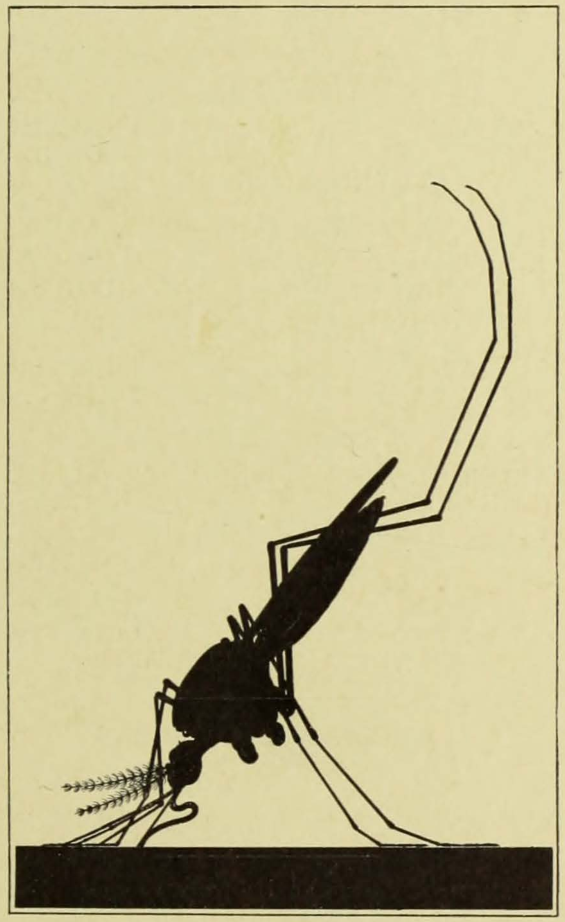
AMERICAN MUSEUM OF NATURAL HISTORY

The Malaria Mosquito



By B. E. DAHLGREN, D. M. D.

Assistant Curator of Invertebrate Zoölogy

GUIDE LEAFLET NO. 27

APRIL, 1908

American Museum of Natural History

Seventy-seventh Street and Central Park West, New York City

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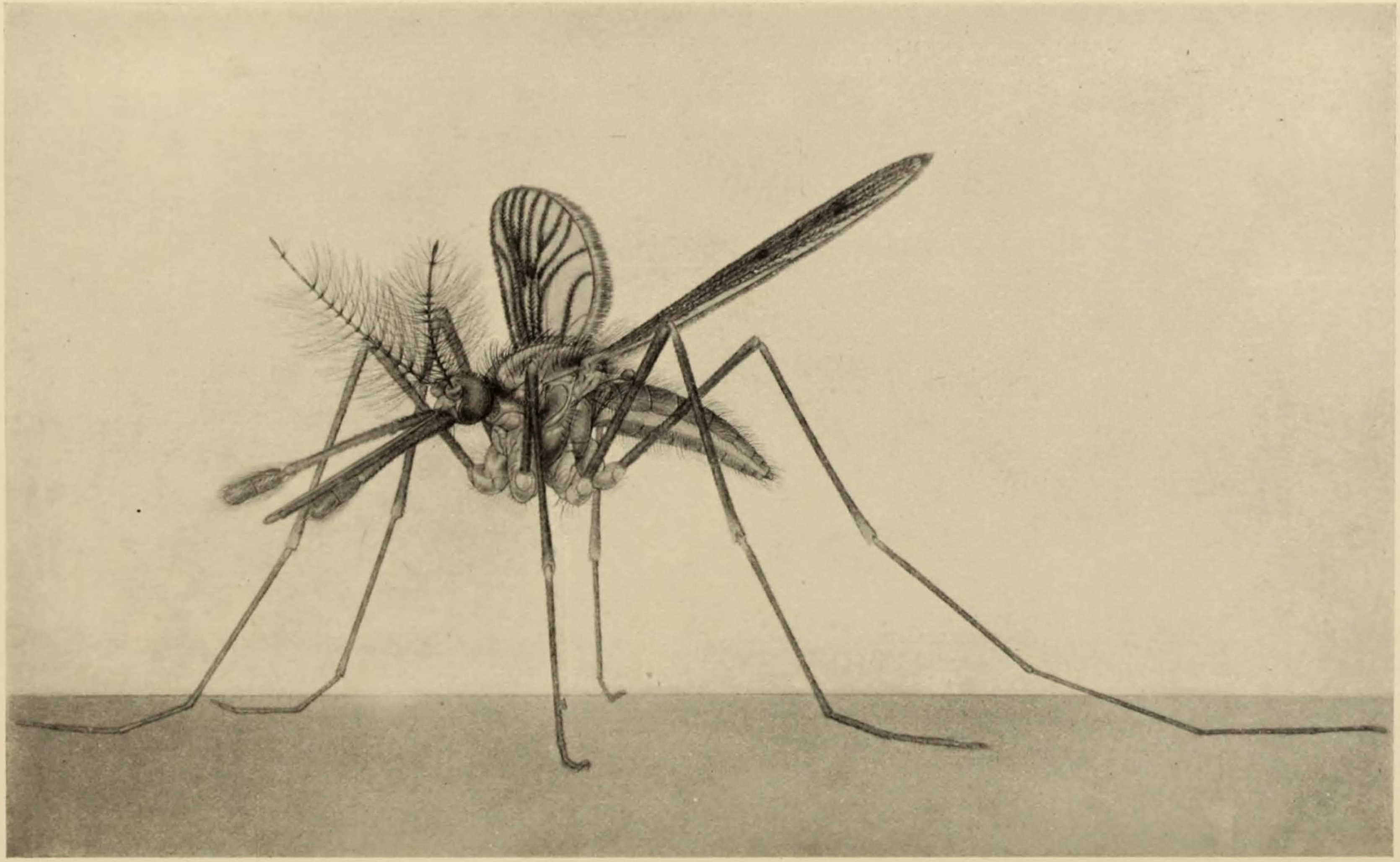


