations in the hairs of the ninth segment are not great in the different genera and their arrangement is very similar in *Anopheles*, *Stegomyia*, and *Culex*.

The Nymph.—The nymph consists of a large body formed by the conjoined head and thorax and of a tail composed of nine segments. The general shape and appearance of the nymph varies a little in the larger groups of mosquitoes, and it is possible by this means to distinguish the nymphs of *Anopheles*, *Culex*, and *Mochlonyx*. The most important structures showing variations are:—

The breathing trumpets.—These rise from the dorsum of the thorax and show variations in the manner in which they project from the nymph, and in the details of their structures. No distinct differences were found by me in species of the same genera, but in different genera important variations were detected. The shape of the breathing trumpets of the nymph are of important generic significance.

The tail fins and last segment are also subject to some variations.

II.

The larval features characteristic of many of the genera can in some degree be noted.

Stegomyia.—The ova of *S. fasciata* were first described by Daniels and Ross.⁷ They are laid singly on the water, and form patterns as do those of *Anopheles*. Each ovum is surrounded by numerous small air chambers.

The larvæ of *Stegomyia* are very characteristic and can be distinguished at once by the naked eye. They are found especially in water of a dark brown colour from decayed vegetable matter, but they are also found in ordinary rain or waste water or indeed in any small collection of water and even in nearly pure water in chatties or other receptacles. Their general appearance is more worm-like than that of other larvæ. The full-grown larvæ are generally loaded with fat and have a plump look. When disturbed they travel by means of a curious twisting and lashing motion seen in some small aquatic worms. When breathing at the surface they adopt a nearly vertical attitude quite different from that of most *Culex* larvæ which rest at a distinct angle to the vertical (Pl. III, figs. 22 and 20). *Stegomyia* larvæ spend much of their time at the bottom. They are voracious feeders and can be seen nibbling at solid substances such as dead insects.

The body of the larva (Pl. I, fig. 19) is cylindrical. The thorax and head

are small in proportion to the length of the body. The whole aspect of the larva is in marked contrast to that of larvæ to which projecting angles and hairs give a spiny look. (*Melanoconion*, *Culex*, etc.)

The head is smooth, and projecting hairs are inconspicuous. The clypeus forms a prominent boss, on which are situated, in some species, hairs very closely resembling the clypeal hairs of *anopheles* (Pl. III, figs. 9, 10, 11). The antennæ (Pl. II, figs. 4 and 5), are very distinctive. They are very small and feeble and appear to have undergone degeneration. They are quite smooth and free from the numerous small thorn-like spines which cover the antenna of most other genera. The large hairs of the basal tuft are represented, as in *anopheles*, by a small branched hair or in some species by a single short bristle only. The median and terminal spines so conspicuous in *Culex*, *Melanoconion*, etc., are represented only by several extremely small spike-like processes. As a rule, the terminal papilla (sense organ?) is well developed and rather conspicuous. On the whole, the antenna of *Stegomyia* larva approximates most nearly to that of *anopheles*, but in several points is still more rudimentary than in this sub-family (compare figs. 1 and 5, Pl. II).

The mental plate of *S. sugens* is shown in Pl. III, fig. 1. Those of *S. fasciata* and *S. scutellaris* are very similar.

The siphon tube is very short and stout. The siphonic index is 2 or even slightly less. The spines on the siphon vary in number according to the species. They extend as a rule about two-thirds up the tube. There are mosquitoes, in which the larva has tubes closely resembling those of *Stegomyia*, which do not appear to belong to the genus; some of these have other features approximating to those of *Stegomyia* and may be really related to the genus.

The anal papillæ are large and well developed.

Specific variation.—Three species were examined: *S. sugens*, *S. fasciata*, and another species, probably *S. scutellaris*. The following variations occurred:—

Clypeal hairs.—These hairs in *S. fasciata* remarkably resembled those of *anopheles*. The external hairs were long and simple. The two inner hairs were shorter and branched. In this species five or six branches were present. In *S. sugens* the inner hairs appeared to be absent and the clypeal hairs consisted only of two outer simple hairs. In larvæ which were probably those of *S. scutellaris* the clypeal hairs were very striking. In this case each outer hair was double and the inner hairs were conspicuously branched (Pl. III, figs. 9, 10, 11).

The antenna.—The basal tuft in *S. sugens* was represented by a small hair divided into three or four branches. In *S. fasciata* a single small hair only was present (Pl. II, fig. 5).

The anal papillæ.—In *S. sugens* and *S. fasciata* these were of moderate size, but in the larva of a third species (*S. scutellaris*?) they were extremely large,

and had obtuse ends. In this species the anal papillæ appear to act as functional gills, since the larva had a habit of remaining long periods at the bottom.

The siphon tube.—In the case of some species a variation in the number of spines was noted. In *S. sugens* and *S. fasciata* these spines numbered about 18. In *S. scutellaris* they were only nine in number. Some variations in the exact number was, however, noted in the same species.

The nymph of Stegomyia.—The shape of the respiratory trumpets in this and the allied species *Desvoidea* are characteristic. The trumpet is short and widens rapidly towards the free end. In mounted specimens the trumpets appear, from flattening, to be broadly triangular. A notch, as shown in the figure, is present (Pl. I, figs. 3 and 4). In the wide trumpet opening, *Stegomyia* again approaches most closely the *anophelina*. In *anopheles*, however, the trumpet is rather flap-like and still more open than in *Stegomyia* (Pl. I, figs. 1 and 2).

Desvoidea.—I have not had an opportunity of seeing the larva and nymph of this genus, but Theobald gives a drawing of the respiratory trumpet of the nymph which is indistinguishable from that of *Stegomyia* (Pl. I, fig. 5). The extremely degraded antenna figured by Theobald (Pl. II, fig. 6) also closely resembles that of *Stegomyia*. The siphon tube is also short. Index 1.7. In addition James also notes that the larvæ adopt a vertical position when at rest. In larval and nymphal features this genus is then almost identical with *Stegomyia*.

