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The Anopheles Mosquitoes of India

D. G. Campd
14 February 1905

A Monograph

OF THE

Anopheles Mosquitoes of India

By

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PREFACE.

THIS book has been written at the request of some of our fellow-workers in India, and, for that reason, we need not apologise for its publication. Its scope is indicated in the title. We have attempted to treat the subject clearly, and to describe the different species in such a manner that any specimen which may be encountered will be easily identified. In our opinion this is the most important requirement of any book dealing with mosquitoes, and, in connexion with it, we venture to hope that our coloured plates, which are strictly accurate in detail, will be found helpful. We are much indebted to our friend Dr. Turkhud, of Bombay, for having drawn them, under our direction, with so much care and skill.

Although we have not felt able to adopt Mr. Theobald's new classification of "Anopheles," we have given a brief account of his system, and have added, under the title of each mosquito described, the generic and specific names by which the insects are known to him.

In common with all medical men in the tropics we owe a debt of gratitude to Professor Ray Lankester for having initiated the work of which Mr. Theobald's admirable treatise is the outcome, to Mr. Theobald himself, and to Colonel Giles, I.M.S.

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PART I.

A MONOGRAPH OF THE ANOPHELES MOSQUITOES OF INDIA.

CHAPTER I

A GENERAL ACCOUNT OF MOSQUITOES

BEFORE commencing the study of any particular kind of mosquito it is necessary to know something of the general characters, life history, and structure of this important family of insects.

Mosquitoes or gnats (*Culicidæ*) belong to the order of insects known as *Diptera*. As is well-known, a typical member of the class *Insecta* has four wings, but it is characteristic of members of the order *Diptera* that the hinder pair of wings are so reduced in size as to form only small knobs called "balancers" or *halteres*, so that *Diptera* are often spoken of as "two-winged flies." Other important characteristics of members of this order are that they possess piercing and sucking mouth parts, and that they undergo complete "metamorphosis"—a term which is explained by Claus in the following manner :—

"The more complete the agreement between the just-born young and the adult sexual animal so much the greater will be the duration of the embryonic development and the more complicated the developmental processes of the embryo. The post-embryonic development will, in this case, be confined to simple processes of growth. When, however, the embryo is born in an immature condition and at a relatively low state of organization, the post-embryonic development will be more complicated, and the young animal, in addition to its increase in size, will present various processes of transformation and change of form. In such cases the just-hatched young, as opposed to the adult animal, is called a *Larva* and develops gradually to the form of the adult sexual animal. The development of larvæ, however, is by no means direct and uniform, but is complicated by the necessity for special contrivances to enable them to procure food and to protect themselves; sometimes taking place in an entirely different medium, under different conditions of life. This kind of post-embryonic development is known as metamorphosis."

The phenomena of metamorphosis are exceedingly well shown in the life history of frogs and in that of most insects. The different stages through which mosquitoes pass before they reach the

adult state may, for example, be briefly described in the following way :—

The adult mosquito lays its eggs on the surface of water. The eggs float on the water for some days (two to four), after which time they hatch and permit of the escape of the larva.

The larva is a free swimming, worm-like animal, which eats greedily and grows rapidly, casting its skin several times in the process, till it reaches its full development. At this stage it suddenly changes its form; casting its skin, the worm-like larva assumes a comma shape, and so becomes the pupa or nympha.

During the pupal period the insect ceases to eat; profound anatomical changes take place within the pupal skin, whereby the masticatory mouth parts of the larva are converted into the suctorial apparatus of the adult insect or *imago*. After a certain number of days the pupa-case ruptures, and the adult insect is liberated, furnished with wings and legs adapted for a life in the air.

The *Diptera* have been divided into two great groups, termed *Orthorrhapha* and *Cyclorrhapha*, according to the manner in which the pupa-case splits to permit of the escape of the perfect insect. In the *Orthorrhapha*, which includes the *Culicidæ* (mosquitoes), the *Chironomidæ* (midges), the *Simulidæ* (sand-flies), the *Cecidomyidæ* (gall-midges), the *Mycetophilidæ* (fungus-midges), the *Tipulidæ* (daddy-long-legs), the *Tabanidæ* (horse-flies), etc., the pupa-case splits longitudinally down the median dorsal line. In the *Cyclorrhapha*, which includes the *Syrphidæ* (hoverflies), the *Oestridæ* (bot-and warble flies), the *Muscidæ* (house flies, tsetse flies, blue and green bottle flies, flesh flies, etc.), the perfect insect escapes by the splitting off of a cap from the head end of the pupa.

The members of some of the above families are not infrequently mistaken for mosquitoes, especially the *Chironomidæ* or midges, the *Cecidomyidæ* or gall-midges, the *Tipulidæ*, the *Simulidæ*, and the *Psychodidæ* or owl-midges. Mosquitoes may, however, be easily distinguished from any other flies by the following characters :—

(1) They possess a long sucking proboscis.*

(2) The veins on their wings are covered with scales.

(3) The arrangement of their wing-veins is characteristic and different from that of the members of any other family.

* Except in the genera *Corethra* and *Mochlonyx*.

The *Chironomidæ* or midges have neither a long sucking proboscis nor scaly wings.

The *Cecidomyidæ* or gall-midges have the body and wings covered with hairs, not scales, and the venation of the wings is simple, no fork-cells being present.

The *Psychodidæ* or owl-midges have the wings densely covered with hairs, not scales.

The *Simulidæ*, *Tipulidæ*, etc., have the wing-veins bare, without hairs or scales.

There is really no difficulty, therefore, in distinguishing mosquitoes from other flies which seem to resemble them.

The family *Culicidæ* is divided, for the purposes of classification, into a number of sub-families, genera, and species. Up to the present, entomologists have based these subdivisions entirely upon differences in the adult insects, but there are good reasons for thinking that differences between mosquitoes in the larval or immature stages of their existence are also of great importance for the purposes of classification and identification. The larvæ of only a few species are, however, accurately known, and at present we must be content to follow, at any rate in the main, the somewhat unscientific methods of classification adopted by entomologists.

Mr. F. V. Theobald, who is the greatest authority upon mosquitoes, divides them into the following sub-families :—

1. The *Anophelina* containing at present 11 genera and about 80 species.
2. The *Megarhinina* „ „ „ 2 „ „ „ 20 „
3. The *Culicina* „ „ „ 17 „ „ numerous „
4. The *Joblotina* „ „ „ 1 genus „ 1 „
5. The *Heptaphlebomyina*„ „ „ 1 „ „ 1 „
6. The *Aedeomyina* „ „ „ 20 genera „ about 55 „
7. The *Corethrina* „ „ „ 2 „ „ „ 18 „

The characteristics of the adult insects upon which these sub-families are based are as follow :—

1. Palpi long in both sexes ; about as long as proboscis *Anophelina.*
2. Palpi long in both sexes ; shorter than the proboscis in the female ; proboscis long and bent ... *Megarhinina.*
3. Palpi long in the male, very short in the female ... *Culicina.*
4. Palpi as in Culicina. Seven instead of six longitudinal veins on the wings ... ... *Heptaphlebomyina.*
5. Palpi as in Culicina. Metanotum with hairs and scales *Joblotina.*

6. Palpi very short in both sexes ... ... *Aedeomyina.*
7. Proboscis short and not formed for piercing .. *Corethrina.*

Many of these sub-families are of importance to the worker on tropical diseases only in so far that some knowledge of their characteristics is essential to enable him to distinguish them from the mosquitoes which he especially desires to study. The *Megarhininæ* are rare and cannot easily be confused with any other members of the *Culicidæ* on account of their large size, brilliant colour, and long curved proboscis. The greater number of species have also a curious caudal tuft of brilliantly coloured hair-like scales at the end of the abdomen on each side. The *Aedeomyinæ* and *Corethrinæ* are at present of no importance from a pathological point of view; the former are easily recognised by their very short palpi in both sexes, and the latter by their very short non-piercing proboscis which somewhat resembles that of the *Tabanidæ* or gad-flies. The *Heptaphlebomyinæ* and *Joblotinæ* may, for all practical purposes, be considered as belonging to the *Culicinae*. Each of these sub-families contains but one species, which, in the case of *Heptaphlebomyina*, was placed in a distinct sub-family because it had seven longitudinal wing veins instead of six, and in the case of *Joblotina* because the metanotum carried hairs and scales.

By far the most important of the sub-families are the *Anophelina* and the *Culicina*, which contain all the species of mosquitoes known to be connected with the transmission of disease. In the former sub-family are included all the mosquitoes usually known as "anopheles," and in the latter most of those usually known as "culex." In fact, for the student of tropical medicine, no very elaborate classification of the family *Culicidæ* is necessary or advisable, and a knowledge of the differences between the two groups "Culex" and "Anopheles," together with a knowledge of the more important characteristics of a few of the genera included in the sub-family *Culicina* are all that are essential before the task of the identification of individual species is commenced. These points will be referred to in the following more detailed account of the different stages in the metamorphosis of mosquitoes.

The Egg or Ovum

The eggs of most "culex" mosquitoes, before being deposited by the female, are collected together, in the angle made by the crossing

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4

FIG. 5.

FIG. 6.

FIG. 7.

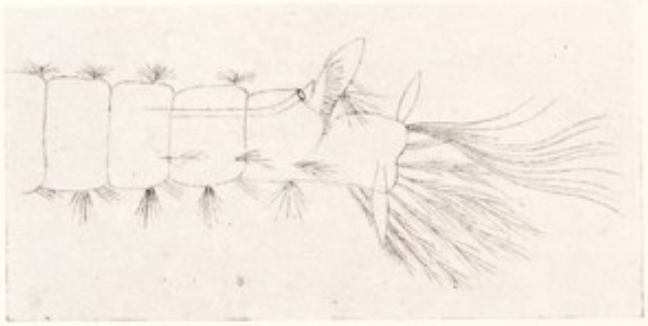


FIG. 8.

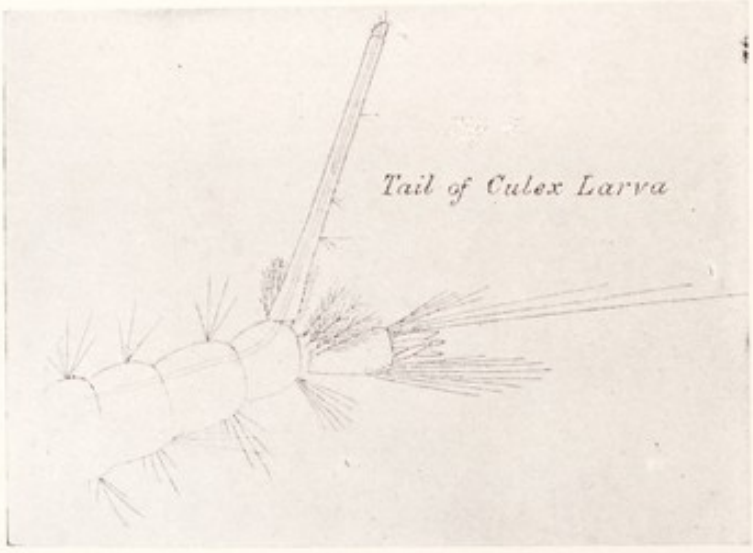


FIG. 9.

PLATE I. Fig. 1.—"*Anopheles*" eggs. Natural size: *Fig. 2.*—Egg of *A. rossi*, magnified, showing the upper surface, the lateral floats, and the beaded rim; *Fig. 3.*—Lateral view of the same; *Fig. 4.*—Raft-like masses of "*Culex*" eggs, natural size; *Fig. 5.*—A raft mass of "*Culex*" eggs, magnified; seen from above; *Fig. 6.*—Lateral view of the same; *Fig. 7.*—Four "*Culex*" eggs, greatly magnified; *Fig. 8.*—Posterior extremity of "*Anopheles*" larva showing sessile stigmatic apparatus and "palmate hairs"; *Fig. 9.*—Posterior extremity of "*Culex*" larva.

of the insect's hind legs, so as to form an elongated boat-shaped mass consisting of several hundred eggs joined to one another by their edges. When this egg-boat or egg-raft has been constructed the insect allows it to drop into the water, where it floats as a small oblong boat-shaped body somewhat raised at each extremity (Pl. I., Figs. 4, 5, 6). The shape and character of these egg-rafts vary in different genera. In the genus *Culex* (sub-family *Culicina*) they are broad and more or less oval in shape ; in the genus *Tæniorhynchus* (sub-family *Culicina*) they are said to be very elongated and to resemble a racing skiff in shape (Stephens and Christophers) ; in the genus *Corethra* (sub-family *Corethrina*), the eggs are collected together in flat, round, jelly-like masses.

The eggs of all "anopheles" mosquitoes, on the other hand, as well as those of a few "culex" moquitoes (*viz.*, those of the genera *Stegomyia*, *Panoplites*, *Psorophora* and *Janthinsoma* of the sub-family *Culicina*) are not collected together into a mass of definite shape before deposition. The reason of this is that the individual eggs do not stick together, so that when laid on a solid object they form only a piled up mass, and when laid on water they quickly separate from one another and float as isolated elements (Pl. I, Fig 1). Owing to physical causes, the eggs, when deposited on water, may arrange themselves in fairly definite star-shaped patterns or in rows, but more frequently they are scattered irregularly over the surface of the water. The individual eggs which compose an egg-raft of "culex" mosquitoes, are oblong in shape, and broader and more rounded at one end than at the other (Pl. I, Fig 7). When joined together to form the raft they lie vertically with the narrow end out of the water and the broad end—from which the larva escapes—submerged. The eggs of mosquitoes of the genus *Panoplites* (Fig. 1*a*) have one end terminating in a fine point (Daniels), and those of the genera *Stegomyia* and *Psorophora* (Fig. 1, *b* & *c*) are peculiar in that, besides being more or less oval in shape, they possess a rim of cells, somewhat resembling the rim or frill present in "anopheles" eggs.

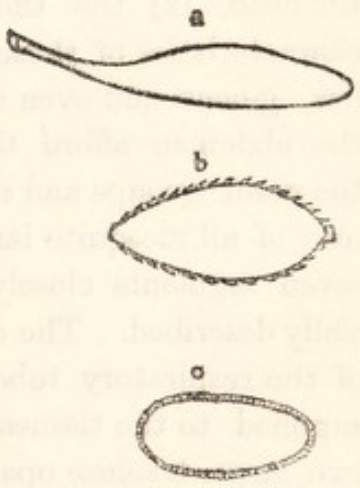


Fig. 1 (*after Daniels*).

A typical "anopheles" egg (Pl. I, Figs. 2, 3) is a boat-shaped body about 0·7 to 1·0 mm. in length. The upper surface or "deck" is flattened, but slightly convex, and is surrounded by a narrow beaded rim or frill. One end of the egg is slightly deeper and fuller than the other, and it is toward this end that the head of the embryo is directed. Along the centre of each side of the egg is attached an oval ribbed air-containing "float" (see also Fig 8). These floats are very characteristic structures and are not present in the eggs of any other kind of mosquito as yet described. Their shape and position differ in the eggs of different species of "anopheles," as does also the width and extent of the beaded rim or frill already described, and Stephens and Christophers have shown that it is possible to distinguish the eggs of some species by the position and characters of these two structures. These distinctions between the eggs of the various species will be described later.

The Larva

The larvæ of all mosquitoes are made up of three regions: (1) the head, (2) the thorax, and (3) the abdomen. The shape and characteristics of these three regions differ in the various sub-families, genera and even species of mosquitoes, but the characters of the abdomen afford the readiest means of distinguishing between the main groups and must therefore be described first. The abdomen of all mosquito larvæ is divided into nine segments. The first seven segments closely resemble one another and need not be specially described. The eighth segment carries the external openings of the respiratory tubes or *tracheæ*, by means of which oxygen is supplied to the tissues of the larva. In all "anopheles" larvæ the two large tracheæ open directly on the upper surface of the eighth segment by two stigmata which are surrounded and supported by a complex apparatus (Pl. I, Fig. 8). In "culex" larvæ, on the other hand, the respiratory tubes do not open directly at the surface of the segment, but are prolonged onwards into a projection from the segment known as the siphon tube (Pl. I, Fig. 9). The absence of a siphon tube in "anopheles" larvæ renders their recognition from among the larvæ of all other kinds of mosquitoes an easy matter. For the identification of the different kinds of "culex" larvæ the length and character of the siphon tube are of great value. Thus

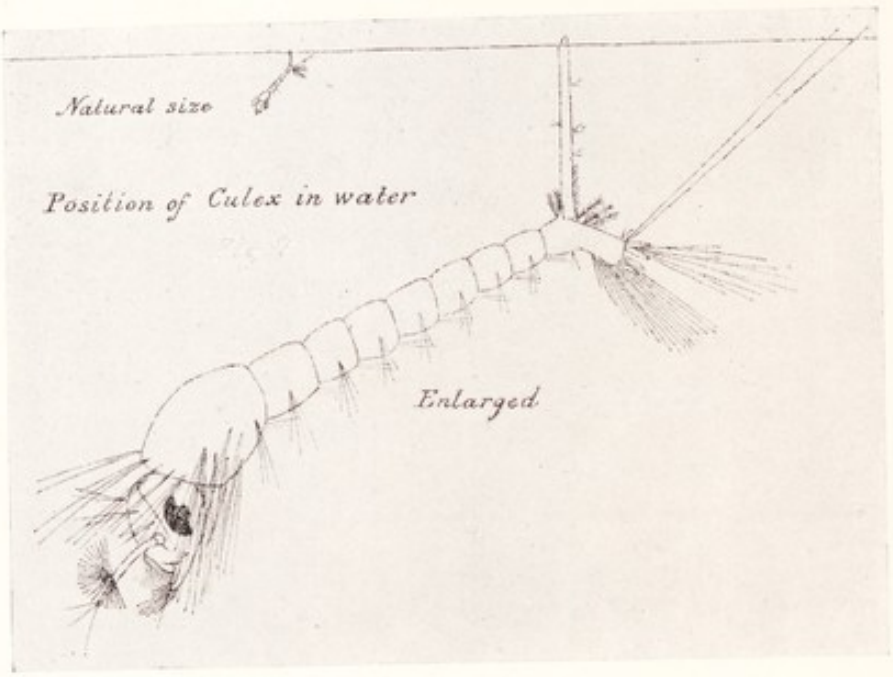


Fig. 1.

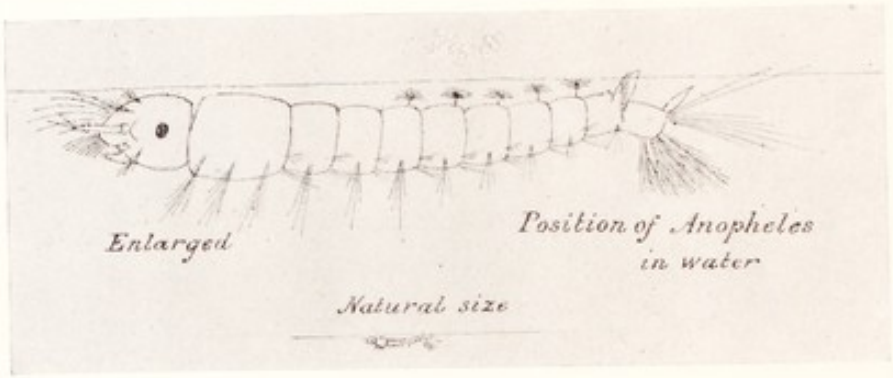


Fig. 2.

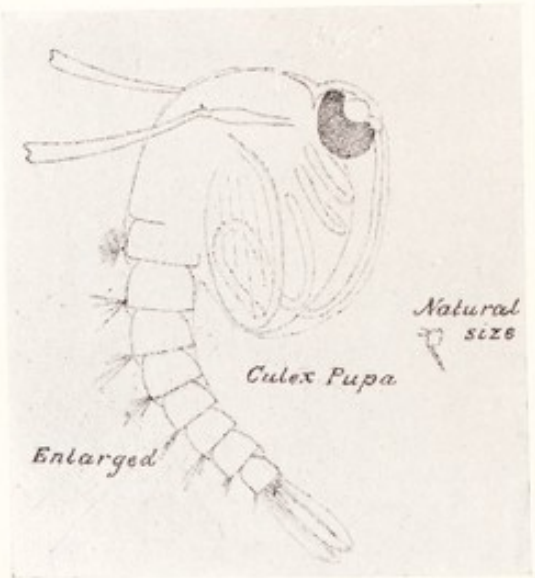


Fig. 3.

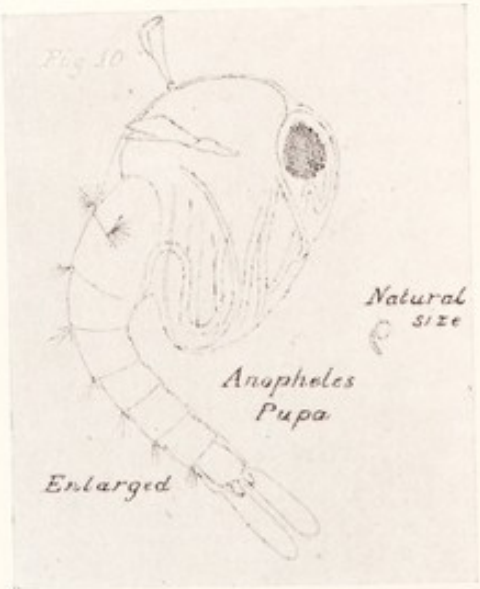


Fig. 4.

PLATE II. *Fig. 1.*—Larva of "*Culex*," showing the position at the surface of the water; *Fig. 2.*—Larva of "*Anopheles*," showing the same; *Fig. 3.*—Pupa of "*Culex*"; *Fig. 4.*—Pupa of "*Anopheles*."

in larvæ of the genus *Stegomyia* the siphon tube is very short and thick, and in those of the genus *Culex* it is long and thin. Stephens and Christophers employ the term "siphonic index" for the figure obtained by dividing the length of the siphon tube by its greatest breadth, and state that for the different species in any genus this figure is very constant. In *Stegomyia* larvæ, for example, the siphonic index is about 2, *i.e.*, the length of the tube is about double its greatest breadth, in *Culex* larvæ it is about 4, and in *Tæniorhynchus* larvæ it may be as much as 13.

The ninth abdominal segment is cylindrical in shape and carries the opening of the anus, around which are symmetrically arranged the four anal papillæ. On the dorso-lateral surface of certain of the abdominal segments of "anopheles" larvæ characteristic structures called "Palmate hairs" are present (see Pl. IV). Each of these hairs has a short stalk, to the apex of which are jointed a number of leaflets, which, when spread out, are arranged somewhat like the ribs of an umbrella which has been turned slightly inside out, or perhaps more nearly like the leaf of a cocoanut palm. Two of these palmate hairs are present on each segment which is provided with them, and it is chiefly by their means that the larva maintains its position close under the surface of the water. They are not present on the larvæ of any other kind of mosquito than "anopheles."

On account of their presence and on account of the absence of a siphon tube "anopheles" larvæ float in the water immediately beneath and parallel with the surface film (Pl. II, Fig. 2).

On account of the presence of a siphon tube and the absence of palmate hairs "culex" larvæ float considerably below and at an angle with the surface film (Pl. II, Fig. 1).

These are the essential differences by which "anopheles" and "culex" larvæ may be distinguished from each other, and it is unnecessary to describe in detail the differences between any other regions of the larvæ of these two kinds of mosquitoes. The head of an "anopheles" larva (Pl. IV) is more or less rounded in shape and is covered by a clearly defined chitinous case. The eyes are situated laterally, and in front of each eye is an eminence which carries the antenna. A broad band of pigment runs across the head between the two eminences from which the antennæ arise, and

this carries six branched hairs which project forward over the head (*see* Pl. IV). Arising from the corner of each eminence, and situated just outside the most external of the six hairs just mentioned, is a characteristic hair that we have called the "Basal hair." It is seen projecting forwards just outside and parallel to the antenna in Plate VII, fig. 2, A, and in the figures of the larvæ of *A. karwari*, *A. culiciformis*, &c. It differs in character in different species and is of value in the identification of larvæ. The anterior median area of the head is called the clypeus, and it carries on each side a large bunch of hairs called the whorl organs or "feeding brushes." Lying directly over each whorl organ is a hair which may be called the external frontal hair or external clypeal hair, and between the whorl organs of each side is a pair of hairs close together which may be called the median frontal or clypeal hairs. These four frontal or clypeal hairs project beyond the head and may be simple or branched. They are of great service in the identification of the larvæ of different species and will be more particularly referred to later. In some larvæ, *e. g.*, *A. turkhudi* and *A. jeyporiensis* a third hair called the "Posterior hair," arises from the clypeus just behind and between the two frontal hairs of each side. This hair is also of some service in identification. It is shown in Plate VII, fig. 2, and in Plate VIII, fig. 2. The sides of the mouth are formed by the mandibles, and its floor by the maxillæ. Each mandible carries a number of stout teeth, which, working in conjunction with those of the mandible of the opposite side, serve to crush the food.

In full-grown larvæ the thorax is broader than the head or than any of the abdominal segments (Pl. IV). It carries a number of branched hairs, and in some species a pair of well-developed palmate hairs similar to those present on the abdominal segments can be easily seen.

A few words may be added regarding the movements of larvæ in water and their method of feeding. "Anopheles" larvæ change their position at the surface of the water by a series of very characteristic jerking, darting movements in a backward direction. When actually occupied in feeding they lie stationary beneath the surface film, only their mouth parts moving. "Culex" larvæ do not dart along at the surface in a backward direction as "anopheles"

larvæ do, but when engaged in feeding they are propelled slowly forwards by the action of their mouth parts alone. Both kinds of larvæ, when disturbed, usually wriggle rapidly to the bottom of the pool, where they lie motionless with their bodies extended. "Anopheles" larvæ sometimes do not wriggle to the bottom, but simply extend their bodies and allow themselves to sink by virtue of their weight. When rising to the surface the movements of these larvæ are much more jerky than those of "culex."

"Anopheles" larvæ feed just beneath the surface film, and, whilst feeding, the head is rotated so that its ventral surface lies uppermost, though the body of the larva remains in its

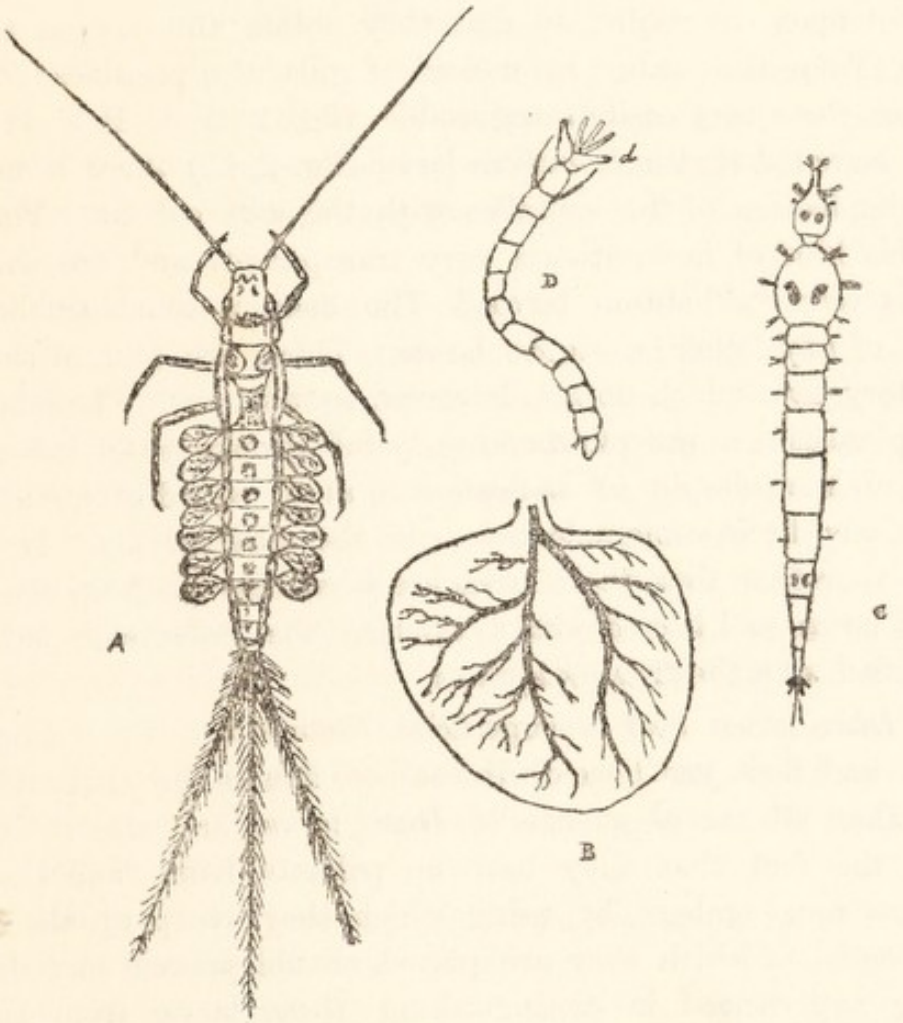


Fig. 2.

original position. This rotation of the head is very characteristic and is peculiar to the larvæ of this kind of mosquito. "Culex" larvæ often feed at the bottom of a pool, moving along

in their natural position and picking up stray bits of food of all kinds.

The larvæ of other flies than mosquitoes are often met with in water and may sometimes be mistaken for mosquito larvæ. The commonest are the larvæ of the flies called *Chironomus, Ephemera* and *Dixa*. *Chironomus* larvæ are often found in large numbers when the mud at the bottom of a small pool is stirred up. They are bright red worm-like creatures and are commonly known as "blood worms." Although their tracheæ open externally in a pair of "respiratory tubes" (fig. 2 D, d) in appearance they bear no resemblance to mosquito larvæ. The larvæ of ephemeral flies differ essentially from those of mosquitoes in that their air-tubes do not open externally, so that they obtain the oxygen they require from the water by means of gills, the presence of which makes them very easily recognisable (fig. 2 A & B. It should also be noted that in *Corethera* larvæ (fig. 2, C.) there is no direct communication of the air-tubes with the external air. The larvæ of this kind of mosquito are very transparent, and are called for that reason "Phantom larvæ." The head is much smaller than that of any other mosquito larvæ. There are four distinct respiratory sacs which do not, however, contain air. The larvæ have no spiracles and, except when nearly full grown, no air-tubes. The four air-sacs simply act as floats, and at no period of larval life is there any direct communication with the external air. It will be seen therefore that these larvæ are very different from other mosquito larvæ, and it is doubtful whether the *Corethrinæ* should be classified with the true mosquitoes.

Dixa larvæ bear a superficial resemblance to "anopheles" larvæ and float just beneath the surface film as the latter do. The fact that all the segments of *Dixa* larvæ are almost equal in size, the fact that they have no palmate hairs, and that they possess four prolegs, by using which they creep up the side of the vessel in which they are placed, should prevent any difficulty being experienced in distinguishing these larvæ from those of "anopheles."

The Pupa or Nymph

The pupæ of mosquitoes are active creatures, rising and falling in the water at will. Unlike the larvæ, they can sink in the water

only by violent exertions with their tails. As soon as these movements of the tail cease, the buoyant pupa floats up to the surface again. Like the larvæ, they breathe air through protruding spiracles; but these air tubes, instead of being at the tail end, as in the larva, are placed on the dorsum of the thorax, as two trumpet-shaped structures, projecting like horns. (Pl. II, figs. 3, 4.)

The length and shape of these spiracles enable "anopheles" pupæ to be distinguished from those of "culex."

"Anopheles" pupæ have short, stumpy, funnel-shaped spiracles (Pl. II, fig. 4), while those of "culex" are longer, more slender, and trumpet-shaped (Pl. II, fig. 3).

The Adult Mosquito or Imago

The adult mosquito is divided into three regions: (1) the head, (2) the thorax, (3) the abdomen. To the head are attached sensory and suctorial appendages; while to the thorax are attached the legs and wings. (*See* Descriptive Diagram of a female anopheles. Coloured plate No. I.)

The head is rounded and attached to the thorax by a narrow neck The portion of the head near the neck is called the nape. Above and in front of the nape is the occiput. In front of the occiput, and occupying the greater part of the antero-lateral portion of the head, are the two compound eyes. Immediately anterior to the eyes, on either side, arise the antennæ, which are long, jointed structures covered with hairs. In the male the antennæ are very prominent hairy organs (Pl. III, figs. 1, 3); in the female they are less conspicuous and almost devoid of hairs. (Pl. III, figs. 2, 4).

In front of the antennæ will be noted a firm median chitinous prolongation, the "clypeus." Beneath the clypeus arise the mouth parts, which consist of seven pieces collectively termed the proboscis.

The mouth parts are:—

(1) the upper lip, made up of labrum and epipharynx;
(2) & (3) two mandibles;
(4) & (5) two maxillæ;
(6) the hypopharynx or tongue;
(7) the lower lip or labium.

The labium is a grooved structure, within which the other six mouth parts are enclosed.

Attached to the maxillæ are two maxillary palpi. The palpi of "anopheles" mosquitoes are very prominent organs, as long as the proboscis in both sexes, and clubbed at their extremity in the males. (Pl. III, figs. 3, 4).

The palpi are less prominent organs in the genera *Culex*, *Stegomyia*, *Panoplites*, etc., except in the case of the males, in which they are even longer than the proboscis, but in the females of these genera they are rather minute structures, just visible to the naked eye. (Pl. III, figs. 1, 2).

The thorax is mainly composed of the middle division or mesothorax; it is large and convex. Behind the main part of the thorax, a prominent ridge runs between the bases of the wings; this ridge is called the "scutellum." Posterior to the scutellum, a horse shoe-shaped area is seen; this is the "metanotum."

Projecting laterally, behind the metanotum, the club-shaped halteres will be noted.

The abdomen is more slender than the thorax, and consists of nine segments: eight of these are easily seen, each segment being composed of a dorsal plate or tergum, and a ventral plate or sternum, joined together by a soft membrane. The anus opens on the ventral surface of the eighth segment, while the genital opening is on the ninth segment, and to this segment are attached the genitalia.

Attached to the under-surface of the thorax are the six legs, three on each side (anterior, middle, and posterior pairs of legs). Each leg consists of the following parts:—Two small segments, the coxa and trochanter (these cannot be seen from the dorsal aspect), two longer segments, the femur and tibia, and, lastly, five tarsal segments. The first tarsal segment is sometimes called the metatarsus. Between the tarsal segments are the tarsal joints.

The wings of mosquitoes are mapped out with veins which are covered with scales. These veins have a very definite arrangement, and a knowledge of the names applied to them is essential in distinguishing the different species.*

The external or anterior border of the wing is called the costa. Running parallel with the costa is the first longitudinal vein.

* The reader will be greatly helped by following these veins as well as other structures noted, on the descriptive diagram of a female anopheles (coloured plate No. 1).

FIG. 1.

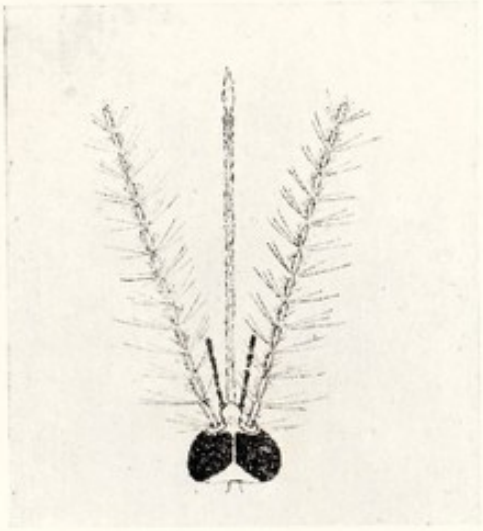


FIG. 2

FIG. 3

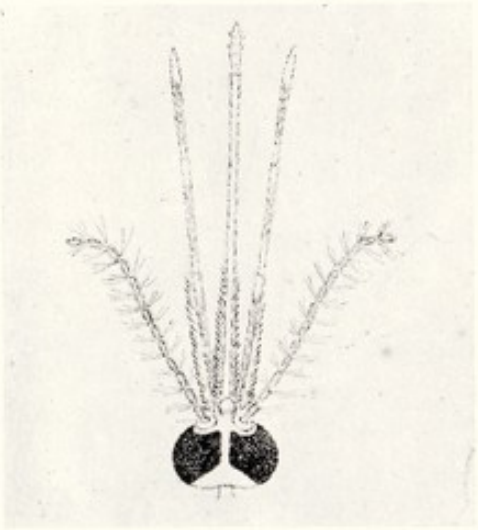


FIG. 4.