FIG. I. THE MALARIA MOSQUITO (*Anopheles maculipennis* Meigen). MALE.

From a photograph of the model (× 75) in the American Museum. Magnification of figure about 9 diameters.

The Malaria Mosquito

A GUIDE LEAFLET

EXPLANATORY OF A SERIES OF MODELS

IN THE

AMERICAN MUSEUM OF NATURAL HISTORY

By B. E. DAHLGREN, D. M. D.

ASSISTANT CURATOR OF INVERTEBRATE ZOOLOGY

NO. 27

OF THE

GUIDE LEAFLET SERIES

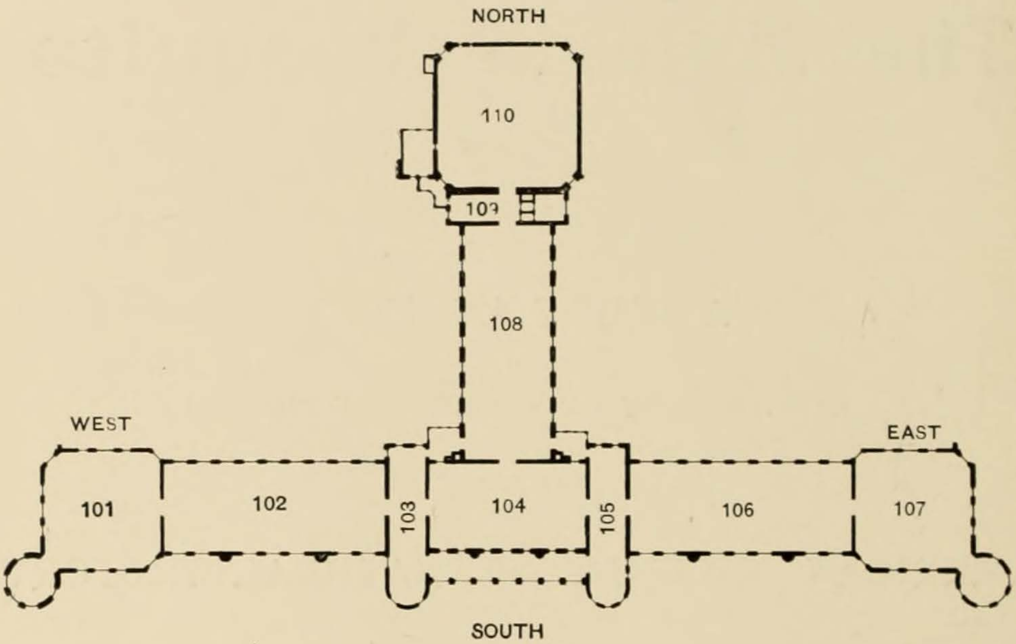
OF THE

AMERICAN MUSEUM OF NATURAL HISTORY

EDMUND OTIS HOVEY, EDITOR

New York. Published by the Museum. April, 1908

FIRST FLOOR



SKETCH PLAN OF FLOOR.