Grabhamia.—Theobald has figured the larva of *G. dorsalis*. The antennæ are distinctly of the *Culex* type, but the respiratory siphon is like that of a *Stegomyia*. The figure is too small to allow of a full description.

Acartomyia.—Theobald's figure shows that the antennæ closely resemble those of *Stegomyia* and differ only in having small spines scattered over them. The respiratory siphon also possesses *Stegomyia* characters, being extremely short. The trumpets of the nymph, on the other hand, appear to resemble those in *Howardina* and *Deinocerites* (both in the sub-family *Ædeomyina*).

Culex.—The species at present forming this genus are so numerous that generalisations cannot be made on the result of the examination of a few species. It appears from my researches that many of the species differ more widely in their immature than in their adult stage. Certain species now classed under *Culex* are, judging by larval characters, sufficiently distinct to be placed in new genera, but we have not at present sufficient material to discuss this group adequately, and, indeed, a proper division of the enormous genus *Culex* is impossible until more is known of the immature stages of the species.

Provisionally, however, we may draw attention to several groups, which from the dissimilarity of their larval characters alone, might well form separate genera.

GROUP I. *Culex* (restricted sense). *Culex (fatigans)*.—The ova are laid

so as to form rafts. The length of the raft is a little greater than the breadth. The micropilar apparatus is "milled" laterally.

The larvæ are found especially in domestic utensils, pots, barrels full of water, etc., and are rarely found in large masses of water or in water with much vegetation.

The head is rather large and quadrangular in shape. Some conspicuous branched hairs arise from the dorsum. The clypeus carries two small thorn-like spines, but no structures at all resembling clypeal hairs.

The antennæ are fully developed. The basal hairs and the median and terminal spines are long and very noticeable. The first and second portions of the antennæ form a straight line. The third portion is rather small. Small spines are scattered over the first and the proximal part of the second portion (Pl. II, fig. 13).

The siphon tube is distinctive; $\cdot 21$ of body length. The siphonic index is $4\cdot 3$. The spines number 6 or 7 in each row and extend over the lower third of the tube (Pl. II, fig. 24).

The nymph of *Culex fatigans* has respiratory trumpets which project laterally as shown in Pl. I, fig. 9. The opening calls to mind the obliquely-cut mouthpiece of a penny whistle (Pl. I, fig. 7). This character, so far as my researches have gone, appears to be peculiar to the restricted portion of genus *Culex* we are discussing.

Specific variation.—A second species belonging to the restricted genus *Culex* showed the following variation from the above.

*C. ?.**—Larva found in wells and cement tanks. Antenna with the second portion longer than in *C. fatigans* (Pl. II, fig. 14).

Siphon tube extremely large and conspicuous; $\cdot 28$ of body length. Siphonic index $4\cdot 1$. Spines number 6 in each row and occupy the lower third of the tube (Pl. II, fig. 25). Trumpets of nymph as in *C. fatigans*.

C. pipiens.—Theobald figures this species which clearly belongs to the above group. The figure given is too small to allow of minute description, but the antennæ are as in *C. fatigans*. The siphonic index $4\cdot 8$. The siphon tube similar in shape to *C. fatigans*.

GROUP II. *C. impellens.*—A group of mosquitoes of the original genus *Culex*, possessing definite larval characters.

Antennæ as in *Culex*, but larger. Siphon tube more attenuated than in *C. fatigans*. Siphonic index 6. Spines number 6 or more and extend over basal one-third of tube (Pl. II, fig. 23).

Larvæ found more frequently away from habitations than are those of *C. fatigans*.

* NOTE.—Identified by Mr. Theobald as *C. fatigans*, but evidently a distinct species.

GROUP III. Adult mosquitoes showing scale arrangement typical of the genus *Culex*, but having larval characters recalling those of *Stegomyia*. Four species, all unfortunately undetermined, were noted. All the forms were found in natural pools.

Species a.—Nymph trumpets, opening wide, somewhat resembling those of *Stegomyia*.

Head rather broad, antennæ like those of *Stegomyia*, but larger and having a few small spines. Basal tufts small and composed of a few hairs. Median and terminal spines abortive (Pl. II, fig. 7). Mental plate resembles that of *S. sugens* (Pl. III, fig. 2). Siphon tube large (Pl. II, fig. 19), $\cdot 18$ of body length. Siphonic index $1\cdot 9$. Sixteen spines in each row shaped as in *Stegomyia*.

Species b.—Nymph trumpet rather broad, but narrower than above. More truncated than in species *a*. Antenna resembles that of *Stegomyia* (Pl. II, fig. 8). Basal tuft small. Two rather large median spines present. No terminal spines. The antennæ are covered with a few short spines.

Siphon tube large, $\cdot 2$ of body length. Siphonic index $2\cdot 7$. Eighteen spines in each row.

Species c.—Trumpets of nymph nearly truncated, but opening slightly obliquely (Pl. I, fig. 16).

Larva long. Rests in nearly vertical position (Pl. III, fig. 26). Head very small and like that of *Stegomyia*. Antennæ comparatively small. Basal tuft short, but composed of many hairs. Median and terminal spines small and inconspicuous. Antenna covered with large and prominent spines (Pl. II, fig. 9).

Siphon tube enormous and very massive, $\cdot 26$ of body length. Siphonic index $5\cdot 9$. Nineteen spines in each row. Whole tube strongly chitinised and opaque (Pl. II, fig. 21).

Species d.—Trumpets of nymph resembling those of species *c*.