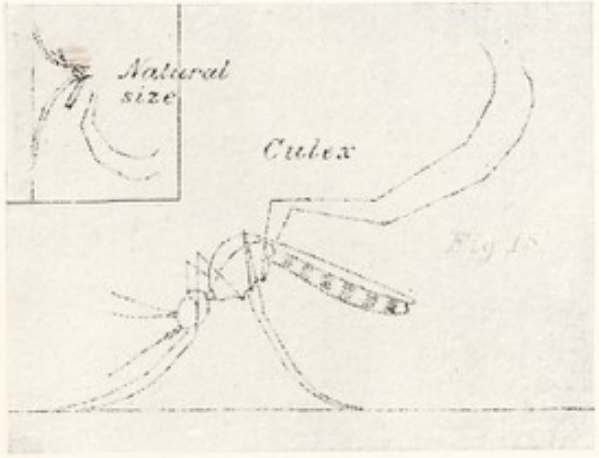


FIG. 5

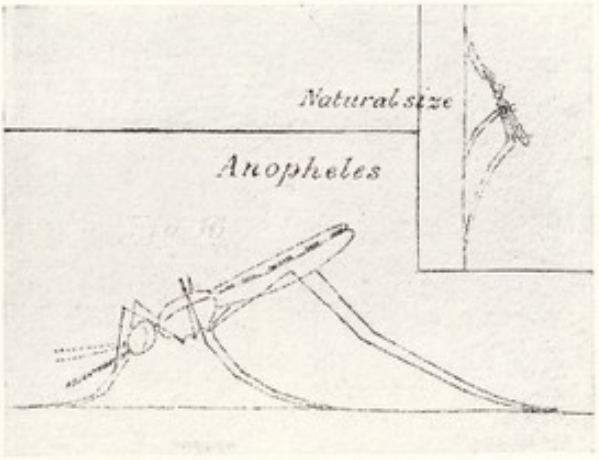


FIG. 6.

Immediately behind and arising about the junction of the inner with the middle third of this vein is the second longitudinal vein. After completing about half of its course this vein divides into two branches, the anterior and posterior branches of the second longitudinal vein.

Behind the second longitudinal vein and arising about the middle of the wing is the third longitudinal vein.

The fourth longitudinal vein arises at the base of the wing, and in the last quarter of its course divides into two branches, anterior and posterior.

The fifth longitudinal vein also arises from the base of the wing ; at about the middle of its course it divides into two branches, anterior and posterior.

The sixth longitudinal vein is unbranched, arises from the base of the wing, and terminates about the middle of the posterior border of the wing.

Joining these longitudinal veins with one another are certain transverse veins.

The most important of these transverse veins is the "the sub-costal" which, arising near the origin of the first longitudinal vein, passes obliquely forwards and outwards to meet the costa about the beginning of the outer third of its course. This is the only transverse vein which is covered with scales.

Joining the first long vein to the origin of the second long vein is a very short transverse vein, "the marginal transverse vein."

Joining the origin of the third long vein to the second long vein is "the super-numerary cross vein." The vein joining the third long vein to the fourth long vein is the "mid cross vein."

The vein joining the fourth long vein to the anterior branch of the fifth long vein is called "the posterior cross vein."

The first, third, and sixth longitudinal veins are unbranched. The second, fourth, and fifth long veins divide in their course into two branches. The areas enclosed between these branches have received names. The area enclosed between the branches of the second long vein is called "the first submarginal cell"; that between the branches of the fourth long vein, "the second posterior cell," and that between the branches of the fifth long vein, "the anal cell." Names have been applied to the other areas of the wing

enclosed between the various veins, but for our present purpose they need not be mentioned. The posterior margin of the wing is always fringed with long scales, "the wing fringe."

No account of the characters of mosquitoes would be complete without some remarks on scale structure, the importance of which has been very ably demonstrated by Mr. Theobald.*

Head scales.—Some or all of the following forms of scales may be found on the head of a mosquito :—

1. "Upright forked scales" (fig. 3, 2) are found chiefly towards the nape. These scales have long stalks with an expanded fan-like head, the angles of which project outwards like the prongs of a fork. They stand out from the surface upon which they are inserted.
2. "Narrow curved scales" (fig. 3, 3 : are long curved scales tapering to their extremities ; the body of the scale is expanded at its widest part to from $\frac{1}{8}$ to $\frac{1}{6}$ of the length of the scale. These scales are chiefly found projecting from the occiput.
3. "Flat scales" (fig. 3,1) have a narrow, pointed base ; the body of the scale rapidly expands from the base. The extremity of the scale is broad, with a flat or slightly convex edge. These scales, in contrast to the scales mentioned above, lie closely applied to the surface from which they arise and overlie one another like the slates on a roof. They are found on the dorso-lateral surface of the head.

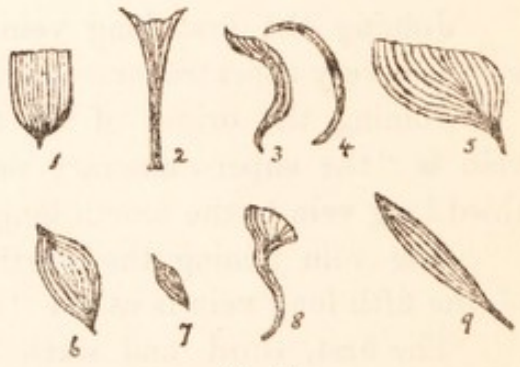


Fig. 3.

Thoracic scales.—Five forms of thoracic scales are described by Mr. Theobald.

1. Narrow hair-like curved scales (fig. 3, 4).
2. Narrow curved scales (fig. 3, 3).

* "A monograph of the Culicidæ of the world" by Fred. V. Theobald, M.A., F.E.S., British Museum (Natural History), Vols. I & II, 1901 ; Vol. III, 1903.

3. Spindle-shaped scales (figs. 3, 6).
4. Flat scales similar to those on the head (figs. 3, 1).
5. Long twisted scales (figs. 3, 8).

Abdominal scales.—In all "culex" mosquitoes and in one "anopheles" mosquito (*Aldrichia error*, Theobald) the abdomen is covered with overlapping flat scales. In some "anopheles" there are no scales on the abdomen, in others a few small flat scales occur in patches, and in others the abdomen is densely covered with scales of various forms.

Wing scales.—In all mosquitoes the veins of the wings are covered with scales which vary in shape and size in different parts of the same wing. Mr. Theobald describes the following forms as occurring on the wings of "anopheles" mosquitoes: 1, lanceolate (figs. 3, 9); 2, long and narrow; 3, large and inflated. On the wings of other kinds of mosquitoes some of the scales may be very large, flat and much expanded (*Panoplites*, figs. 3, 5); broad and asymmetrical (*Aedeomyia*); parti-coloured and pyriform or inflated (*Mucidus*); or broad and elongated (*Tæniorhynchus*).

Leg scales.—In nearly all mosquitoes the legs are clothed evenly with flat scales, which form a complete covering. In a few cases hair-like scales, which occur in tufts, may be present, as in *Sabethes*.

Scales on the proboscis, palpi, and antennæ.—The scales on the proboscis are usually small and flat, but in some "anopheles" they stand out very distinctly at an angle to the surface (*A. sinensis*, *&c.*). The palpi in some mosquitoes may also be densely scaled, as well as the basal and first two or three of the following segments.

Scales on the halteres.—Mr. Theobald makes no mention of scales being present on these structures, but their presence and character can be readily made out in most species of "anopheles."

In the classification of mosquitoes Mr. Theobald relies almost entirely upon scale structure for the distinctions between different genera, and in one case he has used this character alone for the formation of a sub-family (*Joblotina*). The genus *Stegomyia* was separated from the old genus *Culex* by reason of the fact that only two forms of scales, *viz.*, upright forked and flat scales, are present

on the heads of members of this genus, instead of the three kinds usually found on the heads of most other "culex" mosquitoes; and the genera *Panoplites* (= *Mansonia*), *Tæniorhynchus* and others by reason of their peculiarly shaped wing scales. Mr. Theobald has recently adopted a new classification of "anopheles" mosquitoes based almost entirely on scale structure, in which he divides these mosquitoes under 11 new genera as follows :—

Genus	1.	*Anopheles.*	Meigen.
,,	2.	*Myzomyia.*	Blanchard.
,,	3.	*Cyclolepteron.*	Theobald.
,,	4.	*Stethomyia.*	Theobald
,,	5.	*Pyretophorus.*	Blanchard.
,,	6.	*Arribalzagia.*	Nov. gen.
,,	7.	*Myzorhynchus.*	Blanchard.
,,	8.	*Nyssorhynchus.*	Blanchard.
,,	9.	*Cellia.*	Theobald.
,,	10.	*Aldrichia*	Theobald.
,,	11	*Christia.*	Theobald.

The characters upon which these new genera are founded may be tabulated thus :—

SUB-FAMILY ANOPHELINA.

Thorax and abdomen with hair-like curved scales.	Prothoracic lobes simple; no flat head scales.	Wing scales lanceolate...	*Anopheles.*
		Wing scales mostly long and narrow ...	*Myzomyia.*
		Wing scales partly large and inflated ...	*Cyclolepteron.*
	Prothoracic lobes mammilated: median flat scales.	Wing scales lanceolate	*Stethomyia.*
Thorax with narrow curved scales; abdomen hairy.		Wing scales small, lanceolate or narrowed...	*Pyretophorus.*
Thorax with hair-like curved scales; some narrow curved ones in front; abdomen with apical lateral scale tufts and scaly venter, no ventral tuft			*Arribalzagia.*
Thorax with hair-like curved scales; abdominal scales on venter only, with a distinct ventral apical tuft; no lateral tufts ...			*Myzorhynchus.*

Some objections to it.

SUB-FAMILY ANOPHELINA.—(*contd.*)

Thorax and abdomen with true scales.	Abdominal scales as lateral tufts and dorsal patches of small flat scales; thoracic narrow curved or spindle-shaped ...	*Nyssorhynchus.*
	Abdomen nearly completely scaled with irregular scales and with lateral tufts ...	*Cellia.*
	Abdomen completely scaled with large flat scales as in *Culex*	*Aldrichia.*

The Indian species of "anopheles" described by Mr. Theobald are placed by him in the following of these new genera.

In the genus *Anopheles* (1) *lindesayi*, Giles; (2) *gigas*, Giles; (3) *aitkeni*, James; (4) *immaculatus*, Theobald.

In the genus *Myzomyia* (1) *rossi*, Giles; (2) *culicifacies*, Giles; (3) *listoni*, Liston; (4) *turkhudi*, Liston; (5) *leucophyrus*, Dönitz; (6) *elegans*, James.

In the genus *Pyretophorus* (1) *jeyporiensis* n. sp.

In the genus *Myzorhynchus* (1) *sinensis*, Wiedmann; (2) *nigerrimus*, Giles; (3) *indiensis*, Theobald; (4) *barbirostris*, Van der Wulp; (5) *minutus*, Theobald.

In the genus *Nyssorhynchus* (1) *maculatus*, Theobald; (2) *fulginosus*, Giles; (3) *jamesi*, Theobald; (4) *theobaldi*, Giles; (5) *stephensi*, Liston; (6) *willmori*, James; (7) *maculipalpis*, Giles; (8) *karwari*, James.

In the genus *Cellia* (1) *pulcherrimus*, Theobald.

We have given this short account of Mr. Theobald's method of classifying "anopheles," for purposes of reference rather than because we agree that it is the best method by which these insects may be arranged. Omitting any consideration of the result of the new classification, *viz.*, that if it is adopted it will be necessary to say that malaria is transmitted not only by mosquitoes of the genus *Anopheles* but also by those of the genera *Myzomyia*, *Pyretophorus*, *Nyssorhynchus*, etc.,—for in spite of their new names the members of these new genera still remain malaria carriers—we may enumerate some of the more obvious objections to the method.

1. The fact that the scale structure of one species of "anopheles" (*Aldrichia error*, Theobald) is apparently similar

to that of some "culex" mosquitoes, appears to show that generic distinctions cannot be based upon scale structure alone.

2. The classification is based in great part on the shape, and not upon the presence or absence, of scales. Scales of various shapes are present on different parts of the thorax, abdomen, and especially the wings of "anopheles," and it is a matter of great difficulty to decide in some instances what form of scale predominates ; nor does Mr. Theobald give us any indication of what portion of a wing, for example, should be examined to decide this point.
3. The terms "lanceolate," "long and narrow," "true scales," &c., are not sufficiently definite to permit of such scales being easily distinguished from one another—except perhaps by Mr. Theobald himself. It is obvious that the distinction between "hair-like curved scales" and "narrow curved scales" is not great, and also that it would be difficult to decide whether the abdomen is "hairy," or whether it is covered with "hair-like scales" which apparently resemble hairs so closely that they cannot be termed "true scales." As regards the wing again it would certainly be difficult to decide whether most of the scales were "lanceolate" or whether they were "mostly long and narrow" especially as the part of the wing to be examined is not stated, but on this decision alone depends the distinction between the genera *Anopheles* and *Myzomyia*.
4. One of the objects of classification is to simplify the identification of species, but the new classification does not aid this in any way. In practice, it will be found much easier to determine the specific name of any specimen of "anopheles" than its generic name according to the new system.
5. Species which differ widely in their habits and pathological significance (e. g., *rossi* and *culicifacies*) are placed in the same genus, while those which are similar in these important respects (e. g., *listoni* and *jeyporiensis*) are placed in different genera.

6. Species of which the eggs and larvæ—the characters of which are at least as important as the shape of the wing scales in the adult insect—are essentially different (e. g., *culicifacies* and *turkhudi*) are placed in the same genus, while those with eggs and larvæ of the same type are placed in different genera.
7. The distinctions between the different genera are not of equal value, for whereas *gigas* and *rossi*, for example, are placed in different genera because in the one case the wing scales are "lanceolate," while in the other they are "mostly long and narrow," the fact that the abdomen of *stephensi* is densely covered with scales, while that of *maculatus* is, practically speaking, entirely free from them, is not considered sufficient to warrant these two species being placed in different genera. The same argument may be used with reference to *willmori* and some of the other species in the genus *Nyssorhynchus*.

It appears to us, therefore, that while differences in scale structure are undoubtedly of great value in the distinction of *species*, such differences as are present—at any rate among "anopheles"—are not sufficiently important to be considered of *generic* value, and it is for this reason that we have retained the generic term *anopheles* for all the species described in this book. In a later chapter we shall refer to this subject in more detail, and give our own method of classifying these insects, but before doing so we must describe the methods by which they may be caught, examined, and identified.

CHAPTER II.

THE COLLECTION, MOUNTING, EXAMINATION AND IDENTIFICATION OF ANOPHELES MOSQUITOES AND THEIR LARVÆ.

IN recording observations on the habits and life-history of "anopheles" there has been, until recently, a tendency to apply the facts deduced from observations of one species only, to the whole sub-family, without taking into account the fact that different species may vary greatly in their habits and life-history. At the present time, however, it is extremely important to study each species of "anopheles" separately, and it is desirable, therefore, to give briefly some methods that have been found successful for the collection of the adults and larvæ, in order that those who are interested in the subject may find and separate the various species present in their districts before commencing a study of their habits and life-history.

The collection of adult Anopheles.—The collection of the so-called "domestic" species—that is, those species which are never found far from the neighbourhood of human habitations—is, as a rule, an easy matter in India provided search for them is made in the right places. The majority of the known species rest during the day-time in houses, stables, and sheds, and in such haunts they may be easily captured by gently placing the open mouth of a test-tube over them as they rest on the walls or roof. A slight movement of the tube while it is kept pressed against the wall or roof will rouse the mosquito and make it fly towards the closed end of the tube, the mouth of which can then be closed by insinuating a cotton-wool plug between it and the wall or roof. Mosquitoes caught in this manner can either be kept in the test-tubes, or if a large number are required, as for the purpose of dissection, it is preferable to transfer them from the test-tubes into a large bottle with a narrow neck (such as an empty white glass

wine bottle), so that the test-tubes can be used again. In this way if "anopheles" are at all plentiful, fifty or sixty can be caught in a very short time.

But before commencing the search for adult mosquitoes of this kind it is advisable to carefully select a suitable place. A native village with breeding places near (such as a stream, or canal, or ponds) should be chosen if possible. In such a village there will probably be several old unoccupied huts and sheds, and it is in these a good catch is most likely to be made. It is almost useless to search in a new house with whitened walls. The best place of all is in old unoccupied house with smoke-blackened thatched roof and mud walls. It is better to look first in an unoccupied house, because the smoke from the wood fires in houses where people are living, drives most of the mosquitoes out during the day-time into the nearest empty house or shed. Cowsheds in the middle of a village, native carpenters' shops, wood sheds, and the barracks of native soldiers, are also good places in which to search for "anopheles" mosquitoes.

In houses with high roofs it may be necessary to mount on a ladder in order to very carefully examine each section of the thatch. The darker corners, the angles between the rafters and the thatch, and the cobwebs hanging from the roof, are favourite resting places of these mosquitoes. The commoner species, such as *A. rossi*, are usually seen at once, because they are light-coloured and large and stand out against the black background of sootlike little white thorns hanging from the roof, but the smaller darker coloured species are difficult to see. *A. culicifacies*, for example, hides most successfully in holes and corners of the roof, and in many places it would be possible to catch several hundred specimens of *A. rossi* in the time that it would take to catch fifteen or twenty specimens of this species. A difficulty also arises in collecting specimens of this very important species, from the fact that, as it does not assume the characteristic attitude of the majority of "anopheles" mosquitoes when resting on a wall or roof, it is very liable to be mistaken for a small brown "culex." For this reason, as well as for the reason that species of "anopheles" occur in India, the wings of which are entirely unspotted, it is advisable, in rooms which are badly lighted, to catch all the mosquitoes that are seen, without

taking note at the time whether they are "culex" or "anopheles." As each mosquito is caught, the tube containing it can be taken to the light, and the mosquito carefully examined before transferring it to the large bottle.

In occupied houses and in barracks and hospitals, "anopheles" are more likely to be found on dark-coloured clothes hanging in the corners of the rooms or in the cupboards, or resting on the under-surface of the shelves which usually surround the walls of barrack-rooms. Saddles and harness of all kinds are also favorite resting places of this kind of mosquito, and in the harness rooms of the cavalry regiments at Mian Mir as many as twenty or thirty can often be seen resting on the under-surface of each saddle hanging up in the rooms.

In stables and out-houses of Indian villages, it is usual for the natives to store a number of dried mud and straw cakes which are used for repairing their houses, and if one of these heaps of mud cakes is kicked over, a large number of "anopheles" will often fly out. In such a case as this a muslin net will be found very useful for catching the mosquitoes as they fly out. With one sweep of the net it is often possible to catch ten or twelve *A. culicifacies* after disturbing one of these heaps, when it may be difficult to find any specimens of this species resting on the walls or roofs of the houses.

In addition to collecting the species which are commonly found in the neighbourhood of habitations, it is very important to search for those species which are seldom or never found in houses and which may be termed "wild" species of "anopheles." They may sometimes be caught by the following method :—On a night when there is little or no wind a white sheet is hung near the ground under some trees, and a lighted lamp is placed on the ground in front of the sheet. The mosquitoes are attracted by the lamp and alight on the white sheet, when they may be caught by placing a test-tube over them in the usual way. Another plan is to erect a tent in the jungle or other place where we wish to search for these mosquitoes. After a day or two several will almost certainly be found in the corners of the tent and beneath the folds of its hangings. This method is of great service in villages where the inhabitants are unwilling to permit search being made in their houses.

The collection of larvæ.—The collection of adult mosquitoes should be supplemented by collecting the larvæ, which may be kept and bred out into adult mosquitoes.

On account of the fact that pools and streams frequently contain "anopheles" larvæ when none can be seen on the surface of the water, the method of "dipping" should always be employed for their collection.

One of the best things with which to dip for larvæ is a large tin mug, but a calico or muslin net with a long handle is of advantage for fishing in the middle of a pool or stream. Besides the dipper and net, a number of wide-mouthed bottles should be taken when going out to search for larvæ. When any collection of water is reached, the dipper should be scooped along the surface, under the grass or weed at the edge, and brought out full of water. If any larvæ have been caught they can easily be recognised in the dipper when they rise to the surface, and they should then be transferred with some of the water and weed into one of the wide-mouthed bottles. In running streams care should be taken to dip several times in the eddies and beneath the grass overhanging the edge of the water, as in such places larvæ are most likely to be found. The larvæ from different breeding places should be kept in separate bottles, in order that when they have been bred out and identified, the character of the breeding places of the different species will be known.

In searching for "anopheles" larvæ, it is important to note that no collection of water should be passed over without careful examination, for it often happens that the most unlikely-looking collection of water will yield many larvæ.

Each wide-mouthed bottle should be half-filled with water from the pool or stream in which the larvæ were taken. In some cases,—especially in the case of larvæ collected from running streams—it is necessary to change the water daily if healthy larvæ are to be reared. The mouths of the bottles are covered with fine muslin or mosquito netting, and allowed to stand in a warm place, but bright sunlight should be avoided if possible. Each day the adult mosquitoes which have developed from the larvæ may be transferred to a clean dry bottle, in which they should be allowed to remain alive for one or two hours in order that they may attain

their proper colour and size. After this period they may be killed and mounted for examination.

The mounting of Anopheles.—In making a collection of mosquitoes it is desirable to get as perfect specimens as possible, and for this reason the "anopheles" which have been caught or bred from larvæ, should not be kept alive in the bottles longer than is necessary, lest by rubbing their wings against the glass when flying about, some of the scales may be rubbed off. The insects are best killed by dropping a few drops of chloroform on to the muslin covering the mouth of the bottle in which they are confined. Tobacco smoke should not be used for killing mosquitoes as it alters the colour of the markings. Immediately after the insects are dead, they should be turned out on to a clean sheet of cork carpet. If left too long exposed to the fumes of chloroform, the legs become fixed in awkward positions and brittle. Great care should be taken not to touch the insects with the fingers or some of the fine scales will be rubbed off, and if it is necessary to move any of them, a fine needle or pin should be used for the purpose. In order to mount mosquitoes the following articles are necessary :—

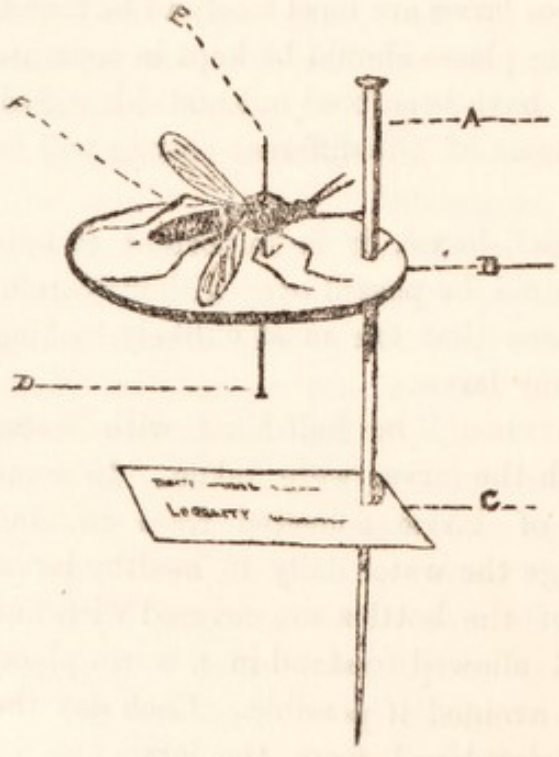


Fig. 4 (*After Theobald.*)

(1) Fine entomological silver pins (No. 20 size).

(2) A pair of forceps for holding the pins.

(3) Common pins.

(4) Small discs of thin cardboard such as are used for gun wads, the size of a 20-bore gun.

(5) A wooden box, in the floor of which is fixed a layer of cork carpet or pith, into which the pins can be inserted and firmly fixed.

A card-disc should be taken, and all the data concerning the specimen to be mounted, should be written upon it. Then one of the No. 20 pins should be firmly grasped

near its point with the forceps and thrust through the centre of the disc until about half its length projects through it. The mosquito, which is lying dead on the sheet of cork, should be turned on to its back with the aid of a pin, and, holding the head of the pin carrying the cardboard disc between the thumb and first finger of the right hand, the point of the pin is thrust into the thorax of the mosquito between the points of origin of the legs, and pressed onwards until it emerges through the dorsal surface of the thorax. When the pin and disc are lifted off the cork and inverted, the mosquito will be in its natural position, right side upwards. The wings and legs may now be carefully arranged with the aid of a fine pin, but this is often unnecessary, and if all the parts can be seen moderately well, it is best not to touch them, as even the most careful manipulation will rub off some of the scales and hairs. An ordinary pin is thrust through the card disc near its margin for the purpose of attaching it to the cork in the floor of the entomological box. (See Fig. 4).

In India, mosquitoes very quickly become covered with mould, and in order to prevent this, and to preserve them properly, they are best kept in the small glass tubes shown in fig. 5.

A flat cork (D) fitting very tightly is first pressed into the tube to its end. On this cork a small muslin bag (C) containing naphthalene is placed. This is kept in position by means of a cardboard disc perforated with holes (B) which is fastened firmly by pins to the cork in the bottom of the tube. The disc carrying the mosquito (A) is pinned to the cork which closes the mouth of the tube. By this method mosquitoes may be preserved in good condition for a long time, and if the tubes are well packed in a tin box with cotton-wool, they may be sent through the post with safety.

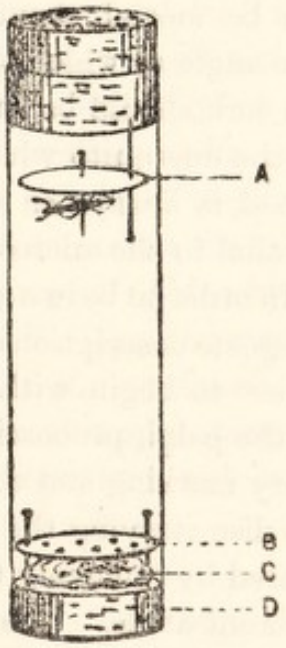


Fig. 5.

In addition to mounting male and female specimens of each species in the manner just described, it is necessary to have certain parts of each species mounted separately on glass slides. These

parts are the wings, the male genitalia, and the male and female ungues (especially the ungues of the fore leg in the male).

The wings are best mounted dry beneath a thin coverslip, which may be kept in place by strips of gummed paper or by ringing it with thick Canada balsam. The wings should, of course, be mounted perfectly flat.

The male genitalia and the ungues should be mounted beneath thin coverslips in xylol balsam.

The examination of adult Anopheles.—For the examination of adult mosquitoes a low power microscope (half or two-thirds inch objective) is necessary. The mosquito to be examined (which has already been mounted on a card-disc in the usual manner) is fixed by a pin thrust through the edge of the card-disc to a flat cork about an inch square. This piece of cork carrying the mosquito is placed on the microscope stage, and can be moved about at will (fig. 6). The angle at which the pin is fixed in the cork should be such that the part of the mosquito which is being examined is always as nearly as possible parallel to the microscope stage.

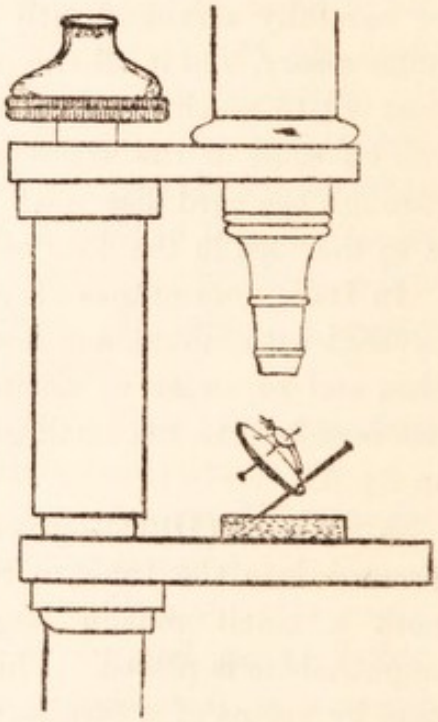


Fig. 6.

In order to be in a position to give a complete description of a mosquito, it is best to begin with an examination of the palpi, proboscis, and antennæ, and to work backwards, noting every marking and character that presents itself. The position of the disc carrying the mosquito will of course have to be frequently altered by removing the pin from the cork and readjusting it at a different angle. The character of the antennæ will at once show whether the mosquito is a male or female, and the length and characters of the palpi whether it is a "culex" or an "anopheles." (See Pl. III, figs. 1 to 4.) In the examination of the palpi it will also be noted whether they are uniformly coloured or whether they are encircled with white bands, and the number, relative size, and position of any such bands will be described. (See coloured plates.) In

addition to definite bands a few white scaled patches may be present on one or more segments of the palpi as in *A. maculipalpis* and *A. stephensi*. Passing on to the examination of the head, the characters of the different groups of scales will be noted, and in particular the characters of the upright forked scales can be readily made out. In most species of "anopheles" a prominent tuft of white hairs projecting forwards from the anterior end of the head will be seen. The thorax will next be examined, and on its dorsal surface a large number of scales and a few hairs will probably be present. The characters of these scales and hairs are of importance in identification and should be carefully described. Passing on towards the abdomen, the scutellum will be examined. In addition to the long bristles which will be readily seen attached to its border, the scutellum sometimes carries a few scales similar to those on the thorax. The bare horse-shoe shaped metanotum will next be seen, and then the halteres, the knobs of which are sometimes clothed with numerous small silvery scales.

The examination of the abdomen is of great importance. In many species, although the abdomen is thickly covered with long hairs, no scales are present. In some species, however, it will be seen that in addition to the hairs covering the majority of the segments, a few golden-brown or dark-coloured scales can be made out, especially on the ventral surface of the last one or two segments only. In other species, again, it will be at once seen that the whole surface of the abdomen is thickly set with white or golden brown scales, which in some species are very broad (as in *A. pulcherrimus*), and in others more or less spindle-shaped (as in *A. stephensi*). It will readily be recognised that the presence or absence and the character of these abdominal scales is a very important aid in the determination of species.

The wings and legs will next be examined.

The most useful way of describing the wing markings is by means of a diagrammatic drawing giving the number and relative size and position of the different dark and light-scaled areas on each vein. The detailed shape of the wing scales, which is a point of some importance, and the relative position of the transverse veins must be noted by a separate examination of a wing mounted under a cover-glass.

The legs should be examined in order, and a careful description of the markings on each leg, commencing with those on the femur and ending with those of the fifth tarsal segment, made. It will be seen that in many species complete bands of white scales encircle the legs near the joints, and the position and characters of these bands should be noted. In addition, small patches of white scales, not amounting to complete bands, will be found in some species on many of the segments of the legs ("speckling"), and in some species one or more of the terminal tarsal segments of the hind legs will be found to be white-scaled in their whole length.

The description will be completed by an examination of the male genitalia and of the ungues (special note being taken of the characters of the fore ungues in the male), these structures being separately mounted on slides for this purpose.

The Identification of adult Anopheles.—The identification of most of the Indian species of "anopheles" is not by any means a difficult matter if one sets about the task in a systematic way. We have just indicated the parts of a mosquito which must be examined in detail if it is desired to give a complete description of the insect, but for identification it is not, as a rule, necessary to examine all these structures minutely, and many of the Indian species can be readily identified by an examination with a hand-lens or even with the naked eye. The first requisite for the task of identification is the possession of a synoptic table such as the one given on page 32. This table is founded chiefly upon the markings of the palpi, which afford a satisfactory basis on which the Indian species may be divided, for purposes of identification, into a number of groups, such as "those with unbanded palpi," "those with three white bands on the palpi," &c. These groups may be subdivided into smaller ones by the markings on the legs, as, for example, among the "three-banded palpi" group a sub-group containing the species in which one or more of the terminal segments of the hind legs are pure white, another sub-group containing the species in which, though none of the hind tarsal segments are pure white in their whole length, there are distinct white bands at the tarsal joints, and a third sub-group containing the species in which the legs are uniformly coloured without any distinct bands. Each of these sub-groups will be found to contain only a few species,

which may be easily distinguished from one another by other characteristic markings. When the probable name of the mosquito we are dealing with has been found out by means of the table the full description of the mosquito of this name may be turned up (in Part II of this monograph), and we can ascertain by a more thorough examination of all the markings, scale structure, &c., whether we have identified the insect correctly.

In selecting the palp markings as the basis of the table of Indian species, we have been guided by the facts that they are less variable than the markings on the legs or wings, and that, whether as a result of coincidence or not, such an arrangement of the Indian species brings together into the same groups the species of which the habits and pathological significance are very similar. It should be noted that the markings of *male* mosquitoes vary so much that it is not advisable to use them for the identification of species and female specimens only should be employed.

A few examples will serve to illustrate the method of using the table.

Example I.—A MOUNTED MOSQUITO FOR IDENTIFICATION.

Antennæ.—With short, inconspicuous hairs at the joints (Plate III, Figs. 2 & 4), showing that the mosquito is a female.

Palpi.—As long as the proboscis (Plate III, Fig. 4) showing that it is an "anopheles."

Wings.—Spotted with dark and light scaled areas. The mosquito therefore comes under group I.

Palpi.—With three white bands or rings, *viz.*, one broad ring including the tips (which are therefore white) and two narrower ones.

It therefore comes under the group C, sub-group 2.

Legs.—None of the tarsal segments of the hind legs are white in their whole length, but there are distinct white bands at the tarsal joints (sub-group *b*).

The mosquito is therefore *A. rossi* or *A. stephensi.* The femora and tibiæ are not speckled with white patches, and the abdomen is not covered with scales.

Diagnosis.—***A. rossi.***

Confirm by comparison of the wing and other markings with the coloured plate of *A. rossi* and with the description of that mosquito.

I.—WINGS SPOTTED.

A.—Palpi unbanded.

1. *A. lindesayi* (Giles) ... ... Wings with one large white spot near the apex. Femora of hind legs with a broad white band.
2. *A. gigas* (Giles) ... ... A large species with three creamy white spots on the costa.
3. *A. barbirostris* (Van der wulp) ... A very large species with black densely-scaled palpi. Costa with two small light spots.

B.—Palpi with four white bands.

1.—LEGS BANDED AND FEMORA AND TIBIÆ SPECKLED WITH WHITE SPOTS.

4. *A. pulcherrimus* (Theobald) ... The third, fourth, and fifth hind tarsal segments white. Abdomen covered with scales.
5. *A. elegans* (James) ... ... None of the hind tarsal segments pure white. No scales on abdomen. A very broad band at the tibio-metatarsal joint of hind legs.
6. *A. punctulatus* (Dönitz) ... ... No broad white band at tibio-metatarsal joint.

2.—LEGS BANDED BUT FEMORA AND TIBIÆ NOT SPECKLED.

7. *A. sinensis* (Wiedmann) and its allied species *A. nigerrimus* (Giles), &c. None of the hind tarsal segments pure white.
8. *A. karwari* (James) ... ... The fifth tarsal segment of the hind legs pure white.

C.—Palpi with three white bands.

1.—TIPS OF PALPI BLACK.

9. *A. turkhudi* (Liston) ... ... None of the hind tarsal segments white.
10. *A. nagpori* (James) ... ... The fourth and fifth hind tarsal segments pure white.

2.—TIPS OF PALPI WHITE.

(*a*) *Tarsal joints banded and one or more of the hind tarsal segments white.*

11. *A. fuliginosus* (Giles) ... ... The third, fourth and fifth hind tarsal segments pure white. Femora and tibiæ not speckled.
12. *A. jamesi* (Theobald) ... ... As No. 11, but femora and tibiæ speckled.
13. *A. maculipalpis* (Giles) ... ... As No. 12, but palpi have two broad and one narrow bands instead of one broad and two narrow ones, and the palpi as well as the legs are speckled.
14. *A. theobaldi* (Giles) ... ... Legs speckled, but only the 4th and 5th hind tarsal segments are pure white.
15. *A. maculatus* (Theobald) ... ... Only the fifth hind tarsal segment is pure white.
16. *A. willmori* (James) ... ... Differs from No. 15, in having many scales on the abdomen.

(*b*) *Tarsal joints banded, but none of the hind tarsal segments white.*

17. *A. rossi* (Giles) ... ... Femora and tibiæ not speckled.
18. *A. stephensi* (Liston) ... ... Femora and tibiæ speckled. Abdomen covered with scales.

(*c*) *Legs uniformly coloured without distinct bands or white segments.*

19. *A. listoni* (Liston) ... ... The third long vein of wing white scaled; the sixth mostly dark scaled. Six white patches on wing fringe.
20. *A. jeyporiensis* (James) ... ... The third long vein of wing white scaled; the sixth mostly light scaled. Seven white patches on wing fringe.
21. *A. culicifacies* (Giles) ... ... The third long vein of wing black scaled. Two white patches on wing fringe.

II.—WINGS UNSPOTTED.

A.—Palpi unbanded.

22. *A. aitkeni* (James).
23. *A. culiciformis* (Liston).

B. Palpi distinctly lighter coloured in their outer third.

24. *A. immaculatus* (Theobald).

Example II.—A FEMALE "ANOPHELES."

Wings.—Spotted.

Palpi.—With three white rings, the outermost of which includes the tips. The two outer rings are broad and the third narrow. In addition to the three complete rings there are one or two small patches of white scales which do not amount to a complete ring or band, on the upper surface of each palpus; *i.e.*, the palpi are marked with three bands and are "speckled" in addition.

The mosquito comes under the group C, sub-group 2.

Legs.—The 3rd, 4th, and 5th tarsal segments of the hind legs are pure white in their whole length.

(NOTE.—It is sometimes rather difficult to determine by the naked eye or with a hand-lens the exact number of tarsal segments which are pure white, for the 5th segment is very short. The matter can easily be decided by an examination under a low power of the microscope.)

The mosquito is therefore either *A. fuliginosus*, *A. jamesi*, or *A. maculipalpis*.

The femora and tibiæ are brilliantly speckled with white scales.

This excludes *A. fuliginosus*, and the speckling of the palpi together with the fact that there are two broad and one narrow bands on the palpi, instead of one broad and two narrow ones, excludes *A. jamesi*, so that the diagnosis is *A. maculipalpis*.

