MOSQUITOES IN RELATION TO HUMAN PATHOLOGY.—The special importance of the mosquito as an agent in the transmission of disease has been thoroughly demonstrated by recent discoveries, a brief synopsis of which may be given as an introduction to the subject.

HISTORY.—In 1880 Manson, by establishing the connection of mosquitoes with elephantiasis, gave the first demonstration of their culpability in spreading disease. It was the same year (1880) that Laveran discovered the intraglobular parasites now universally acknowledged as the cause of malaria. The transference of these hæmatozoa from one host to another by means of mosquitoes was conjectured as early as 1883 by King and in the following year by Koch and Laveran; but was first actually demonstrated by Ross, in a series of experiments between 1895 and 1899; these facts have been abundantly confirmed by many subsequent investigators. In 1897 MacCallum first observed the sexual phase in the allied avian hæmatozoa, and the further elucidation of the life history of the parasite was brought about by contributions of Ross, Bastianelli, Bignami, Grassi, and others, while unimpeachable evidence of the agency of the mosquito in carrying the disease was furnished by the positive infection experiments of Manson, who imported

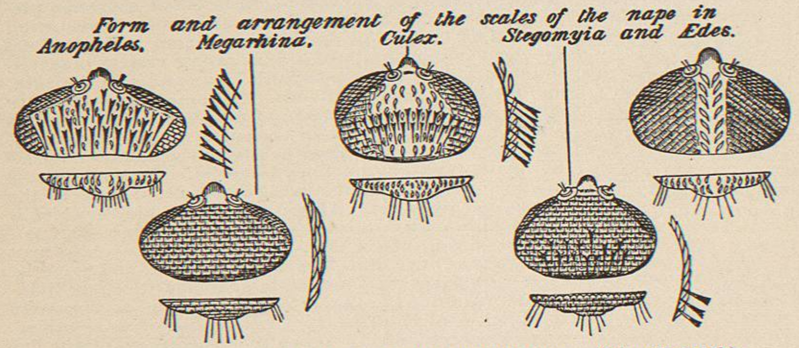

FIG. 3363.—Graphic Key to Scale Arrangement of Leading Genera. (After Theobald.)

from Rome tertian infected *Anopheles*, which evoked the disease in those whom they were permitted to bite in London.

The connection of the mosquito with yellow fever, conjectured by Finlay of Havana as early as 1881, waited until 1900 for its experimental demonstration in the investigations of the Yellow Fever Commission, consisting of Drs. Reed, Carroll, Lazear, and Agramonte, in the course of which two members of the Commission acquired the disease and one, Dr. Lazear, succumbed to it.

Kinds of Mosquitoes.—It is necessary now to consider the various types of mosquitoes before taking up more specifically their relations to disease. In all about three hundred species of mosquitoes have been described, of which only thirty-six species have been recorded in North America. Of these five belong to the genus *Anopheles*, three to *Stegomyia*, and no less than eighteen to *Culex*. It would be impossible within the limits of an article even to outline the complete classification of the group, but some of the most important facts may be stated briefly. The order and family have been sufficiently characterized by Professor Osborn (see *Insects*). It is extremely uniform in character, and only recently has Theobald found a basis for subdivision in the form and arrangement of the scales on the body and wings. His classification with some additions suggested by Giles is followed here. The sub-families are distinguished as follows:

Section A. Proboscis formed for piercing.

I. Brilliantly colored insects with a very long, curved proboscis.

(*a*) Palpi, about as long as the proboscis in both sexes (*Megarhina*); or long in male, shorter in female (*Toxorhynchites*). *Megarhinina.*

II. Dull-tinted insects with straight proboscis.

(*b*) Palpi about as long as the proboscis in both sexes: those of the male clubbed at the end, those of the female linear. *Anophelina.*

(*c*) Palpi about the length of the proboscis in the male but much shorter in the female, being here usually very short. *Culicina.*

(*d*) Palpi very short in both sexes. *Ædomina.*

Section B. Mouth parts not formed for piercing, there being no true proboscis. Palpi small. *Corethrina.*