Larva long (Pl. I, fig. 22). Rests in nearly vertical position (Pl. III, fig. 26). Head small and shaped much as in *Stegomyia*. Antennæ long and well developed. Basal tuft short but composed of many hairs. Median spines fairly well developed. Third portion of antenna readily seen. Terminal portions short and inconspicuous. The whole antenna is densely covered with long spines (Pl. II, fig. 10). Siphon tube enormous, not so massive as that of species *c*, but very similar in its horn-like appearance, $\cdot 28$ of body of length. Siphonic index $7\cdot 5$ (Pl. II, fig. 22).

These larval characters certainly suggest that the group concerned have little in common with the *Culex fatigans* group.

GROUP IV. *Culex mimeticus*.—Theobald figures the siphon tube and

I have been able to study the larva which occurs abundantly in the Nilgiris. The larval characters have no relation to any other *Culex* larvæ. A curious point is that the spines on the siphon tube, which is long and thin, are very large and curved, thus differing from those of the great majority of larvæ which are short, straight spikes.

GROUP V. *C. concolor*.—The larval characters of this species are quite unlike those of any of the other groups. The larva of *C. concolor* is cannibal in its habits and has the morphological characters of cannibal larvæ. (*Vide* description given later of cannibal larvæ.)

Theobald has figured parts of the larva of *C. tigripes*. It is evident from his drawings that the larvæ of this species and that of *C. concolor* are very similar. These two species alone amongst mosquitoes, of which the larva has been described, possess the peculiar rudder-like group of hairs on the siphon. Theobald, studying the adult insects, doubted whether they should be retained in the genus *Culex*. If he has not already renamed these two species, I would propose that they be placed in a new genus *Jamesia*, from the name of the first describer of a cannibal larva (see also later).

Theobaldia.—The larva of *Theobaldia annulata* is figured by Theobald. The characters are almost identical with those of *C. fatigans*—

Ova laid in boat-shaped masses. The siphon tube as in *C. fatigans*,

Siphonic index 4. Antenna as in *C. fatigans*.

Melanoconion.—The ova of *Melanoconion* are laid in the form of rafts. The rafts are more elongated than those of *Culex*. The individual ova resemble those of *Culex*.

The larvæ of *Melanoconion* are peculiar and can be readily distinguished by the naked eye (Pl. I, fig. 20). They resemble in general aspect the larvæ of *Tæniorhynchus* and like these are often bright green and very transparent. From the great development of the antennæ and hairs these larvæ have a "spiny" look. They occur in clear natural water where there is much vegetation.

The head is widened transversely and is plentifully supplied with hairs. There are two spines on the clypeus as in *Culex*. The mental plate is comb-like (Pl. III, fig. 3).

The antennæ are extremely large and well developed. They form antler-like projections which are very characteristic of the genus. The three portions of the antennæ are very distinct, and the first may be curved. The hairs and spines are all long and stout (Pl. II, fig. 15).

The hairs on the thorax are numerous and long. Immediately behind the head two large hairs arise from papillæ near the middle line. These project over the head and have already been mentioned as possibly being tactile in function.

The siphon tube is long and very thin ; $\cdot 23$ of body length. The siphonic index is 7. There are about 10 spines in each row which are rather long and slender and extend over a little more than the basal third of the tube (Pl. II, fig. 26).

The nymph of *Melanoconion* has distinctive respiratory trumpets. They are peculiarly long and narrow and project in a more distinct curve than do those of *Culex*. The end is more truncated than in *Culex* and the opening is on this account more circular (Pl. I, figs. 8 and 10).

Tæniorhynchus.—The ova of *Tæniorhynchus* have been described by Stephens and Christophers.⁸ They are laid in the form of rafts which are extremely long and narrow, and resemble in shape a racing skiff.

The larva is found in natural waters where much vegetation is present and is often bright green in colour (Pl. I, fig. 21).

The head is comparatively small. The clypeus is conical and so differs from that of most larvæ. From the clypeus arise a few short, curved hairs. The antennæ are well developed and resemble those of *Culex*. The basal portion only is covered with spines (*T. tenax*, Pl. II, fig. 16).

The mental plate is highly characteristic, and was similar in two species. It is triangular in shape and the two free edges carry very fine teeth which are at least four times smaller than those of other larvæ. The mental plate of *Tæniorhynchus* has a remarkable resemblance to a shark's tooth (Pl. III, fig. 4).

The siphon-tube is peculiar, being extraordinarily long and thin (Pl. II, fig. 27), $\cdot 37$ of body length. Siphonic index 12. There are about seven spines in each row confined to the basal tenth of the tube. The hairs arising from the tube are very short and insignificant.

The nymph has respiratory trumpets which project anteriorly and nearly meet in the middle line (Pl. I, fig. 11). The trumpets are large and pointed, with an oblique opening (Pl. I, fig. 13). I have seen no other nymph in which the trumpets project forward as they do in *tæniorhynchus*.

Mansonia.—The nymph of *Mansonia uniformis* has been figured by Theobald. The trumpets appear to project forward as in the last-mentioned genus.

Ædeomyia.—Of the large number of genera in this sub-family I am only able to describe a very few, and those imperfectly.

Deinocerites.—Theobald has figured parts of the larva and pupa. The siphon tube is large. The siphonic index (from Theobald's drawing) $5\cdot 6$. The nymph has abruptly truncated trumpets.

Howardina.—The nymph has somewhat conical and abruptly truncated trumpets (Pl. I, fig. 15).

Joblotia.—Theobald has figured the head and siphon tube of this larva. He

describes curious quadrangular frontal processes, but these appear to be the widely opened maxillæ. The bodies he describes as antennæ are apparently the maxillary palps. The siphon tube is very short and, from Theobald's drawing, appears very unlike that of other larvæ.