Confirm as for example I.

Example III.—A FEMALE "ANOPHELES."

Wings.—Spotted.

Palpi.—With three white rings, the outermost of which includes the tips.

As in the other examples, the mosquito comes under the group C, sub-group 2.

Legs.—Uniformly coloured without distinct bands at the tarsal joints.

(NOTE.—In several of the unbanded legged species the segments may be *lighter coloured* at the tarsal joints, and in *A. jeyporiensis* this may be so marked as to form faint whitish spots. It will readily be recognised, however, that this lighter colouration does not amount to the fairly broad "distinct white bands," about the presence or absence of which there can be no doubt even with the naked eye.)

The mosquito is either *A. listoni*, *A. culicifacies*, or *A. jeyporiensis*.

Separate by careful examination of the wing markings. (See coloured plates and descriptions.)

The following, which are described as Indian species by Mr. Theobald, are not included in the synoptic table :—

(1.)	*Anopheles*	(*Myzomyia*)	*leptomeres.*
(2.)	,,	(*Myzorhynchus*)	*vanus.*
(3.)	,,	,,	*minutus.*
(4.)	,,	(*Aldrichia*)	*error.*

Some remarks regarding these species will be found in Part II.

The examination and identification of larvæ.—The larvæ of mosquitoes may be examined when alive or when killed and mounted on slides. In order to examine a larva when it is alive it is caught in a small spoon—care being taken not to injure it—and transferred with a drop of water on to a glass slide. A cover glass is then dropped very gently on to it. This has the effect of preventing the larva from continually wriggling out of the field of the microscope, and, if carefully done, it does not break any of the larval hairs or injure it in any way.

Permanent specimens of larvæ may be obtained either by mounting them simply in a solution of formalin in hollow ground glass slides, applying a cover glass and ringing it with thick Canada balsam, or by the following more permanent method, first recommended by Dr. Christophers.

(*a*) Kill the larva by immersing it in strong formalin solution, and allow it to remain in this solution for at least twelve hours.

(*b*) Immerse the larva after treatment in the formalin solution, in absolute alcohol for fifteen minutes.

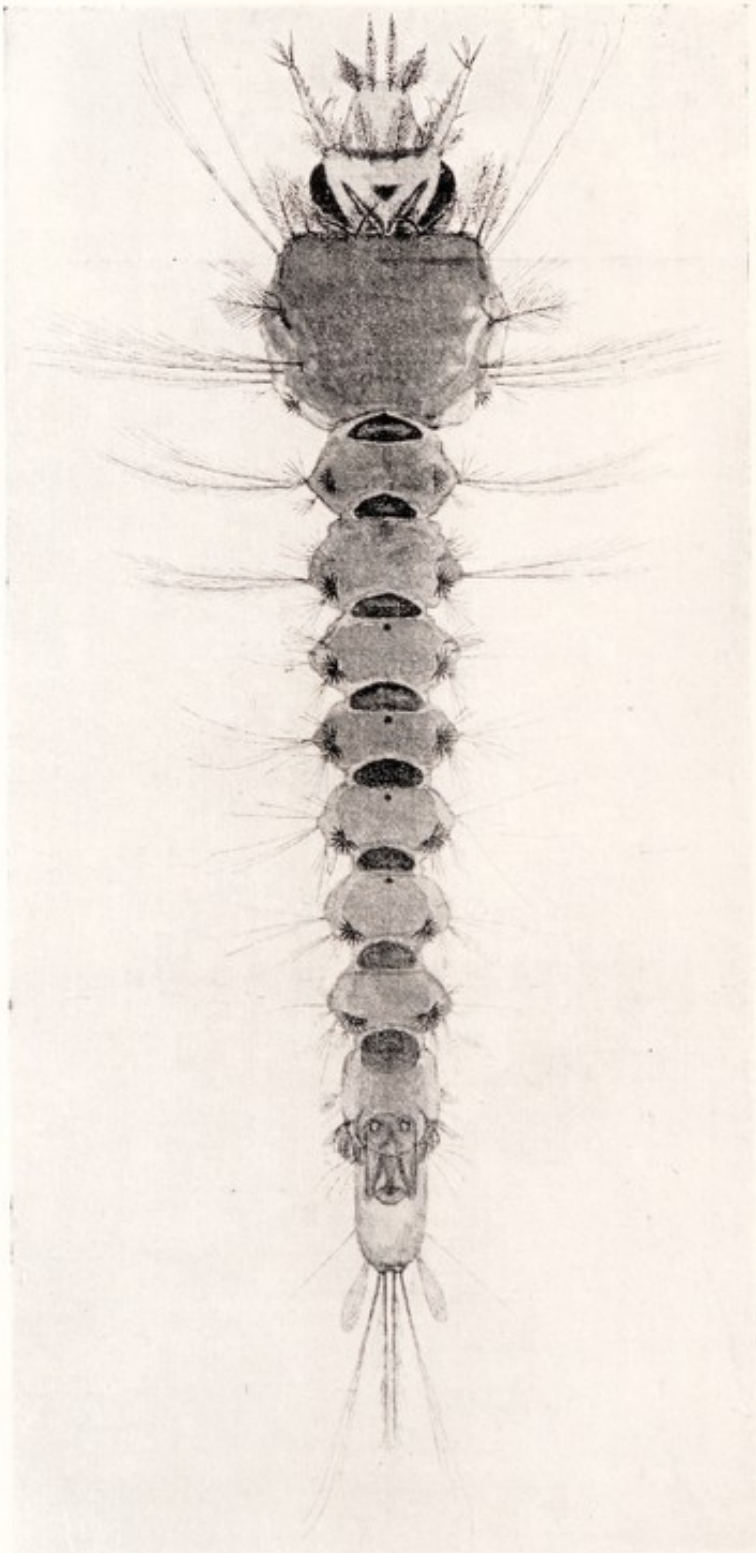
(*c*) Immerse it in oil of cloves.

(*d*) Clear with xylol and mount on an ordinary flat slide under a cover glass in xylol balsam.

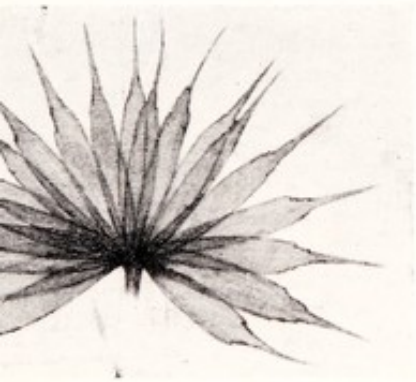
During the above process very great care must be taken to handle the larvæ gently so as not to break any of the finer hairs. They are best removed from one dish to another by lifting them up very gently on the edge of a piece of stiff paper.

Another plan, which shows the palmate hairs and some other characters of the larvæ exceedingly well, consists in mounting the

A.



B.



C.

PLATE IV. The larva of *A. maculipalpis*; *A.*—General view of the full grown larva; *B.*—One of the palmate hairs magnified; *C.*—The frontal hairs (Median and External) of the right side, magnified.

cast larval skins. These skins are very transparent, but they can be seen without difficulty floating near the surface of the vessel of water in which the larvæ are kept. Dr. Cogill recommends that the larval skin, after having been transferred to a glass slide, should be allowed to dry thoroughly and then mounted in thin Canada balsam beneath a cover glass.

It is of great advantage to be able to identify the different species of "anopheles" by an examination of their larvæ alone, without the necessity of breeding out the larvæ into adults. Grassi was the first to show that this could be done for some of the Italian species, and recent work by the members of the Royal Society's Malaria Commission in India has shown that the majority of the known Indian species can also be differentiated in the larval stage of their existence.

The structures by which the larvæ of different species of "anopheles" may be identified are as follow :—

(1) *The Frontal or Clypeal hairs* (Pl. IV, A & C).—These are four fine hairs which project from the dorsal surface of the anterior end of the head. They may be called the external and the median frontal hairs. The external hairs are placed one at each corner of the dorsal chitinous end of the head, and exactly overhang the prominent so-called whorl organs or "shaving brushes." When the whorl organs are pushed out, the external (corner) hairs are difficult to see, but when the whorl organs are drawn in, they stand out prominently. The median hairs arise close together near the middle line and project forward in front of the head. They are easily seen under a $\frac{1}{4}$ or $\frac{1}{2}$ inch objective.

A very important difference between the larvæ of different species depends upon the fact that the characters of these external and median frontal hairs differ in different species. The details of these differences are given under the descriptions of the several species.

(2) *The Palmate hairs* (Pl. IV, A & B).—If the dorsal surface of the abdomen of an "anopheles" larva is examined under the microscope, a pair of little fan-shaped organs will be seen on the majority of the segments. These are the so-called "Palmate hairs." Each consists of a short stalk surmounted by a bundle of about 15 to 18 hairs which are arranged round the stalk like the petals of a flower. When the larva comes to the surface

these leaflets spread out and form a series of little cup-shaped organs which serve to keep the larva floating in the horizontal position. Both the number of the palmate hairs and the shape of each leaflet differ in different species of "anopheles," so that in this fact we have a second means of distinguishing the larvæ of different species.

(3) *The Antennæ* (Pl. IV, A.)—These structures are very easily recognised, and in the majority of Indian species they differ but little. A very small hair should be noted on the outer side of the antenna at about the junction of its middle and lower third in the majority of the larvæ.

The larvæ of two of the Indian species of "anopheles," however are readily distinguished from those of any other species by the presence of a stout branching hair on the inner side of each antenna, quite distinct from the small external hair referred to above. The characters of this large branching hair are shown in the diagram of the larva of *A. barbirostris* (Plate V, Fig. 1, A and D).

(4) *The pattern of the head markings.*—Although the pattern on the dorsal surface of the head of "anopheles" larvæ is formed by dots of pigment only, and is therefore liable to considerable variation, yet in some species the head pattern is sufficiently constant to be of assistance in the identification of larvæ. The inverted triangular area enclosing four dots of pigment on the dorsal surface of the head of the larva of *A. rossi*, for example, is very characteristic (Pl. VI, Fig. 1, A), as is also the complete absence of any pattern on the head of the larvæ of *A. stephensi* (Pl. VI, Fig. 2, A). The usual markings on the heads of these and other larvæ are given in the diagrams.

(5) *The Basal hair.*—We have already described in Chapter I the position of this hair. Its shape and character are particularly remarkable in the larvæ of *A. culiciformis* and at once serve to differentiate the larvæ of this species from all others.

(6) *The Posterior hair.*—In some larvæ, as we have already mentioned, two hairs arise from the clypeus behind and between the frontal hairs. In the larvæ of *A. turkhudi* (Pl. VIII, Fig. 2) these hairs are unbranched and very long. In the larvæ of *A. jeyporiensis* (Pl. VII, Fig. 2) they are short but branched.

It should be noted that in the identification of any particular larva, too much stress should not be laid on any one of the

above structures alone, but that a careful consideration of the characters of all the structures taken together will yield the most accurate results. This is necessary because, as Dr. Cogill has recently shown, the characters of the frontal hairs may occasionally vary even among a series of larvæ from the same batch of eggs.

As an aid to the identification of the larvæ of some of the Indian "anopheles," we may arrange those of which the characters are known in the following table, which is a modification of that given by Stephens and Christophers :—

I.—ANTENNÆ WITH A LARGE BRANCHED HAIR.

A.—With simple unbranched frontal hairs.

1. *A. lindesayi.*

B.—With branched frontal hairs.

2. *A. barbirostris* ... ... Median frontal hairs unbranched. The branches of the external frontal hairs arise from the main stem and from other branches.
3. *A. nigerrimus* ... ... Median frontal hairs unbranched. The branches of the external frontal hair all arise from the main stem.

II.—ANTENNÆ WITHOUT A LARGE BRANCHED HAIR.

A.—With fully developed palmate hairs on the thorax.

(a) *With simple unbranched frontal hairs.*

4. *A. culicifacies* ... ... The filaments of the palmate hair leaflets rather long.
5. *A. listoni* ... ... Palmate hairs very large and distinct on the thorax and abdominal segments. Filaments of leaflets shorter. Characteristic head pattern.
6. *A. culiciformis* ... ... Basal hair characteristic. Median frontal hairs long. Leaflets of palmate hairs taper to a point.

(b) *With branched frontal hairs.*

7. *A. jeyporiensis* ... ... Two small branched posterior hairs in addition to the frontal hairs. Palmate hairs very large and distinct. Filaments of leaflets short.
8. *A. maculipalpis* ... ... No posterior hair. Filaments of palmate hair leaflets rather long.

B.—Without fully developed palmate hairs on the thorax.

(a) *With simple unbranched frontal hairs.*

9. *A. rossi* ... ... Characteristic head pattern. Fully developed palmate hairs on the 3rd to the 7th segments of abdomen. Filaments of leaflets very long.
10. *A. stephensi* ... ... No head pattern. Filaments of palmate hair leaflets shorter.
11. *A. theobaldi* ... ... Filaments of palmate hair leaflets very short and blunt.
12. *A. maculatus* ... ... Filaments short but sharp pointed.
13. *A. elegans* ... ... Leaflets of palmate hairs taper to a point; no distinct filaments.
14. *A. turkhudi* ... ... Two very long unbranched posterior hairs in addition to the frontal hairs. Fully developed palmate hairs on the fourth, fifth and sixth abdominal segments only.
15. *A. karwari.*

(b) *With branched frontal hairs.*

16. *A. fuliginosus* ... ... Frontal hairs very much branched.
17. *A. pulcherrimus* ... ... Frontal hairs only slightly branched or frayed.
18. *A. ailkeni* ... ... External frontal hairs unbranched, median forked.

How to collect and examine the eggs.

The examination and identification of eggs.—In order to obtain eggs of "anopheles" it is necessary to preserve some female mosquitoes of this kind that have been caught in a native village, until they have deposited their eggs. The best method of keeping mosquitoes alive for this purpose is that recommended by Drs. Stephens and Christophers. A glass "chutney" or "pickle" jar with a wide mouth and a hollow glass stopper is obtained, and after it has been thoroughly cleaned and dried a piece of cardboard is placed in it of such a size that after being forced into the jar it remains firmly fixed (Fig. 7). The stopper is filled nearly to the brim with water, and a thin piece of cork covered with white paper is put to float in it. The mosquitoes that have been caught (both males and females) are transferred from the collecting tubes into the jar, which is then placed upside down upon the stopper in a dark cupboard. If mosquitoes from a village are used, it will usually be found that even after one night some of them will have deposited their eggs. Some of the eggs will almost always be found on the white paper, which can then be removed and placed on the microscope stage, the eggs being examined by reflected light with a half or two-thirds inch objective.

Fig. 7.
(after Stephens and Christophers.)

Great care should, of course, be taken that all the mosquitoes in the jar are of the same species, for, if more than one kind is introduced, it will be impossible to tell to which species the eggs belong.

The points to which attention should be directed in the examination of an "anopheles" egg are:

(1) *The upper surface.*—The width of the upper surface should be carefully measured, and it should be especially noted whether the floats almost touch each other on this surface, or whether their inner edges are wide apart.

(2) *The floats.*—The character, size and extent of the floats should be noted, and it should especially be seen whether their inner edges encroach on the upper surface of the egg, or whether the floats are inserted laterally so that their inner edges are wide apart on the dorsum of the egg.

(3) *The rim or frill.*—It should be noted whether the rim is wide or narrow and whether the floats appear to arise from it, or whether they arise behind it, in which case it would be continued uninterruptedly round the upper surface of the egg.

(4) *The lower surface.*—It should be noted whether the lower surface is smooth and uniformly coloured, or whether it is marked with silvery lines dividing it into a number of polygonal areas.

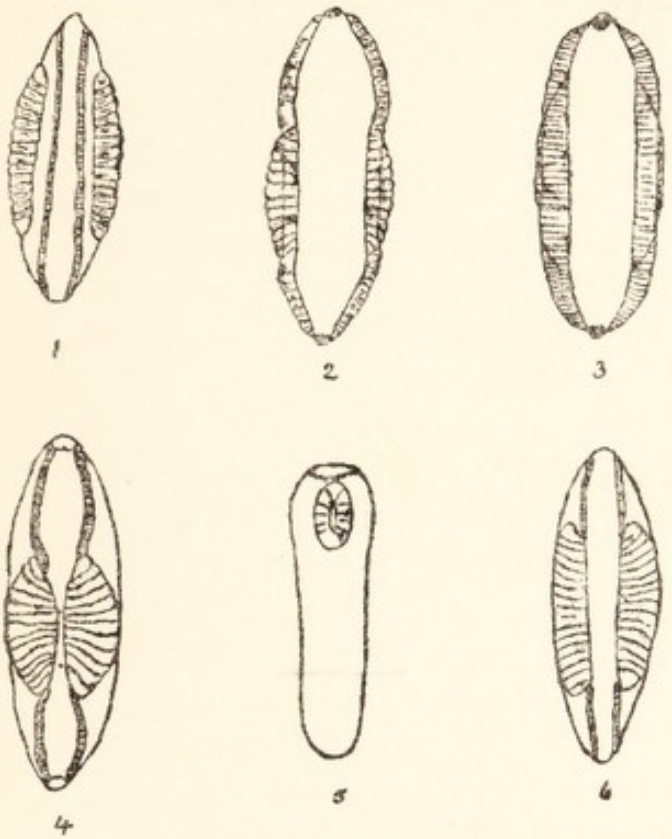


Fig. 8. (*After Stephens and Christophers.*

1, *A. culicifacies*; 2, *A. pulcherrimus*; 3, *A. rossi*; 4, *A. stephensi*; 5, *A. turkhudi*; 6, *A. maculipalpis.*

The following types of "anopheles" ova have been described by Drs. Stephens and Christophers :—

Type 1.—Ova having the upper surface very narrow, the rim or frill being continued uninterruptedly round this surface and the lateral floats not touching its margins (Fig. 8, 1).

Some species with ova of this type are :—*A culicifacies, A. listoni, A. barbirostris, A. nigerrimus.*

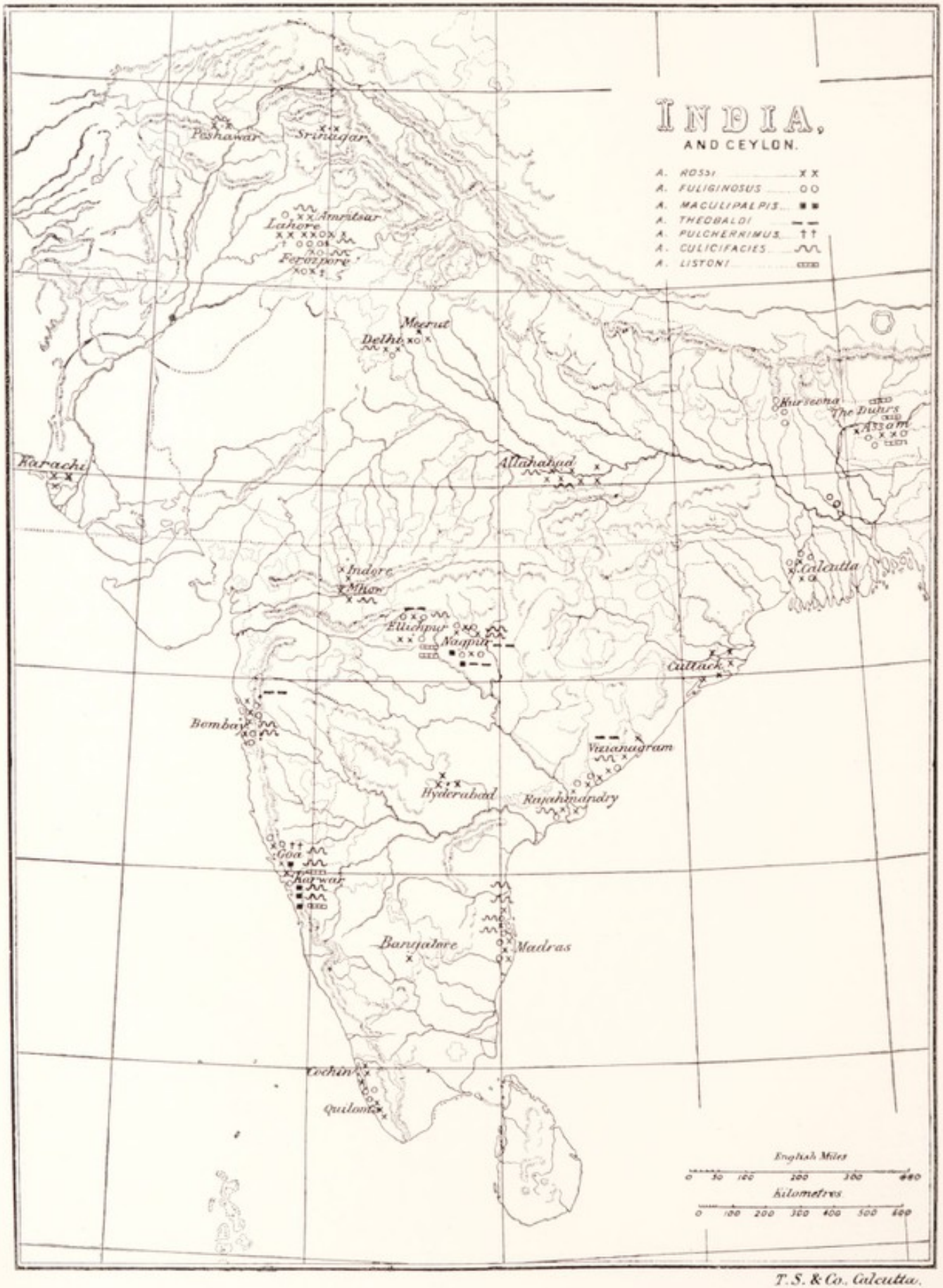
Type 2.—Ova having a more or less broad upper surface with the lateral floats touching its margins and apparently arising from the frill (Fig. 8, 2, 3, 4, 6.)

Some species with ova of this type are :—*A. rossi, A. pulcherrimus, A. fuliginosus, A. stephensi.*

Type 3.—Ova with no floats and with the upper surface rudimentary (Fig. 8, 5.)

Only one species, viz., *A. turkhudi,* is at present known to have ova of this type.

Further details regarding the ova of different species will be found in Part II.



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CHAPTER III.

THE HABITS OF INDIAN ANOPHELES.

Distribution and prevalence.

IT may perhaps be owing to the fact that "anopheles" mosquitoes have been more closely studied in India than in any other tropical region, that the number of species recorded from this country is greater, and the known distribution of individual species appears to be wider, than in any other part of the world. Indeed, there is as yet no trustworthy record of the absence of "anopheles" from any part of India, and they have been shown to be present more or less abundantly wherever careful search for them has been made. Even in places at a height above the sea-level of between 6,000 and 7,000 feet they frequently occur, and throughout the plains they are exceedingly prevalent. To ascertain, with any approach to accuracy, the exact distribution of each species that occurs in India, would be a task requiring the attention of many trained observers for a considerable period of time, and at present it is impossible to do more than indicate, in a general way, the partial distribution of some of the better known species. This we have attempted to do on the outline map which accompanies this chapter, in the hope that those whose work or pleasure takes them to parts as yet unexplored from this point of view, will fill in the bare spaces at present occupying so large a part of the outline.

So far as our knowledge goes, it would seem that many species such as *A. rossi*, *A. fuliginosus*, *A. barbirostris*, *A. nigerrimus*, and *A. culicifacies*, occur throughout the length and breadth of the country. Others, such as *A. pulcherrimus*, and *A. maculipalpis*, have been found as far north as the Punjab and as far south as Travancore, but have not been recorded from the intervening territories, probably because they have not been searched for in those parts by competent observers. It is also known that some, at least, of the species occur in other countries as well as in India—*A. maculipalpis*, for example, which is a common African species, *A. barbirostris*,

which occurs in Java, the Malay Archipelago, Old Calabar, &c., and *A. maculatus*, which occurs in China. The group of Indian species, including *A. listoni* and *A. culicifacies*, is also very near, if not identical with, the African group, including *A. funestus* and its allies, and the unspotted winged species *A. aitkeni* is a near neighbour of the European species *A. bifurcatus*, and the Algerian species *A. algeriensis*. It would seem, therefore, that many of the Indian species have a wide distribution in nature. But a distinction must be made between the general distribution of a species and its distribution in the particular countries where it occurs. There seems no reason to doubt that some "anopheles," such as *A. rossi*, do not habitually act as carriers of malaria in nature. To whatever cause this is due—whether to the fact that such species have become immune to the malaria parasite, or because they habitually feed on the blood of domestic animals rather than on that of man—it is the chief reason why a knowledge of the local distribution of individual species is so important. Although the geographical distribution of a species may be wide, its local distribution may be very limited. *A. listoni*, for example, though it has been found in India as far north as the foot of the Himalayas and as far south as Goa in the Bombay Presidency, is quite unknown in the Punjab. *A. rossi* and *A. stephensi*, also, though they are very common in Calcutta, are very rare or absent in many parts of the Duars, which is only a comparatively short distance away. *A. jeyporiensis*, again, has been found up to the present only in two districts, namely, the Jeypore agency in the Madras Presidency, and Nagpur in the Central Provinces; and *A. elegans* in only one place in the Bombay Presidency. It even happens, not infrequently, that the anopheles fauna of two places only a few miles apart is entirely different. In some cases this localized distribution of species is due to differences in the character of breeding grounds. In Calcutta, for example, almost the only breeding places are ponds and pools of water - the favourite breeding grounds of *A. rossi*, while in the Duars the prevailing breeding grounds are running streams—the favourite breeding places of *A. listoni*. Climate is also an important factor, as in the cases of *A. lindesayi* and *A. gigas*, which are found only in hill districts, and a particular kind of food supply may also have some influence, as in the case of *A. rossi*, which is never found very far from human dwellings.

As regards the *abundance* of "anopheles" present in any district, it is well known that they may be very numerous in one place and scanty or almost unknown in another, and also that, while one species is very abundant, another may be very rare. Other things being equal, this dissimilarity in prevalence is due to differences in the number, extent, and character, of breeding grounds, and, as a general rule, it may be said that there is a direct relation between the extent and proximity of breeding grounds and the number of "anopheles" present in any place. The prevalence of these insects varies also according to the season of the year, and the influence of this factor is more marked in the case of some species than of others. The accompanying chart illustrates the seasonal

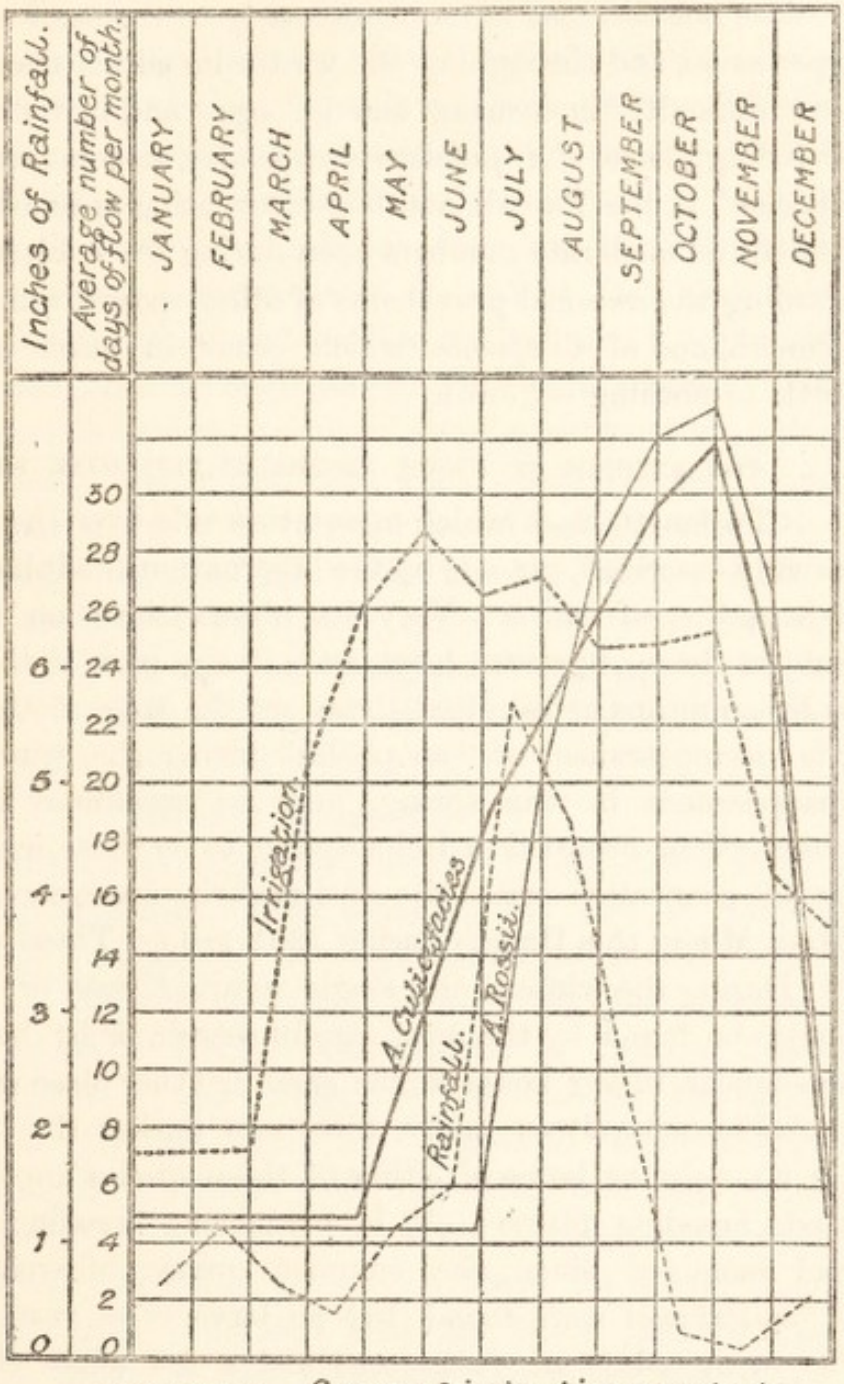


Fig. 9.

prevalence of *A. culicifacies* and *A. rossi* in the Punjab. It will be seen that *A. culicifacies* begins to be prevalent in May, while *A. rossi* does not appear until July, and that both species diminish rapidly in numbers towards the end of November. *A. fuliginosus* is most prevalent in the Punjab in September, but as the winter advances it does not decrease in numbers nearly to the same extent as other species do, and throughout the winter its adults may be found without difficulty in houses, and its eggs and larvæ in newly-formed breeding places. *A. pulcherrimus* is also, to some extent, a "winter species" in the Punjab, and non-hibernating specimens can be collected in moderate numbers even during the coldest months. Regarding the seasonal prevalence of other species which occur in the Punjab, and of all species which occur in other parts of India, little or nothing is known.

THE METHODS BY WHICH ANOPHELES TIDE OVER THE WINTER.

Two methods of which mosquitoes tide over the cold season are usually described, *viz.* (1) by the hibernation of adults, and (2) by the hibernation of larvæ. Very few observations on this important subject have, however, been made in any part of the world, and it is by no means certain that these are the sole methods by which the disappearance of "anopheles" during the winter, and their reappearance in the spring, may be accounted for. The only observations recorded in India appear to be those made by one of us in connection with the anti-malarial operations carried out at Mian Mir in the Punjab during 1901-1903. These were as follow: (1) During the winter not a single adult *A. rossi* or *A. culicifacies* could be found by the most careful search, or by burning culicidal substances, in any house, stable, shed, or other place where it seemed probable mosquitoes might hibernate during the cold weather; (2) no eggs or larvæ of either of these species appeared in newly-made breeding places; (3) in permanent breeding places, which had remained since the summer, many hibernating larvæ of *A. culicifacies* were found, but no larvæ of *a. rossi* were present; (4) many adult *A. fuliginosus* and a few adult *A. pulcherrimus* were found throughout the winter in houses and sheds. The habits of these species were, however, the same during the winter as during the summer, and they did not "hibernate" in the correct sense of the term; (5) eggs, young larvæ and pupæ of these two

species were found throughout the winter in newly-made breeding places.

It will be seen, therefore, that none of these four species hibernated in the adult form, but *A. culicifacies* was undoubtedly able to tide over the winter by hibernating in the larval form. *A. fuliginosus* and *A. pulcherrimus* appeared to be able to pass the winter without any change taking place in their habits. Both adults and larvæ of *A. rossi* so far as it was possible to ascertain by careful search and experiment, seemed to have disappeared entirely during the winter. There are other facts which lend weight to the supposition that *A. rossi* disappears from the Punjab during the winter, one of which is the recently discovered fact that this species can fly a long distance, and another the fact that it cannot be found in the Punjab until the beginning of July. If adults of this species were present in houses in a hibernating condition during the winter, it is practically certain that they would become aroused from their state of torpor and that the species would become sufficiently prevalent to be easily found in April, when the hot weather begins. It is perhaps not too much to conclude from these facts that at the onset of the winter, *A. rossi* "migrates"—perhaps by short stages—to places further south, and when the summer comes, reappears in the same way.

DISTANCE OF FLIGHT.

With regard to this question, also, very few trustworthy observations have been recorded. It is usual to say that the normal distance of flight of "anopheles" does not exceed half a mile. Evidence in support of this statement was obtained by the members of the Royal Society's Malaria Commission in India. These observers found that in certain villages in the Central Provinces *A. culicifacies*, *A. stephensi*, and *A. fuliginosus* were always present in abundance if there were extensive breeding places within a quarter of a mile, but that villages, which were distant half a mile from such breeding places, contained few or no "anopheles." From this they concluded that the latter distance was beyond the normal flight of these species. In Mian Mir three groups of rain-formed pools afforded an opportunity of making further observations on this point. The first group was 450 yards distant from any house, the second 750 yards distance,

and the third upwards of three quarters of a mile. On repeated occasions the pools of the first group were found to contain larvæ within a week of a shower of rain, on three out of four occasions the pools of the second group contained larvæ, but on no occasion were larvæ found in the pools of the third group. These experiments appeared to show that *A. rossi*, which was the species concerned, would readily fly to a breeding place a quarter of a mile away, that it would less readily fly to breeding places 750 yards away, and that it would never fly to breeding places three-quarters of a mile away. It is obvious, however, that from none of these experiments can any knowledge of the *maximum flight* of "anopheles" be obtained; they prove only that when these insects are once established in a village they naturally select the nearer breeding places in preference to those which are further away. But in their search for food adult "anopheles" often become attracted to villages which have no breeding places near at hand, and recent observations have shown that they may be abundant in a place even when there are no breeding grounds within a very long distance. Captain James, I.M.S., in the operations at Mian Mir already referred to, found on one occasion that numerous adult *A. fuliginosus* were present in the bazaars and houses when no larvæ of this species were to be found nearer than two and a quarter miles, and Dr. Christophers, during the same operations, found that the limit of flight of *A. rossi* had not been reached at three quarters of a mile, and that although all breeding places of this species had been obliterated up to this distance, it still appeared in increasing numbers in the houses. The latter observer draws the following conclusions from his experiments :—

(1) In every case where an abundant food supply existed, anopheles travelled long distances (half a mile or more) to reach it, and traversed an equal distance, if necessary, to lay their eggs. Where, however, a suitable breeding place lay near at hand they did not appear to pass it over.

(2) The maximum distance of flight of *A. rossi* is not known with certainty, but under the conditions at Mian Mir the experiments showed that they flew to and fro a distance of more than half a mile.

(3) The breeding places of *A. fuliginosus* were in no case nearer than 1,000 yards from the situation where the adults were captured.

(4) In the later part of the season it was difficult to understand where adult *A. culicifacies* came from unless distances of half a mile or more were traversed by this species.

It is obvious that in any attempt to estimate the probable efficacy and practicability of efforts at destruction of "anopheles," these conclusions are extremely important.

Mode of Dispersal.

The usually accepted fact that "anopheles" do not disperse any considerable distance from the place where they were born may also be contested. In our opinion, which is based chiefly upon observations made by one of us, and by Dr. Christophers, in Mian Mir, four ways of dispersal of "anopheles" are constantly in action in India, *viz.*:

(1) By direct flight over considerable distances. Examples of this method have already been given.

(2) By eggs and larvæ being carried long distances by streams and canals.

(3) By the gradual spreading of "anopheles" adults in all directions, by short stages, from areas in which they are abundant. This results from the fact that all newly hatched mosquitoes do not return to the house or village from which their parent came, but fly to houses in the opposite direction; and having found their food there, proceed to breeding places still further removed from the original village.

(4) Adult mosquitoes are constantly conveyed—sometimes long distances—in carriages, carts, and other vehicles. This must be a matter of common observation to any one who has occasion to travel much in India.

Observers who consider that "anopheles" can be materially reduced in numbers by the obliteration of all breeding places in the immediate vicinity of dwellings, rely chiefly upon the suppositions that the range of flight of these insects is very limited, and that they do not disperse any considerable distance from their breeding

grounds. It would appear probable, from the observations just recorded, that such suppositions are incorrect, and if this is so, the task of materially reducing the numbers of "anopheles" in any place will undoubtedly be one of great magnitude.

THE BREEDING PLACES OF ANOPHELES.

The fact that, taking "anopheles" as a whole, it is almost impossible to mention any collection of water in which their larvæ may not occasionally be found, is now well known. It has an important application when any practical measures at extermination of larvæ are attempted, in that it leads us not to overlook even the most unlikely places in our search for larvæ; for unless we search systematically *every* collection of water, temporary or permanent, we may easily allow an important breeding place to remain, when we think all possible breeding grounds have been done away with.