For the determination of the genera the form and arrangement of the scales, which are all-important, are shown diagrammatically in the figure (Fig. 3363). So far as the species are concerned, it is impracticable to make more than a preliminary determination without referring to a monograph, and there will be mentioned only a few of the more important forms, in those genera which are now known to be responsible for the transmission of disease. A few hints as to methods of collecting and examining will doubtless be useful to the practitioner. The adult mosquitoes are very delicate, so that the parts are easily broken and the arrangement of the scales easily obscured by rough handling. The female may be readily caught on the hand or arm when biting, or even on the wall of a room, by inverting an ordinary vial over it; once trapped a whiff of tobacco smoke or a drop of chloroform will kill it immediately and leave the specimen in good condition for examination or transportation on cotton in a pill box. A good killing vial may be made by confining a small piece of cyanide of potassium at the bottom of a shell vial by a disc of blotting paper cut to fit the vial. After it has been inverted over the mosquito, the cork may be slipped into the mouth of the vial and the insect succumbs almost instantly and without damage. Mosquitoes may be mounted dry on pieces of thin card or cork, but should not be enclosed in balsam as this destroys colors and renders identification difficult. Most of the characters can be determined with a triplet; all with the low power of a compound microscope.

For collecting larvæ, which are often difficult to distinguish against the dark background in a pool, a white cup is useful; or a coffee strainer may be drawn through the vegetation at the margin of a pond or stream and the material obtained may be examined more carefully in a cup of water or on a white plate. Larvæ may be bred in jars, which should be covered with mosquito netting to prevent the escape of the adults when they emerge, while the latter may be kept in frames of netting, but should be provided with a little water and pieces of banana or dates on which they feed. If desired larvæ may also be preserved in dilute formalin or in alcohol. Further data may be found in any of the manuals cited.

Anopheles Meigen (1818).

Head with both flat and narrow curved scales, but mainly covered with large upright forked scales; palpi long in both sexes, usually about the length of the proboscis, four-jointed in the female, three-jointed in the male, in which the last two joints are short and thick; constrictions at the base make the palpi possess apparently one or two extra joints in each sex. Antennæ, fourteen-jointed, filiform, pilose in the female, fifteen-jointed and plumose in the male.

Thorax sometimes nude on the dorsum, usually with narrow curved or small spindle-shaped flat scales. Abdomen generally pilose, but sometimes with a few scales

and rarely with many. Wings covered with small scales of normal form or inflated, with the first submarginal cell longer and narrower than the second posterior cell; both

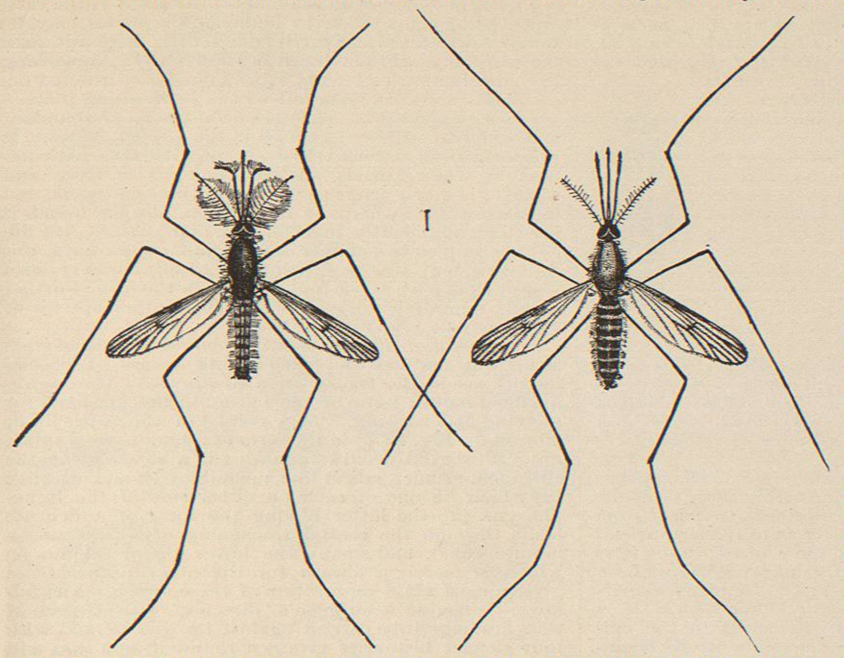

FIG. 3364.—*Anopheles maculipennis* Meig. Male at left, female at right. (After Howard, Bull. United States Dep. Ag.)

the second and third long veins run past the cross veins into the basal cells, a very marked characteristic.