Cannibal larvæ.—James¹ was the first to describe a species (*C. concolor*) in which the larvæ possessed cannibal habits. Theobald notes that the related species *C. tigripes* is also cannibal. The larvæ of *Megarhinus* and *Toxorhynchites* have been described by Theobald, and from the structure of their mouth parts, are obviously also cannibal species. *Lutzia* and *Psorophora*, according to Lutz,² are actively cannibal. I have lately found the larva of *Mucidus scataphagoides* to be cannibal and to possess the modified mouth parts which appear to be characteristic of all these species. The following genera may be noted as containing, and possibly consisting entirely of species having larvæ of cannibal habits:—

Megarhinus.

Toxorhynchites.

Mucidus.

Psorophora.

Lutzia.

Famesia { *C. concolor*.
 { *C. tigripes*.
(new genus).

In all cases in which the habits have been described in detail the larvæ are characterised by their extreme voracity and their habit of preying solely upon other mosquito larvæ. Although the species observed by us (*C. concolor* and *M. scataphagoides*) were seen to swallow small water-crustacea (*Daphnia*), yet in the main they fed upon other larvæ. In both cases the larvæ lay horizontally, quite motionless, with the modified brushes widely extended. When another larva approached within a certain distance it was suddenly seized, no matter its size or how vigorously it struggled. Small larvæ were often swallowed whole. Larger specimens were devoured except the head-case and siphon tube. When food was abundant, these larvæ increased in size with remarkable rapidity and ultimately became conspicuous as giant larvæ. In Mian Mir both *C. concolor* and *M. scataphagoides* were exceedingly common and were found wherever other *Culex* larvæ abounded. The larvæ of *M. scataphagoides* occurred in pools with much vegetation. *C. concolor*, on the other hand, was found together with *C. fatigans* in pots, small dirty puddles, etc. In Mian Mir, and probably elsewhere, cannibal species must play an important rôle in the reduction of the numbers of mosquitoes. From the examination of the two species already mentioned and from Theobald's drawings of *Megarhinus*, *Toxorhynchites*, and *C. tigripes*, it is

evident that the larvæ of these genera are very similar in structure and appearance. They all adopt a horizontal attitude. All have specially modified mouth parts and possess conspicuous "clasping organs" in place of the feeding brushes. The general appearance in all is similar; the shape of the head and clypeus is identical. The anal papillæ are rudimentary or absent.

Mucidus scataphagoides.—The full grown larva is very large, and its horizontal attitude and the curious truncated appearance of the head are characteristic.

The head is smooth and globular. Three long, conspicuous hairs arise on each side. These differ from hairs in other larvæ in not being branched. The clypeus overhangs the mouth and forms a curious concave edge, and not, as in non-cannibal larvæ, a prominence. On each side of the clypeus a modified feeding brush arises.

The feeding brushes are highly modified and form clasping organs. When the larva is at rest, they project laterally as dark, horn-like structures. Each brush is composed of a number of slightly curved chitinous bars, which have minute comb-like projections on the concave side (Pl. III, fig. 14). The bars lie generally closely approximated, so that the clasping organ at first sight appears to be composed of a single dense piece of chitin. The mental plate in both *Mucidus* and *C. concolor* is very similar and differs widely from that of any other larva I have seen. In both species it carries only a few teeth, but these are of great size (Pl. III, figs. 5 and 6). In *Mucidus* the maxillary palps are very small and do not cover in the mandibles as in non-carnivorous species. The mandibles are conspicuous, and the mandibular plate is very solid and massive.

The antennæ are small and resemble in general appearance those of *Stegomyia*. The small basal tuft, however, rises very near the termination of the antenna. The median and terminal spines are represented by a few inconspicuous processes. There are a few small spines scattered over the antenna (Pl. II, fig. 12).

The thorax is smooth and globular. The hairs arising from it and also the hairs arising from the abdomen are simple and spring from well-marked and chitinised papillæ. The siphon tube is long, the siphonic index being 4.6. There are about 22 spines in each row and two conspicuous tufts of hairs above these. There is no rudder-like fan of hairs rising from the median line as in *C. concolor* and *C. tigripes*. The ninth segment differs from that of most larvæ in possessing only rudimentary anal papillæ. The ventral fan of hairs has also a more extended origin (Pl. III, fig. 16).

Megarhinus and *Toxorhynchites*.—The larva of *T. speciosus* figured by Theobald corresponds in almost every detail with the above description. The chief differences are in the presence of short, notched hairs arising from the

thorax of the larva of *Toxorhynchites* and the absence (?) of the spines of the siphon tube in this species. Siphonic index is 2.5 (Pl. III, figs. 12 and 19).

C. concolor.—In general appearance the larva exactly resembles that of *Mucidus*. The antennæ and siphon-tube are, however, different. The antennæ are small and very unlike those of any other larva (Pl. II, fig. 11). The siphon tube is highly characteristic and possesses a structure not represented in any other larva yet described (with the exception of the related species *C. tigrripes*). This is a large fan of hairs springing from the median posterior line of the siphon tube (Pl. III, figs. 17 and 18). The shape also of the siphon tube in *C. concolor* and *C. tigrripes* is quite unlike that of any other larva. The nymph has respiratory trumpets differing from those of *Culex*. They project in a characteristic way from the body of the nymph (Pl. I, figs. 14 and 23).

Psorophora.—From Howard's description of *P. ciliata* it is evident that the larva is morphologically adapted for cannibal habits and resembles closely that of *Mucidus*.

Lutzia.—The characters of this larva, so far as I am aware, have not been described.

III.

From the above descriptions it will be seen that the most important variations occur on the following structures:—

1. The respiratory trumpet of the nymph.
2. The antenna of the larva.
3. The siphon tube of the larva.
4. The mental plate of the larva.
5. The feeding brushes of the larva.
6. The anal papillæ of the larva.
7. The form of the ovum.
8. The arrangement of ova in rafts or otherwise.
9. The form of the raft.