But under favourable conditions—by which we mean abundance of breeding places of all kinds near at hand—"anopheles" will not, as a rule, lay their eggs in an unsuitable collection of water, and there is no doubt that, under such circumstances, not only do these mosquitoes select their breeding places, but that *each species* has a particular kind of breeding ground that it prefers over any other. This observation which was first made by Dr. Christophers at Jalpaiguri in Bengal, is a very important one.

At Jalpaiguri two species of anopheles were common, *viz.*—*A. rossi* Giles, and *A. nigerrimus*. The breeding places of *A. rossi* were invariably found to be the small, shallow, muddy puddles and pools close to, and among, the native huts. *A. nigerrimus*, on the contrary, was breeding entirely at some ditance from the village in the deep natural pools of a swampy marsh. *A. rossi* larvæ were never found in these pools, and *A. nigerrimus* larvæ never in the shallow muddy pools near the huts.

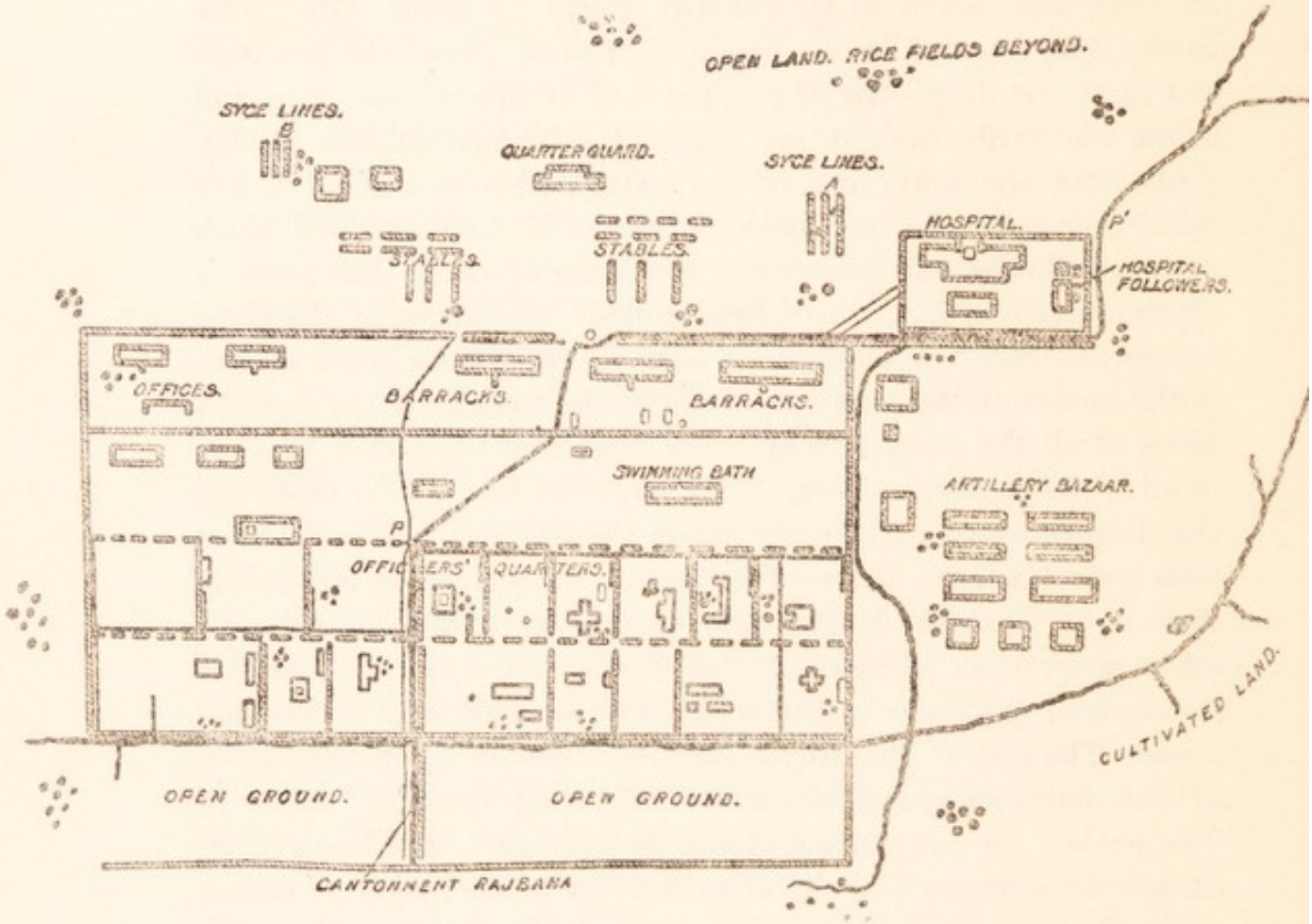
In the Duars, the same selection of breeding places by *A. rossi* and *A. listoni*, was found to exist, *A. rossi* larvæ being found only in the shallow muddy pools near the coolie huts, and *A. listoni* larvæ (the adults of which were nevertheless more common in the huts than those of *A. rossi*) being only found at some distance from the lines in the small clear pools formed by a mountain stream, and by dipping in the water among the grass and weed at the edge of the stream itself.

The principle indeed extends to all the species of Indian "anopheles," and an excellent example of its application to the three species *A. culicifacies* (Giles), *A. fuliginosus* (Giles) and *A. rossi* was found in an isolated bazaar at Mian Mir. This bazaar is surrounded by an irrigation channel about four feet wide and three feet deep. At the upper end of this water-course and about ten yards from it are a number of broad shallow muddy pools. At the lower end of the water-course and about thirty yards from the bazaar is a swampy piece of land covered with thick trees and shrubs, and containing a number of deep clear pools in which water plants and weed have grown. The adults of the three species *A. rossi*, *A. culicifacies*, and *A. fuliginosus* were present in the houses of the bazaar, and we should have expected that the larvæ of all the species would have been found together in some or all of the breeding places. This, however, was not the case. In the irrigation channel no other larvæ than those of *A. culicifacies* were ever found, in the shallow muddy pools no other larvæ than those of *A. rossi*, and in the clear deep pools under the trees no other larvæ than those of *A. fuliginosus*. It is evident therefore that each of these species had selected a particular kind of breeding place. The plan of the Royal Artillery lines in Mian Mir, given on the following page, illustrates the chief breeding places of "anopheles" in this portion of the cantonment. The larvæ of *A. culicifacies* were confined almost exclusively to the irrigation canals, while those of *A. rossi* were present only in the numerous rain formed pools which covered the plain on every side.

In another part of Mian Mir an example of selection of breeding places by another species of "anopheles" was found. In this place several species were present in the barracks of the native troops, and there were abundance of breeding places of different kinds near. The larvæ of only one species, however, *viz.*, *A. stephensi* were found in the earthenware vessels of water kept in the lines, and the larvæ of this species were never found in any of the other breeding places,—a good example of selection of a breeding place by this species.

The breeding grounds of the species of "anopheles" at Mian Mir agreed with what had been found for the same species in other parts of India, and it is possible to divide the Indian "anopheles,"

as regards their breeding grounds, into at least three groups, *viz.* (1) those which breed almost exclusively in running water, (2) those which breed in shallow muddy pools in the vicinity of dwellings



Plan of Royal Artillery Lines in Mian Mir.

and in tins and *gumlahs* of water; and (3) those which breed at some distance from houses in deep natural pools with much aquatic vegetation and in marshes.

The favourite breeding grounds of some of the species of Indian "anopheles" may now be summed up :—

A. listoni.—The larvæ of this species are found most frequently in quickly running streamlets with grassy edges. Their presence in a stream can be detected only by dipping with a tin among the grass and vegetation at the edge of the stream and in the pools and backwaters.

A. culicifacies.—This species is essentially a breeder in slowly moving water. It will be found in canals, ditches and streams when quite absent from neighbouring shallow stagnant pools. Irrigation

canals are its favourite breeding place in the Punjab. In places where there is no running water it may be found in clear pools, as at Ennur, near Madras, where it was breeding in the borrow-pits by the side of the railway. It has also been found in rocky pools in the bed of a river.

A. nigerrimus.—The larvæ of this species are found chiefly in deep dark natural waters with much aquatic vegetation Favourite breeding places are deep overgrown canals, swamps in the jungle, and ponds with water weeds. Its breeding places are not, as a rule, found near houses. The larvæ are generally scattered singly among the water plants at the edges of the pool and can be caught only by dipping with a tin or muslin net among the plants and weed.

A. barbirostris.—The breeding places of this species are practically the same as those of *A. nigerrimus*. In Lahore the larvæ were present in the lily ponds in the public gardens until the end of November.

A. fuliginosus (Giles).—The larvæ of this species are often found along with those of *A. nigerrimus*. As a rule, however, it prefers more open water and more sunlight. In Madras and in the Central Provinces it was common in the large open tanks with grassy edges.

A. jamesi (Theobald).—In the Central Provinces the larvæ of the species were found among the grass and water weeds at the edge of a large open lake In Travancore (Quilon) in a large sandy tank.

A. rossi.—The breeding places of this species have already been sufficiently referred to. Its larvæ are never found at any distance from houses. Shallow muddy pools are its favourite breeding ground, and hundreds of larvæ are usually present in the same small pool, so that the larvæ of this species are the ones which are most frequently found by observers, as they are easily detected by inspection. The larvæ of most other species have to be fished for with a tin or net. In Madras, *rossi* larvæ are common in the irrigated rice-fields and in the muddy tanks, as well as in pools made by digging for building purposes, in brick-fields and in cultivated areas.

A. stephensi.—In Mian Mir (Punjab) this species was found to be breeding only in the earthenware *gumlahs* and tins kept full of water in the lines of the native troops. In Madras it was found to be breeding only in the disused wells in the native

and Eurasian houses. It is probable that since the introduction of a pipe water-supply into Madras city, the numbers of this species have largely increased, for its larvæ are only found in those wells which, since the introduction of the pipe water-supply, have been unused.

A. maculatus.—The larvæ of this species may be found further from houses than those of *A. rossi*, and whereas larvæ of the latter species are usually found in muddy water, the larvæ of *A. maculatus* prefer clear sandy or rocky pools. In the Duars its larvæ were found in clear pools on a rice-field. In Hong-Kong (China) its larvæ were found by one of us in the small marshy pools on the granite soil of Kowloon.

Sufficient observations have not been made with regard to the remaining species of "anopheles" to enable their favourite breeding places to be particularised, but details of the breeding places in which their larvæ have been found will be given in Part II.

Under unfavourable conditions the selection of suitable breeding places by the different species is not of course so apparent, and many instances might be given tending to show that if all the suitable breeding places near a village are dried up, "anopheles" will lay their eggs on any collection of water of any kind. The "test-pool" experiment of Stephens and Christophers in Africa is sufficient to prove this, and the same expedient for finding out whether adult "anopheles" are really present in a place or not, when all the natural breeding places have disappeared, has been frequently resorted to by observers in India.

Even without making artificial pools in a village many examples of the fact that in the absence of more suitable breeding places, "anopheles" will lay their eggs in almost any collection of water, may, be found in nature. In one part of Calcutta (Hastings) in Junes when no breeding place could be found anywhere near, and no adults could be caught in the houses, larvæ were found in the cisterns of water on the roofs of the houses. During the hot weather in Mian Mir (Punjab) also, when the irrigation canals had been stopped for some time, and there were no natural breeding place of any kind, "anopheles" larvæ were found in very curious situations, as for instance in the swimming bath, in the horse troughs, in tins of water accidentally left about, in the small drains

which carry off the water from the stand-pipes, and in the small stone reservoirs in the gardens.

These facts point to the necessity of constant and careful search in every collection of water when any efforts at extermination of larvæ are attempted, and although we may certainly say that under favourable conditions we are more likely to find "anopheles" larvæ in certain collections of water than in others, and that under such conditions the different species will select different kinds of breeding places, no hard-and-fast rule, which might perhaps prevent us from searching a particular place, can be made.

DOMESTIC AND WILD SPECIES. THE DIFFICULTY OF ESTIMATING THE RELATIVE ABUNDANCE OF DIFFERENT SPECIES.

It is a well recognised fact that some species of "anopheles" are more commonly found near villages and dwellings than others. We may, in fact, divide these insects broadly into two classes: the "domestic" species, which are usually found near human dwellings, and the "wild" species, which are rarely found in houses. Of the first class, *A. rossi* is a typical example, and of the second *A. barbirostris*. Some species would appear, as regards this habit, to occupy a place intermediate between the typically domestic and the typically wild species. *A. fuliginosus*, for example, may, in certain parts of India, be found in enormous numbers in the sheds and outhouses on the outskirts of a village, while in other parts, though large numbers may be caught in tents pitched at some distance from a village, few or none will be found in the houses of the village itself.

It is usual to say that the greater the number of "anopheles" there are in a place, the greater will be the prevalence of malaria. This is not by any means borne out by experience. We have already mentioned that some species of "anopheles" are better malaria-carriers than others, and apart altogether from the fact that "anopheles" may be abundant in a place without there being any malaria there at all, it often happens that the species which is present most abundantly is not the one which is carrying malaria at the time. It is, however, a difficult matter to estimate the relative abundance of different species in any place, for some are much more easily seen than others, and the habits which some

species have of secreting themselves among the straw of a thatched roof and of resting only upon objects which are as nearly as possible the same colour as they are themselves, are very important. In order to exemplify this, it seems worth while to recount an instance which happened in our experience. In the malarious village of Ennur in the Madras Presidency, *A. rossi* was so abundant that on almost every straw of the thatched roof of every house three or four specimens of this species were resting. A careful search in the ordinary way did not reveal the presence of any other species, and it is certain that, had there been no other object in the search than the mere determination of the species of "anopheles" present in the village, the observer would have gone away quite satisfied that *A. rossi* was alone present. But the village was an extremely malarious one, and knowing that *A. rossi* was an inefficient carrier of malaria in nature, he was unwilling to believe that no other species was present in the houses. Fixing his mind, therefore, upon the thought that he was looking for *A. culicifacies* and not for *A. rossi*, he again commenced the search with great care, and was rewarded not only by detecting the presence of *A. culicifacies*, but by catching a sufficient number of this species during several days' work, to prove that it was the species responsible for the prevalence of malaria in the place and not the very much more abundant species *A. rossi*.

THE FOOD OF ANOPHELES. THEIR NOCTURNAL HABITS.

Mr. Theobald reports that one species of "anopheles," *viz.*, *A. maculipennis*, does not habitually feed on blood in England. Nuttall and Shipley, however, found that this species readily sucked blood in laboratory experiments. All the species known to us in India certainly feed chiefly, if not entirely, on the blood of men or of animals. In laboratory experiments seven species, with which experiments were made, readily sucked blood every night for several weeks, in spite of the fact that they had not completely digested their previous meals. *Fuliginosus*, *culicifacies*, *listoni*, and *rossi* also fed readily on the blood of pigeons and sparrows.

Anopheles feed almost exclusively at night or in the early morning just before dawn. During the daytime, even if they are taken into a dark room, it is almost impossible to get them to suck blood. Exceptional instances have been recorded—and have

occurred in our own experience—in which "anopheles" flew about and even attempted to feed in broad daylight, but, as a rule, they are strictly nocturnal in their habits. This fact was long ago brought forward by one of us in support of the view that in many parts of India these mosquitoes act as the usual intermediate hosts of *Filaria nocturna*, the embryos of which, as is well known, are present in the peripheral blood only at night. The readiness with which "anopheles" can be killed by placing the bottle containing them for a short time in bright sunlight, the fact that they are found during the daytime only in the darkest corners of rooms, that they seldom or never rest upon light-coloured clothes or on cleanly whitewashed walls, and the fact that whereas "culex" mosquitoes emerge from the pupa case at any time of the day or night, "anopheles" very rarely emerge until evening, all point to the conclusion that these insects are essentially nocturnal in habits.

THEIR LENGTH OF LIFE.

The usual length of life of adult "anopheles" is not known with any exactness, but it is certainly considerable. Although the habit of hibernation has not been observed in any of the Indian species, Annett and Dutton have described it in the English species *A. maculipennis*, which must therefore be capable of living at least some months. It is also well known that adult "anopheles" can survive throughout the whole of the hot weather in India and Africa, even when all breeding places are dried up. According to Stephens and Christophers the adults remain during this time in the houses, and though they feed regularly, they do not lay eggs, even when artificial breeding places are made. One of us has also recorded the fact that "anopheles" caught in houses at Ellichpur, in the Berars, between March and June did not lay eggs, though they readily did so at other times of the year. Stephens and Christophers describe the habit of remaining in houses during the hot weather under the term "æstivation." Adult "anopheles" may, with care, be kept alive in captivity for two months or more.

THE "SWARMING" OF ANOPHELES.

In his account of the anti-malarial operations at Mian Mir, Dr. Christophers describes, under the heading of "The Swarming of Anopheles," a habit which had not previously been noted with

regard to these insects. *A rossi* exhibited the phenomenon in the greatest degree. In July, larvæ of this species were practically never seen, and even for some time after the onset of the rains its larvæ were never found in the numerous pools then formed. By the third week after the commencement of the rains its larvæ were present in many pools, and by the sixth week they were very abundant. By the middle of September larvæ of this species were present in enormous numbers in all the pools round the bazaars and in most of the pools throughout the whole country-side. The adult insects showed a corresponding increase, and though found with the greatest difficulty before the onset of the rains they were present in immense numbers in every bazaar and village in the neighbourhood a few weeks later. In spite of the fact that a reduction in breeding places occurred at the end of September, they remained in large numbers until the end of October and then rapidly disappeared.

THE CHARACTERISTIC POSITION ASSUMED BY ANOPHELES WHEN RESTING ON ANY SURFACE.

Many mosquitoes can be immediately recognised as "anopheles" by the characteristic position which they assume when resting on a wall or roof. From a short distance they look somewhat like thorns projecting from the surface (Pl. III, 5, 6). The reason why "anopheles" rest in such a characteristic position would seem to be that the proboscis, head, thorax and abdomen of a mosquito of this kind lie in one straight line, so that when the proboscis is directed towards any surface, the abdomen is directed away from that surface. The angle formed between an anopheles and the wall on which it is resting differs with different species, and with practice it is often possible to name a species by merely observing the angle which it forms with the wall. *A. rossi*, for example, rests at an angle of about 45° with the wall, while *A fuliginosus* forms very nearly a right angle with it. *Culicifacies, aitkeni* and *culiciformis* lie almost, if not quite, parallel to the surface on which they are resting, and Annett and Dutton have shown that in a state of hibernation *maculipennis* does not form an angle with the surface upon which it is resting, but lies with its whole body nearly touching the wall. It will be noticed, however, that the proboscis, head, and body of an "anopheles," in whatever position it is resting, are always

in the same straight line. On the other hand, the abdomen and thorax of a "culex" always form an angle with the head and proboscis, so that these mosquitoes appear "hunch-backed."

SOME CHARACTERISTICS OF THE LARVÆ AND EGGS NOT DESCRIBED IN THE PRECEDING PAGES.

1. *The food of anopheles larvæ.*—This consists chiefly of minute water animals, which abound among algæ and other water plants. Larvæ cannot subsist upon a vegetable diet alone, and the duration of the larval stage depends chiefly upon the supply of animal food. When this is small in proportion to the number of larvæ, the stronger larvæ kill and eat the weaker.

2. *The duration of the egg stage and the resistance of ova to drying.*—When anopheles eggs are laid on water, they almost invariably hatch out into larvæ in 48 hours. When they are laid, as they frequently are, upon damp mud, the development of the embryo goes on inside the egg, and when water is added to the mud the larvæ hatch out immediately. This observation, which was first made by Captain Liston at Ellichpur in the Berars, has lately been confirmed by Dr. Christophers at Mian Mir. The latter observer found that, after the water in an irrigation canal or pool had been emptied out, "anopheles" still laid their eggs on the soft mud, and if water was again allowed to enter the canal or pool before the mud had become completely dry, numerous young larvæ would almost immediately be found in it. It is not difficult to detect eggs which are laid on the edges of pools in this way. Dr. Christophers collected a number from pools of different degrees of dryness and placed them on water with the following results.

Character of mud.	Number of ova taken.	Number of larvæ hatched in 15 minutes.	Additional number eventually hatched.
Quite soft ...	12	0	12
Cracked but moist ...	10	2	8
Quite dry ...	25	5	1
Slab of soft mud with ova; dried 12 hours.	A large number in the sun	0	0

It will be seen, therefore, that pools which are, to all intents and purposes, quite dry, may contain numerous larvæ almost immediately after a shower of rain.

Other characteristics of larvæ and eggs.

3. *The resistance of larvæ to drying.*—Dr. Christophers also found that larvæ could remain alive on soft mud even after exposure to the sun for several hours. If the mud had so far dried as to lose its glistening surface the larvæ were found to be dead.

4. *The duration of the larval stage.*—Dr. Liston found that, under suitable conditions, "anopheles" larvæ became pupæ in about a week, but that with an unsuitable or deficient food-supply they remained as larvæ for more than a month. At Mian Mir in September (the most favourable month), Dr. Christophers found that *A. rossi* did not pupate until the twelfth day after the eggs were laid. No difference was noted in the case of shallow or deep pools, although the temperature of the water in the shallow pools was high, *viz.*, 96° F. to 102° F., while that of the deep pools was only 90° F. or less. The adult insects emerged two days after pupation, so that fourteen days (two in the egg form, ten in the larval form and two in the pupal form) would appear to be about the minimum time required for the development of *rossi* from the egg to the adult stage. The least time in which *culicifacies* developed from the egg to the adult stage was thirteen days. The same observer remarked that "anopheles" were slower to develop than any other kind of mosquito, taking three days longer than *Culex* and four days longer than *Stegomyiæ*.

In the winter months the development of larvæ may be almost indefinitely delayed, and, as already mentioned, the larvæ of some species may remain without developing into pupæ throughout the whole winter (hibernation of larvæ). Whether this is due to the temperature of the water being lower, or to a difference in food-supply, is not known, but the experiments of Dr. Christophers recorded above would seem to show that the temperature of the water has little or no effect. There is also a great difference between different species in this respect, for in the Punjab while the larvæ of *culicifacies* remain in a hibernating condition throughout the winter, those of *fuliginosus* develop into pupæ and adults even in the coldest months.

CHAPTER IV.

THE CLASSIFICATION OF ANOPHELES.

WE shall attempt to consider this subject from the points of view of the amateur naturalist and of the worker on tropical diseases. When reviewing a large number of animals or plants naturalists divide them into groups which resemble one another in different degrees. The largest group or class includes many groups of orders. Each order includes subordinate groups called families, and each family subordinate groups called genera, under which again are grouped a number of species. Finally each species includes a number of varieties. The foundation of all these groups is laid in the groups of species, and in order to be able to appreciate the value of any classification, it is necessary to know exactly what is meant by this term. The word literally means a look, an appearance, a kind; beings which look the same are said to be of the same species. In its natural history sense a species means a group of individuals which closely resemble one another. A species is subordinate to a genus—a wider group of similar, but less closely similar forms—and is superior to a variety, of which there may be several in a species. We may attempt to define the limitations of the term "species" by the aid of examples. If, for instance, we were to examine a number of children of the same pair of parents we should note differences in their stature, features, complexion, and in the colour of their hair and eyes, but it is obvious that such differences—which Darwin has termed "individual differences"—cannot be ranked as specific. The first limitation of the term "species" must therefore be that individuals, which are classed as belonging to different species, must present greater differences than are exhibited between the offspring of any single pair of parents.

The second limitation would appear to be that the differential characters of species must be constant from generation to generation.

That this must be so is shown by the occasional appearance of "monstrosities," which differ markedly from their progenitors, but which cannot be classed as belonging to a different species because they are incapable of handing down to succeeding generations such abnormal differences. By many authorities a third defining limit has been applied to the term "species." They believe that true species, when intercrossed, are often sterile, and, when fertile, the hybrids produced are almost always sterile. Varieties, on the other hand, are almost always fertile.

The idea of species, then, must rest on three orders of facts: (1) the morphological resemblances between individuals; (2) the lineal transmission of distinctive characters; and (3) the sterility of first crosses between species or their hybrids.

Although the practical application of this definition of species is involved in many difficulties, we may reasonably expect that some attempt to conform to it should be made by naturalists. It is well known that entomologists are particularly neglectful in this respect, and that they have recorded a vast number of forms as distinct species on the strength of single specimens and without any knowledge of their generation. In the large majority of cases the species of mosquitoes have been established solely on the morphological characters of dead specimens. We think it is not unreasonable to expect that before an entomologist decides to class any mosquito as the representative of a new species, or a new genus, he should consider whether it represents merely an "individual difference," a "monstrosity" or a "variety." To workers in India it is well known, for example, that the different individuals hatched out from the same batch of mosquito eggs vary greatly in size, and we have found that the adults developed from any batch of eggs of *A. culicifacies* can almost always be readily divided into a group of large and a group of small individuals. Yet size is a character not infrequently relied upon by Mr. Theobald for the separation into distinct species of two mosquitoes alike in other respects. His species *Myzomyia minutus*, for example, which was described from a single specimen forwarded to him from Lahore, would appear to have been founded upon this character alone, and the same character is used as one of the points of distinction between *A. funestus* and *A. rhodesiensis*. Under the heading of "individual differences" comes also the question

of dimorphism, one instance of which among "anopheles" mosquitoes is well known to us. Major Adie, I.M.S., found that in the Punjab two distinct forms of *A. fuliginosus* are prevalent during October and November, *viz.*: the usual form with three white bands on the palpi and three white hind tarsal segments, and a second form with four white palp bands, only two white hind tarsal segments, and slightly different wing markings. It is quite certain that, had specimens of these two mosquitoes been sent to England for identification, they would have been described as distinct species, for Mr. Theobald has founded many of his species upon less marked differences than exist between these two forms. Breeding experiments showed, however, that both forms could be produced from a single pair of parents presenting the characteristic markings of the more usual form, *viz.*, that with three white palp bands and the three terminal hind tarsal segments white. Observations carried on throughout the winter showed that in December and January the usual form was replaced almost entirely by the second form, and that with the onset of spring a return to the ordinary form occurred—an excellent instance of seasonal dimorphism.

Secondly, there is the question of abnormal forms or monstrosities. During his examination of the types of *A. rossi* deposited in the British Museum, Mr. Theobald encountered a specimen the abdomen of which was covered with scales arranged as in mosquitoes of the genus *Culex*. Many thousand specimens of "anopheles" of all kinds had been examined, and this was the only instance in which the abdominal scale structure had resembled that of "culex" mosquitoes. To us it appears very probable that this is an instance of a monstrosity, and from the remarks in the introduction to his "Revision of the Anophelina" it is evident that Colonel Giles shares the same view. Mr. Theobald, however, classifies the insect without question as the type of a new genus (*Aldrichia*). Another instance of a monstrosity, which is perhaps even more marked than the above, is the specimen on which Mr. Theobald has founded a new sub-family called Heptaphlebomyina. The single insect, on the characters of which this new sub-family rests, was provided with seven longitudinal veins on its wings instead of only six, as had been the case with every mosquito examined up to that time.

Variation.

Lastly, there is the difficult question of variation. To any one who has read Mr. Theobald's monograph carefully it will be apparent that he takes little or no account of the numerous variations which occur among the different species of mosquitoes, and that he considers the slightest differences, often microscopic, as of specific value. In the limited space at our disposal it is impossible to describe even the structural variations which are met with in members of the same species of mosquito, but by taking an example we may note the slender grounds upon which many of Mr. Theobald's species are based. For this purpose we may consider the four mosquitoes, *funestus*, *listoni*, *culicifacies* and *rhodesiensis*. In the first volume of Mr. Theobald's monograph these four species are distinguished from one another chiefly on account of differences in the relative positions of the cross veins of the wings—a character upon which, as being structural, the author laid much stress. We were able, however, to show that even in a series of individuals of any species from the same batch of eggs the relative positions of the cross veins varied greatly, and in the third volume of his monograph Mr. Theobald admits that the character is of no value as a means of differentiating closely allied species, and relies entirely upon colour differences. As regards *funestus* he says: "It comes very near *listoni*, but can be at once told by the palpal banding being different, the three white bands being unevenly disposed, the two apical ones being nearer together than in *listoni*. The latter species has also a very prominent white-scaled third longitudinal vein; in *funestus* it may be entirely dark or may have a white patch, but is never so markedly pale as in the Indian species." Thus the two points upon which Mr. Theobald relies for specific distinction are differences in the palp banding and differences in the markings of the third longitudinal vein. Unfortunately, however, he is not consistent, for in the preface to this volume he says: "These (palp) bands are only colour effects, and specific distinctions cannot be based on such; moreover, specimens may frequently be met with showing variations in this respect." He also recognises that great variations occur in the markings of the third longitudinal and other veins of the wings, and describes two varieties of *funestus*, in one of which the third longitudinal vein is dark, as in *rhodesiensis*

(and *culicifacies*), and in the other it is pale scaled in the middle (as in *listoni*). Without entering into details it will suffice to say that we have found varieties of *listoni* and *culicifacies*, which present exactly the same markings as Mr. Theobald would have us believe are constant characteristics of *funestus* and *rhodesiensis*, and it will therefore be apparent that such characters are insufficient for the separation of these species.

While we are thus enable to recognise any constant difference between *listoni* and *funestus*, except that the former is found in India and the latter in Africa—a fact which loses its significance when it is known that several other species of "anopheles" occur in both countries—we are also unable to state definitely that *culicifacies*, for example, is a species distinct from *listoni*. We should be inclined to class these "anopheles" in Wallace's local forms, or geographical races or sub-species; they are moderately constant and distinct in each locality, but when all the forms from several localities are compared, the differences are seen to be so slight and graduated that it is impossible to define or describe them, though at the same time the extreme forms are sufficiently distinct.

In view of the difficulties which we have attempted to outline above, we have decided not to adopt any dogmatic opinion as to the distinctness of many of the species of "anopheles," until further study of these insects in their natural state has been made.

For the same reasons we are unable to accept Mr. Theobald's new classification of "anopheles" into different genera, for not only do the differences between many of the new genera appear to us to be so slight as to be of no more than specific importance, but it has yet to be shown that the shape and arrangement of the scales are constant in the individuals of any given species of mosquito. Darwin has laid it down that "a classification founded on any single character, however important that may be, has always failed; for no part of the organism is invariably constant," and we think that if a sufficient number of individuals of any species of "anopheles" were examined, considerable variations in the shape and arrangement of the scales would be found.

The question may also be looked at from the point of view of the worker on tropical diseases. In recent years entomologists

have taken up the study of mosquitoes solely on account of their importance in tropical medicine, and, in the words of Professor Ray Lankester, "so as to enable the medical men engaged in tracing the connection between mosquitoes and human disease to identify and speak with precision of the species implicated." The ease or difficulty with which mosquitoes can be identified depends, to a great extent, upon the method by which they are classified, and it would therefore have been advantageous to medical men in the tropics if Mr. Theobald had chosen some more marked and more easily recognisable character than scale structure for the foundation of his classification. The three questions which a worker on tropical diseases might reasonably ask when he comes across a new method of classifying mosquitoes are :—

(1) Is the new classification necessary ?

(2) Will it render the identification of species an easier matter than before ?

(3) Does it bring those species which are alike in habits and pathological significance into the same groups ?

We believe that, as regards Mr. Theobald's new classification of "anopheles," all these questions must be answered without hesitation in the negative.

That the further sub-division of the genus *Anopheles* (Meigen) is unnecessary, is shown by the fact that in any particular country the number of valid species of "anopheles" is so small that there is no real difficulty in distinguishing between the different species. Even after having worked for only a week or two at the subject an observer easily learns to ascertain the specific name of any specimen of "anopheles" which he encounters.

As regards the second question, we believe we are expressing the opinion generally felt by medical men in the tropics when we say that the new classification adds much confusion to an already difficult subject, and renders the correct identification of specimens a much more difficult matter than before. We have not yet met any one who could, in all cases, correctly ascertain the generic names of specimens of "anopheles," according to Mr. Theobald's classification, and the fact that numerous changes have been made in the position of species since the new classification was first instituted

indicates that Mr. Theobald is himself somewhat uncertain about the matter. Colonel Giles gives an instance of a species which formerly figured as the type-species of a genus, but which has now been relegated to a humble position in quite another genus, and we have ourselves sent home specimens of A. *stephensi* which, on one occasion, were identified by Mr. Theobald as belonging to the genus Nyssorhynchus and on another to the genus Cellia. If the author of a classification finds it difficult to place specimens in their correct genera it is scarcely to be expected that the medical man in the tropics will be able to do so, and, as a matter of fact, the method which most workers in the tropics—and, so far as we have been able to ascertain, most entomologists—who desire to follow Mr. Theobald's classification of "anopheles" adopt, is first to ascertain the specific name of the specimen and then to refer to Mr. Theobald's synoptic table for the generic name. This shows that the differences between the different species are more marked and more easily found out than are the differences between the various genera—a fact which is opposed to all the principles of classification. In view of these difficulties we are somewhat surprised to see that authors who have recently written upon methods for the study of tropical diseases, have adopted without question the many new genera which Mr. Theobald has created; but we find some consolation in thinking that in doing so they have been influenced rather by the fear lest their books may not be considered up-to-date than by their own personal opinions on the matter. In the preface to the second edition of his book on mosquitoes, Colonel Giles frankly admits that he has followed implicitly Mr. Theobald's monograph, and says: "It must be understood that I merely reproduce, and desire to imply no personal opinion as to the justness or otherwise of the conclusions involved." Drs. Stephens and Christophers in their book on the practical study of malaria, and Dr. Daniels in his book entitled "Laboratory Studies in Tropical Medicine," have also merely reproduced Mr. Theobald's synoptic table of the *Anophelina*, and have not attempted to explain how the different genera under which these insects are placed may be distinguished from one another by anyone who has not the type-insects before him.

Lastly, it is not difficult to show that Mr. Theobald's method of classification does not bring species which are alike in habits and pathological significance, into the same groups. No two mosquitoes, for example, are more unlike each other than *rossi* and *culicifacies*. The former can be recognised at a glance as a typical "anopheles," the latter looks very like a small brown "culex"; the former breeds exclusively in rain-formed puddles near houses, the latter is one of the typically stream breeding species; the former, though so abundant, is scarcely, if at all, concerned in the spread of malaria, while the latter is perhaps the most active agent in the spread of this disease in India. When we consider further that the seasonal prevalence of these two species, at any rate in the Punjab, does not correspond, and that their larvæ and eggs have entirely different characters, we may well ask ourselves whether a classification is correct which places these two species in the same genus (Myzomyia), while two mosquitoes, which resemble each other so closely in their adult and larval states, in their habits, and in their pathological significance, as *listoni* and *jeyporiensis*, are placed in different genera (Myzomyia and Pyretophorus).

After a consideration of the facts which we have attempted to outline above, we have decided, until further study of "anopheles" mosquitoes under natural conditions has been made, to classify these insects only into groups containing closely allied forms. Under each group we have described and illustrated two or more fairly constant types, which we are inclined to regard rather in the light of sub-species or varieties than true species. In defining the groups we have not been guided by any one character (as the scale structure of the adults, for example), but have considered the structure, colour markings, and habits of the adults, the structure and habits of the larva and pupa, and the general appearances of the eggs. In each group, however, members are met with which partake of some of the characters of one group and of some of another, and these individuals act as the connecting links between the different groups. We believe that the most typical member of each group probably represents a true species, while the other members constitute sub-species or varieties, but whether this is so or not, the arrangement will doubtless simplify matters considerably for medical men in the

tropics. By placing individuals with similar characteristics in groups the difficulties of deciding whether two individuals really belong to distinct species are, to a great extent, overcome; for the general appearance, habits, and above all the pathological significance of the species of each group are the same, and for those who are unable to undertake the minute examination necessary to accurately determine the species, it is of some advantage to determine the group to which any specimen belongs. If two individuals such as *listoni* and *funestus*, for example, are alike in their general characters, in their habits and breeding places, and in their power of carrying malaria or other tropical disease, it is really unnecessary, except from a purely entomological point of view, to separate them as distinct species. The object of the worker on tropical diseases is to separate into distinct genera and species only those insects which, from some marked difference in habits, or from any other reason, exert a different influence on any tropical disease. If, for example, it were proved that all "anopheles" mosquitoes were alike in habits and in their power of carrying malaria, the tropical worker would have little object in separating them even into different species: it would be sufficient for him to study "anopheles" mosquitoes as a whole. It is known, however, that the habits of different species differ markedly, and, for this reason, their influence on the spread of disease must be different. A species which habitually lives and finds its food apart from man cannot have the same influence on the prevalence of malaria as a species which is always found near human dwellings. In any rational classification of "anopheles," therefore, the question of habits in nature is a very important one—of more importance, we think, than a slight, though constant, structural difference in any one stage of the insect's life.

We have accordingly divided the Indian "anopheles" into ten groups.

GROUP I.