The etiological importance of this genus has been thoroughly demonstrated in its transmission of malaria, and it has also been shown to be instrumental in transmitting filiariasis. As a genus it is widely distributed, with the exception of the higher latitudes. Nuttall has shown that in England this distribution compares exactly with the old limits of ague, but the genus also occurs in districts where no ague is known to have existed. It does not follow that because *Anopheles* are found, malaria is present; but wherever the latter occurs, the presence of *Anopheles* in considerable numbers has been demonstrated. *Anopheles* is moreover accustomed to fly and to bite only after sunset, so that by keeping within well-screened houses after that hour malaria is avoided even in the worst infected localities. The bite of this genus is believed to be less irritating than that of other mosquitoes and from its habits of lurking near the ground it is less likely to be discovered. Its hum is said to be less distinct than that of *Culex* and of a lower pitch. The adults hibernate in woods, and the larvæ may be found both in fresh and in salt water, even after frost has occurred.

Anopheles punctipennis Say. Wings with the costa black, interrupted by a single large ferruginous spot a little outside the transverse veins, with also a smaller apical spot and some yellow spots near the tips of the long veins. Legs and tarsi nearly uniformly black. Thorax and abdomen deep brown, nude except for some yellowish-brown hairs; wings much longer than abdomen; head black with a scanty whitish frontal tuft, palpi and proboscis dark yellowish-brown unbanded, but rather lighter at the tips, length 5 to 7 mm.

This species is very widely distributed over our continent and is said to be called the "winter mosquito," having been taken when the temperature was only 6° F.

Anopheles maculipennis Meigen (1818) (Fig. 3364). Wings with four tufted spots on the wing field, the costa being uniformly dark except at the apex, where its color fades to form a fairly distinct spot; tarsi unbanded but with an apical yellow spot at the first joints. Thorax with four broad ferruginous stripes formed of golden hairs with the darker ground color left bare between and a tuft of large golden scales on the anterior border. Abdominal segments brown with yellowish basal markings. Anterior femora not thickened at the base. In the female the head with two patches of creamy scales divided by a central line, otherwise with black scales; a small tuft of white hairs in front and the borders of the eyes white. Male with antennæ banded, proboscis black, palpi dark brown. Length of male 4 to 7.5 mm., of the female 8 to 10 mm.

To illustrate the great variation of this species in size, Giles has drawn the wing of an Italian specimen over the wing outline of a Canadian specimen from the British Museum in a figure which is here reproduced (Fig. 3365).

The sub-family of the Culicina is the largest among the mosquitoes, and its type genus *Culex* includes more than one hundred and fifty species. In addition to the characteristics mentioned in the synopsis above it may be noted that the anterior fork cell is at least as long as the hind one. Of the dozen genera only two are noted.

Stegomyia Theobald 1901. Palpi short, four-jointed in the female; long, five-jointed in the male. Head clothed completely with an armour of broad, flat scales; mesothorax covered with either narrow curved or spindle-shaped scales. Scutellum always with broad flat scales on the middle lobe and usually also on the lateral lobes; abdomen completely covered with flat scales, banded or unbanded, but always with white lateral spots. The female palpi are small, never more than one-third the length of the proboscis; those of the male are as long as, or longer than, the proboscis. Wings of similar venation to those of *Culex*, but the fork cells are short. With hardly an exception they are colored jet black contrasted with pure white in bands and stripes on the legs and thorax, which is often elaborately adorned; in all black predominates, and they have a characteristic smooth satin-like appearance.

As these mosquitoes are rarely found north of 40° North latitude, they are characteristically tropical and

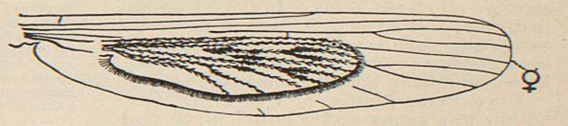

FIG. 3365.—Wing of *Anopheles maculipennis*. Outer outline to show size variation. (After Giles.)

subtropical forms. They are said to be good sailors and as a result *S. fasciata* belts the world with its colonies, being the most widely distributed of all mosquitoes.