The shape of the nymph trumpets appears to vary little in species of the same genus, but to be of great importance in the distinction of different genera. By means of the variations on the trumpets the following groups may be obtained.

1. Trumpets expanded to form a flap (Pl. I, figs. 1 and 2) . . . *Anophelina*.
2. Trumpets expanded broadly triangular in shape (Pl. I, figs. 3, 4, and 5) { *Stegomyia*.
Desvoidea.
3. Trumpets narrow with oblique opening (Pl. I, figs. 7 and 9) . . . *Culex*.
4. Trumpets extremely long and narrow; opening not so oblique as above (Pl. I, figs. 8 and 10). *Melanoconion*.
5. Trumpets project forwards (Pl. I, figs. 11 and 13) . . . { *Tæniorhynchus*.
Mansonia.

- | | | |
|--|---|----------------------|
| 6. Trumpets abruptly truncated (Pl. I, fig. 15) | { | <i>Deinocerites.</i> |
| | | <i>Howardina.</i> |
| | | <i>Acartomyia.</i> |
| 7. Trumpets contracted at opening; opening circular | | <i>Mochlonyx.</i> |
| 8. Trumpets contracted at opening; opening slit like | | <i>Corethra.</i> |

Two types of antennæ occur in the above descriptions.

1. *Stegomyia* type figs. 4, 5, 6, 7, 8, 9, 10, seen in *Stegomyia, Desvoidea, Acartomyia.*
2. *Culex* type figs. 13, 14, 15, 16, seen in *Culex, Melanoconion, Tæniorhynchus, Grabhamia.*

The differences in the two types is so fundamental as to suggest that the siphonate *Culicidæ* are derived from two main types, one giving rise to the *Stegomyiæ*, the other to the *Culicinae* (restricted sense, see later). The antennæ of *C. concolor* and *Mucidus* appear distinct from either, though that of *Mucidus* approaches more closely to the *Stegomyia* than the *Culex* type.

The siphon tube is of specific value since it is subject to considerable variation in nearly related species. In many cases the characters of the siphon tube appear also to be of generic significance, *i.e.*, *Culex, Stegomyia, Tæniorhynchus*, etc.

The mental plate is a structure well worth further study. Very distinct characters were present in *Stegomyia, Culex, Melanoconion, Tæniorhynchus, C. concolor*, and *Mudicus*.

It is evident that, in general, genera based upon the adult characters are established still more firmly by a consideration of the characters of the immature stages. But there are many points brought out very clearly by immature characters which are not so evident on consideration of adult characters alone. Theobald's classification according to adult characters is briefly as follows. (The reasons for the groups are not given. See, however, manual of the *Culicidæ*.)

SUB-FAMILY.

Sec. A.	{	1. Sub-fam. <i>Anophelina</i>	<i>Anopheles, etc., etc.</i>
		2. „ <i>Megarhinina</i>	<i>Megarhinus.</i> <i>Toxorhynchites.</i>
		3. „ <i>Culicina</i>	{ <i>Fanthinsoma.</i> <i>Psorophora.</i> <i>Mucidus.</i> <i>Stegomyia.</i> <i>Desvoidea.</i> <i>Theobaldia.</i> <i>Lutzia.</i> <i>Culex.</i> <i>Gilesia.</i> <i>Lasionocops.</i> <i>Melanoconion.</i> <i>Grabhamia.</i> <i>Acartomyia.</i> <i>Tæniorhynchus.</i> <i>Mansonia.</i>

Sec. A.	{	4. Sub-fam. <i>Foblotina</i>	<i>Foblotia</i> .
		5. „ <i>Heptaphlebotomyia</i>	<i>Heptaphlebotomyia</i> .
		6. „ <i>Aedeomyia</i>	<i>Deinocerites</i> .
			<i>Howardina</i> and 18 other genera.
Sec. B.		1. Sub-fam. <i>Corethrina</i> .	

In the first place the position occupied by *Stegomyia* is too subordinate. A consideration of the characters of *Stegomyia* show that these mosquitoes differ much more from *Culex* than do *Melanoconion*, *Tæniorhynchus*, etc. Theobald's classification might be modified by removing the *Stegomyiæ* altogether from the *Culicina*. This I propose to do and to place them in a division *Stegomyina*. The groups of genera *Culex*, *Theobaldia*, *Melanoconion*, *Tæniorhynchus*, and *Mansonia* will then form a natural division differing widely from the last mentioned.

Stegomyina.

Ova * laid separately upon the water. Each ovum surrounded by small air chambers.

Larva long and worm-like. Attitude vertical. Antennæ degenerate. Basal tuft represented by small hair. Median and terminal spines rudimentary. Siphon tube short and stout. Index=2.

Nymph trumpets expanded. Broadly triangular in shape.

Imago. Habits diurnal. Scale structure distinctive.

Culicina (restricted sense).

Ova cemented together to form rafts.

Larva more or less spiny in appearance. Antennæ fully developed. Siphon tube rather long. Index 4 to 12.

Nymph trumpets narrow. Openings oblique.

Imago. Habits nocturnal. Scale structure distinct.

In the second place it is doubtful if *Megarhinus* and *Toxorhynchites* by themselves should be placed in a separate sub-family—a division of equal importance to that of *Anophelina* and *Culicina*. The character of the palps in this case does not seem to me a sufficiently important feature upon which to found the division, especially since in *Toxorhynchites* the female palps are not much longer than in *Mucidus*. The genera *Megarhinus*, *Toxorhynchites*, *Mucidus*, and *Psorophora* appear to be a group of closely related genera showing the following features in common :—

Larva specially modified for cannibal habits. Attitude horizontal, etc.