The series of enlarged models (× 75 diameters) the construction of which led to the studies upon which this Leaflet is based in part were prepared at the Museum by and under the direction of Dr. B. E. Dahlgren, the author of the Leaflet. The models have been placed on exhibition in the middle of the Synoptic Hall, No. 107, at the east end of the ground floor of the building.

EDITOR.

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THE MALARIA MOSQUITO.[1]

By B. E. Dahlgren, D. M. D.

Assistant Curator of Invertebrate Zoölogy.

Introduction.

THE word "mosquito," supposedly of West Indian origin, is the Spanish diminutive of "mosca," a fly, and the name is correctly applied, since mosquitoes belong to the order of two-winged insects, or true flies, Diptera. They constitute the family Culicidæ, of which some four hundred fifty species are known at the present time.

Distribution

Since the discovery of the agency of mosquitoes in the spreading of malaria and yellow fever, they have received a great deal of attention, and new species are constantly being found. The great majority are tropical, but their range of distribution is nearly universal, extending from the Equator northward and southward, over the temperate zones into the arctic and antarctic regions. About forty species have been described from the neighborhood of New York.

Though mosquitoes occur in general in low and swampy districts, they are also recorded from high altitudes, and Stephens and Christopher in a Report to the Malaria Commission of the Royal Society, state that they are troublesome in the Himalayas at a height of 13,000 feet. A well known malarial species is recorded by them at 5,000 feet. In the United States mosquitoes are numerous not only along the coasts, in the low-lying regions of the South and on the plains and prairies, but also in many places in the woods of the Adirondacks and Rocky Mountains. In Alaska, on the coast of Greenland and on the tundras of the North where other insects are few, they at times constitute a severe scourge, and Arctic explorers relate accounts of mosquitoes on the snow which make a New Jersey swamp seem a desirable resort. Nansen, quoted by Theobald, states that at high latitudes, they literally covered the hands of the voyagers like "rough woolen gloves." In ancient Greece, and in Asia Minor, entire cities[2] were abandoned by their inhabitants, who were

[1] Guide Leaflet No. 27 of the American Museum Series.

[2] Mionte in Ionia, Pergamo in Asia. Howard, Mosquitoes, p. 40.

obliged to flee from the intolerable swarms of gnats that descended upon them.

Dissemination

Certain artificial agents seem to play some rôle in the dissemination of mosquitoes. Railway trains are said to be responsible for the distribution of the insects, and tracts which have been practically free from the pest are thought to have been invaded as the railroad lines opened up the country. One species occurring in Australia is supposed to have been "imported from Europe in the watertanks of some old sailing vessel."[1] At the port of New York a