The description of this cosmopolitan species is as follows:

Stegomyia fasciata (Fabr.). Wings (Fig. 3366) densely clothed with very long black scales of three lengths. Last hind tarsal joints and all but the apex of the next snowy; all the other joints of the hind, the upper three of the mid, and the upper two of the fore legs of the otherwise black tarsi basally white banded. Thorax from a velvety black with reddish reflections to a golden brown in some specimens, elaborately marked with rather broad silvery lines arranged in the form of a lyre (Fig. 3367). First abdominal segment creamy white, the others black with narrow basal bands and brilliant lateral tufts of snowy white. Proboscis unbanded, black. Head black with narrow white orbits and two faint patches of white on the occiput divided by delicate median and lateral black lines. Of moderate size, often very small, some even with wing length not exceeding 2 mm. In some places a pure rainy weather species.

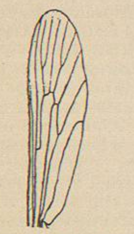

FIG. 3366.—*Stegomyia fasciata*. (After Giles.)

FIG. 3367.

The extreme variation in size and color markings has led to the frequent redescription of this form as a distinct species. Giles says that specimens hatched from the same tank vary so very widely as to render varietal limits decidedly uncertain. In the United States it is common throughout all the Southern States, having been found about as far north as Norfolk, Virginia, while its previous or occasional range as far as Philadelphia, New York, and Providence is clearly indicated in the epidemics of yellow fever at those places about the beginning of the last century. It is said to be troublesome in the early afternoon and again at night, in contradistinction to the majority of mosquitoes, which are twilight flyers. It certainly is a hardy species, and individuals infected with yellow fever have been kept alive seventy-one days, thus showing how contagion of yellow fever may cling to a building which has been vacated more than two months. According to Gorgas it breeds principally in yards in more thickly settled parts of the city, in all fresh-water collections, such as rain-water barrels.

Culex Linnæus. Palpi short, three- or four-jointed in the female, with the last joint usually large; long, three-jointed in the male with the last two joints swollen much as in *Anopheles*, or narrower with the last pointed. Antennæ fourteen-jointed; pilose in the female, plumose in the male, where the last two joints are long and thin. Head with narrow curved scales over the occiput and upright forked scales thick on the back of the head, with flat scales on the sides. Thorax with narrow, curved, hair-like or spindle-shaped scales. Scutellum with narrow curved or spindle-shaped scales only. Abdomen with flat scales. Wings (Fig. 3368) with small median scales on the veins and more or less thin linear lateral ones on some or all of the veins. In the wings the first submarginal cell is longer and narrower than the second posterior cell, and the posterior cross vein is always nearer the base of the wing than the mid-cross vein.

The extreme number of species included within this genus makes it difficult to find one's way even with the aid of a monograph. Here only a few of the most characteristic forms may be briefly mentioned. So far as is known *Culex* is responsible for the transmission to man of filarial disease only, although avian malaria is certainly transmitted by members of this genus. Experiments have shown that it is not concerned in the transmission of human malaria. The salt-water or ring-legged mosquito of the Atlantic coast, *Culex solicitans*, is a small gray mosquito with the legs banded in black and white. It breeds abundantly in the brackish swamps of the eastern coast from Florida to Maine. The larvæ may be found where the water carries one-fourth more salt than the sea, but it will not breed in fresh water. According to Smith it swarms twenty miles inland and is found occasionally as far as forty miles from its breeding place.

Culex pungens (Fig. 3369) is one of the most abundant and widely distributed species in the United States. It breeds in fresh water exclusively, and its larvæ are common in water barrels, cisterns, hollows in trees, and stumps, in city gutters as well as in transient pools, and in fresh-water swamps. In Havana, Gorgas found it breeding abundantly in cesspools and drains. Its life cycle occupies in summer a minimum of ten days, but its larvæ may live over winter, and adults have been reared from such larvæ found frozen in the ice. Further details regarding the genus and some other species of *Culex* may be found under *Insects*.