Imago large and conspicuous species. The palps in the female longer than in *Culex*.

* I think the observation by Skuse that the ova of *S. notoscripta* are laid in rafts needs confirmation before it can be accepted.

To remove *Mucidus* and *Psorophora* from the *Culicina* and to adopt provisionally a new division including *Megarhinus*, *Toxorhynchites*, *Mucidus*, *Psorophora*, and possibly *Fanthinsoma* and the genera *Lutzia* and *Jamesia*, would seem to be more natural.

The larval stages of the *Aedeomyina* are so little known that I make no attempt to consider the position of this group. In the few species described there are however some features, e.g., the larval antennæ, which suggest a distant relationship to the *Stegomyina* rather than to the *Culicina*.

The affinities of the *Culicidæ* would then be shown as follows:—

- | | | | |
|--------------------------------|---|---|---|
| 1. Sub-fam. <i>Megarhinina</i> | . | { | <i>Megarhinus.</i>
<i>Toxorhynchites.</i>
<i>Mucidus.</i>
<i>Psorophora.</i>
<i>Fanthinsoma.</i>
<i>Lutzia.</i> (?)
<i>Jamesia.</i> (?) |
| 2. Sub-fam. <i>Stegomyina</i> | . | { | <i>Stegomyia.</i>
<i>Desvoidea.</i> |
| 3. Sub-fam. <i>Aedeomyina</i> | . | { | <i>Howardina.</i>
<i>Deinocerites</i> and 18 other genera (<i>acartomyia</i> ?). |
| 4. Sub-fam. <i>Culicina</i> | . | { | <i>Culex.</i>
<i>Theobaldia.</i>
<i>Melanoconion.</i>
<i>Tæniorhynchus.</i>
<i>Mansonia.</i>
<i>Grabhamia.</i> (?) |

I do not claim the above as, in any sense, a rigid classification, but it appears to me that a truer proportion exists in the groups than in the original classification by the adult characters alone. Classification by the scale structure has been shown even by the consideration of immature characters to be a very natural one, but in the variations of the ovum, larva, and nymph, we have a most important additional means of determining the natural affinities of mosquitoes.

REFERENCES.

- Stephens and Christophers. Reports to the Malaria Committee of the Royal Society. 7th series. Harrison & Sons.
- Also later "The Practical Study of Malaria." Longmans, Green & Co.
- James, who was associated with us, has also described the immature stages of most of the Indian anopheles "Malaria in India." Scientific Memoirs by officers of the Medical and Sanitary Departments of the Government of India. New series, No. 2. *Vide* also James and Liston. Anopheles Mosquitoes of India. Thacker, Spink, Calcutta.
2. Meinart. De Encephale Myggelarver. K. Danske veiden scabernes Selskabs Skriften. III, Copenhagen, 1886.

3. Howard. The Mosquitoes of the United States. Bulletin No. 5. N. S. U. S. Department Agriculture, Division Entomology, 1896.
4. James. Indian Med. Gazette. The collection of mosquitoes and their larvæ., December 1889.
5. James : Letter to Theobald. Manual of the Culicidæ, Vol. II, p. 110.
6. Theobald. Manual of the Culicidæ. Chiefly Vol. III.
7. Daniels and Ross. Quoted by Theobald.
8. Lutz. Communication to Theobald. Vol. I, p. 48.

EXPLANATION OF PLATES.

PLATE I.

- Figs. 1—16. Respiratory trumpets of nymph.
1. *Nyssorhynchus fuliginosus*.
 2. *Myzomyia Rossii*.
 3. *Stegomyia sugens*.
 4. *Stegomyia fasciata*.
 5. *Desvoidea fusca*.
 6. A culex the larval characters of which differ from the type group. See Pl. II, figs. 7 and 19, and Pl. III, fig. 2.
 7. *Culex fatigans*.
 8. *Melanoconion* (n. sp.).
 9. Nymph of *Culex* showing position of trumpets.
 10. " *Melanoconion* showing position of trumpets.
 11. " *Tæniorhynchus* " " "
 12. " *Culex concolor* " " "
 13. *Tæniorhynchus*.
 14. *Culex concolor*.
 15. *Howardina* (n. sp.).
 16. An atypical culex. See Pl. II, figs. 9 and 21, also Pl. III, fig. 7.
- Fig. 17. The eighth and ninth abdominal segments of larva of *Stegomyia sugens*.
Fig. 18. The head of *Melanoconion* showing mental plate, structure of antenna.
Fig. 19. Larva of *Stegomyia sugens*.
Fig. 20. " *Melanoconion*, n. sp.
Fig. 21. " *Tæniorhynchus tenax* (Theo.).
Fig. 22. " A culex related to species shown in Pl. I, fig. 16. See Pl. II, figs. 10 and 22, and Pl. III, figs. 8, 23, and 24.
Fig. 23. " *Culex concolor* (cannibal larva).

PLATE I.