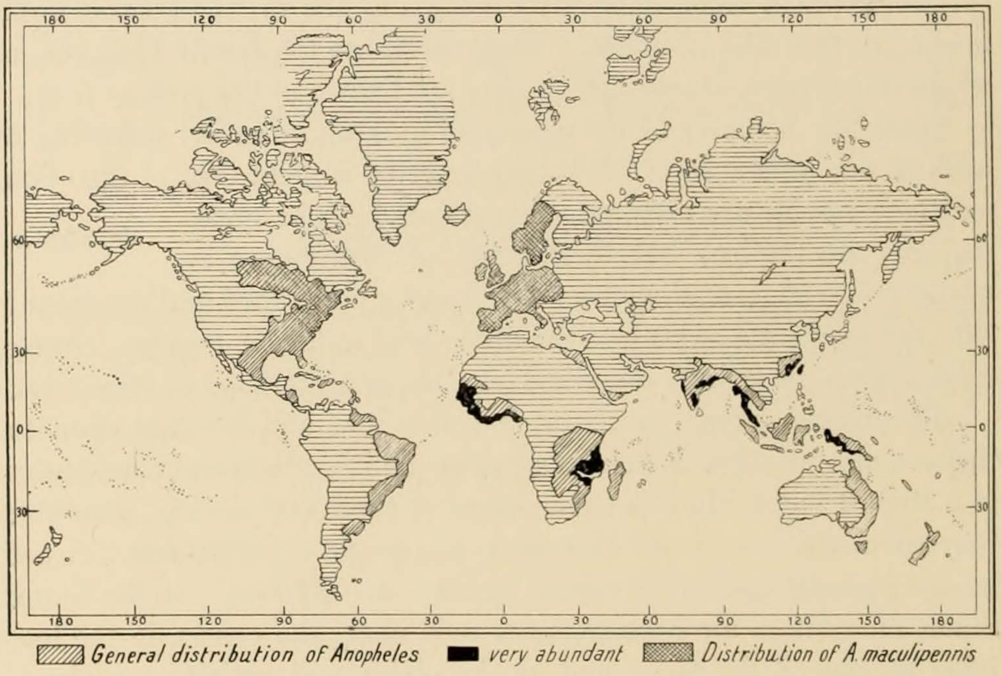


FIG. 2. THE DISTRIBUTION OF ANOPHELES.
After Theobald.

dozen foreign species have been observed on ships in quarantine. Mosquitoes are also carried by the wind. The fact that hosts of adult mosquitoes are to be found in localities where not a single larva of the species may be discovered, led Professor John B. Smith, of New Jersey, to investigate the question of migration of mosquitoes, and he has learned that large swarms of them may, with a moderate wind, fly or drift thirty or forty miles. Shore mosquitoes are found far inland, and, on the other hand, swarms have been seen many miles out at sea.

[1] Skuse, as cited by Theobald, Culicidæ of the World, Vol. 1, p. 82.

The number of mosquitoes in a large swarm is beyond comprehension, and accounts of "immense clouds filling the air"—"like a column of smoke," or "like a dense wall, miles in length," are by no means infrequent. L. O. Howard,[1] Chief of the Bureau of Entomology at Washington, describes a swarm observed in Texas, the main body of which was three miles wide, and which required nearly five days to pass a given point. Such migrations of mosquitoes, though they are usually on a smaller scale, account for the sudden appearance of the insects in areas from which they were previously absent, and their equally sudden disappearance.

Mosquito Swarms

As a rule, mosquitoes are frail insects and weak flyers. In rain or winds they hastily seek shelter. The Malaria Mosquito (*Anopheles*) avoids places where draughts exist, and seldom flies more than a few hundred yards. An Indian species of the genus is known which flies a quarter of a mile, but rarely as far as half a mile. The Malaria Mosquito as a rule, spends its entire life in the immediate neighborhood of human dwellings.

Habits

Mosquitoes are most active at early dawn and after sunset. They seem in general to avoid strong light and to prefer dark colors. The hours of daylight are spent by most species hiding in some secluded spot in a tuft of grass or a bush, while the Malaria Mosquito finds some dark corner indoors, where it passes the day. There are, however, some notable exceptions to this general rule. The Yellow Fever Mosquito flies at almost any time of day, except noon, and several tropical species resemble it in this respect.[2]

In the autumn all the males die, while the fecundated females seek winter quarters. The Malaria Mosquito, which is essentially a house mosquito, may be found hibernating in dark corners in cellars, sheds or attics. The strictly out-of-door species find winter quarters in the woods or in the fields. In the arctic regions mosquitoes find suitable hibernating places under moss. Large numbers of the insects undoubtedly perish during severe winters, but, under ordinary conditions, enough mature females survive to furnish locally the first brood of the following season. A warm day in early spring brings the insects out of their stupor; on a sunny day in mid-winter

Hibernation

[1] Mosquitoes, How they live, etc., p. 22. See also Theobald's Monograph of the Culicidæ of the World for several interesting accounts.

[2] One of the local species of Anopheles (*A. crucians*) is a "daylight mosquito."