The "anopheles" of this group are, as a rule, large black mosquitoes with long spidery legs. The wings are marked with two minute yellow or white spots on the costal border. Very many varieties occur among the mosquitoes of this group, to which many names have been given. We have described two types,

viz. :—*A. barbirostris*, which has entirely black palpi and very broad spindle-shaped scales, and *A. nigerrimus*, which has four bands on the palpi and less broadly spindle shaped scales. These two represent the common types of these mosquitoes in India. The larvæ of this group are very characteristic and can readily be distinguished from all other "anopheles" larvæ. The external frontal hairs have a brush-like appearance forming the so-called "cockades." The antennæ have a large branching hair on their inner sides. The pupa is also characteristic (as was first pointed out by Cogill) and can readily be distinguished by the shape of the breathing horns. The tube, before expansion, arches up over the dorsum of the thorax almost meeting that of the opposite side in the middle line, and is then bent on itself at right angles to the dorso-ventral plane of the pupa, thereby becoming inverted U shaped. The tube at its outer extremity expands into a cavity, somewhat resembling the shape of an open mussel shell. The enveloping membrane of the eggs of the mosquitoes of this group consists of a layer of cells of extremely regular hexagonal outline more regular than in the eggs of any other "anopheles."

Breeding places.—The larvæ are generally found separately or scantily in pools overgrown with weed, hence tanks are common breeding grounds.

Observation.—This group is practically Theobald's genus Myzorrhynchus.

We have retained the name *nigerrimus*, although the description given under that name of the type specimen in the British Museum in Theobald's "Culicidæ of the World," Vol. I, page 145, does not quite correspond with the specimens we have found in India; indeed we have never noted a specimen with black tips to the palpi. Our type most nearly corresponds with Theobald's description of *Myzorrhynchus minutus*, but our drawing was made from a very large specimen, one of the largest "anopheles" we have seen; the name *minutus* would therefore be misleading.

The following recorded species in other countries than India belong to this group :—*umbrosus* (Theobald), *albotaeniatus* (Theobald), *sinensis* (Wiedmann), *malayensis* (Theobald), *pseudopictus* (Grassi), *mauritianus* (Grandpré), *paludis* (Theobald), *tenebrosus* (Dönitz), *bancroftii* (Giles).

GROUP II.

This group includes moderately large mosquitoes, in scale structure approximating to the above group, *i.e.*, with long white and golden hair-like scales on the thorax, the wing scales spindle-shaped, not so broad as in *nigerrimus*. It includes *elegans* and *punctulatus*. The only specimens of this group, so far as we are aware, collected in India, were taken by Dr. Cogill in Karwar. Dr. Donitz has found species of this group in Sumatra and Borneo.

Habits and character of the larva.—The larvæ of *elegans* were found, when water was abundant, in the open, but, as a rule, they were found in jungle springs. The larva has simple unbranched frontal hairs, and well developed palmate hairs.

Observations.—Little is known of this group. It may be remarked that in many characters *rossi* approximates to this group, *e.g.*, in the character of the scales and hairs on the thorax and abdomen, and in some of the larval characters and habits, but the wing scales of this group are considerably broader and somewhat shorter than in *rossi*.

GROUP III.

This group includes at least two known Indian species, *pulcherrimus* and *willmori*. Probably also *stephensi* should be included in this group ; it has, however, been classed with *rossi* in a separate group because of its similar habits and its marked association with human habitations.

The mosquitoes of this group are very beautiful and are covered with broad white and dark brown scales on the thorax, abdomen and wings. They are comparatively rare and little is known of their habits ; they are at once recognised by their very scaly structure. The larvæ have been found in clear pools of water ; those of *pulcherrimus* have the median frontal hairs simple, while the external angular are branched.

GROUP IV.

This is a large group of black and white mosquitoes, the majority of which have one or more tarsal segments of the hind legs white. The larvæ have well developed palmate hairs ; each leaflet, as a rule, has a well-marked blade and rather a short terminal filament. The frontal hairs are more or less branched, most branched in *fuligmosus*

which most closely approaches *nigerrimus* in its structure and habits, and practically simple and unbranched in the case of *theobaldi* and *maculatus* which in their habits (being for the most part stream breeders) most closely approach the next group.

The larvæ of the majority of the members of this group are found in deep green pools, tanks, lakes, etc., but *maculatus* and *theobaldi* are frequently found in streams. The shape of the eggs of this group vary considerably, but the majority have rather a narrow deck surface, and the lateral floats encroach upon this surface—that is, they are placed high up on the sides of the egg.

Observations.—Certain seasonal variations have been noted in *Juliginosus* which so alter the appearance of this mosquito that the winter form might have been considered as a distinct species on as good grounds as those upon which some species are at present differentiated from one another.

There can be little doubt that some of the types we have described may be shown simply to be a seasonal, geographical, or other variation of some other type.

We would specially draw attention in this connection to *theobaldi* and *maculatus*, which seem to have distinct and separate geographical distributions.

A. fuliginosus is the only member of this group which has, up to the present, been found infected in nature with sporozoites resembling those of malaria.

GROUP V.

This is by far the most important group of "anopheles" because of the marked malaria-carrying powers of its members. They have frequently been found infected with sporozoites in nature and are, as a rule, abundantly found in all notoriously malaria-infected localities. They are all rather small, very dark mosquitoes, and when resting on any surface they are very difficult to detect.

These mosquitoes are typical stream breeders, but *culicifacies* can accommodate itself to almost still water. The larvæ have simple unbranched frontal hairs, except in the case of *jeyporiensis* which has branched frontal hairs. Palmate hairs are present on all the abdominal segments except the eighth, and a pair also is found on the thorax. These hairs are very large and well developed in all except *culicifacies*.

Observations.—The breeding places of these mosquitoes deserve special attention, for they are the most important malaria-carrying anopheles and their larvæ are generally overlooked by the so-called "mosquito brigades." Paraffin oil, as a rule, will not affect them. The little streamlets and irrigation canals in which they occur are generally passed over with the remark "larvæ could not breed here, the water is flowing too rapidly." This certainly is not the case; in the little quiet eddies by the side of such streams the larvæ can usually be taken after patient fishing with a white saucer or net. Hardly any natural stream, because of the side eddies and grassy edges, flows too rapidly to afford shelter for these larvæ.

The three types we have described in this group are fairly constant, but individuals are frequently met with, which possess some of the characters of one type, some of another. Some of these variations have been mentioned under the description of each type. To this group belong the majority of the mosquitoes classed by Mr. Theobald in his genus Myzomyia. In addition to the types we have described, Theobald's *albirostris*, *funesta*, *rhodesiensis* and *leptomeres* undoubtedly belong to this group. Some remarks have already been made on the probable identity of some of these species with the types we have described.

GROUP VI.

This group includes two very distinct species, *viz.*, *rossi* and *stephensi*, which have been classed together more on account of their habits than because of any structural relation. Superficially the two species very closely resemble one another, but structurally they are very distinct. They are placed here because of their very intimate connection with man, for they are never found far from human habitations, and are, as a rule, the most common "anopheles" found in India. They are typically "domestic" species, for they are readily captured in almost any house in India at a suitable season. But, despite these facts, they appear to play a very minor part in the propagation of malaria. Large numbers, especially of *A. rossi*, have been caught even in markedly infected houses (where anopheles of group V were shown to be infected) and on dissection have been found to be uninfected.

Groups VI, VII, VIII.

These mosquitoes are of moderate size and of a light brown colour. Their colour permits them to be readily seen on any dark surface on which they rest. The larvæ are, for the most part, found in puddles, shallow pools, and pots. They have simple unbranched frontal hairs. The eggs have a broad "deck" surface, the floats are placed rather low down in *rossi* and higher up in *stephensi*, so that in the latter the deck area is encroached upon.

Observations.—The mosquitoes of this group contrast with those of group V in being light coloured and therefore readily seen and caught ; they breed in still water ; and probably play little part in the propagation of malaria, although intimately connected with man. Under the detailed description of each mosquito will be found arguments for placing *rossi* near to *punctulatus* and *stephensi* near to *willmori*. The close resemblance of *rossi* to *costalis* of Africa, both in structure and habits, is noteworthy.

GROUP VII.

In this group at present we can class only one Indian mosquito, *viz.*, *turkhudi*. This mosquito in the scale structure of the adult approaches closely to group V and has been classed by Theobald in his genus *Myzomyia*. It differs, however, from all other Indian anopheles (except *nagpori*, a single specimen of which alone has been taken) in having the tips of the palpi black, although there are three light bands on the palpi. The larval and egg characters too contrast markedly with other "anopheles." *Turkhudi* is a large brown mosquito with characteristic long thin palpi. The larvæ are always found in still water, chiefly by the side of river-beds in the pools formed in the soft mud by the feet of cattle. The larva has simple unbranched frontal hairs, and an additional hair is also found overhanging the mouth. The palmate hairs are small and badly developed, and found only on a few of the abdominal segments, hence the larva does not lie quite flat on the surface of the water like an ordinary "anopheles." The eggs are peculiar in that the floats are practically absent.

GROUP VIII.

The two mosquitoes included in this group, *viz.*, *gigas* and *lindesayi*, have been found only in the hills. Little is known of their life-history or habits.

GROUP IX.

This group at present contains only one Indian species, *viz.*, *aitkeni*. It has unspotted wings and assumes a "culex-like" attitude when at rest. For these reasons is very liable to be mistaken for a "culex." Details of its larva will be found under the description of the mosquito in Part II.

GROUP X.

This group also contains a single mosquito *A. culiciformis*. It has unspotted wings like the above, and is even more "culex-like" in its attitude and appearance. Certain structural characters of this mosquito, both in its adult and larval form, are so distinct and different from any other "anopheles" as to be of undoubted generic value. For details the reader is referred to the description in Part II.

PART II.

SYSTEMATIC DESCRIPTIONS OF THE ANOPHELES MOSQUITOES FOUND IN INDIA.

GROUP I.

Types :—*A. barbirostris* and *A. nigerrimus.*

1. Anopheles barbirostris (Van der Wulp).

(Coloured Plate II. Plate V, Fig. 1. Plate X, Fig. 1.)

References :—Leyden Museum Notes VI, p. 48 ; Theobald, Mon. Culic., Vol. I, p. 146, Vol. III, p. 86 ; Dönitz, Zeitschrift f. Hyg. XLIII, p. 227 ; Giles, Handbook Mosq., 2nd Ed., p. 308, and Rev. of Anoph., p. 39.

Synonym, *Myzorhynchus barbirostris* (Theobald).

THIS is a large mosquito very easily recognised by its thick black unbanded palpi and dark wings.

Palpi entirely black and covered with large, broad, black scales.

The proboscis is in like manner thickly covered with dark scales.

The head is for the most part covered with black upright forked scales ; some white scales occur on the occiput, and there is a prominent frontal tuft of white hairs. The dorsal and lateral aspects of the thorax are covered with brown and black hairs and hair-like scales.

The abdomen is of a dark purple colour, and is covered with many hairs. A few white scales are present on the ventral surface of some of the segments, and on the venter of the last segment there is a tuft of black scales.

The wing veins are thickly covered with large broad spindle-shaped scales. (Pl. X, Fig. 1.)

The costa is almost entirely black, save for a few white scales at its distal extremity, and a few at the junction of the outer and middle-third of its course.*

The first long vein has a few white scales near its commencement, and again a few at the situation of the inner spot on the costa.

The second long vein is entirely dark scaled, except for two small patches of white scales on its posterior branch.

The third long vein is mainly covered with dark scales, but the dark scales are interrupted here and there throughout the length of the vein by a few white scales.

The fourth long vein is dark-scaled on the main trunk, but the dark scales are mingled with light scales on both anterior and posterior branches.

The fifth long vein is irregularly covered with dark and light scales ; the light scales only predominate at two points on each branch of this vein, forming here distinct light spots.

The sixth long vein shows two distinct white-scaled spots, one near the middle of the vein, another near its termination.

The wing fringe is for the most part dark, but there is a light distinct spot at the apex of the wing, and another opposite the extremity of the posterior branch of the fifth long vein.

The legs are of a dark brown colour, and have light scales at all the joints. None of the hind tarsal segments are white in their whole length.

Characters of the larva.—Pl. V, fig. 1. The larvæ of this species are easily identified by the naked eye from their large size, black colour, and the fact that when resting at the surface of the water they are nearly always bent more or less in the shape of an S. Their microscopical characters are shown in the figure. The external frontal hairs are converted into a large tuft or "cocade," which is easily seen projecting from the front of the head. On the inner side of each antenna is a large branching hair.

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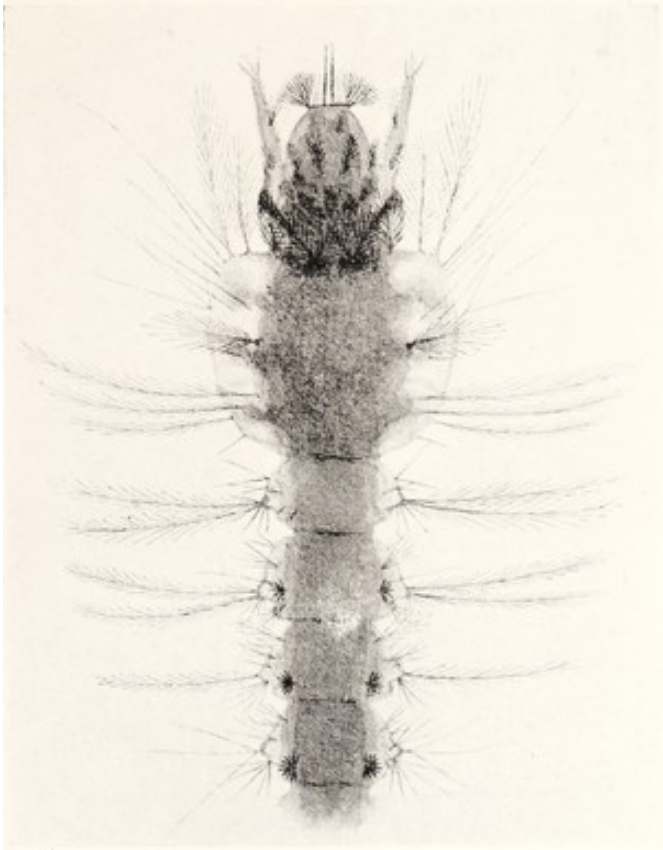
* The reader is strongly advised to refer constantly to the coloured plates when going through the descriptions of the markings on the palpi, wings, and legs of the different species. He will obtain little profit from merely *reading* the descriptions, and, unless he carefully follows out on the coloured plates the markings that are described in the text, he will find the subject very confusing and uninteresting. The beginner may, at this stage, derive some help from a second reading of pages 28 to 33, and the table on page 32 should be kept constantly in mind.

FIG. 1.



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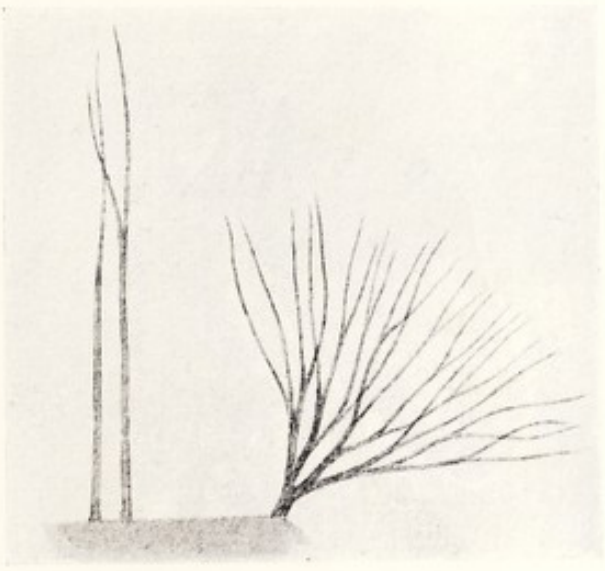

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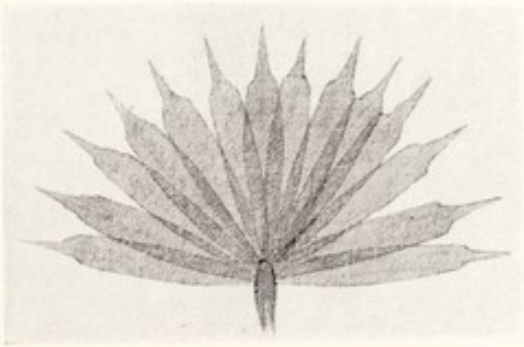
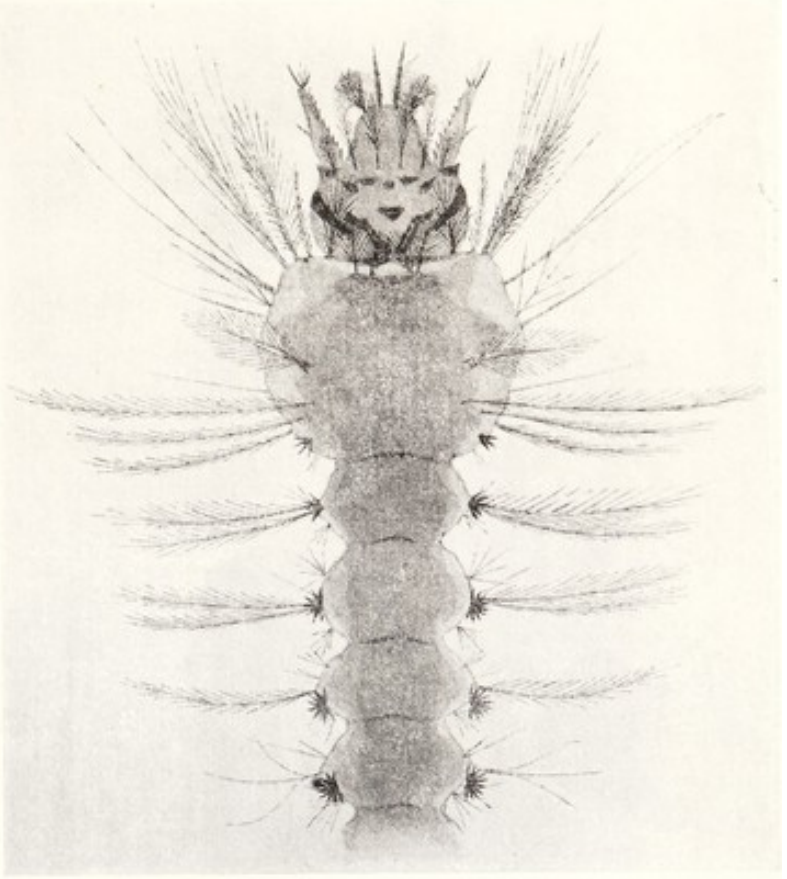


C.

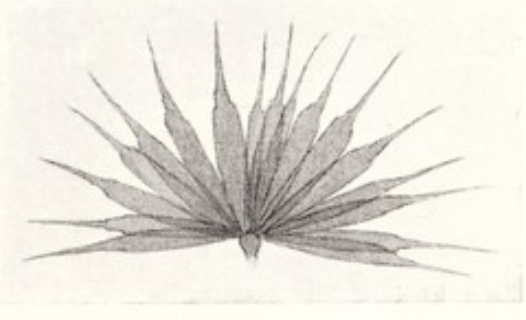
FIG. 2.



A.

D.

B.



C.

PLATE V. Fig. 1.—The larva of *A. barbirostris*. *A.*—General view; *B.*—The frontal hairs magnified; *C.*—A palmate hair magnified; *D.*—The branching hair on the inner-side of the antenna of *A. barbirostris* larva. *Fig. 2.*—The larva ½ of *A. fuliginosus*. *A.*—General view; *B.*—The frontal hairs magnified; *C.*—A palmate hair magnified.

Habitat and observations.—This species occurs in the outskirts of Calcutta and in several places in the plains of Bengal, in the Central Provinces, in the Punjab (Lahore), in Assam, and in the South of India. It has also been met with in Bombay and many other parts of India where suitable breeding grounds are present. Outside India it occurs in Burmah, the Straits Settlements and the Malay States. Its larvæ are usually found in deep dark pools with much vegetation. In Lahore they occur in the lily ponds of the public gardens. Tanks overgrown with green weed are also favorite breeding grounds. It has been shown that, under experimental conditions, human malaria parasites can develop in this species, but it is doubtful whether it ever acts as a carrier in nature owing to its rarity in houses.

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2. ANOPHELES NIGERRIMUS (Giles).

Coloured Plate III.

References:—Giles, Handbook Mosq., 1900, p. 161 ; 2nd Ed., p. 306, and Rev. of Anoph., p. 38 ; Theobald, Monog. Culicid., Vol. I, p. 150 ; Dönitz, Zeit. f. Hyg., XLIII, p. 228.

Synonym, *Myzorhynchus minutus* (Theobald).

This is a dark brown mosquito with thick palpi and rather light wings, somewhat resembling *A. barbirostris.*

Palpi with four light bands. The tips of the palpi are white, then come a few dark scales, then again another light-scaled band. The remaining two light bands occur at the joints between the fourth and third, and third and second, segments of each palp. There are also some light scales mingled with the dark scales on the second segments of the palpi.

The proboscis is covered with dark scales except at its tip which is of a yellowish white colour.

The head is covered with black and white upright scales, the former predominating on the nape, the latter on the occiput. There is a well-marked frontal tuft of white hairs.

The dorsal surface of the meso-thorax is covered with light brown and white scales and hairs.

The abdomen is covered with light brown hairs, and there are a few scales on its posterior extremity.

The veins of the wings are covered with broad spindle-shaped scales, not so broad, however, as those found on *A. barbirostris.*

The costa is for the most part black, but there are three minute white spots in the outer third of its course; one of these spots is situated at the junction of the outer and middle third of the costa, another at its distal extremity; the third and largest white spot lies close to the distal extremity, separated from the distal white spot by a few dark scales.

The first long vein is covered with light and dark scales, two indistinct large light spots, where the light scales predominate over the black scales, are found, one near the middle of the vein, another in its inner third. There is a distinct light spot opposite the largest white spot on the costa, and the outer extremity of this vein has a few white scales.

The second longitudinal vein, like the first, is covered with a mixture of dark and light scales, the latter predominate opposite the middle light spot of the first long vein and extend to the bifurcation of the vein. There are light scales forming indistinct spots on each of the branches of the vein.

The third long vein is for the most part covered with light scales, except at its origin and termination.

The fourth long vein is covered with light and dark scales almost evenly intermixed throughout the course of the vein, except near its origin and at the termination of its branches, where black scales are most numerous.

The fifth long vein has black scales at its origin, but white scales predominate throughout the rest of the course of the vein and its branches; the extreme tips of the anterior and posterior branches of this vein have black scales.

The sixth long vein is mostly light-scaled, but there are two dark-sealed spots on this vein.

The wing fringe is dark-scaled except at the apex of the wing.

The legs are of a dark-brown colour, but there are light scales at all the joints. None of the hind tarsal segments are white in their whole length.

Variations in the details of the markings on the wing field are frequent, but the two light spots on the costa as well as the apical spot are constant.

The wing fringe is, as a rule, uninterrupted by light scales, but it is not uncommon to find a few opposite some of the long

veins, especially opposite the anterior and posterior branches of the fifth long vein.

Characters of the larva.—The larva of *A. nigerrimus* resembles that of *A. barbirostris* very closely. The median frontal hairs are unbranched but may be bifurcated at their extremities. The external frontal hairs are very much branched, so that they form distinct "cocades" in front of the whorl organs. The antennæ possess a large branching hair on their inner side as in the larva of *A. barbirostris*. Palmate hairs are borne by the second to the fifth abdominal segments.

Habitat and observations.—This is a fairly common species in the outskirts of Calcutta and in other places in the plains of Bengal. It also occurs in Travancore and in the Madras and Bombay Presidencies.

It has been shown that the embryos of "Filaria Bancrofti" can develop in this species as well as in *A. rossi*. Its larvæ are usually found in deep shady pools, containing grass and water weed, at some distance from habitations, and the adults are seldom met with in houses.

A large number of species closely resembling *A. nigerrimus* have been described, but it is very probable that the majority are only varieties (or perhaps representatives of local races or sub-species) of a single type. The following forms are described as distinct species by Mr. Theobald :—*vanus*, *sinensis*, *minutus*, *indiensis*, *pseudopictus*, and *alboannulatus*. *A. vanus* is recorded as occurring in Travancore, *A. minutus* in Lahore, and *A. indiensis* in Madras. According to Colonel Giles, who has apparently examined the single specimen of *A minutus* in the British Museum, its only difference from other members of the "sinensis group" is the fact that the wing spots are white instead of yellow—a distinction which, of course, is no value. Between *A. alboannulatus* and *A. vanus*, Colonel Giles cannot detect any difference; and *A. indiensis*, differs from *vanus* only in a detail of wing venation—a character which has been shown to be very variable.

GROUP II.

Types :—*A. leucophyrus* and *A. punctulatus.*

3. Anopheles leucophyrus (Dönitz).

Figures facing page 83 and in text. Plate IX, Fig. 4.

References :—Dönitz, Insect. Borse, January, 1901, p. 37 ; Theobald, Monog. Culicid., Vol. III, p. 51 ; Giles, Handbook Mosq., 2nd Ed., p. 312.

Synonyms, *Anopheles elegans* (James).

Myzomyia elegans (Theobald).

The specimens which we now regard as a variety of *A. leucophyrus* (Dönitz) are described in Mr. Theobald's monograph as a separate species under our manuscript name *elegans*. Mr. Theobald places it in the genus *Myzomyia*, but is not sure whether it ought not to be classed in the genus *Nyssorhynchus*, in which case—unless mosquitoes can produce varieties belonging to different genera—it cannot be a variety of *leucophyrus* as he says is possible and as appears to us to be very probable. The following is our description of this species :

A dark mosquito, the wing veins of which are thickly clothed with rather broad spindle-shaped black and white scales, which form numerous small spots on the wing field, so that the wing has a beaded or mottled appearance. Legs thickly mottled with black and white scales. Palpi with four white bands. Abdomen with long golden hairs but no scales. Thorax with long narrow whitish scales and hairs.

Palpi with four white rather narrow bands. A few white scales are present on the bases of the palpi ; tips of the palpi white.*

Proboscis brown with a lighter tip.

Head with broad white forked scales in front and dark ones behind, with a scanty tuft of long white hairs projecting forwards.

Antennæ brown with white hairs.

Thorax chiefly covered with white hairs, but also with a few spindle-shaped creamy scales. Dark longitudinal lines and two dark eye-like spots can be made out on the dorsum of the thorax.

Halteres with the knobs covered with creamy white scales.

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* *i. e.*, the outermost of the four white bands on each palp includes the tip.

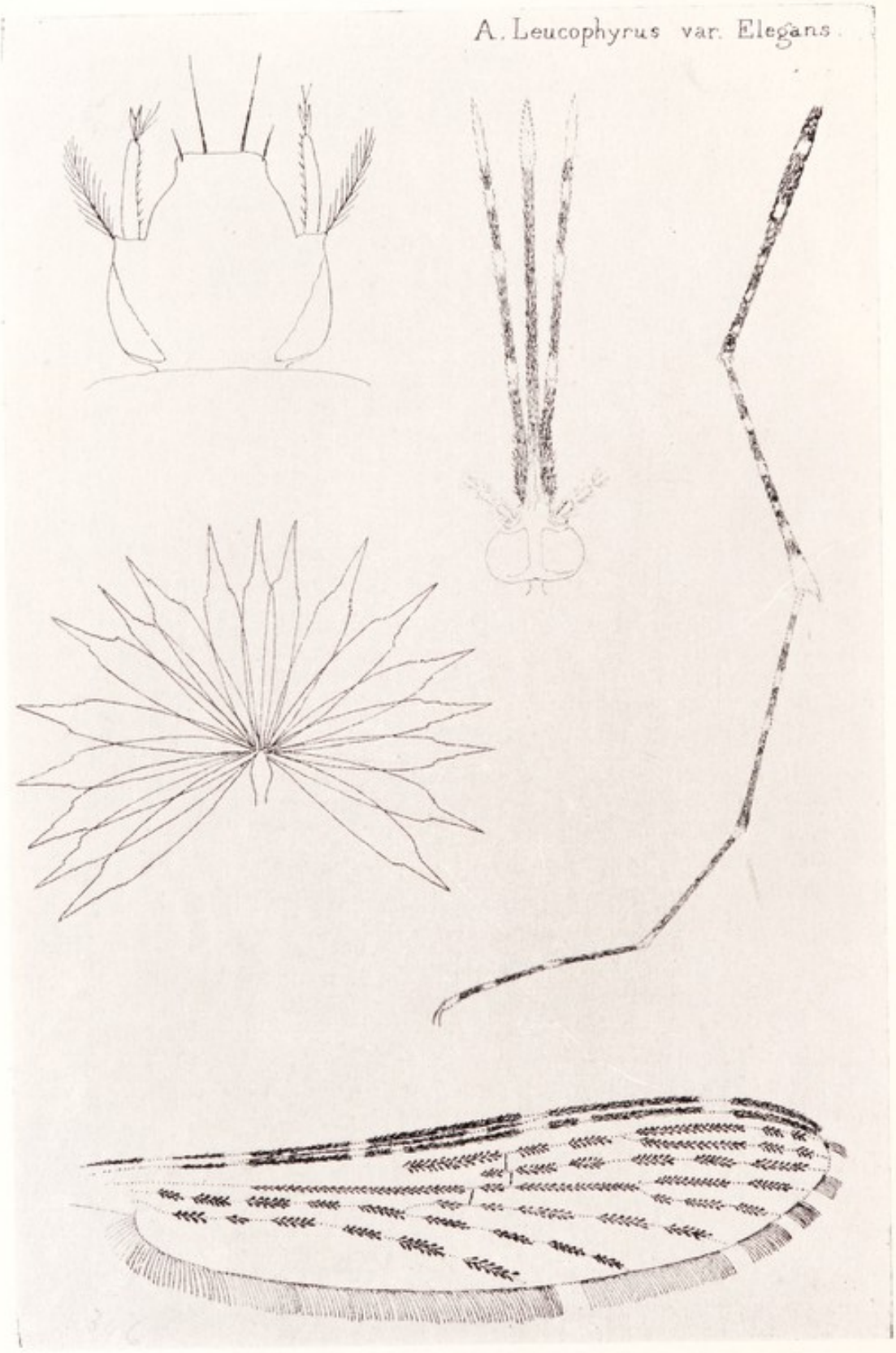


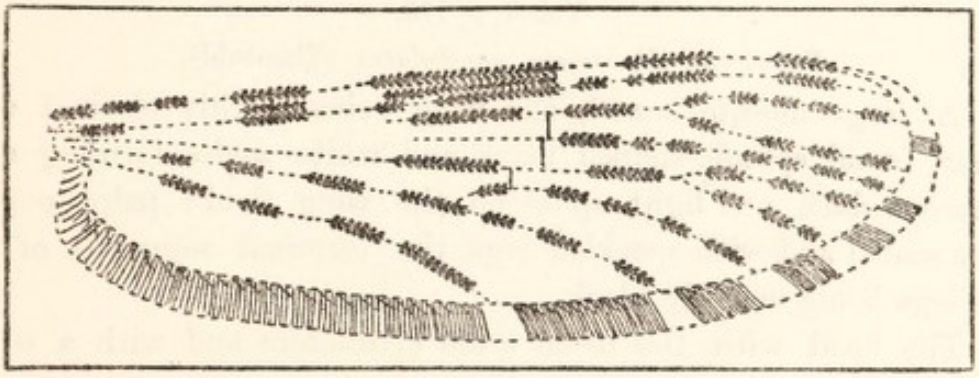
PLATE XII. *Anopheles leucophyrus* variety *elegans*.

Anopheles leucophyrus.

Abdomen black, thickly covered with golden hairs but without scales. A very marked golden apical tuft of hairs.

Wing veins covered with rather broad scales forming numerous black and white spots arranged as follows :—The costa shows four large black-scaled areas and three (sometimes only two) small ones ; the first longitudinal vein shows seven dark-scaled areas of different sizes arranged as shown in the diagram ; the main stem of the second longitudinal vein has three black-scaled areas, the anterior branch has three spots and the posterior three ; the third longitudinal vein has seven (sometimes only six) small black areas ; the fourth longitudinal vein has three large black areas on its main stem and generally three on each of its branches ; the fifth longitudinal vein has four dark spots on its main stem and one at its bifurcation, its anterior branch has five dark areas and its posterior four ; the sixth longitudinal vein has four or five (sometimes six) dark areas.

As will be seen from the accompanying drawing of the wing of another specimen, the number of dark and light-scaled areas on some of the veins is not constant, and two or three of the small spots may sometimes be joined together so as to form one long dark-scaled area.



The wing fringe is interrupted by a light-scaled area at the termination of each of the longitudinal veins.

The legs are speckled with white scales on a brown ground ; in the fore legs the fifth tarsal segment has a few white scales at its tip, and there are apical white scales which extend over the joint so as to form a band to each of the other tarsal segments. The first tarsal segment is speckled with white scales in addition to the apical banding, and the tibia and femur are also speckled. The

markings of the mid legs are the same as those of the fore legs. In the hind legs (see figure) the femora and tibiæ are speckled with white scales. At the lower end of the tibia and the upper end of the first tarsal segment (metatarsus) there are broad white bands, the two together forming a very broad and characteristic band at this joint ; at the other tarsal joints also there are white bands. The tip of the fifth tarsal segment has a few white scales. None of the tarsal segments are wholly white.

Characters of the larvæ.—The larvæ of this species were found by Dr. Cogill "in pools in the open while water was abundant, but as a rule in jungle springs, and it was particularly partial to water containing decaying leaves." The larva has simple unbranched frontal hairs and well-developed palmate hairs on the first seven abdominal segments. The terminal filaments of the palmate hairs are rather short (see figure).

Habitat.—Bred from larvæ by Dr. Cogill in Karwar. The adults were never found in houses.

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4. Anopheles punctulatus (Dönitz).

(Figure facing page 85).

References :—Insecten Borse, January 1901, p. 37 ; Theobald, Monog. Culicid., Vol. I, p. 175.

Synonym, *Myzomyia punctulatus* (Theobald).

A large mosquito with the wing veins thickly clothed with rather broad spindle-shaped black and white scales forming very numerous dark and light spots on the wing field ; palpi mostly white scaled and with speckled legs, the terminal segments of the hind legs being entirely black.

The head with the usual scale characters and with a white frontal tuft.

Palpi with four broad white bands. The anterior half of each palp is practically white, but it has two narrow black bands which divide it into three white scaled portions. The posterior half of each palp is mostly black-scaled, but divided into two by a narrow light-scaled band. A few white scales also occur on the dorsal surface of each palp near the base.

Thorax covered with golden brown and white hair-like scales and hairs.

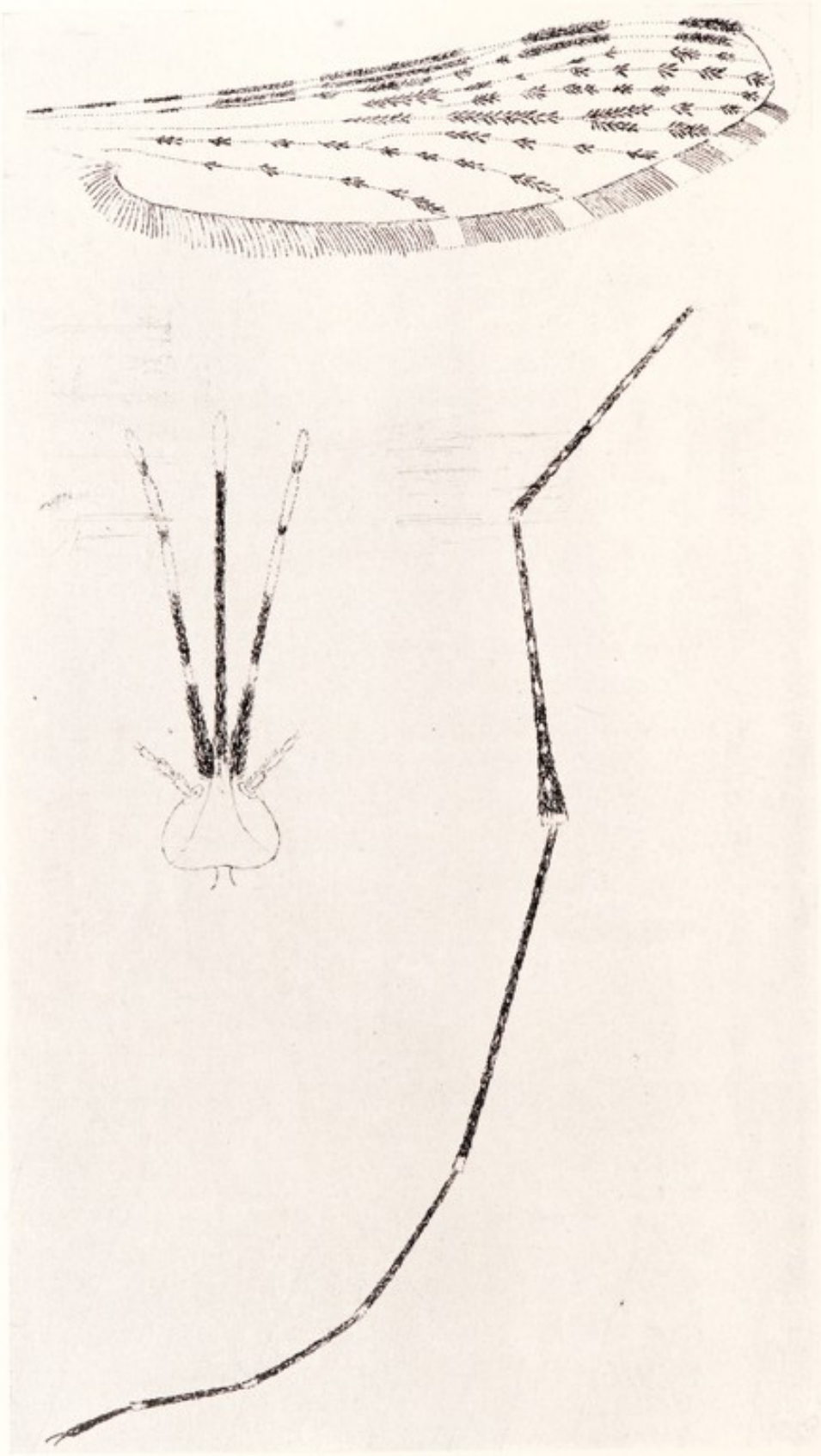


PLATE XI. *Anopheles punctulatus.*

Abdomen thickly covered with golden hairs, especially accumulated at the posterior extremity, forming a brilliant yellow termination to the abdomen.