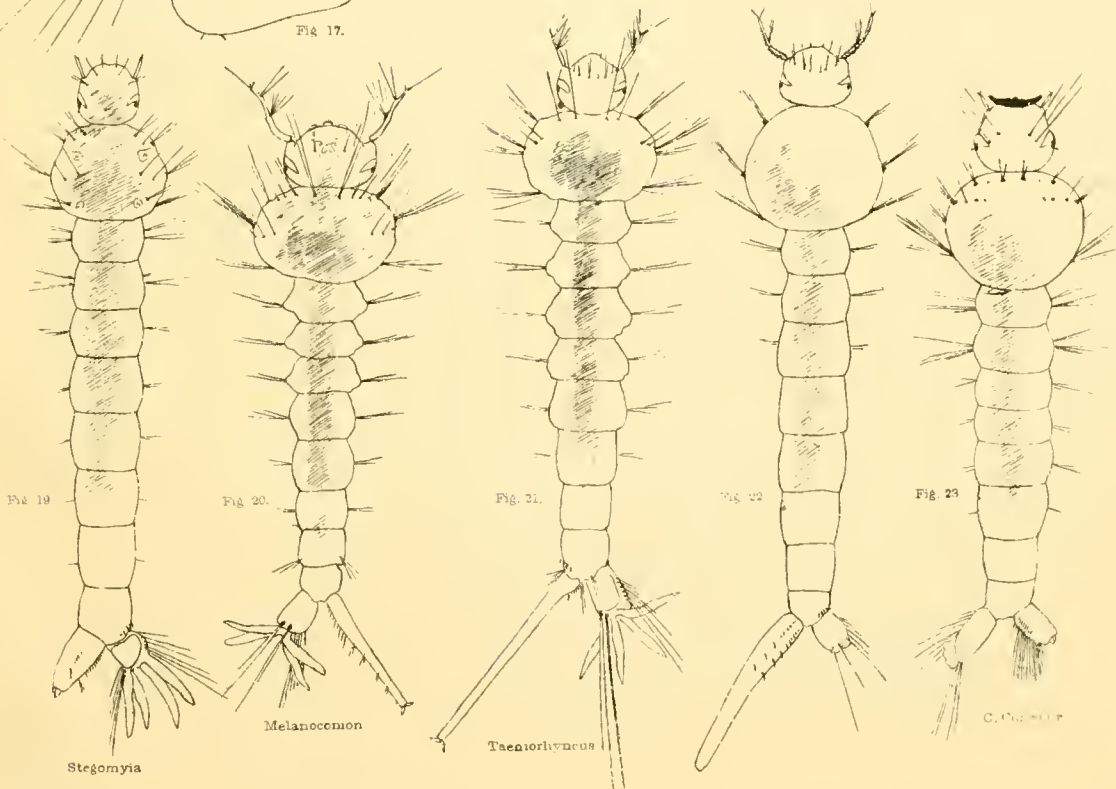
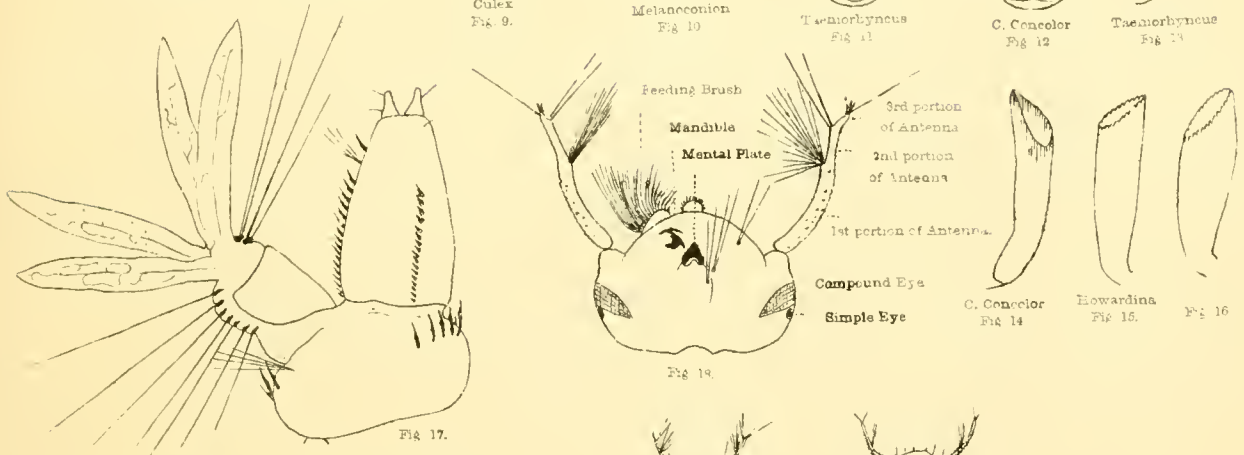
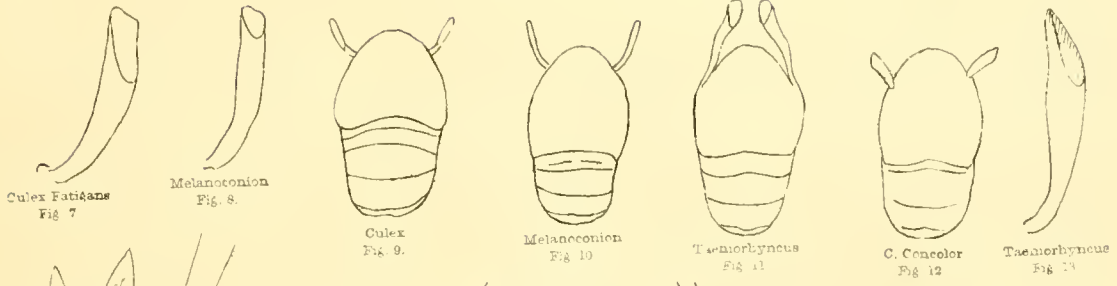
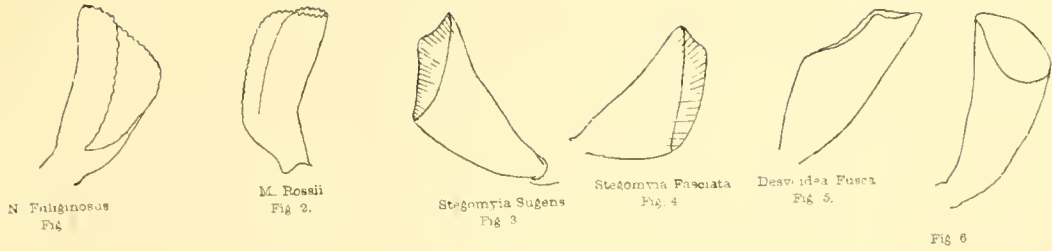


PLATE II.