Structure and Habits.—Mention should be made of such structural features and such habits as are of special importance in the transmission of disease. The highly modified mouth parts of the mosquito are arranged for piercing and sucking. They consist of the upper lip or labrum (*a*, Fig. 3370) in the form of a long narrow spine, grooved ventrally and terminating in a sharp point, the still more slender lancet-like mandibles (*b*) and maxillæ (*w*) which lie one of each on either side of the hypopharynx (*k*), the latter having the form of a delicate blade through the central thickening of which runs a minute canal, and finally the lower lip or labium (*c*) which is merely a sheath for the other parts. Giles gives a most vivid description of these structures as follows: "Imagine a surgeon's 'director,' with a piece of thin drainage tube carried against its groove, and with four slender bistouries grouped round it, and you will have a fair working model of the malaria-inoculating apparatus of the mosquito." The upper lip bears at its base a bulb in which are muscle fibres serving as extensors and retractors. Its groove forms somewhat more than a semicircle, and is converted into a complete canal by the flattened hypopharynx lying just below; it is through this canal that blood flows into the mouth cavity. The delicate tube noted above, as piercing the hypopharynx, is the continuation of the salivary duct and through it the salivary secretion, with the "sickle spores" or sporozoites of the malarial parasites, is injected into the vertebrate host, while at the same time the blood of this host is flowing back through the labrum into the digestive cavity of the mosquito. In biting, the mandibles and maxillæ appear to cut a passage through the skin by the thrust of the head and the labrum is forced into the opening thus made, while the flexible labium holds together and directs the other parts, its stem being looped down out of the way as the latter proceeds deeper and deeper into the skin.

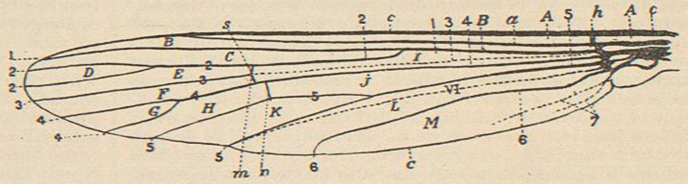

FIG. 3368.—Wing of *Culex concolor* (male) to illustrate Terminology. *c*, Costa; *a*, auxiliary vein; 1–6, first to sixth longitudinal veins and branches; 7, seventh or false (unscaled) longitudinal vein; *VI*, unscaled vein between fifth and sixth longitudinal veins; *h*, humeral transverse vein; *s*, supernumerary transverse vein; *m*, middle transverse vein; *p*, posterior transverse vein; *A*, costal cells; *B*, subcostal cells; *C*, marginal cell; *D*, anterior fork cell or first submarginal cell; *E*, second submarginal cell; *F*, first posterior cell; *G*, hinder fork or second posterior cell; *H*, third posterior cell; *I*, first basal cell; *J*, second basal cell; *K*, anal cell; *L*, axillary cell; *M*, spurius cell.

The course taken by the spores of the malarial parasite in reaching the new host can be reasonably set down about as outlined above; with the embryonic filariæ, however, the case is different and much less satisfactorily explained. These worms are known to bore their way out from the stomach of the mosquito into the muscles and thence through the connective tissue and lymph spaces through which they penetrate, even into the labium which possesses a considerable amount of suitable tissue. Here, in the opinion of Grassi, they produce swelling, and when the organ is sharply bent in biting the delicate covering is ruptured and the worms are set free, to find their way along the mouth parts and into the tissues of the new host. Bancroft maintains that the embryos of *Filaria immitis* always escape at the extreme tip of the labium as if a natural orifice existed there. On the other hand, the investigations of Kellogg in Samoa seem to show that the embryos of *Filaria Bancrofti* (= *F. sanguinis hominis*) are liberated from mosquitoes which die and fall into pools of water, and are taken up by the natives in drinking from these pools.

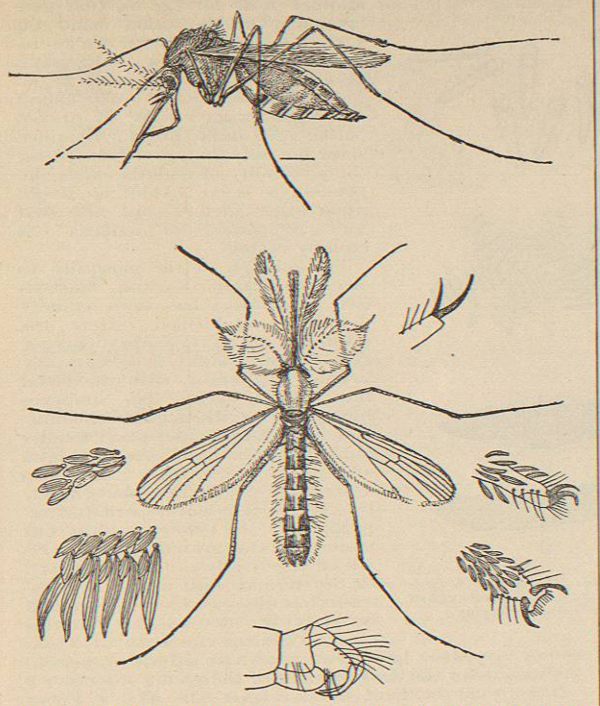

FIG. 3369.—*Culex pungens*. Female above, male below. Enlarged. (After Howard, Bull. United States Dep. Ag.)