Wings much spotted, the veins clothed with rather broad spindle-shaped scales. The costa has seven dark areas separated by white-scaled portions increasing in size from base to apex. Apex of wing white-scaled; base black-scaled.

The first longitudinal vein has black-scaled areas opposite the five outermost on the costa, but the area opposite the middle and largest costal spot is divided on the first longitudinal into three by two small white-scaled spots.

The second longitudinal vein has a long black-scaled area at its commencement and two other minute black-scaled portions before it divides; each branch of this vein has four or five dark-scaled portions.

The third longitudinal vein has many minute dark-scaled spots.

The fourth longitudinal vein at its inner third is chiefly light-scaled, its middle third is chiefly black-scaled, while its branches have each two or three dark-scaled portions.

The fifth and sixth veins have small alternate areas of black and white scales.

The wing fringe is light scaled at the apex and to the level of the third long vein, thereafter it is dark-scaled except where it is interrupted by light scales at the terminations of the long veins.

The legs have the tibiæ and femora speckled and white scales at the apex of all the segments except the two terminal segments of the tarsus.

Habitat and observations.—This mosquito very closely resembles *A. leucophyrus* and may be a seasonal variety of that species. It was found in Dr. Cogill's house in Karwar during the rains only, while *leucophyrus* was bred by him from larvæ in the cold weather. The larvæ of *punctulatus* were not found. Dr. Cogill remarks that in *punctulatus* the supernumerary cross vein is opposite to the mid cross vein, while in *leucophyrus* the mid cross vein is internal to the supernumerary cross vein.*

A single specimen of *A. punctulatus* was taken in a house at Parel near Bombay, in August. Outside India it occurs in the Straits Settlements, in Sumatra and in Borneo.

* Our specimens show that this character is not constant (see figures).

GROUP III.

Types :—*A. pulcherrimus* and *A. willmori.*

5. Anopheles pulcherrimus.

Coloured Plate IV, Plate IX, Fig. 6.

References :—Theobald, Proc. Roy. Soc., Vol. LXIX, 1902, p. 369, and Monog. Culicid, Vol. III, p. 107. Synonym, *Cellia Pulcherrima* (Theobald).

This species may be taken as the type of a group of species characterised especially by the fact that the abdomen is thickly scaled, the scales forming distinct tufts at the sides of each segment.

The palpi are equal in length to the proboscis and are densely-scaled. The tips of the palpi are white and each has four white bands. The terminal band includes the tip and is separated from the next by only a few black scales : the remaining white bands are at the joints between the third and fourth, and the second and third segments of the palpi. In addition to the bands the palpi are speckled with many white and brown scales.

The proboscis, which is also covered with scales, especially near its base, is brown with a white tip.

The head is densely covered with dark brown and white scales, and a well marked frontal tuft of white hairs projects forwards ; the antennæ are brown with white bands and white hairs at each joint.

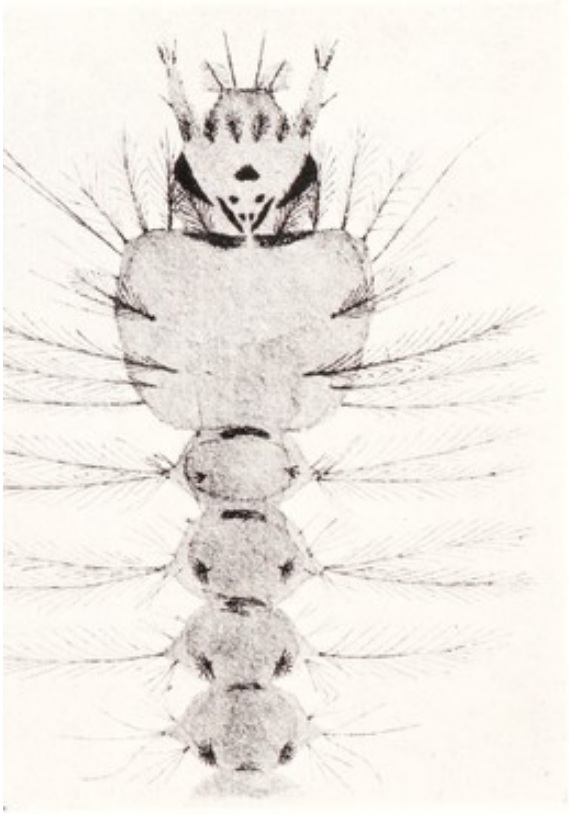
The thorax is covered with broad silvery-white scales inserted on a dark brown ground and interspersed with white hairs ; the pleuræ are also densely scaled.

The scutellum is tri-lobed and more or less covered with silvery scales ; the metanotum is dark brown.

The halteres are yellowish brown and their lobes carry a number of small silvery scales.

The abdomen is thickly covered with silvery white scales and golden hairs ; the scales are flat and broad. Projecting laterally from the apex of each segment is a tuft of dark brown scales.

The wing veins are covered with large broad scales of brown and white colour, the latter predominating ; the costa shows four prominent dark-scaled areas and two smaller dark spots ; the first longitudinal vein has dark-scaled areas corresponding with the four large dark areas on the costa, but the second dark area is divided



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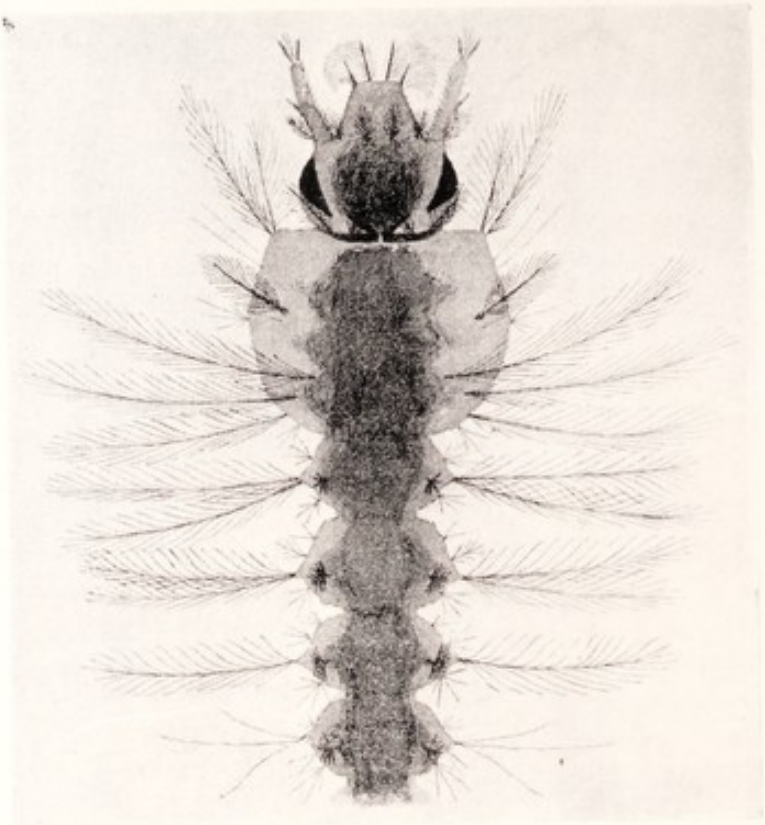

A

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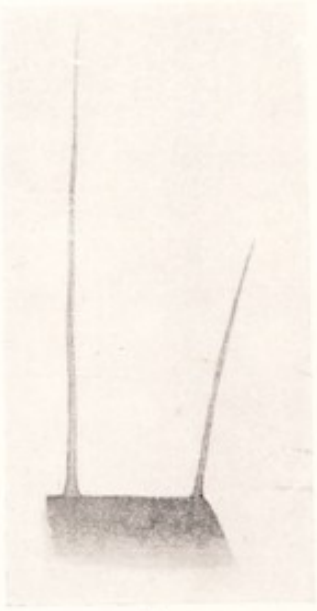
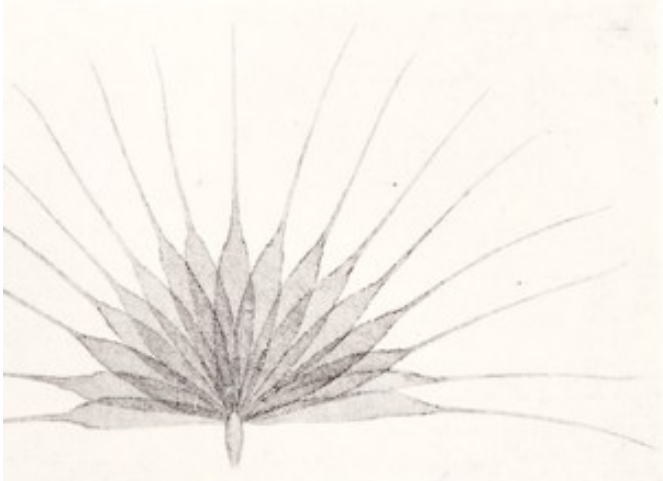


B



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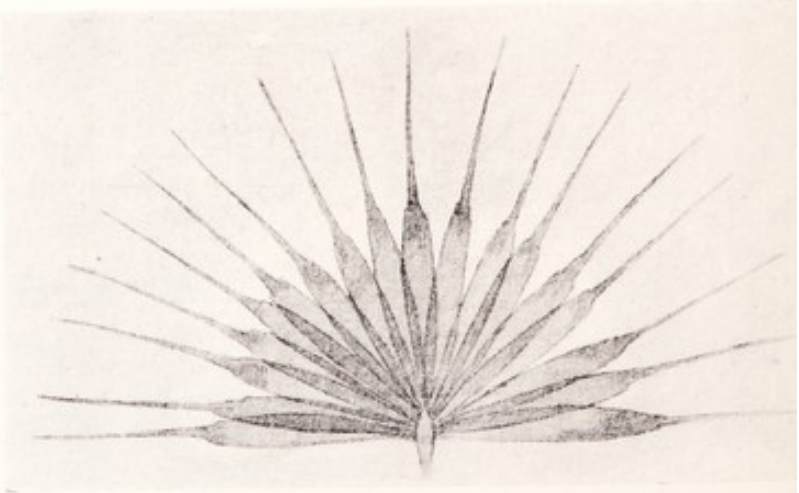

C

PLATE VI. Fig. 1.—The larva of *A. rossi*. *A.*—General view; *B.*—Frontal hairs magnified; *C.*—A palmate hair magnified.

into three by two collections of white scales ; the main stem of the second longitudinal vein is white-scaled ; on its anterior branch there are two dark-scaled spots corresponding with the outer two on the costa ; on its posterior branch there are also two small spots ; the third longitudinal vein is white-scaled throughout except for a few black scales near its origin and termination ; the fourth longitudinal vein has black scales at its bifurcation, and there are two small black-scaled spots on each of its branches ; the fifth longitudinal vein has a single dark-scaled patch on its main trunk, three black-scaled areas on its anterior, and one on its posterior branch ; the sixth longitudinal vein has three small black-scaled spots.

The wing fringe is interrupted by light-scaled areas at the terminations of all the long veins and by a long area on the inner fourth of its course.

The legs are covered with brown and white scales ; the fore legs have the femora and tibiæ white on their under surfaces and speckled with brown scales on their upper surfaces ; the tarsal segments, except the fourth and fifth, have apical white bands ; in the mid legs the femora have a large white patch near their apices ; the tibiæ and tarsal segments, except the fourth and fifth, have apical white bands ; the femora of the hind legs have also a white patch near their apices and the last $3\frac{3}{4}$ hind tarsal segments are pure white.

The palpi of the male have five broad, almost equal, white bands separated from one another by very narrow bands of black scales. The other markings do not differ materially from those of the female.

Characters of the eggs and larvæ.—The eggs are of the same type as those of *A. rossi*. The larvæ have the median pair of frontal hairs simple and the external pair branched. Palmate hairs are present from the second to the seventh abdominal segments, and the terminal filaments of the leaflets are long.

Habitat and observations.—This is a somewhat rare species. It occurs with a limited seasonal prevalence in the Punjab (Lahore, Meean Mir, Ferozepore). In Meean Mir it was found in small numbers in the barracks of the native troops and in outhouses of the native bazaars, and in September its larvæ were found in an overflow pool of an irrigation watercourse. During the winter a few adult specimens were found in a village near Lahore, and it appears

to be one of the few species which can tide over the Punjab winter in the adult condition. It has recently been found to occur in Goa in the Bombay Presidency.

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6. Anopheles willmori (James).

Reference :—Theobald, Monog. Culicid., Vol. III, p. 100.

Synonym, *Nyssorhynchus Willmori* (Theobald).

Palpi with three white bands. Thorax dark brown, covered with white scales and hairs. Abdomen brown with many golden scales and hairs. Legs deep brown thickly speckled with white ; the last tarsal segment of the hind leg pure white. Wings spotted.

Head black with some upright white scales ; antennæ light brown with white hairs ; palpi scaled and with three white bands, the two terminal of which are equal and broad and the third narrow ; proboscis dark brown.

Thorax dark brown covered with white scales and a few hairs ; pleuræ black ; scutellum with a few white scales and long bristles.

Abdomen deep brown, with many golden hairs and scales ; the scales and hairs on the last segment are very closely packed together, so that this segment is almost entirely of a golden brown colour ; some of the scales which project from the sides and termination of this segment are dark brown in colour.

The halteres carry a number of short thick scales. Legs dark brown thickly speckled with white spots ; in the fore and mid legs there are apical white bands to the femora, tibiæ and to all the tarsal segments except the fourth and fifth ; the femora, tibiæ and the first and second tarsal segments are brilliantly marked with bands and patches of white scales ; the apical banding of the first, second and third tarsal segments extends over the joint to the base of the next segment. In the hind legs the femora, tibiæ and first tarsal segment are thickly speckled with white patches ; the tibia and first tarsal segment have apical white bands, and the second, third and fourth tarsal segments have both apical and basal bands ; the last tarsal segment is wholly white.

The wing veins are clothed with black and white scales ; the costa shows four large and three small black areas, the latter being near the base of the wing ; the first longitudinal vein has four

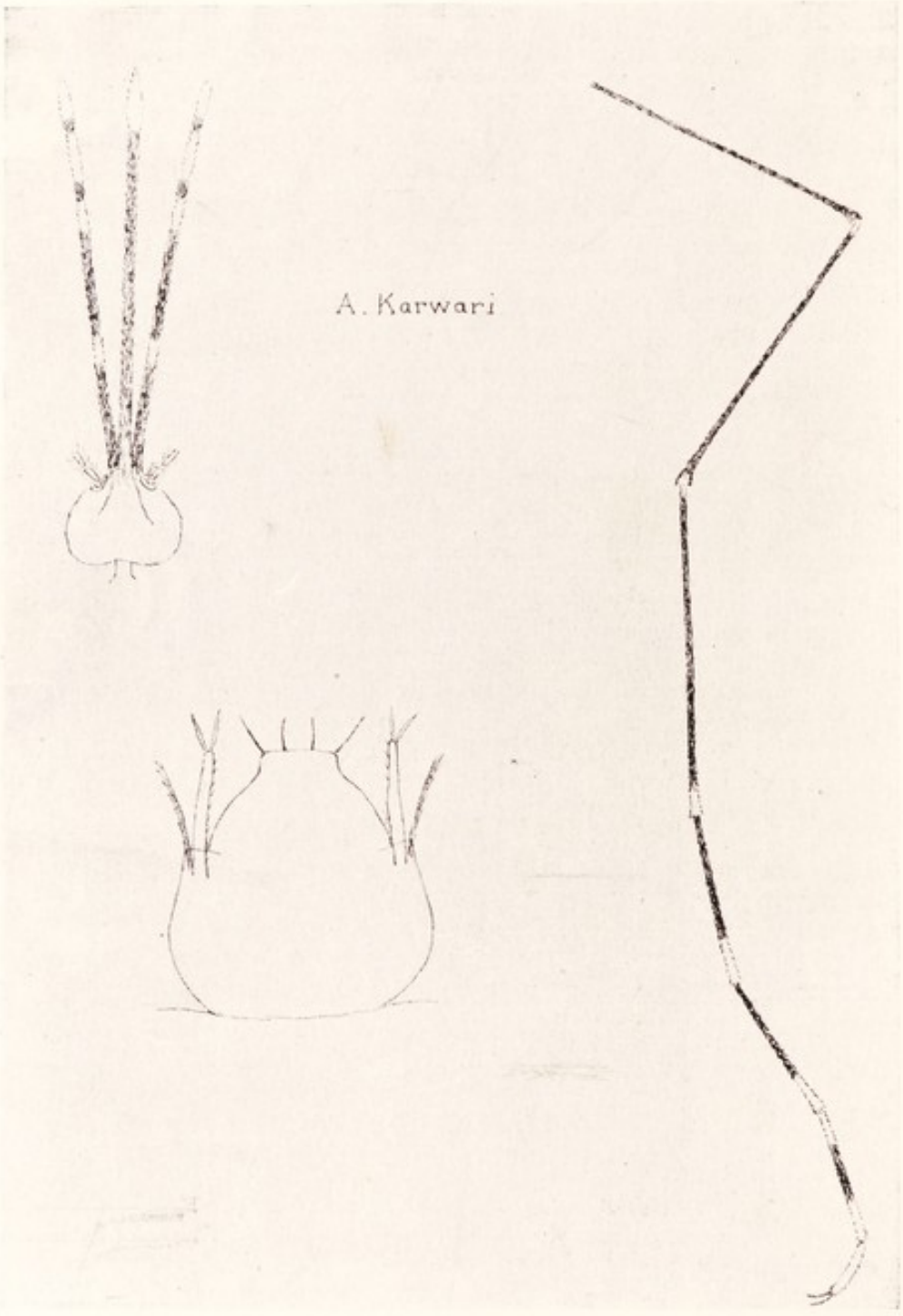


PLATE XIV. *Anopheles karwari*; showing the markings on the palpi and hind leg, and the head of the larva.

black spots corresponding to the large areas on the costa; the second longitudinal vein has three small dark spots on its main stem and two on each of its branches; the third longitudinal vein is white-scaled except for a small dark spot at its commencement and another at its termination; the fourth longitudinal vein has three dark-scaled areas on its main stem and two on each of its branches; the fifth longitudinal vein has a small spot at its commencement, two spots on its anterior branch and one on its posterior; the sixth longitudinal vein has three small dark spots. The wing fringe is interrupted by light-scaled areas at the terminations of all the longitudinal veins.

Habitat and observations.—Collected by Lieutenant Willmore, I.M.S., in Kashmir. Its larvæ were found in a small clear puddle formed by a spring at a height of 4,800 feet.

It differs from *A. stephensi* in its abdomen being more thickly scaled and having fewer hairs, as well as in the wing markings and in having the terminal segment of the hind tarsus pure white.

From *A. maculatus* (Theobald) it differs in having a thickly-scaled abdomen.

GROUP IV.

Types :—*A. karwari*, *A. fuliginosus*, *A. jamesi*, *A. maculipalpis*, *A. theobaldi* and *A. maculatus*.

7. Anopheles karwari (James).

Reference :—Theobald, Monog. Culicid, Vol. III, p. 102.

Synonym, *Nyssorhynchus Karwari* (Theobald).

Palpi with four white bands. Thorax covered with snowy white scales and some hairs; abdomen thickly clothed with golden hairs and with some scales on the last two segments. Legs not speckled; the terminal tarsal segment of the hind legs pure white.

Head with white upright forked scales in front and dark ones behind; a small tuft of white hairs projecting forwards from the head.

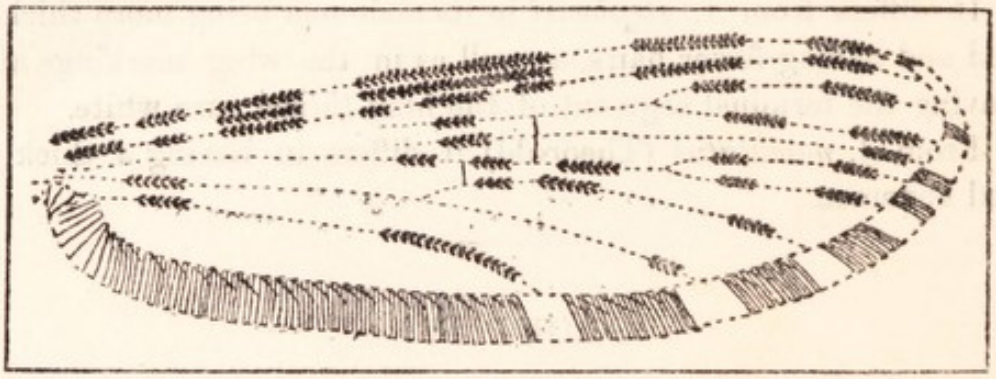
Palpi thickly clothed with scales and marked with four white bands; tips of the palpi white; the two terminal bands are broad and equal, the other two are narrow. (See figure.)

Antennæ black with silvery hairs.

Thorax black, covered with numerous snowy white spindle-shaped scales on its dorsal aspect. Three longitudinal dark lines devoid of scales can be made out on the dorsum as well as a lateral eye-like bare spot on each side and a median bare spot posteriorly. Pleuræ black with two indistinct longitudinal white lines on each side.

Scutellum with some scales like those on the thorax and with bristles.

Abdomen black, thickly clothed with golden hairs ; on the last two segments the hairs are very dense, and a number of scales are also present on these segments, those which project from the sides of the segments being dark coloured and the others golden brown ; the remainder of the abdomen is devoid of scales.



Wings with the veins clothed with black and white scales forming dark and light areas as follows :—The costa shows four large dark-scaled areas and two small ones ; the first longitudinal vein shows dark-scaled areas exactly corresponding to those on the costa except that the large middle area is divided into three by two small white spots. The second longitudinal vein has one dark spot on its main stem and two on each of its branches. The third longitudinal vein is white-scaled except for a small dark area at its beginning and another at its termination. The fourth longitudinal vein has three small spots on its main stem, and two on each of its branches. The fifth longitudinal vein has one small dark area on its main stem, three on its anterior branch, and one on its posterior. The sixth longitudinal vein shows two dark-scaled areas. The wing fringe is interrupted by light-scaled areas at the terminations of all the longitudinal veins and their branches.

The legs are black ; in the fore and mid legs each tarsal segment, except the fourth and fifth, has an apical white band ; in the hind legs the tibia and the first and second tarsal segments have apical white bands, the third and fourth tarsal segments have both basal and apical white bands, and the fifth tarsal segment is wholly white.

Habitat.—Karwar (Bombay Presidency) ; Goa.

Time of capture.—Karwar in June (Dr. Cogill) ; Goa in February (E. H. Aitken).

Observations.—This species differs from *A. maculatus* (Theobald) in the presence of scales on the last segments of the abdomen, in the palp mrakings, and in its unspotted legs.

The characters of the head of the larva are shown in the figure.

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8. ANOPHELES FULIGINOSUS (Giles).

Coloured Pl. V. Pl. V, Fig. 2 ; Pl. X, Fig. 4.

References :—Giles, Handbook Mosq., 1st Ed., p. 160 ; Theobald, Monog. Culicid., Vol. I, p. 122 ; Vol. III, p. 93 ; Liston, *Ind. Med. Gaz.*, 1901, p. 441.

Synonym, *Nyssorhynchus Fuliginosus* (Theobald).

This is a very dark mosquito with white spots on the wing, without speckled femora or tibiæ, and with the last three segments of the tarsus of each hind leg white.

The palpi have white tips, and there are white-scaled bands at the joints between the fourth and third, and third and second, segments of the palpi. The dark scales on the second segment are longer than those on the other segments.

The proboscis is black-scaled with a white tip.

The head is covered with black and white scales, the latter being most numerous on the occiput.

The dorsal surface of the thorax is covered with white scales. A median and two lateral darker longitudinal lines can be indistinctly made out. The lateral aspects of the thorax are dark.

The abdomen is dark coloured, and covered with numerous light yellow hairs ; a few dark scales are to be found on the posterior extremity of the abdomen.

The wing veins are covered with short spindle-shaped scales, and the wings are for the most part black. The costa has five small white spots, one of which is situated at the apex of the wing.

The first longitudinal vein has six white spots. The outer two correspond to the outer two on the costa. The next two are very minute, and situated behind the third dark-scaled area counting from the apex of the wing. The fifth white-scaled portion corresponds to the fourth on the costa. The sixth white spot is situated behind the fifth on the costa, but is considerably larger than that costal spot.

The second long vein has a very few white scales at its bifurcation, and a few on its posterior branch.

The third longitudinal has three white-scaled portions, one small one near its origin, a median long light-scaled portion, and a terminal small white spot.

The fourth longitudinal has a few white scales at its bifurcation, and a white-scaled portion on each of its branches.

The fifth longitudinal has two white-scaled areas on the main trunk, two white-scaled portions on its anterior branch, and only one on its posterior branch.

The sixth longitudinal has three white spots. The terminations of all the long veins are white-scaled, and at these points the wing fringe is interrupted by white scales.

The legs are of a dark brown or black colour. In the fore legs there are white scales at the distal extremities of the femora, tibiæ and all the tarsal segments except the last two. The middle legs have corresponding white points to those on the fore legs, but there is also a characteristic large white spot on the posterior aspect of each femur near its apex. There are no white scales at the distal extremities of the three last segments of the tarsus. There are white scales at the distal extremities of the femur, tibia, first and second tarsal segments of each hind leg. The last three tarsal segments are entirely white.

Characters of the larva (Pl. V, Fig. 2).—The median frontal hairs are slightly branched ; the external frontal hairs are much branched so as to form a small tuft in front of the whorl organs.

There is no branching hair on the antenna as the larvæ of *barbirostris* and *nigerrimus*. The thorax does not carry a pair of palmate hairs.

Habitat and observations.—This is a very common and widely distributed species in India. It occurs in Calcutta and many places in the plains of Bengal, in Kurseong (at an elevation of 5,000 feet),

in the Punjab (Lahore, &c.), in Madras, and several places on the East Coast, in the Central Provinces (Nagpur, &c.), in Southern India (Travancore), in Bombay, in the Berars (Ellichpur), and in Goa.

In Calcutta it was the commonest species in the Fort, and in Nagpur it was also found in large numbers in the houses; in other places it is rarely found in houses, and approaches in habits to *barbirostris* and *nigerrimus.*

In Nagpur and in Madras its larvæ were found in large natural ponds with grass and weed at the edges; in the Punjab its larvæ occur along with those of *nigerrimus* and *barbirostris* in shady, weed-grown pools under trees. In Bombay it is frequently found in tanks.

The characters of *fuliginosus* are sufficiently well marked to easily distinguish it from other Indian species; the white patch near the lower end of the femur in the mid legs is a very constant and characteristic marking.

Variations.—Major Adie, I.M.S., has noted that the number of white bands on the palpi and the number of pure white hind tarsi, as well as the distribution of white scales on the veins of the wings, are not by any means constant in this species. A common variety having four white palpal bands and two white hind tarsi is found in the Punjab throughout the winter. This variety, if examined alone, might easily be taken for a new species, but breeding experiments have shown that it is not so. An interesting observation by Major Adie, confirmed by one of us, is that at the end of the autumn in the Punjab the ordinary form of this mosquito is gradually replaced by the variety with four white palpal bands and two white hind tarsi, and that in the spring a return to the ordinary form occurs—an excellent instance of "seasonal variation" in mosquitoes.

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9. Anopheles jamesi (Theobald).

(Coloured Plate VI.)

References:—Theobald, Monog. Culicid., Vol. I, p. 134; Giles, Handbook Mosq., 2nd Ed., p. 299, and Rev. of Anoph., p. 43.

Synonym, *Nyssorhynchus Jamesii* (Theobald).

This is rather a small black and white mosquito with three narrow light bands on its palpi, with speckled femora and tibiæ,

and with the last three segments of the tarsus in the hind legs entirely white.

The palpi have three light-scaled bands; the terminal white band is broader than the other two, which are situated at the joints between the second and third, and third and fourth, segments of the palpi. The proboscis is black, with white scales at its tip. The head is covered with white and black scales; the former more numerous on the occiput, the latter on the nape.

The dorsal aspect of the meso-thorax is covered with white scales, the lateral surfaces are darker and less covered with hairs and scales.

Abdomen dark coloured, adorned with hairs and scales, the latter being, as in *A. fuliginosus*, most numerous towards the posterior and lateral surfaces of the abdomen.

The wing veins are covered with black and white scales.

The costa has four distinct white spots, as well as a white-scaled area at its distal extremity and some white scales on its proximal portion.

The first long vein has white spots corresponding to those on the costa, except that the proximal white spot is large and extends from the base of the wing to the second costal spot. There are in addition two minute white spots beneath the central large black-scaled costal area.

The second long vein, mostly white-scaled, has a black-scaled area on the middle of the main trunk, one black-scaled area on the anterior branch, and two on the posterior branch.

The third long vein has a few white scales at the points where the transverse veins join this vein, also a larger white-scaled area in the middle of its course.

The fourth long vein is mostly white-scaled, but has two dark-scaled areas on the main stem, and two on each of its branches.

The fifth long vein is mostly white-scaled, with one black spot on its main stem, and some dark scales at its bifurcation. There are two dark spots on the anterior and one on the posterior branches.

The sixth long vein has three dark-scaled spots. All the legs have white-speckled femora, tibiæ and first tarsal segments. There are white scales at all the joints of the legs. The third, fourth and fifth tarsal segments of the hind legs are entirely white.

Characters of the larva.—Both the median and external frontal hairs are branched, but not so thickly as in the larva of *maculipalpis.*

There is a pair of palmate hairs on each segment of the abdomen from the first to the seventh and a rudimentary pair on the thorax. The shape of the leaflets resembles that of the palmate hairs of *maculipalpis.*

Habitat and observations.—This mosquito is rare in India, though several closely allied species have been described under its name. It occurs in the Central Provinces (Nagpur), in Bombay, in Southern India (Travancore), and Calcutta. It most nearly resembles *fuliginosus*, but is distinguished by having speckled legs.

From *maculipalpis* it may be distinguished by the characters of the palp markings, by the presence of white scales at all the joints of the legs and by having a white tip to its proboscis.

From *theobaldi* it may be distinguished by its darker wing, and by having the last three hind tarsal segments pure white instead of only two as in that species.

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10. Anopheles maculipalpis (Giles).

Coloured Plate VII, Plate IV, Plate X, Fig. 5.

References:—Giles, Handbook Mosq., 2nd Ed., p. 297, and Rev. Anoph., p. 42; Theobald, Monog. Culicid., Vol. III, p. 96.

Synonym, *Nyssorhynchus Maculipalpis* (Theobald).

This is a beautiful black and white mosquito very much like *A. fuliginosus*, but with lighter wing and speckled legs. It has, in addition, white scales on the dorsal surface of the third segment of the palpi.

The palpi have three distinct white bands, and in addition a few scattered white scales on their third segments. The two anterior light bands are broader than the posterior band. The proboscis is black including the tip, but there are a few light scales at the labellar joints. The head is covered with white and black scales, the former predominating on the occiput, the latter on the nape.

The dorsal surface of the thorax is covered with white scales and hairs; the lateral surfaces of the mesothorax are darker and mainly adorned with dark hairs.

The abdomen is of a dark colour and thickly covered with light and dark hairs. As in *fuliginosus* and *jamesi*, scales are present only on the last one or two segments of the abdomen.

The wings are covered with black and white scales, the former being most numerous.

The costa has three distinct white spots, and in addition the distal extremity is white, and there are two minute white spots on the proximal portion.

The first long vein has three white spots corresponding to the three prominent ones on the costa. Its distal and proximal extremities are also white-scaled. In addition there are two white spots beneath the largest central black-scaled area on the costa.

The second long vein has white scales at the points where the transverse veins meet it, and at its bifurcation, and one spot on each of its branches.

The third long vein is white-scaled at the position of the transverse veins, and it has two other white-scaled portions between that point and its termination, which is also white-scaled.

The fourth long vein is for the most part dark-scaled, except at its proximal extremity, at the position of the transverse veins, at its bifurcation, and at a spot on each of its branches.

The fifth long vein is for the most part light-scaled. It has two dark spots on its main trunk, three on its anterior branch, and two on its posterior branch.

The sixth long vein is for the most part light-scaled, but has three dark-scaled spots.

The wing fringe has light scales at the distal extremity of all the long veins.

The femora, tibiæ, and first tarsal segments of all the legs are speckled with white spots, and the joints between these segments have white scales. There are light scales at the joints between the tarsal segments, except between the fourth and fifth segments in the fore and mid legs, and between the first and second segments in the hind legs. The three terminal segments of the hind legs are entirely white.

Characters of the larva (Pl. IV).—The median and external frontal hairs are thickly branched, the branches of the external

rontal hairs being arranged like the veins of a leaf. A prominent pair of palmate hairs is present on the thorax in addition to those on the abdominal segments. The shape of the palmate hair leaflets is shown in the figure (B).

Habitat and observations.—This species occurs in small numbers in the Central Provinces (Nagpur), and more commonly in some parts of the South of India, Travancore, Goa, &c., and in the Bombay Presidency (Karwar). Outside India it occurs in Mashonaland and Mauritius. A variety in which the hind legs are less banded is described by Mr. Theobald under the term *indiensis*.

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11. Anopheles theobaldi (Giles).

(Coloured Plate VIII.)

References:—Giles, Handbook Mosq., 2nd Ed., p. 299, and Rev. of Anoph., p. 43; Liston, *Ind. Med. Gaz.*, Dec. 1901; Theobald, Monog. Culicid., Vol. III, p. 95.

Synonym, *Nyssorhynchus Theobaldi* (Theobald).

Palpi with three white bands, the two anterior of which are broad and the posterior narrow. Wings light coloured, spotted with black. Legs speckled; the last two segments of the tarsi of the hind legs pure white.

Palpi black with three white bands; the apex is white-scaled, the second band is at the joint between the apical and the third segment, and the third band is at the joint between the third and second segments.

Proboscis black with a white tip.

Head covered with black and white scales; a prominent bifid tuft of white hairs projects forward from the head.

The thorax is covered on its dorsal surface with white scales and hairs inserted on a dark ground, the scales and hairs being arranged so as to show a median and two lateral darker lines. The lateral aspects of the thorax are of a dark colour.

The abdomen is intensely black. It is covered with long white hairs. Mr. Theobald says that the apical segments have "small flat scales of a dull golden hue." We have been unable to detect the presence of these scales in the examination of a number of specimens, and Colonel Giles originally described the abdomen as "nude." The point is of importance, as the position of the mosquito in the

genus *Nyssorhynchus* apparently depends upon the presence or absence of these few scales.

The wings are covered with spindle-shaped scales. The costa has six black-scaled areas. The black-scaled portion on the centre of the costa is the largest. Two very small dark spots are situated at the inner end of the wing.

The first longitudinal vein has four dark markings corresponding with the four outer large dark areas on the costa. The third dark area from the outer end is almost always divided into three by the interposition of two small white-scaled spots.

The second longitudinal is for the most part white, but shows two black-scaled areas on the main trunk and two dark spots on each of its branches.

The third longitudinal vein is white except for three dark spots.

The fourth long vein has two long black spots on the main trunk and two small black spots on each of its branches.

The fifth longitudinal has only one dark spot on the main trunk, three on its anterior branch, and one on its posterior branch.

The sixth long vein has three dark spots.

The distal extremity of all the veins is light-scaled, and at these points the wing fringe is interrupted by light scales.

The legs are much adorned with white scales and differ in detail in the anterior, mid and hind legs. The femora and tibiæ of all the legs are covered with dark and light-scaled spots. The first tarsal segments too have some white spots. The distal extremities of the second and third tarsal segments in the fore and hind legs are white, but black at these points in the middle legs. The fourth and fifth segments in the hind legs are entirely white, while they are entirely black in the other legs.

Characters of the larva.—The frontal hairs are slightly branched or frayed. There are palmate hairs on the abdominal segments and a rudimentary pair on the thorax. The shape of each leaflet is characteristic, and the terminal filaments are very short and blunt.

The larva of this species differs from most of the others in this group in that it is more frequently found in streams than in still water.

Habitat and observations.—The Berars (Ellichpur); the Central Provinces (Nagpur); the Jeypore State; Behar, Bombay.

The separation of this mosquito, as a distinct species, depends chiefly on the characters of the larva, for except in colour markings there are few or no structural characters in the adult by which it can be separated from allied species.

For purposes of identification, however, the fact that only the last *two* hind tarsal segments are pure white will serve to distinguish it from other species.