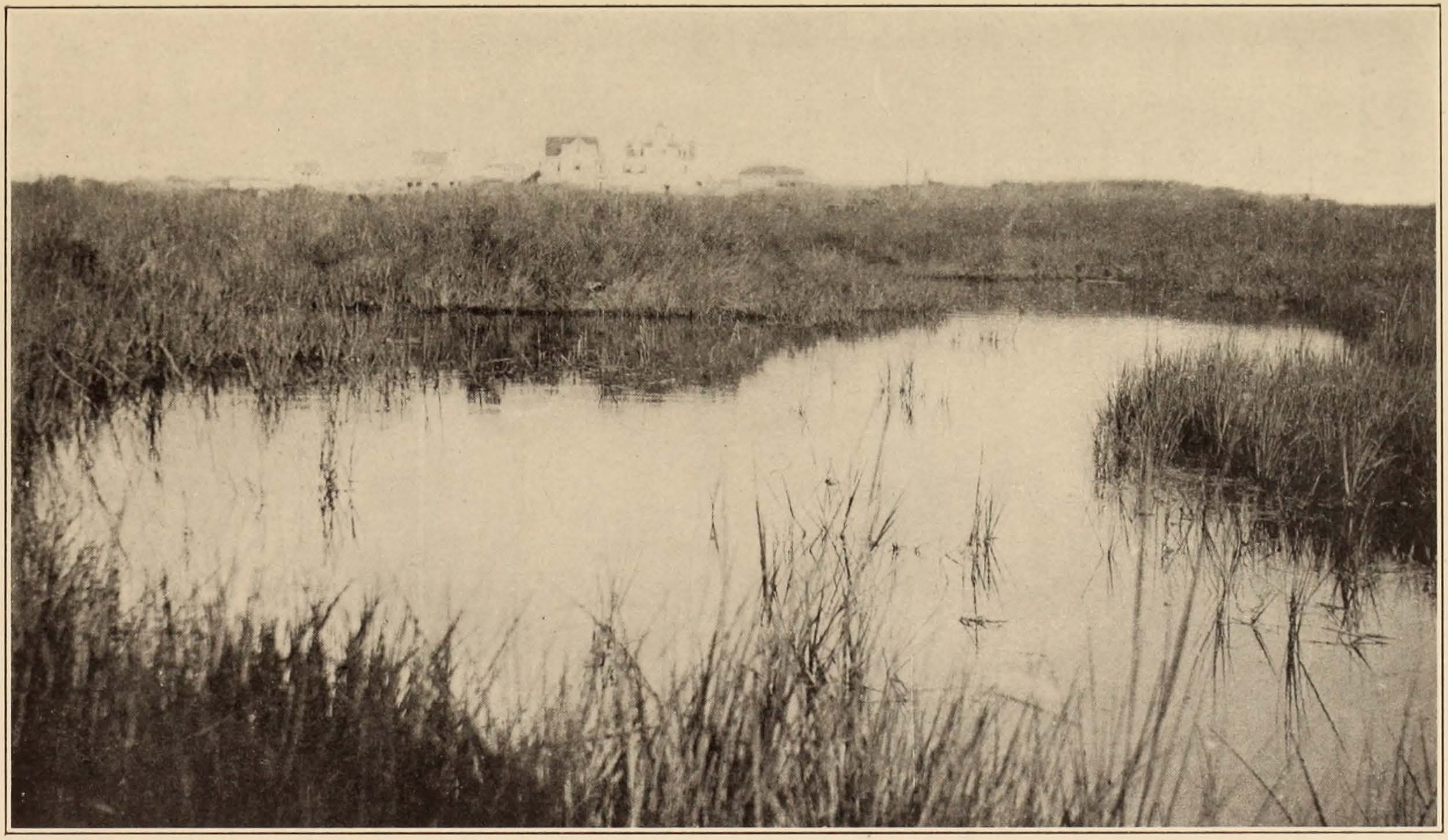
they may occasionally be seen on the snow. In tropical countries the dry season is the period of inactivity for the mosquitoes.

The food of mosquitoes consists ordinarily of the nectar and juices of plants and fruits. This is always true of the males, whose mouth-parts are not at all adapted for stinging. In certain species neither sex seems to have any taste for blood, while on the contrary, it is well known that mosquitoes living far in the woods, in the swamps, or in the Arctics where their chances of obtaining a meal of blood may be almost infinitesimal, nevertheless, will seize greedily upon the opportunity when it offers. It has been thought that a full meal of human blood is necessary for the female Malaria Mosquito, in order that she may lay her eggs, but this is certainly questionable. Theobald maintains that, in England at least, the Malaria Mosquito seldom sucks blood. Mosquitoes of sanguinary taste by no means confine themselves to human, or even mammalian blood, they suck with eagerness the blood of birds and reptiles whose skin they may be able to pierce. They have frequently been observed feeding upon other insects and on caterpillars. Howard asserts that they will attack small fish when these come to the surface of the water. In captivity, mosquitoes are fed with success on slices of banana or apple. They require water, but may exist for months without any food whatever. On the other hand, they may feed as often as they have opportunity, though several hours are required for the digestion of a full meal.