Figs. 1--16. Antennæ of larvæ.

1. *Myzomyia Rossii*.
2. *Anopheles Lindesayi*.
3. *Myzorhynchus nigerrimus*.
4. *Stegomyia sugens*.
5. *Stegomyia fasciata*.
6. *Desvoidea fusca*.
7. } Species of culex with antennæ not of type form.
8. }
9. }
10. }
11. *Culex concolor*.
12. *Mucidus scataphagoiæ*.
13. *Culex fatigans*.
14. *Culex*. (?)
15. *Melanoconion*, n. sp.
16. *Tæniorhynchus tenax* (Theo.).

Figs. 17--27. Siphon tubes of larva.

17. *Stegomyia sugens*.
18. *Stegomyia fasciata*.
19. } Tubes of atypical species of culex.
20. }
21. } Enormous siphon tubes (culex).
22. }
23. *Culex impellens*.
24. *Culex fatigans*.
25. *Culex*. (?)
26. *Melanoconion*, n. sp.
27. *Tæniorhynchus tenax*.

PLATE II.



Myzomyia Rossii
Fig. 1



Anopheles Lindesayi
Fig. 2



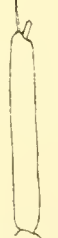
Myzorrhynchus Nigerinus
Fig. 3



Stegomyia Suigens
Fig. 4



Stegomyia Fasciata
Fig. 5



Desvoidia Fusca
(after Theobald)
Fig. 6

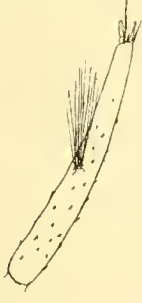


Fig. 7

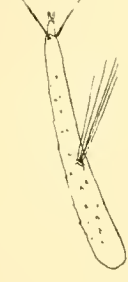


Fig. 8



Fig. 9



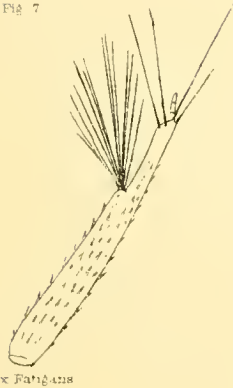
Fig. 10



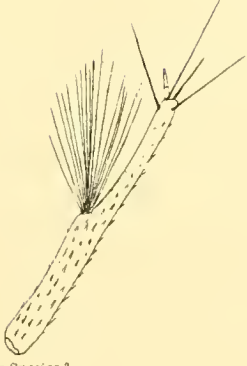
Culex Concolor
Fig. 11



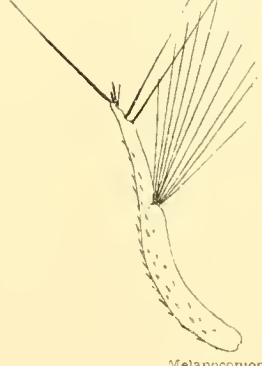
Mucidus Scutaphagoides
Fig. 12



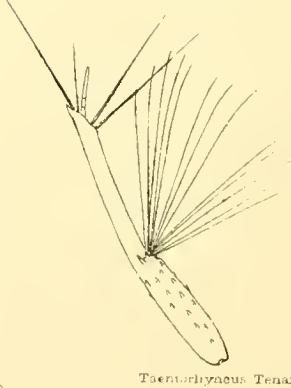
Culex Fatigans
Fig. 13



Culex Species ?
Fig. 14



Melanoconion
Fig. 15



Taeniorhynchus Tenax
Fig. 18



Stegomyia Suigens
Fig. 17



S. Fasciata
Fig. 16



Fig. 19

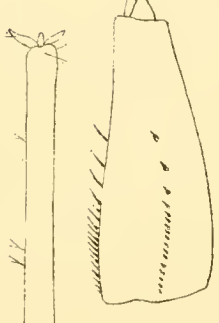


Fig. 20



C. Impellens
Fig. 23



C. Fatigans
Fig. 24

Fig. 25



Fig. 26



Fig. 27

Melanoconion

Taeniorhynchus Tenax



Fig. 21



Fig. 22

C. Species ?

PLATE III.

- Figs. 1—8. Mental plates of larva.
1. *Stegomyia sugens*.
 2. *Culex* (atypical).
 3. *Melanoconion*, n. sp.
 4. *Tæniorhynchus tenax*.
 5. *Culex concolor*.
 6. *Mucidus scataphagoïdes*.
 7. *Culex* (atypical).
 8. " "
- Figs. 9—11. Clypeal hairs.
9. Clypeal hairs of *Stegomyia sugens*.
 10. " " " *fasciata*.
 11. " " " *scutellaris*. (?)
- Fig. 12. Head of *Toxorhynchites speciosus* (after Theobald).
- Fig. 13. Head of *Culex concolor*.
- Fig. 14. Mouth parts of *M. scataphagoïdes* showing concave clypeus, modified brushes, mandibles, and small maxillæ.
- Fig. 15. Mouth parts of *Culex concolor*.
- Fig. 16. Eighth and ninth abdominal segments of *M. scataphagoïdes*.
- Fig. 17. " " " " *Culex tigripes*.
- Fig. 18. " " " " *Culex concolor*.
- Fig. 19. " " " " *Toxorhynchites* (after Theobald)
- Fig. 20. Position at rest of *Culex fatigans*, larva.
- Fig. 21. " " *Tæniorhynchus tenax*, larva.
- Fig. 22. " " *Stegomyia*.
- Fig. 23. Position in progression of larva with enormous siphon tube.
- Fig. 24. " at rest " " " "
- Fig. 25. " " *Culex concolor*, larva.