It has been proved that, under experimental conditions, human malaria parasites can develop in this mosquito.

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12. Anopheles maculatus (Theobald).

References:—Theobald, Monog. Culicid., Vol. I, p. 171; Vol. III, p. 96.

Synonym, *Nyssorhynchus Maculatus* (Theobald).

Palpi with three white bands. Thorax covered with white scales; abdomen black, with many hairs but no scales. Legs speckled; last tarsal segment of the hind legs pure white. Wings spotted.

Head black, with white upright scales in front and black ones behind; a prominent tuft of white hairs projects forwards from the head.

Palpi with dark scales, and three white bands, the outermost band includes the tip and is separated by only a few black scales from the next which is equal to it in breadth; the third band is narrow; proboscis brown with a white tip; antennæ brown with white hairs.

Thorax covered with white spindle-shaped scales and some golden hairs; scutellum with white scales and long bristles.

Abdomen dark brown with many golden brown hairs, but no scales except on the abdominal processes.

Legs with the femora, tibiæ and first tarsal segments speckled with white scales; in the fore and mid legs the tarsal segments except the fourth and fifth have apical white bands; in the hind legs the first tarsal segment (metatarsus) is brilliantly spotted with white spots and has an apical white band, the second tarsal segment is unspotted and has a broad apical band, the third has broad basal

and apical bands, the fourth has also broad basal and apical bands, and the fifth is pure white throughout its length.

Wings with the veins clothed mostly with pale narrow scales and with some black ones, forming spots arranged almost exactly as in the wings of *theobaldi*.

Characters of the larva.—The frontal hairs are simple and unbranched. Palmate hairs are borne by the second to the seventh abdominal segments ; the terminal filament of each leaflet is very short.

Habitat and observations.—This species occurs in Lahore in March and April ; in the Bengal Duars (August and September), and at Kurseong at an elevation of 5,000 feet. It also occurs in Hong-Kong (China) and in the Straits Settlements.

This "anopheles" very closely resembles *theobaldi* and is probably only a geographical variety. The difference in the frontal hairs of the larva is noteworthy, but such minor differences have been noted in larvæ of undoubtedly the same species. As in *theobaldi* we have been unable to detect any scales on the abdomen (excluding the abdominal processes) of this species, and for this reason we should be inclined to remove it, with *theobaldi*, from the genus *Nyssorhynchus*, in spite of the fact that Mr. Theobald regards it as the type-species of that genus. At any rate, if scale structure is of any generic value, it seems wrong to place this species in the same genus as *stephensi* and *willmori*, the abdomens of which are almost entirely covered with large scales.

The different mosquitos in this group are very liable to be mistaken for one another. They can readily be divided into two groups according as the tibiæ and femora are (*a*) unspotted, (*b*) spotted.

Under (*a*) would come *karwari* and *fuliginosus*. As a rule, *karwari* has four bands on the palpi while *fuliginosus* has only three, but in this latter mosquito there are occasionally four bands on the palpi. Again, *karwari* has, as a rule, only one segment entirely white in the hind tarsus, while *fuliginosus* has three, but occasionally only two. These mosquitos, however, are most easily distinguished from one another by the fact that the wing of *karwari* is very much lighter than that of *fuliginosus*.

Under (*b*) come *jamesi*, *maculipalpis*, *theobaldi*, and *maculatus*. The two former can be separated by the fact that they have

at least three hind tarsal segments entirely white, while the others have less than three.

Jamesi is most readily distinguished from *maculipalpis* by an examination of the palpi, the former has a broad terminal and two narrow white bands without additional speckling, while the latter has two broad distal and one narrow basal band and has additional speckling.

Theobaldi is distinguished from *maculatus* only by the fact that the former has two segments in the hind tarsus wholly white, while the latter has only one.

We may here refer to a specimen which Mr. Theobald (Monograph, Vol. III, p. 96) thinks probably represents a distinct species, and which for the purposes of our synoptic table (page 32) we have named *A. nagpori*. It was found by Dr. Stephens at Nagpur (Central Provinces). Its main characteristics are as follow:--(1) The palpi are marked with three narrow white bands, the terminal of which is some distance below the tip so that *the tips of the palpi are black*. The base of each palp is densely black-scaled. (2) In the fore leg there are no white bands at the apices of the femur and tibia, but there is a small white band at the apex of each tarsal segment. In the middle leg there are no white bands at any joints. In the hind leg there is a faint white spot at the apex of the tibia, and a white spot at the apices of the first and second tarsal segments. The fourth and fifth and two-thirds of the third tarsal segments of the hind leg are pure white. (3) There is no speckling of the legs or palpi.

GROUP V.

Types :—*A. jeyporiensis*, *A. listoni*, and *A. culicifacies*.

13. Anopheles jeyporiensis (James).

(Coloured Plate IX, Plate VII, Fig. 2.)

References :—James, "Malaria in India," p. 32 ; Theobald, Monog. Culicid., Vol. III, p. 66.

Synonym, *Pyretophorus Jeyporiensis* (Theobald).

A small dark mosquito. Palpi with three white bands. Thorax with many narrow curved creamy scales in the middle, dark brown at the sides. Abdomen black with many golden hairs, but

no scales. Legs black, but with minute white bands at the tarsal joints formed by white scales on the apices of the segments.

Palpi black, covered with scales and with three light-scaled bands ; the terminal band, which includes the tip, is broader than the other two, which are situated at the joints between the third and fourth, and second and third segments.

Proboscis dark brown with a paler tip.

Head black with white upright-forked scales in front, black ones behind ; a dense tuft of white hairs projects forwards from the head ; antennæ brown with silvery hairs.

Thorax dark with a patch of long narrow curved white scales on the dorsum and black hairs forming longitudinal lines.

Scutellum black with dark border bristles ; abdomen blackish brown, thickly covered with fine golden brown hairs, but with no scales.

The wing veins are covered with long spindle-shaped scales. The costa is dark brown in colour, and interrupted by five minute yellowish white areas ; in addition the distal extremity of the costa is white. The proximal white-scaled interruption is very minute.

The first long vein has four white-scaled portions, corresponding to the four distal white-scaled areas of the costa. In addition there is a large white-scaled portion extending from the base of the wing to the second most internal costal white spot.

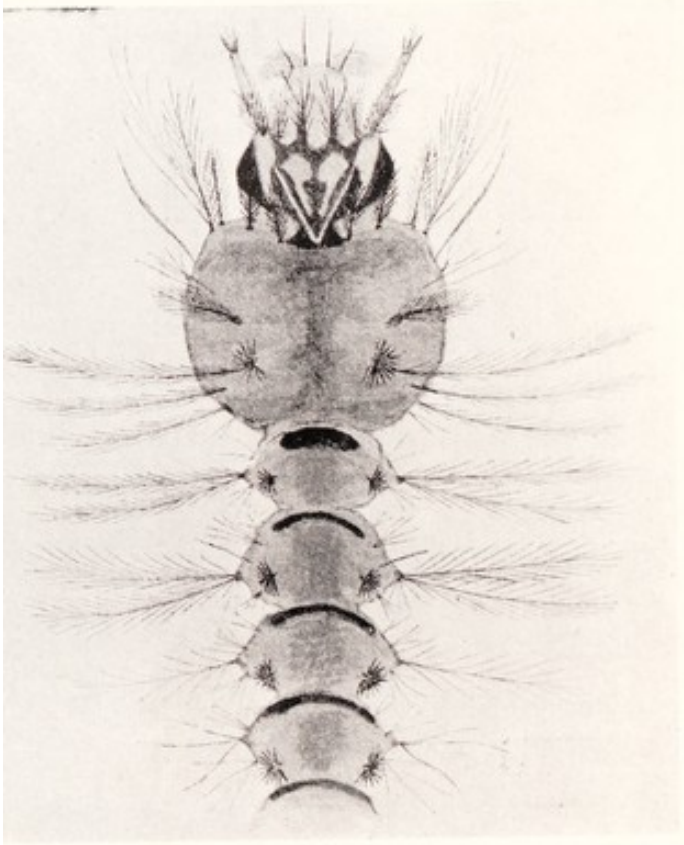
The second long vein has a few white scales at the points where the transverse veins join it. There are a few white scales at the point of bifurcation, and at the distal extremity of each branch of this vein. There is, in addition, a white-scaled portion in the middle of the anterior branch.

The third long vein is mostly white, except for a small portion just beyond its origin.

The fourth long vein is white-scaled at its proximal extremity ; it is dark-scaled for the rest of its course, except where the transverse vein joins it. There are also two white-scaled areas on each of the branches ; the distal extremities of the branches are white-scaled.

The fifth long vein is chiefly white-scaled. There is one black-scaled area on the middle of the main trunk. This vein is also dark-scaled at its bifurcation. There are two dark-scaled spots on the anterior branch and one on the posterior branch.

FIG. 1.



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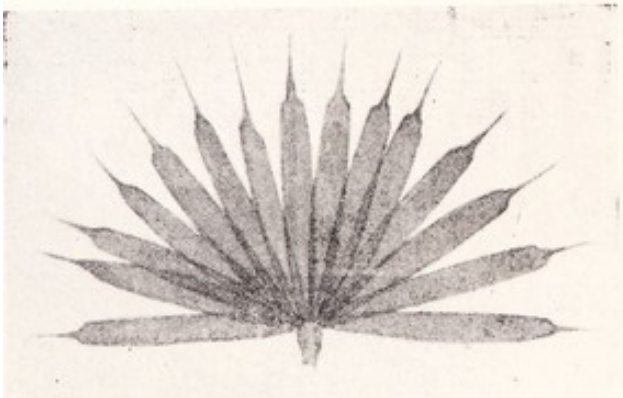

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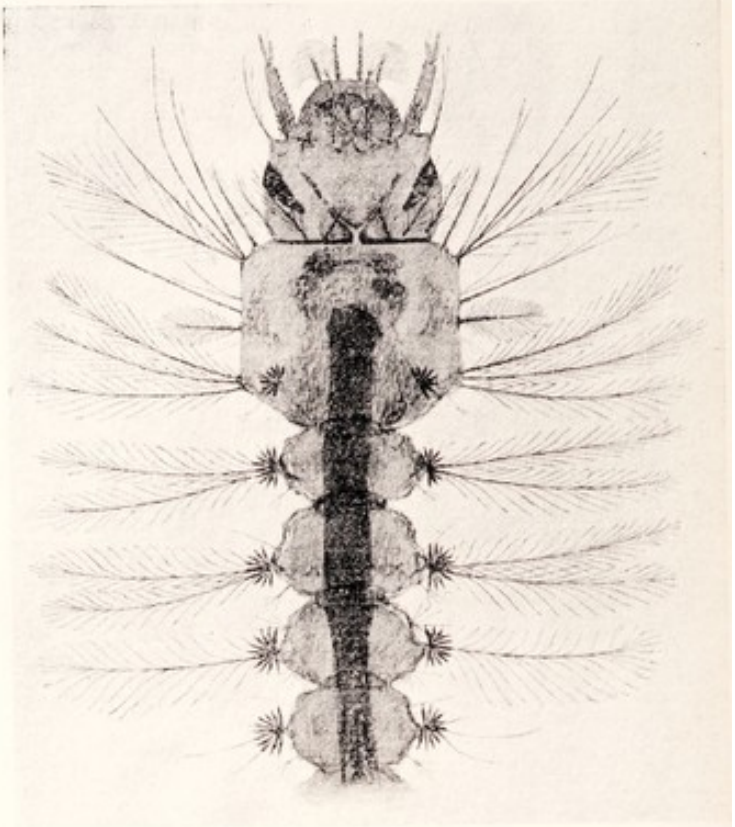
FIG. 2.



A.

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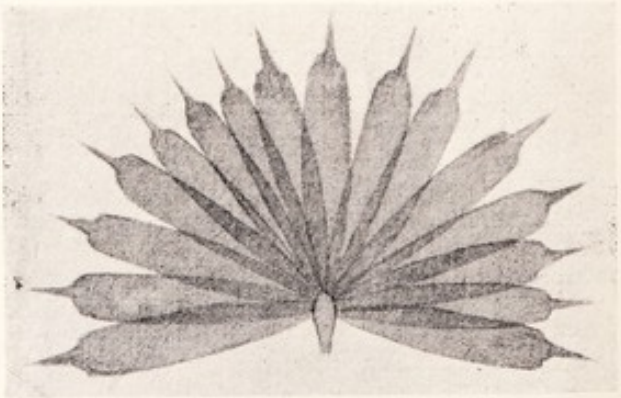

C.

PLATE VII. *Fig.* 1.—The larva of *A. listoni*. *A.*—General view; *B.*—Frontal hairs magnified; *C.*—A palmate hair magnified.
Fig. 2.—The larva of *A. jesporiensis*. In figure B the "posterior hair" of the right side is seen.

The sixth long vein is covered with white scales, except for a few dark scales about the middle of its course and a few near its termination.

The wing fringe has light-scaled areas opposite the extremities of each long vein.

Legs quite black but with minute white bands at each joint formed by white scales on the apices of the segments.

Characters of the larva (Pl. VII, Fig. 2).—Both the median and external frontal hairs are thickly branched, this character enabling *jeyporiensis* to be at once separated as a species distinct from *listoni* and *culiciafcies*, the larvæ of which have simple frontal hairs. The thorax carries a prominent pair of palmate hairs in addition to those on the abdominal segments.

Habitat and observations.—This new species was first found in the Jeypore State by Drs. Stephens and Christophers. It also occurs in the Central Provinces (Nagpur), and a specimen has lately been sent by Mr. Aitken from Jakot (Southern India). It has frequently been found in Bombay. In all these places it was found breeding either in streams or in the flowing water of rice-fields. It is evidently closely allied to *listoni* and *culicifacies*. From the former the adults can be distinguished by the differences in the wing markings and by the presence of light scales at all the joints of the legs; from the latter by the differences in the wing markings. According to Mr. Theobald the meso-thoracic scales are "narrow curved" in *jeyporiensis* and "hair-like" in *culicifacies*, but these differences are not easy to make out.

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14. Anopheles listoni (Liston).

(Coloured Plate X, Plate VII, Fig. 1.)

References:—Liston, *Ind. Med. Gaz.*, Dec. 1901; Theobald, Proc. Roy. Soc., Vol. LXIX, p. 378, and Monog. Culicid., Vol. III, p. 27; James, "Malaria in India," p. 31; Giles, Rev. of Anoph., p. 28.

Synonyms, *Myzomyia Listoni* (Theobald).
A. fluviatilis (James).
A. christophersi (Theobald).

This is a very dark, small mosquito, readily distinguished by its entirely black legs and white third longitudinal vein. The palpi have three almost equal white-scaled bands, one at the apex,

another at the junction between the fourth and third, and a third at the joint between the third and second segments.

The proboscis is brown with a yellowish-white tip. The head is covered with the usual dark brown and white upright scales, and there is a frontal tuft of hairs.

The thorax is covered with white hair-like scales, and yellowish hairs, inserted on a dark black background.

The scales and hairs are so arranged as to show a median, and two less distinct, lateral, longitudinal darker lines. The lateral aspects of the meso-thorax are of a black colour.

The abdomen is of a dark black colour and is covered with numerous long yellowish-white hairs.

The wings are covered with long spindle-shaped scales.

The costa has four yellowish-white areas. The smallest of these is situated at the apex of the wing; the others increase in size from this point inwards.

The first long vein has four light-scaled areas corresponding with the four light-scaled areas of the costa, but in addition there is a larger white-scaled portion at its inner extremity.

The second long vein shows three small white-scaled areas, the outermost is situated at the bifurcation of the vein and in part involves both branches. The other two are situated at the position of the transverse veins.

The third long vein, in contrast to the other veins, is for the most part light-scaled, but has two small dark-scaled areas towards its inner extremity, and one dark-scaled portion at its outer end.

The fourth long vein is for the most part dark-scaled, except for a short distance at its inner extremity, where it is light-scaled, and for a few light scales at the transverse veins, and at its bifurcation.

The fifth long vein is white for most of its inner portion, except for a small dark-scaled spot towards its inner end. This vein is black-scaled at its division into branches. The anterior branch is dark throughout, except for a few light scales at the transverse vein and at its outer extremity. The posterior branch has a short white-scaled portion shortly after it leaves the parent trunk, and has a few light scales at its distal end. The remainder of this branch is dark-scaled.

The sixth long vein is for the most part black-scaled, but shows two small white areas, the one at its inner extremity, and the other between the two black-scaled portions. The distal extremities of all the long veins, except the sixth, are white-scaled, and at these points the wing fringe is interrupted by light scales.

The legs are dark-scaled throughout.

Variations.—The following are the most common variations —

(1) the long dark basal costal spot is occasionally interrupted by a few light scales about its middle;

(2) the length of the white-scaled area on the third long vein may be considerably diminished by the encroachment of black scales from either end of the vein; indeed this vein is occasionally found black throughout;

(3) a light-scaled interruption occasionally occurs on the middle of the anterior branch of the fifth long vein;

(4) light scales may occasionally be found at the distal extremity of the tibiæ, and there may sometimes be a tendency to formation of light bands at the tarsal joints.

Characters of the larva (Pl. VII, Fig. 1).—The frontal hairs are simple and unbranched. In addition to the palmate hairs on the abdominal segments there is a well-developed pair on the thorax. The terminal filament of each leaflet is short.

The characteristic pattern on the dorsum of the head of the larva is shown in the figure.

Habitat and observations.—This species occurs in the Berars (Ellichpur), in the Central Provinces (Nagpur), in the Bengal Duars, in the Jeypore State, in Goa, Bombay, and the Hyderabad State (Aurungabad).

It is apparently absent from the Punjab.

Its larvæ are usually to be found in clear streamlets with grassy edges. It has been shown to be the carrier of malaria in the Duars; experimentally also it has been proved that the parasites of human malaria readily develop in it.

In the adult stage this species closely resembles *jeyporiensis*, but it may be distinguished by the differences in wing markings and by the fact that, as a rule, the legs have no white scales at the joints.

Considerable confusion has arisen regarding the correct specific name of this species, and it seems necessary to give the following

brief history of its discovery. It was first found by Captain Liston who sent it with specimens of *culicifacies* to Colonel Giles, at the same time pointing out the differences between the two species. Colonel Giles proposed to name it *listoni*, and it was therefore described under this title by Captain Liston (*Ind. Med. Gaz.*, Dec., 1901). In the meantime the labels on Colonel Giles' specimens were apparently lost, and when his description appeared it was evident that under the title *listoni*, he had only redescribed a specimen of *culicifacies*. Thus *listoni* (Giles) is merely a variety of *culicifacies* (see Rev. Anoph., p. 30). In 1902 the same mosquito was found in the Duars by the Royal Society's Malaria Commissioners. At first they considered that it was identical with the African species *funestus* (Giles), but as this view was not shared by Mr. Theobald, the mosquito was described by Captain James under the title *fluviatilis* ("Malaria in India," p. 31). The specimens sent to Mr. Theobald were described by him about the same time under the title *christophersi*. Subsequently we were able to point out to Mr. Theobald that the species was identical with that originally described by Captain Liston under the title *listoni*, and the latter name must therefore be regarded as correct. Our illustrations were prepared before the correct nomenclature of this species had been worked out, and in the coloured plate it appears under the title *fluviatilis*. We have already pointed out, however, that there is no good reason for regarding this species as distinct from *funestus* (Giles), and it is very probable that all the other names will soon be sunk under the latter title.

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15. Anopheles culicifacies (Giles).

(Coloured Plate XI. Plate IX, Fig. 2; Plate VIII, Fig. 1.)

References:—Giles, *Ento. Mo. Mag.*, 1901, p. 197; Handbook Mosq., 2nd Ed., p. 317, and Rev. of Anoph., p. 29; Theobald, Monog. Culicid., Vol. III, p. 39; Liston, *Ind. Med. Gaz.*, Dec., 1901.

Synonym, *Myzomyia Culicifacies* (Theobald).

This is a small dark mosquito closely resembling *listoni*, but distinguished from that mosquito by having the third longitudinal vein dark-scaled, and by the presence of a few light scales at the tibio-metatarsal joints.

The palpi have three small, almost equal, yellow areas, namely, at the apex, at the joint between the third and fourth segments, and at the joint between the third and second segments.

The head is covered with yellowish-white and brown upright scales, and has a small frontal tuft of white hairs.

The thorax is covered with brown and yellow hairs and hair-like scales inserted on a dark back-ground. There is a distinct median, dark, longitudinal line. The lateral aspects of the thorax are darker than the dorsum.

The abdomen is of a dark brown colour and is covered with long yellow hairs but is without scales.

The wing is covered with narrow spindle-shaped scales.

The costa has five yellowish-white scaled portions, the innermost of which is of very small size ; the outermost is apical in situation.

The first longitudinal vein shows five small yellow-scaled areas corresponding exactly with the similar costal areas.

The second long vein has three light-scaled portions, the two inner are situated at the transverse veins, while the outer is situated at the bifurcation of the vein, and involves, for a short distance, both branches.

The third long vein is dark-scaled throughout, except at its origin.

The fourth long vein has three light-scaled areas, one towards its inner end, one at the situation of the transverse veins, and one at the point of bifurcation ; the light-scales are continued on the branches for a short distance.

The fifth long vein has only one light scaled area on the main stem, and one on each of its branches.

The sixth long vein has one light-scaled spot. The distal extremities of the posterior branch of the fourth longitudinal, and the anterior branch of the fifth longitudinal are alone light-scaled, and only at these points is the costal fringe interrupted by lighter scales.*

The legs are of a dark brown colour throughout, but sometimes show, at the distal extremity of the tibia, a small spot of yellowish scales.

Variations.—There may be (1) an increase in the number of light-scaled interruptions in the wing fringe ; (2) a tendency to

* These two light-scaled areas on the wing fringe are sometimes indistinct. This is shown in the wing of the right side in the specimen from which the coloured plate was drawn.

banding at the tarsal joints ; (3) variations in the relative positions of the transverse veins.

Characters of the larva (Pl. VIII, Fig. 1).—Both the median and external frontal hairs are simple and unbranched. There is a pair of palmate hairs on the thorax as well as those on the abdominal segments, but the thoracic pair are not as well developed as in the larvæ of *listoni* or *jeyporiensis*, and the terminal filament of each leaflet is longer than in either of those larvæ. The pigment dots on the dorsum of the head are arranged in a characteristic manner.

Habitat and observations.—This species is widely distributed in India. It occurs in the Punjab (Lahore, Mian Mir, Ferozepore, &c.), in Madras, and several places on the East Coast (Ennur, Armagaon, &c.), in the Central Provinces (Nagpur), in the Jeypore State, in the Berars (Ellichpur), in Goa, in Bombay, and in the Hyderabad State (Secunderabad and Aurungabad).

In the Punjab its larvæ can be found in the irrigation watercourses throughout the year, but adults cannot be detected in houses during the cold months from December to March. It is commonly found in drying up river beds in the Deccan, and is found in houses there throughout the hot and cold weather.

In the south of India it has been found breeding in rice-fields (Aitken), in "borrow pits" by the side of railways, and in pools in the beds of rivers.

The adults are peculiar in that they do not adopt the characteristic attitude of other "anopheles" when resting on a wall or roof, but sit more or less like a "culex" with the body parallel to the wall.

This species has been proved to be a very efficient malaria-carrier in Mian Mir (Punjab) and in Ennur (Madras). Experimentally also it has been shown that the parasites of the three varieties of malarial fever can readily develop in it.

A. culicifacies can be distinguished from *listoni* and *jeyporiensis* by the fact that it has the third longitudinal vein entirely black-scaled, and by having only two white interruptions on the wing fringe instead of several as in those species.

A peculiarity of this species is the fact that the relative positions of the transverse veins of the wing to one another vary considerably. (*See* James, "Malaria in India," p. 29.)

FIG. 1.

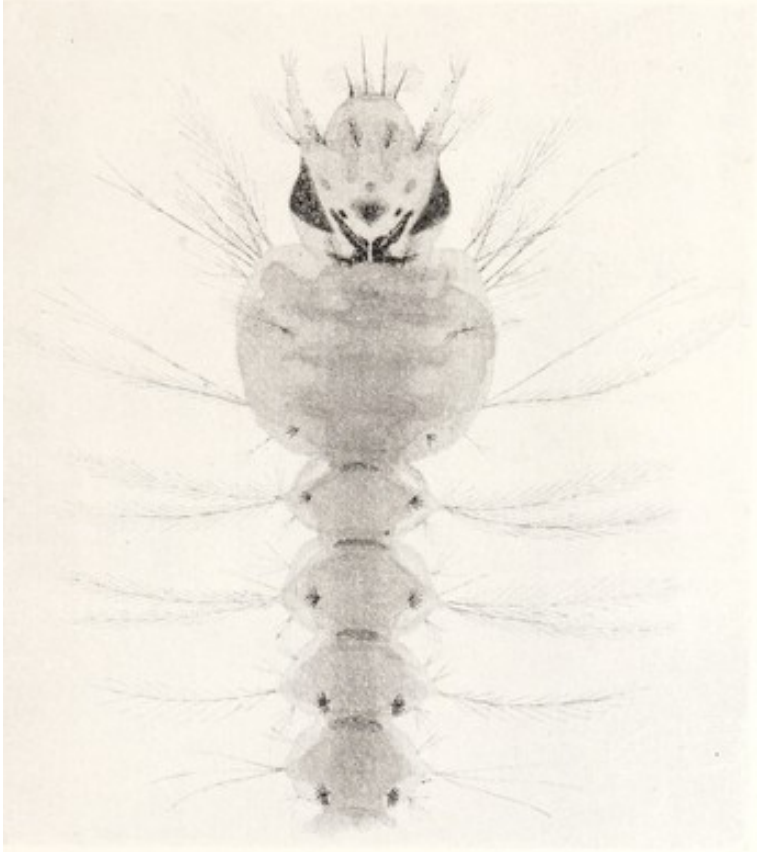
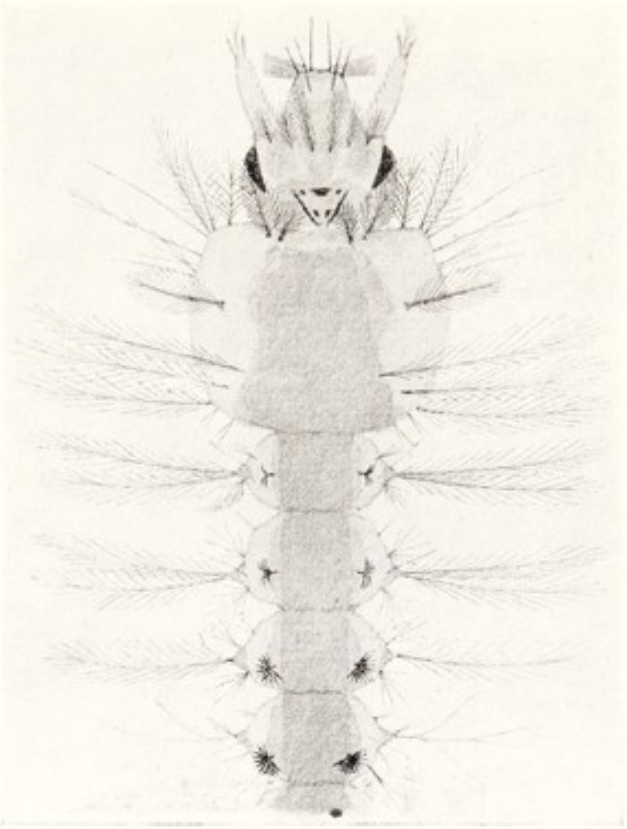


FIG. 2.



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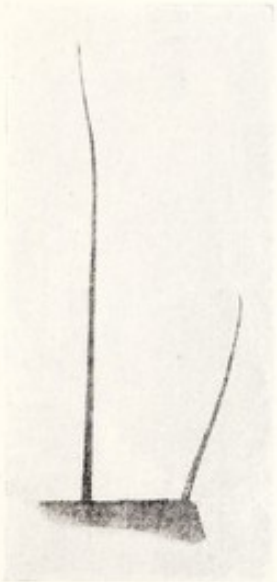

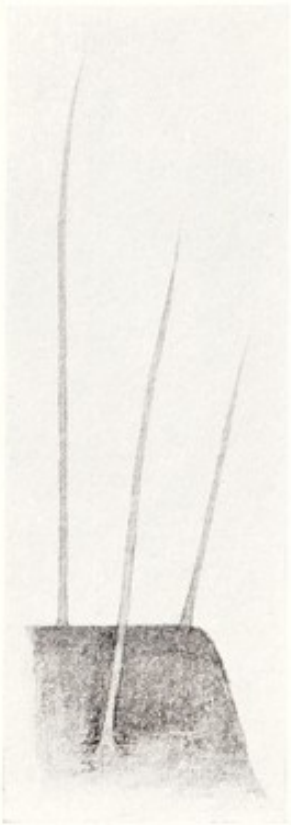

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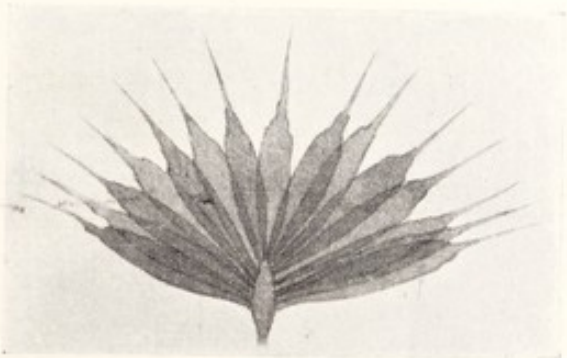

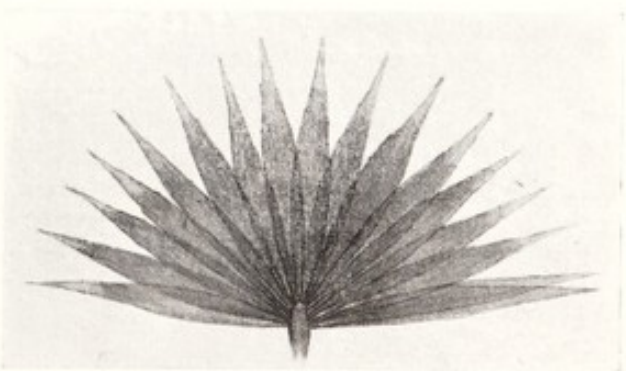

Anopheles rossi.

Colonel Giles, in the 2nd Edition of his Handbook, describes the abdomen as being completely clothed with yellowish and deep brown scales. This is incorrect, for the abdomen is devoid of scales. The male genitalia are also wrongly described as being characteristic. These points are corrected in his "Revision of the Anophelinæ."

Mr. Theobald now admits that his *indica* is nothing more than a specimen of *culicifacies.*

GROUP VI.

Types :—*A. rossi* and *A. stephensi.*

16. Anopheles rossi (Giles).

(Coloured Plate XII. Plate VI, Fig. 1 ; Plate X, Fig. 3.)

References :—Giles, Handbook Mosq., 1st Ed., p. 149 ; Theobald, Monog. Culicid., Vol. I, p. 154, and Vol. III, p. 45.

Synonym, *Myzomyia Rossii* (Theobald).

A light brown mosquito. Thorax with scattered whitish scales, especially anteriorly and at the sides, and many hairs ; abdomen with numerous yellow hairs ; palpi with three white bands : legs not speckled but with tarsal bands ; wings spotted.

Head covered with black and white scales and with a well-developed frontal tuft of white hairs projecting forwards. Palpi with three white bands, the outermost of which includes the tips of the palpi and is broad ; the other two bands are narrow ; the first is situated at the junction of the fourth and third segments, and the other at the junction of the third and second segments of the palp.

Proboscis brown with a yellow tip ; antennæ brown with pale hairs. Thorax furnished with golden hairs and narrow hair-like scales, the latter predominate anteriorly and laterally ; the scales and hairs are so arranged that three somewhat indistinct longitudinal lines can be made out, the most conspicuous being the central one.

The abdomen is densely covered with yellowish brown hairs.

The scales on the wings are spindle-shaped.

The costa has seven black-scaled areas. The black spot on the middle of the costa is the largest. Three of the black spots at the

inner end of the costa are very small, and may be more or less united together.

The first long vein shows five dark spots: the outer four of these have a similar situation to the outer four on the costa; the fifth lies close to the inner end of the vein.

The second long vein has two dark spots before its bifurcation. There are, as a rule, two black-scaled spots on each of the two branches into which this vein divides.

The third long vein has three dark spots, all small in size.

The fourth long vein has two dark-scaled portions before its bifurcation, and on each of its branches there are two dark spots.

The fifth long vein, before it bifurcates, has one dark spot; its anterior branch has three dark spots, while the posterior has only one.

The sixth long vein has two dark spots—one near the middle, the other near the termination of the vein.

The distal extremity of all the wing veins is light-scaled and at these points the wing fringe is interrupted by light scales.

The legs are of a brownish hue and show lighter scaled spots of a yellowish colour at the distal extremities of the femur, tibia, and all the tarsal segments except the last. The marks on the tarsi are at the joints between the segments. The marks on the tarsal joints of the hind legs are smaller than those on the other legs.

The chief variations to be found in this mosquito are:

1. Variations in the number of costal spots. This is brought about by the union of one or more of the normal costal spots, especially those situated near the base of the wing. Other minor differences are to be found in the number and arrangement of the dark areas in other parts of the wing field.

2. There is occasionally a tendency to mottling on the femur and tibia, but this is always indistinct as compared with *stephensi*.

3. The markings on the tarsi may be more distinct in some specimens than in others.

4. Like many other "anopheles" the relative position of the transverse veins to one another is variable.

Characters of the eggs and larva (Pl. VI, Fig. 1).—The eggs of this species are characterised by having a very broad deck surface and by the presence of a broad fringe passing all round the

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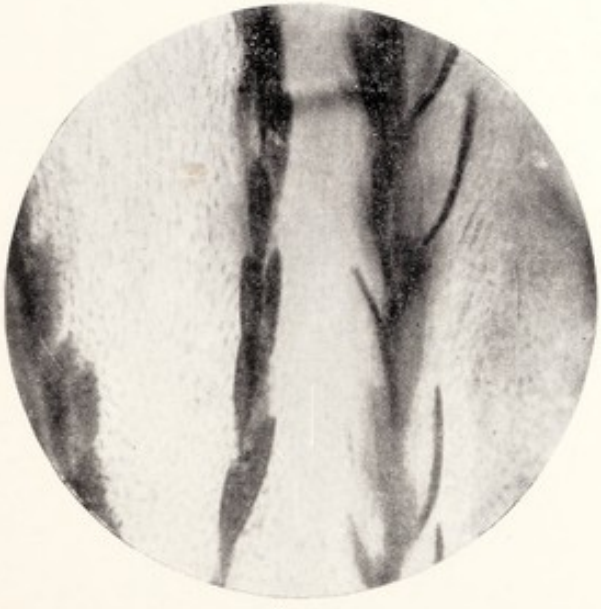

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PLATE IX. Wing scales of "*Anopheles*."

1. *A. maculatus.* 2. *A. culicifacies.* 3. *A. aitkeni.* 4. *A. leucophyrus* variety *elegans.* 5. *A. listoni.* 6. *A. pulcherrimus.*

edge of this surface (p. 39, fig. 8, 3). Both the external and median frontal hairs of the larva are simple and unbranched. Palmate hairs are present from the second to the seventh abdominal segments; the terminal filament of each leaflet of the palmate hairs is very long. The pattern on the dorsal surface of the head of the larva is characteristic and fairly constant.

Habitat and observations.—A. rossi is common throughout India, and has been found at elevations above 5,000 feet. Its favourite breeding place is usually a muddy pool or shallow tank among native huts, and after the rains both larvæ and adults may be present in enormous numbers. In the Punjab (Lahore, Mian Mir), it is rare before the commencement of the rains, owing probably to the absence of suitable breeding places, for it does not usually breed in the irrigation watercourses as *A. culicifacies* does. In September, October and November, however, enormous numbers can be caught in the native huts. The larvæ of this species have occasionally been found in very foul water, and at Ennur near Madras, its larvæ were found in water containing 2·8 per cent. of salt.

In the Deccan, in Bombay, and in Calcutta the larvæ are found in tanks during the dry weather. During the rains they disappear from the tanks and are found in large numbers in the small shallow muddy pools which are then so common by the roadside and in the open fields.

In the south of India, where suitable breeding places are present all the year round, *A. rossi* has no special seasonal prevalence and is common throughout the year. In the Madras Presidency it breeds largely in irrigated rice-fields.

Adult insects of this species are very commonly found in India in railway carriages, as well as in almost every kind of road conveyance, and this is possibly one of the ways by which the species has become so widely distributed throughout the country.

Outside India it occurs in Penang, the Malay States and Sumatra.

It has been shown that under experimental conditions the parasites of human malaria are capable of developing in this species, but, although so prevalent throughout India, it has never yet been found infected in nature. In the south of India it is one of the carriers of Filariasis.

Characters distinguishing this mosquito from other species.—From *A. stephensi* it is distinguished by the absence of scales on the abdomen, by the markings on the palpi, and by the absence of speckling of the legs.

This mosquito might be confounded with those of Group II, especially with *punctulatus*, but an examination of the palpi would prevent any error, for the members of that group have four bands on the palpi.