Food

The average length of life of female mosquitoes is not less than a month or two, but hibernating females must live at least six or even eight months. The life of the males is much shorter, and may not exceed a few days in duration. The point is difficult to determine, since in captivity death may be the result of various artificial conditions. To compensate for the shortness of life of the males, they greatly outnumber the females. In several broods hatched in aquaria in the Museum the ratio of males to females was eight or nine to one. Since a recently hatched mosquito becomes full grown in two or three days, and it may lay its first batch of eggs within a week, there may be as many as a dozen or more generations in the course of a year, in favorable localities, but seasonal conditions necessarily exert great influence on the number of broods. In dry climates breeding is confined to the rainy season, in humid tropical climates it may extend throughout the greater part of the year, while in

Length of Life



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Courtesy of J. B. Smith.

FIG. 3. MOSQUITO-BREEDING POOL ON CAPE MAY.

This pool, with an area of 1,894 square feet, had a population of ten and a half millions of mosquito larvæ (*Anopheles crucians* Wied), the sixth brood of the season. (Smith, Report on Mosquitoes, p. 403.)

the Arctics it must naturally be very short. In temperate climates the first brood generally appears in April or May, while in October and November the fecundated females seek their winter quarters.

The female mosquito lays its eggs, from fifty to two hundred in number, on the surface of any convenient quiet body of water. Certain mosquitoes prefer to lay their eggs on brackish water. Thus, the females of *Culex cantator* and *C. sollicitans*, both salt-marsh mosquitoes, which were found by Professor Smith in inland swarms, were observed returning to the shore with developed ovaries, and this seemed to him "in the nature of a return migration for oviposition."

Breeding places

Though mosquitoes of the various species may differ widely in many minor details such as size, color, form of scales and markings on the body, wings and legs, in all essential respects of structure and life-history they are similar. The following description, however, applies particularly to the local Malaria Mosquito (*Anopheles maculipennis* Meigen), which is represented by a series of large-scale (× 75 diameters) models in the Museum. Other mosquitoes are treated of incidentally, as they differ from the Malaria Mosquito in some important respect.

The Malaria Mosquito.

The Egg.

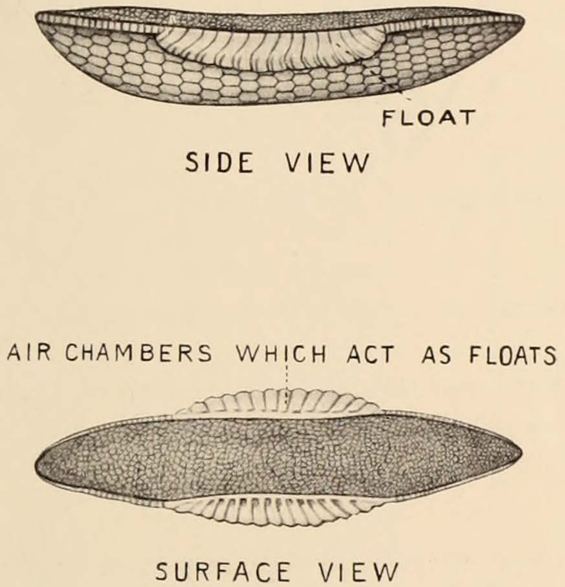
Mosquito eggs are minute bodies, measuring only one half to one millimeter (one fiftieth to one twenty-fifth of an inch) in length. They are generally ovoid in form, but the particular configuration of their covering, or shell, of chitin varies considerably in different species. The egg of Anopheles (Fig. 4) is boat-shaped with one end somewhat pointed, the other rounded. The lower surface, the bottom of the boat, is strongly convex and reticulated, the upper surface, the deck, is more flattened. The egg is provided on the sides with corrugated air chambers which serve as floats. When recently laid the eggs appear almost white in color, but they darken rapidly and in a few hours become nearly black.