The organism which produces yellow fever has not yet been discovered, and all statements regarding the precise mode of introduction into man by the mosquito are purely conjecture. The interval of twelve days or more which, according to the investigations of the Yellow Fever Commission, must intervene after contamination before the mosquito can carry the infection, shows clearly that the organism of the disease is not merely adherent to the mouth parts of the insect but enters its body and undergoes some part of its life history within the tissues, at the termination of which only is it in condition for transference to a new human host. In many ways it recalls the case of malarial parasites and a similar method of transference appears probable.

In other cases in which the mosquito acts as a supposed transmitter of diseased germs, the occurrence is more probably only a passive carrying, from one human host to another, of the germs which chance to adhere to the mouth parts. The case cited by Giles and mentioned more in detail below seems to fall into this class.

Though some species are active and annoying during the day, adult mosquitoes are generally nocturnal or twilight flyers, shunning the direct rays of the sun, which they cannot endure even for a short period. They hibernate in warm, dark places, and may be found in barns, cellars, and other out-of-the-way spots during the winter. During cool days in summer they do not feed, and their abundance and virulence are clearly related to rainfall and temperature. The natural food of all species is probably plant juices, and the male with rare exceptions does not go beyond this. For experimental purposes banana or dates constitute the most acceptable food articles. Even to the female, however, a meal of blood does not seem to be essential to reproduction in spite of the efforts made to obtain it. It was formerly believed that a female mosquito, after having had a single meal of blood, laid her eggs and then died. Several investigators have recently found that she may survive and bite again either before or after oviposition. It is this occurrence which inoculates man with malaria or yellow fever germs or filariæ.

When resting all mosquitoes support themselves on four legs, the last two being held waving in the air; but the posture of the body is sufficiently different to distinguish most forms of the two common genera. *Culex* stands with a noticeable hump, the head and mouth parts forming a decided angle with the thorax and abdomen, which moreover droops, while in *Anopheles* these regions form a single straight line which is oblique or even vertical to the surface on which the mosquito is resting. So far as known, this characteristic attitude has but a single exception (*Anopheles culicifacies* Giles), a species foreign to this continent.

Life History.—The female mosquitoes always deposit their eggs in water, and while the precise environment selected by each species is usually characteristic, the general statements made regarding different genera are often misleading. On the other hand, eggs and larvæ can be found and distinguished with ease. The eggs of *Culex* are deposited in an elongated boat-shaped mass (1, Fig. 3371) about the size and color of a caraway seed. These masses float on the surface until the embryos are hatched. *Anopheles'* eggs are deposited singly or in irregular detached groups, and each is provided with a floating organ (7, 8, 9, Fig. 3371) of air chambers to keep it at the surface. The eggs of *Stegomyia* (6, Fig. 3371) are also deposited singly and provided with a floating organ.

According to Carroll, Agramonte, and Lazear, they may be held dry for a month and yet develop when brought into water again.

The larvæ of all mosquitoes, familiarly known as "wrigglers," float at the surface for respiratory purposes, and if they leave this position it is only for a short time. Those of *Culex* possess a very large head, a long respiratory siphon, and hang head downward at a considerable angle with the surface (Fig. 3372). *Stegomyia* larvæ assume nearly the same position, though somewhat more nearly transverse since the respiratory tube is shorter.

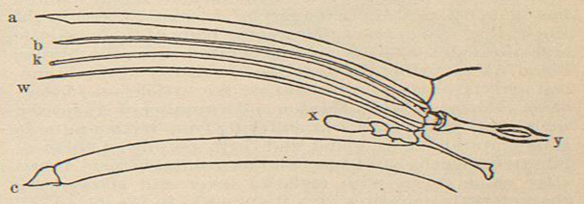

FIG. 3370.—Mouth Parts of Female Mosquito, diagrammatic. *a*, Labrum; *b*, mandible; *c*, labium; *k*, hypopharynx; *w*, maxilla; *x*, maxillary palp; *y*, basal joint of maxilla. (Paired organs represented by left member only.) (After Giles.)