This mosquito very closely resembles *costalis* but differs from it chiefly in the fact that *costalis* has a white interruption in the black area on the first longitudinal vein, opposite the penultimate black costal spot, and has three black spots on the sixth longitudinal vein in place of two. These, however, are merely colour variations and can hardly be considered of specific value.

We can confirm Colonel Giles' statement that there is a tuft of white scales on the front of the thorax as well as a small patch of spindle-shaped scales on the last abdominal segment. Mr. Theobald apparently considers that these scales are absent, and for that reason has placed the species in the genus *Myzomyia*. A classification based upon characters about which it is possible for so much difference of opinion to exist, cannot, we think, be considered a very useful one.

We may here refer to a specimen which Mr. Theobald has placed as the type of a new genus *Aldrichia*. This genus is based on a single specimen, which was found among the types of *A. rossi* deposited in the British Museum. It differs from all other "anopheles" in the fact that the entire dorsum of the abdomen is covered with flat imbricated scales arranged exactly as in mosquitoes of the genus *Culex*. In other respects the specimen, which has been named *Aldrichia error*, appears to resemble *rossi* very closely, and Colonel Giles is of opinion that in all probability it represents merely an abnormality. He states that when examining a number of specimens of *culicifacies* he came across one the abdomen of which was similarly scaled (*see* his description of this species, Handbook, 2nd Ed., p. 317, and his Revision of the Anophelinæ, pp. 9 and 29), so that observers should certainly be on the look out for specimens presenting this curious character, in order that the question as to whether such specimens are abnormalities or not may be cleared up.

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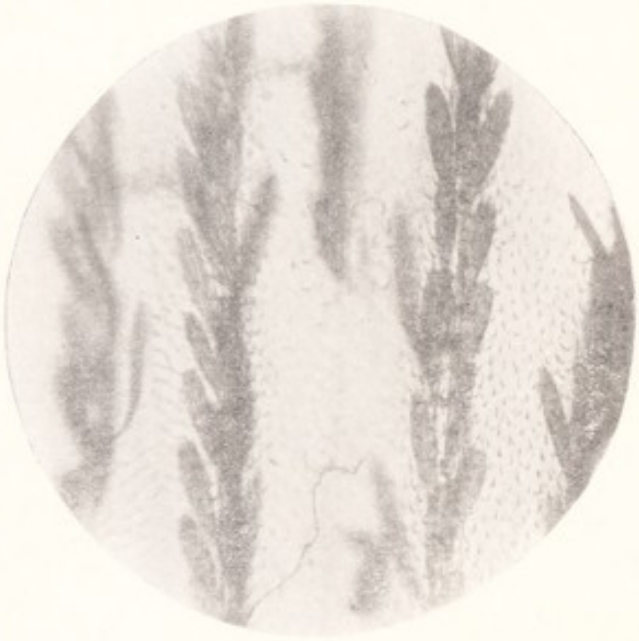

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PLATE X. Wing scales of "*Anopheles.*"

1. *A. barbirostris.* 2. *A. jamesi.* 3. *A. rossi.* 4. *A. fuliginosus.* 5. *A. maculipalpis.* 6. *A. stephensi.*

17. Anopheles stephensi (Liston).

(Coloured Plate XIII. Plate VI, Fig. 2, Plate X, Fig. 6.)

References :—Liston, *Ind. Med. Gaz.*, December, 1901 ; Theobald, Monog. Culicid., Vol. III, p. 93.

Synonyms, *Nyssorhynchus Stephensi* (Theobald).
A. metaboles (Theobald).

Palpi with three white bands and some speckling ; thorax covered with white scales ; abdomen with many scales and hairs ; legs speckled but with none of the hind tarsal segments white in their whole length ; wings spotted.

Head covered with brown and white upright-forked scales ; a prominent frontal tuft of white hairs projects forwards ; palpi with three white bands ; the two outer equal and broad, the third narrow ; tips of the palpi white ; on the dorsal aspect of the third segment of each palp there are in addition one or two white-scaled spots.

Proboscis brown-scaled with a yellowish tip ; antennæ dark-brown.

Thorax covered on its dorsum with white scales and showing an indistinct median and two lateral longitudinal dark lines ; lateral aspects of the thorax dark.

Scutellum with white scales and dark bristles.

Abdomen brown, covered with numerous hairs and scales.

Wing veins clothed with rather broad spindle-shaped scales.

The costa shows six black-scaled areas ; the base of the costa has dark scales, while the apex has white scales.

The first long vein has four dark-scaled areas corresponding to the four outer dark-scaled areas on the costa, but the third dark-scaled area from the apex is divided into two by a narrow white-scaled interruption, and is shorter than the corresponding costal mark.

The second long vein has a single black-scaled area on the main stem, and one on each of its branches ; the point of bifurcation is white-scaled.

The third long vein shows two small dark-scaled dots, one near its origin, and the other near its termination.

The fourth long vein shows two dark-scaled areas on the main trunk, two on the anterior branch, and one on the posterior branch.

The fifth long vein has a single dark-scaled spot on the trunk, three on the anterior branch, and one on the posterior.

The sixth long vein has sometimes three, and occasionally only two dark-scaled spots.

The costal fringe is interrupted by light scales at the outer extremity of all the longitudinal veins.

The femora and tibiæ of all the legs are speckled with white scales. The distal extremities of the femora and tibiæ are covered with yellowish white scales. The distal ends of the tarsal segments of the middle and hind legs have yellowish white-scaled bands, except those of the terminal segments. In the anterior legs, the second and third tarsal segments have distal yellowish-white bands, and the first tarsal segment has two additional yellow-white bands. The fourth and fifth segments are wholly covered with brown scales.

Characters of the larva.—(Plate VI, Fig. 2).—The frontal hairs are simple and unbranched. The palmate hairs are borne by the first to the seventh abdominal segments; the filaments of the leaflets are shorter than those of *rossi*, and this character and the complete absence of any head pattern serve to distinguish the larva of this species from that of *A. rossi*.

Habitat and observations.—This species occurs in the Punjab (Lahore, Mian Mir, &c.), in Calcutta, in Madras, in the Central Provinces (Nagpur), and at Ellichpur in the Berars. In Calcutta the adults were found in native huts along with *A. rossi;* in Madras, it was also found in native houses, and here it was breeding almost entirely in disused wells. In Mian Mir its breeding places were found to be the tins and vessels of water which are kept in the lines of native troops in case of fire. This species has not been found in Bombay, but is very common in Karachi.

It has been proved that under experimental conditions the parasites of human malaria are capable of developing in this species.

A. stephensi is in many respects related to *pulcherrimus* and *willmori*, but the wing and thoracic scales are not so broad and there are fewer scales on the abdomen and more hairs. It can be readily distinguished from them by the absence of white tarsal segments on the hind legs.

Mr. Theobald has classed this species in his genus *Nyssorhynchus*, but an examination of the thoracic scales, on which he lays

so much stress, will readily show that these scales differ in shape from those of most of the other species which he has placed in this genus, and approximate much more closely to those of *willmori* and *pulcherrimus*. The abdomen of *stephensi* is also much more heavily scaled than that of other species classed in the genus *Nyssorhynchus*, and it seems to us not improbable that Mr. Theobald has confused some specimens of this species with specimens of *maculatus*. This is certainly the case in the Royal Society's Reports (sixth series, page 11) in which the descriptions of the habits and of the larva of the so-called *A. metaboles* (= *stephensi*) should be read as referring to *maculatus* and not to *metaboles* at all. In the same way his figure and description of the larval palmate hairs of *stephensi* (Vol. III, pages 47 and 85), are incorrect, and should be read as referring to *maculatus*. The terminal filaments of the palmate hair leaflets of the larva of *stephensi* are long and pointed as in Plate VI, Fig. 2.

GROUP VII.

Type :—*A. turkhudi.*

18. Anopheles turkhudi (Liston).

(Coloured Plate XIV. Plate VIII, Fig. 2).

References :—Liston, *Ind. Med. Gaz.*, December, 1901, p. 441 ; Theobald, Monog. Culic., Vol. III, p. 48.

Synonym, *Myzomyia Turkhudi* (Theboald).

A large brown mosquito with characteristic black tips to the palpi.

The tips of the palpi are black-scaled. There are, however, three white bands on each palp. One circle is situated on the middle of the terminal segment, while the other two are situated at the anterior extremities of the second and third segments.

The proboscis is covered with dark scales, but is yellow at its tip.

The head is covered with brown and white scales. There is a small frontal tuft of white hairs.

The thorax is covered with long thin golden and white hair-like scales. The scales are so arranged as to show a median and two less distinct dark longitudinal markings. The lateral aspects

of the thorax are covered with brown scales. The abdomen is of a dark olive green colour, and is covered with many light yellow hairs. The wings are covered with long spindle-shaped scales.

The costa shows six white-scaled portions; one of these is apical.

The first longitudinal vein has white areas corresponding with the outer five white areas on the costa. There is, however, in addition, a small white-scaled interruption at the position of the transverse vein.

The second longitudinal vein has five white-scaled areas; two at the position of the transverse veins, one at the bifurcation of the vein and two on its anterior branch.

The third long vein has two light-scaled portions—one at the position of the transverse veins, and the other immediately below the white area on the bifurcation of the second long vein.

The fourth long vein is white-scaled at its base, and has in addition a white-scaled portion at its bifurcation, and another at the position of the transverse veins.

The trunk of the fifth longitudinal is white-scaled, except for a single small dark-scaled portion. At its bifurcation it is dark-scaled; and its branches are dark-scaled, except for one white-scaled portion on each.

The sixth long vein has a single white-scaled area. The wing fringe is interrupted by light scales at the distal extremities of all the veins except the sixth.

The legs are dark-scaled throughout, except for a few yellowish-white scales at the distal extremities of the femora and tibiæ.

The extremities of the claspers of the male genitalia are of a different shape to those in most other "anopheles."

Characters of the eggs and larvæ.—Dr. Christophers has shown that the eggs of this species are very peculiar in that the lateral floats are exceedingly rudimentary and sometimes are scarcely to be made out at all (Fig. 8, p. 39).

The larvæ are also peculiar in that there are, as a rule, no palmate hairs on the first three abdominal segments, these hairs being borne only by the fourth to the seventh segments. For this reason the larvæ rest at the surface of the water in a somewhat oblique attitude. The shape of the palmate hairs is shown in the figure; in

addition to the two pairs of unbranched frontal hairs, a third pair of simple hairs ("Posterior" hairs) project over the mouth parts behind and between the frontal hairs.

Habitat and observations.—First found at Ellichpur in the Berars. It also occurs in the Central Provinces (Nagpur), in Aurungabad (Hyderabad State), and in Kashmir.

The black-tipped palpi serve to distinguish this species from all other Indian "anopheles" except *nagpori*, which, however, is easily recognised by the presence of white hind tarsi.

It has been proved that, under experimental conditions, the parasites of human malaria are capable of developing in this species.

GROUP VIII.

Types :—*A. lindesayi* and *A. gigas.*

19. Anopheles lindesayi (Giles).

(Coloured Plate XV).

Reference :—Giles, Handbook Mosq., 1st Ed., p. 166.

Anopheles Lindesayii (Theobald).

A dark brown mosquito with one large yellowish-white spot on its wing near the apex and with thin black unbanded palpi. The femora of the hind legs are marked with a characteristic long white band.

Palpi entirely black, covered with short dark scales. Proboscis black.

Head for the most part covered with dark scales, except over the occiput where they are white.

Thorax covered with hair-like scales; the dorsal aspect of the thorax is of a light grey colour; the lateral aspects are darker.

Scutellum with a few scales and long bristles. Abdomen black, covered with many long hairs. Wings with the veins covered with narrow long spindle-shaped scales.

Costa dark brown; white at its termination.

First longitudinal vein dark brown except at its distal extremity, where it is covered with yellowish white scales.

Second long vein entirely covered with brown scales, except at the tip of each of the branches, where there are light scales.

There is an additional white spot on the posterior branch near its termination.

Third long vein with light scales near its inner extremity, and also at its outer extremity; otherwise covered with dark brown scales.

Fourth long vein covered with dark scales except for a light spot on each of its branches; the spot on the anterior branch is on the middle of its course; the spot on the posterior branch is at its outer extremity.

Fifth long vein for the most part covered with dark scales, except at its bifurcation where there are white scales. There are, in addition, two light-scaled areas on its anterior branch.

Sixth long vein covered with dark scales except at its tip.

The wing fringe is interrupted by light scales.

The legs are for the most part covered with dark scales. There are light scales at the distal extremities of the femora and tibiæ in all the legs. The hind femora have a characteristic broad white band in the middle third of their length.

Characters of the larva.—Dr. Christophers states that the larval antennæ of this species are provided with a small rudimentary branched hair somewhat like the branched hair on the antennæ of the larvæ of *barbirostris* and *nigerrimus*. The frontal hairs are simple and unbranched. There are no thoracic palmate hairs.

Habitat and observations.—This species appears to occur only in hill districts. A few specimens were obtained at Reneghat (Bengal) at an elevation of about 4,000 feet. It also occurs at Bakloh (6,000 feet) in the Punjab, and at Naini Tal (6,500 feet).

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20. Anopheles gigas (Giles).

(Ento. Mo. Mag., Vol. XXXVII, 1901, p. 196.)

Anopheles gigas (Theobald).

We regret that we have not been able to obtain specimens of this mosquito. The following description is extracted from Mr. Theobald's Monograph, Vol. II, p. 308.

Thorax fawn-coloured in the middle, dark brown on each side; abdomen dark brown; legs dark brown with basal pale bands, pale at the base; wings with two large black spots along the costa and black patches on the wing field; fringe with pale areas.

Anopheles gigas.

Head brown grey in the middle; proboscis long, deep brown, curved; palpi long with deep brown scales, rather thin, not quite as long as the proboscis; antennæ pale brown.

Thorax pale fawn-coloured in the middle; dark rich brown on each side, and a narrow thin dark median line; the middle area with frosty grey tomentum and narrow curved hairs; scutellum pale; metanotum chestnut brown.

Abdomen deep brown with long golden hairs. Wings large the costa black with three creamy spots, the black forming two large black spots which extend over the first long vein and upper branch of the second and base of the fork cell, there is also a black patch on the lower branch of the sub-marginal cell, and two on the stem, one basal; a small dark patch at the base of the third long vein, all the rest creamy-yellow; a black patch at the apex of each branch of the second posterior cell and another at the base of the cell, greater part of the stem dark-scaled; three black patches, the median one large, on the upper branch of the fifth vein, base of the fork dark, and another dark patch towards the base of the vein; sixth vein mostly black-scaled with a median pale patch; fringe pale where the veins join the border of the wing, except at the ends of the fifth vein, which have no pale fringe spot, but a pale area between the two branches; supernumerary cross vein nearer the apex of the wing than the mid-cross vein, the posterior cross vein nearly three times its length distant from the mid-cross vein. Halteres with dense black knob.

Legs long, with coxæ and trochanters pale, almost white, remainder deep brown with traces of basal pale banding especially to the metatarsi and tarsi of the hind legs.

Habitat.—Coonoor, Nilgherri Hills, India, 6,000 feet.

GROUP IX.

Types :—*A. aitkeni* and *A. immaculatus.*

21. Anopheles aitkeni (James).

(Figure facing page 120, Plate IX, Fig. 3.)

Reference :—Theobald, Monog. Culicid., Vol. III, p. 22.

A small mosquito of a uniformly dark colour and with unspotted wings.

Head black, with a few white spindle-shaped scales in front and long narrow deep brown upright-forked scales behind. There is no marked frontal tuft of hairs. Palpi covered with small black scales and with no trace of banding. Antennæ with long black hairs at the joints. Proboscis brown.

Thorax dark brown, with long brown hairs but without scales. Scutellum with long dark bristles.

Abdomen black, without scales, but with many long brown hairs.

Wings with the veins completely clothed with dark scales. The first sub-marginal cell is much longer and narrower than the second posterior cell.

The supernumerary cross vein is internal to the mid-cross vein. Posterior cross vein internal to mid-cross vein and nearly opposite supernumerary cross vein.

Legs brown throughout. The coxæ are pale. There is no trace of banding at any of the joints. The hind first tarsal segment (metatarsus) is longer than the tibia.

Characters of the larva (Fig. facing text).—Median frontal hairs stout and bifurcated like the prongs of a pitchfork ; external angular hairs simple, short, and unbranched. Palmate hairs well-developed on the second to the seventh segments. Terminal filament of each leaflet not sharply marked off from the body and rather short.

Habitat and observations.— Collected near Karwar by Dr. Cogill, and on the hills above Karwar (Goa frontier) by Mr. Aitken.

This mosquito very closely resembles *bifurcatus* and *algeriensis*, but according to Mr. Theobald it can be at once distinguished from those species by the striking dissimilarity in the size of the fork cells.

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22. Anopheles immaculatus (Theobald).

References :—Theobald, Monog. Culicid., Vol. III, p. 23 ; James, "Malaria in India," p. 45.

Anopheles immaculatus (Theobald).

The single representative of this species was caught by Dr. Stephens, of the Royal Society's Malaria Commission, at Ennur, near Madras. The following is Mr. Theobald's description :—

Thorax ashy-brown, with darker marks and pale hairs ; abdomen brown, with golden hairs, most dense apically ; palpi shorter than usual, brown, becoming ochraceous to almost white apically ; legs

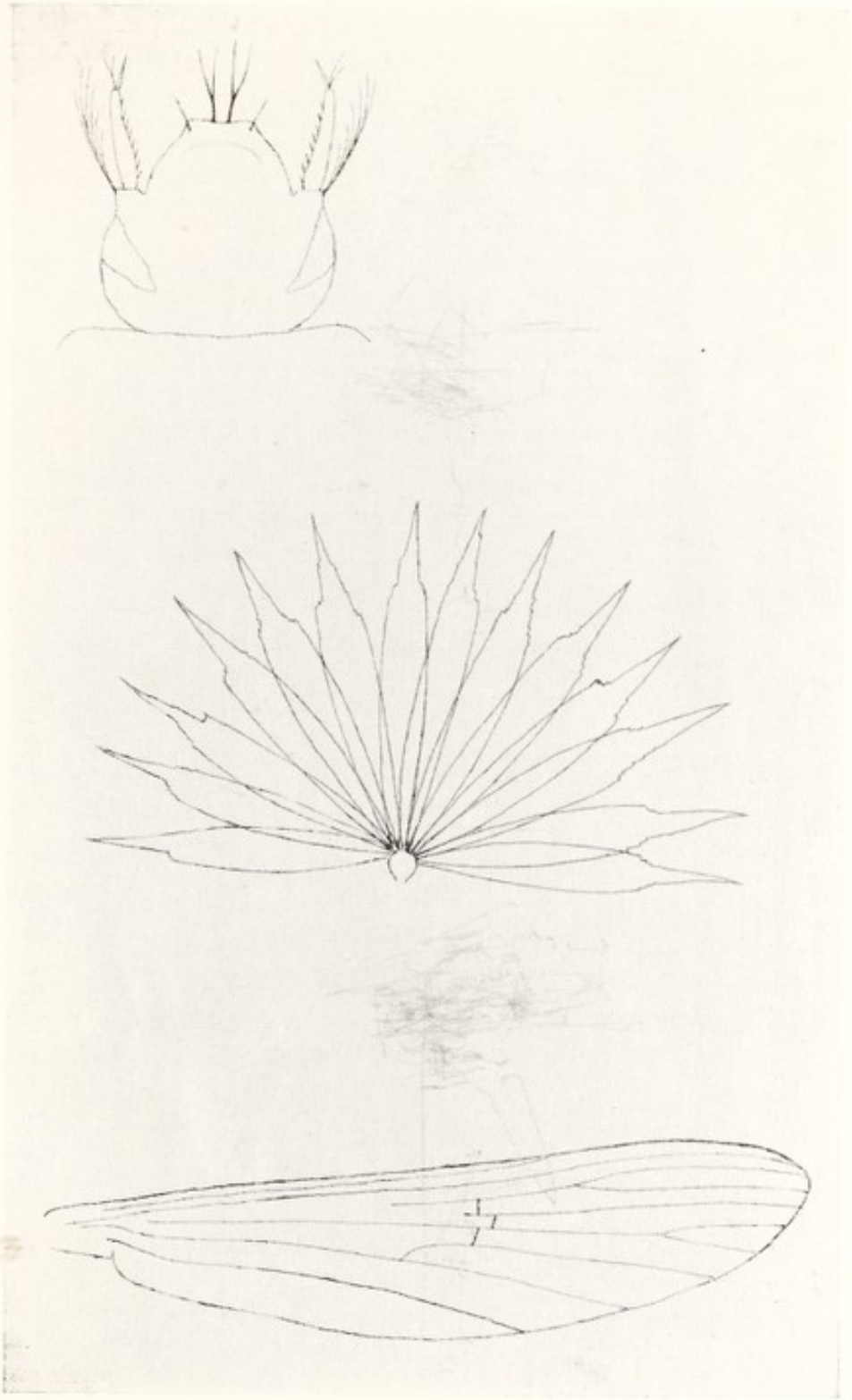

PLATE XIII. *Anopheles aitkeni ;* showing the head of the larva (note the "basal hairs" external to the antennæ), a palmate hair, and the outline of the wing.

brown, with ochraceous reflections, the tarsi dark in some lights, with pale apical bands ; wings with ochraceous veins, unspotted.

Head dark brown, with grey upright-forked scales in front, ochraceous and darker ones behind, while narrow-curved scales in front form a more or less projecting mass, beneath which arises a tuft of long white hair-like scales ; antennæ brown, the basal joint bright testaceous, the next few joints with pale scales ; palpi short for an *Anopheles*, rather thick, covered with dense brown, grey and ochraceous scales, the brown scales basal, the others forming most of the apical covering ; proboscis about the same length as the palpi, ochraceous brown with a paler tip.

Thorax ashy-brown with slaty reflections, with darker longitudinal lines, one being median, the surface with pale golden, hair-like curved scales, a tuft of pale scales projecting over the head in front ; scutellum with narrow-curved, hair-like, pale golden scales, and brown border bristles ; metanotum deep brown.

Abdomen deep brown to black, with golden hairs, which are very dense on the apical segments.

Legs ochraceous with brown scales, scantily set on the femora, so that they appear dull ochraceous ; the tarsi are darker, especially on the hind legs, which have the apices of the joints banded with ochraceous ; to some extent this banding may be seen in the fore and mid legs ; ungues equal, simple, deep brown, large for an *Anopheles*.

Wings unspotted, with yellowish veins and pallid scales ; fork-cells rather short, the first sub-marginal longer and narrower than the second posterior cell, their bases nearly level, the stems longer than the cells ; supernumerary and mid-cross veins apparently in one line, the posterior cross-vein about three times its own length behind the mid-cross vein ; halteres ochraceous.

Habitat and observations.—Mr. Theobald says the specimen is " evidently from Goa," and that it was given to him by Captain Liston. This is incorrect. It was captured at Ennur—a small village on the East Coast about ten miles from Madras—and sent to Mr. Theobald by Dr. Stephens.

The markings on the palpi must have faded somewhat by the time the specimen reached Mr. Theobald, for in the fresh state three white bands were distinctly present—a very broad apical one extending over nearly the outer half of each palp, and two very narrow basal ones.

GROUP X.

Type :—*A. culiciformis.*

23. Anopheles culiciformis (*sp. n.*)

(Figure facing page 122).

This is a rather large, brown "anopheles," for some time confounded with the much smaller *A. aitkeni* till separated by Dr. Cogill by its very markedly "culex" like attitude, by the relative position of the transverse veins, and particularly by the marked difference in the structure of the larva. This mosquito might be Theobald's *Stethomyia nimba*, but he states that in that mosquito the halteres have a pallid stem and fuscous knob, while this species has a black knob covered with brown scales. Another important difference is found in the characters of the male insect, for while Theobald states that *S. nimba* has the fore ungues in the male unequal, the larger uniserrated, Dr. Cogill has drawn our attention to the fact that there is only one claw on each fore leg of *culiciformis* and that has only a single tooth. In all other respects this mosquito conforms with Theobald's description of *S. nimba*.

The palpi are entirely covered with brown scales; without any bands; rather shorter than the proboscis.

The head is chiefly covered with brown upright-forked scales, but there are a few white spindle-shaped scales in the middle line in front; there is no distinct frontal tuft of hairs. There are rather more numerous and stronger brown hair-like bristles around the eyes and on the front of the head than is usual in other "Anopheles." Thorax covered with a few white hair-like scales and many long brown bristles. Prothoracic lobes distinctly mammilated as in Theobald's *Stethomyia nimba*. Scutellum with long brown bristles; in the middle there are a few short scale-like bristles.

Abdomen brown, covered with numerous fine golden and coarse brown hairs.

Wings unspotted and covered with rather broad spindle-shaped scales approximating in shape to those found on *nigerrimus*. Venation as in other "Anopheles." Transverse veins almost in one line.

Halteres with light stem and dark brown knob covered with brown scales.

Legs long and thin, entirely brown and covered with scales.

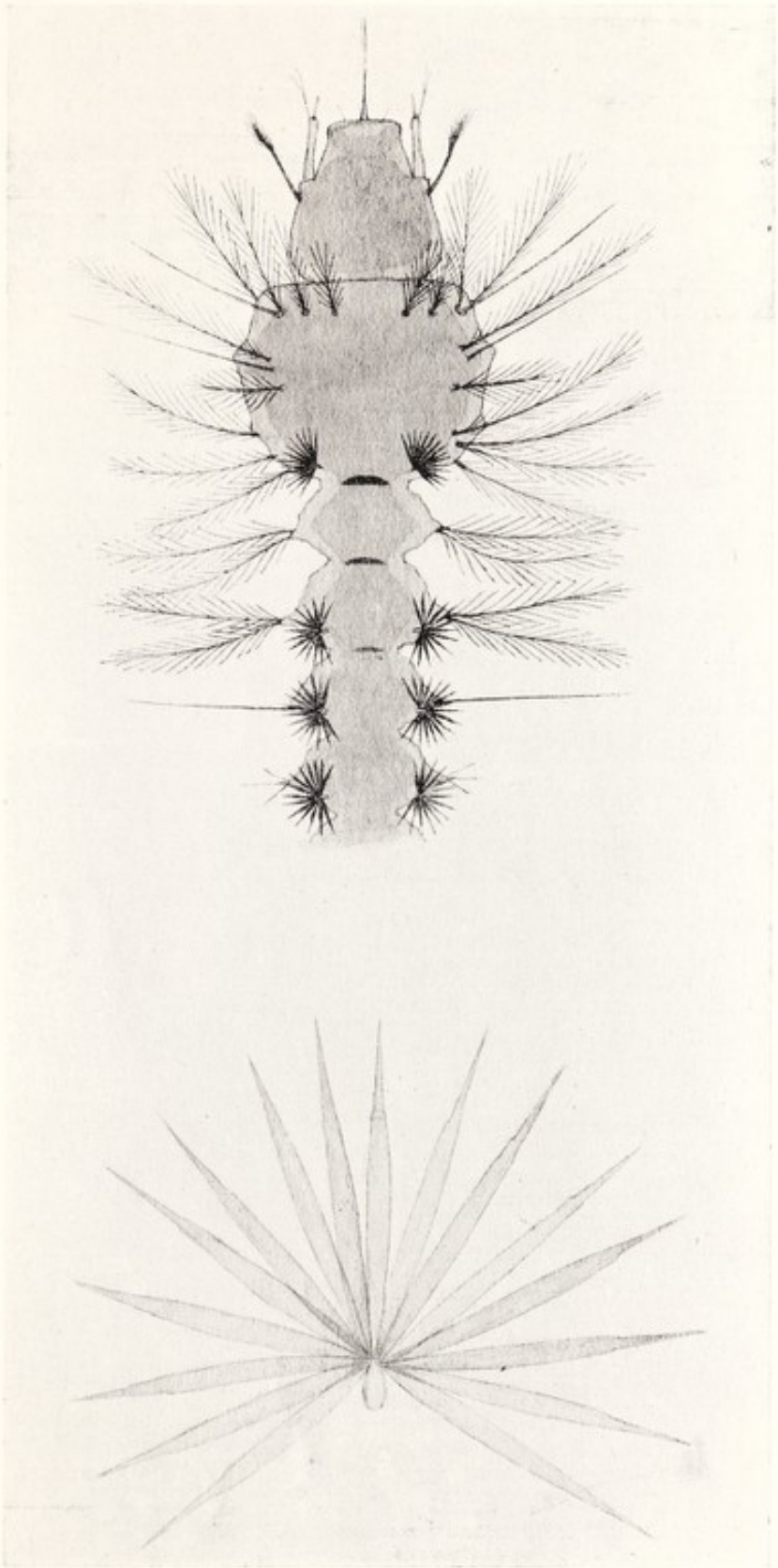

PLATE XV. The larva of *A. culiciformis ;* showing the characteristic "basal hairs" external to the antennæ, the absence of palmate hairs on the first abdominal segment, and the shape of the palmate hair leaflets.

Anopheles culiciformis.

The male of this mosquito differs from all other "anopheles" in that the claws on the fore legs are single and uniserrated. There are structural differences too in the larva which differentiate this mosquito from all others.

Characters of the larva (Fig. facing page 122).—The frontal hairs are simple and unbranched; the median hairs are very close together and long; the external angular very short. The most characteristic and constant feature of this larva is the peculiar structure of the "basal hair." In most "anopheles" this hair is much branched; in the larva of this species it is made up of a long stalk covered with a few hairs; the extremity appears as if jointed to the stalk, and is somewhat swollen and covered with a corona of fine hairs. The next point in which this larva differs from other "anopheles" is that the "balancer" hair on the third abdominal segment is simple and unbranched. A third peculiarity is found in the fact that well-developed palmate hairs are found on all the abdominal segments except the first and last, and there is also a pair on the thorax. The shape of the leaflets of each palmate hair most nearly resembles that of the leaflets of the palmate hairs of the larvæ of *barbirostris*. There is no well defined blade as contrasted with the terminal filament in each leaflet.

Habitat and observations.—This mosquito was bred from larvæ collected near Karwar, in the Bombay Presidency, by Dr. Cogill. There seems to us to be no doubt that it would be placed by Mr. Theobald in his genus *Stethomyia*.

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INDEX OF SPECIES.

The principal reference to each species is printed in heavier type.

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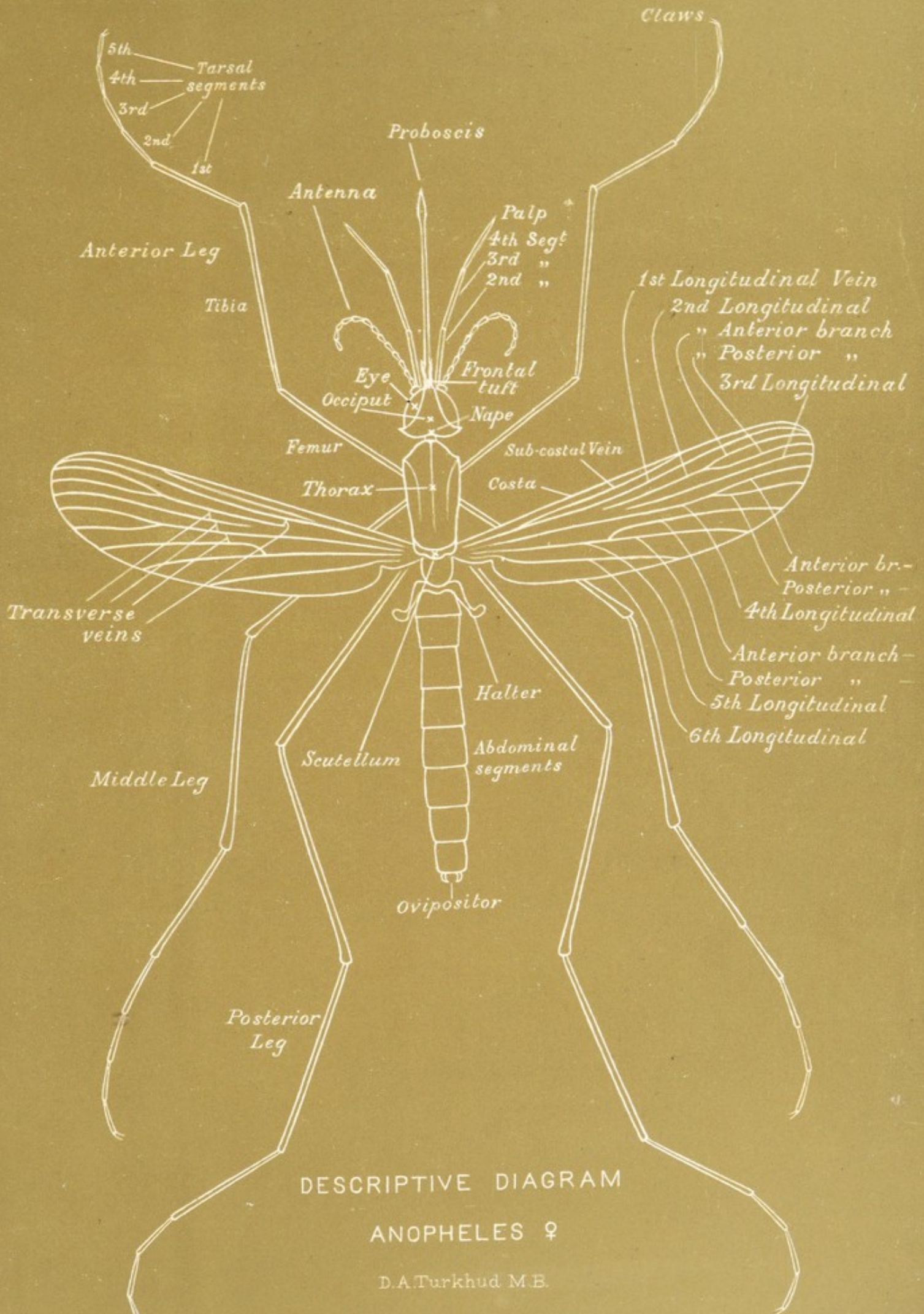
COLOURED PLATE No. I.

Descriptive Diagram of a Female "Anopheles."

Description on page 13.

Description on page 15



DESCRIPTIVE DIAGRAM

ANOPHELES ♀

D.A.Turkhud M.B.

COLOURED PLATE No. II.

Anopheles (Myzorhynchus) barbirostris.

Description on page 77.

Anopheles (Myzorhynchus)
barbirostris.

ANOPHELES BARBIROSTRIS

♀

D.A.Turkhud.M.B.

COLOURED PLATE No. III.

Anopheles (Myzorhynchus) nigerrimus.

Description on page 79.

ANOPHELES NIGERIMUS

♀

D. A Turkhud M.B.

Anopheles (Cellia) pulcherrimus.

Description on page 86.

ANOPHELES PULCHERRIMUS

♀

D. A. Turkhud M.B.

COLOURED PLATE No. V.

Anopheles (Nyssorhynchus) fuliginosus.

Description on page 91.

COLOURED PLATE No. I.

Anopheles (Nyssorhynchus)
fuliginosus.

Description on page 91.

ANOPHELES FULIGINOSUS

♀

D.A.Turkhud M.B.

COLOURED PLATE No. VI.

Anopheles (Nyssorhynchus) jamesi.

Description on page 93.

COLOURED PLATE No. VI.

Anopheles (Nyssorhynchus) jamesi.

Description on page 93.

ANOPHELES JAMESII

♀

D.A.Turkhud M.B.

Anopheles (Nyssorhynchus)
maculipalpis.

ANOPHELES MACULIPALPIS

♀

D.A.Turkhud M.B.

Anopheles (Nyssorhynchus) theobaldi.

Description on page 97.

COLOURED PLATE No. VIII

Anopheles (Nyssorhynchus)
theobaldi.

Description on page 97

ANOPHELES THEOBALDI

♀

D.A.Turkhud M.B.

COLOURED PLATE No. IX.

Anopheles (Pyretophorus) jeyporiensis.

Description on page 101.

COLOURED PLATE No. IX.

Anopheles (Pyretophorus)
leyporiensis.

Description on page 101

ANOPHELES JEYPORIENSIS

♀

D.A.Turkhud.M.B.

COLOURED PLATE No. X.

Anopheles (Myzomyia) listoni.

Synonym, Anopheles fluviatilis.

Description on page 103.

ANOPHELES FLUVIATILIS

♀

D.A.Turkhud M.B.

COLOURED PLATE No. XI.

Anopheles (Myzomyia) culicifacies.

Description on page 106.

COLOURED PLATE No. XX

Anopheles (Myzomyia) culicifacies.

Description on page 100

ANOPHELES CULICIFACIES

♀

D.A. Turkhud M.B.

COLOURED PLATE No. XII.

Anopheles (Myzomyia) rossi.

Description on page 109.

Anopheles (Myzomyia) rossi.

ANOPHELES ROSSII

♀

D.A.Turkhud M.B.

Anopheles (Nyssorhynchus) stephensi.

Description on page 113.

ANOPHELES STEPHENSI

♀

D. A. Turkhud M.B.

COLOURED PLATE No. XIV.

Anopheles (Myzomyia) turkhudi.

Description on page 115.

COLOURED PLATE No. XIV.

Anopheles (Myzomyia) turkhudi.

Description on page 115

ANOPHELES TURKHUDI

♀

D.A.Turkhud M.B.

COLOURED PLATE No. XV.

Anopheles (Anopheles) lindesayi.

Description on page 117.

ANOPHELES LINDESAII

♀

D.A.Turkhud M.B.