Anopheles Eggs

In the process of deposition the eggs of the Common Mosquito unite to form raft-like masses, which are known as "egg-boats" or "floats" (Fig. 5). The eggs of Anopheles, however, are deposited separately, but they may be found arranged in various patterns on the surface of the water, forming

Arrangement of Eggs

star-shaped groups or adhering side by side to make miniature pontoon-bridges (Fig. 6). The eggs of certain species are never laid on water, but on mud, perhaps at the edges of pools, and are said not to develop at all, unless they be left dry for at least twenty-four hours.



FROM NUTTAL AND SHIPLEY
FIG. 4. THE EGG OF THE MALARIA MOSQUITO.
Magnification about 60 diameters.

Resistance The eggs of some mosquitoes will survive drying for two or three months, while those of others with a thinner chitinous shell, easily perish if the mud or water of the pool in which they have been laid dries up. Ordinarily, mosquito eggs are not resistant to cold and will not survive freezing, though those of some species are actually known to hibernate.

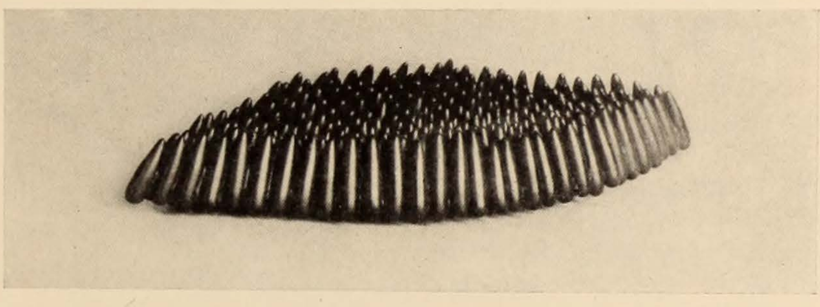
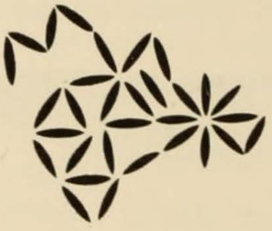


FIG. 5. "EGG-RAFT" OR EGG-BOAT OF THE COMMON HOUSE MOSQUITO (*Culex pupiens* Linn.).
Magnification 12 diameters.

Hatching When the eggs are ready to hatch, in about two to four days after they are laid, a small cap-like portion of the envelope bursts off at the rounded end of the egg and the larva escapes.

In the "egg-boats" of Culex the rounded end of each egg is directed


STAR SHAPED ARRANGEMENT.

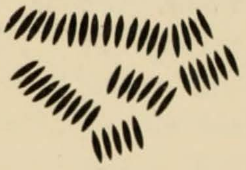

PONTOON BRIDGE ARRANGEMENT
AFTER GRASSI

FIG. 6. EGGS OF THE MALARIA MOSQUITO.
Characteristic arrangements on the surface of the water. Magnification 7 diameters.

downward and the larvæ escape into the water from the lower surface of the float (Fig. 7).

The Larva.

Mosquito larvæ are popularly known as "wigglers" or "wrigglers," because of their peculiar motions in swimming. At the time of hatching, the larvæ of the Malaria Mosquito are minute. The transparent body is cylindrical and is exceeded in diameter by the small, brownish, rounded head. As soon as freed from the egg the larva begins to feed. It grows rapidly, and, if the food supply is abundant and the temperature of the water is not too low, it attains its full size in a few days. The body is divided into the head, the thorax and the cylindrical abdomen of nine rings or segments (Fig. 8). In a newly

Divisions of the body

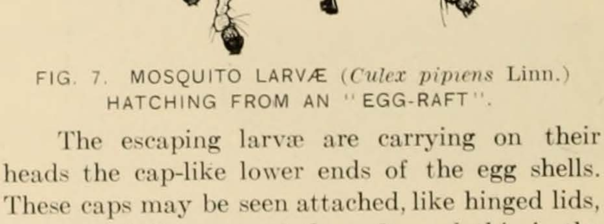


FIG. 7. MOSQUITO LARVÆ (*Culex pipiens* Linn.) HATCHING FROM AN "EGG-RAFT".

The escaping larvæ are carrying on their heads the cap-like lower ends of the egg shells. These caps may be seen attached, like hinged lids, to some of the eggs of the raft, and this is the usual condition. The egg-raft was in this case disturbed, and the instant and simultaneous hatching of the larvæ occurred with such sudden violence that the lids were carried away on the larvæ heads. Magnification about 12 diameters.

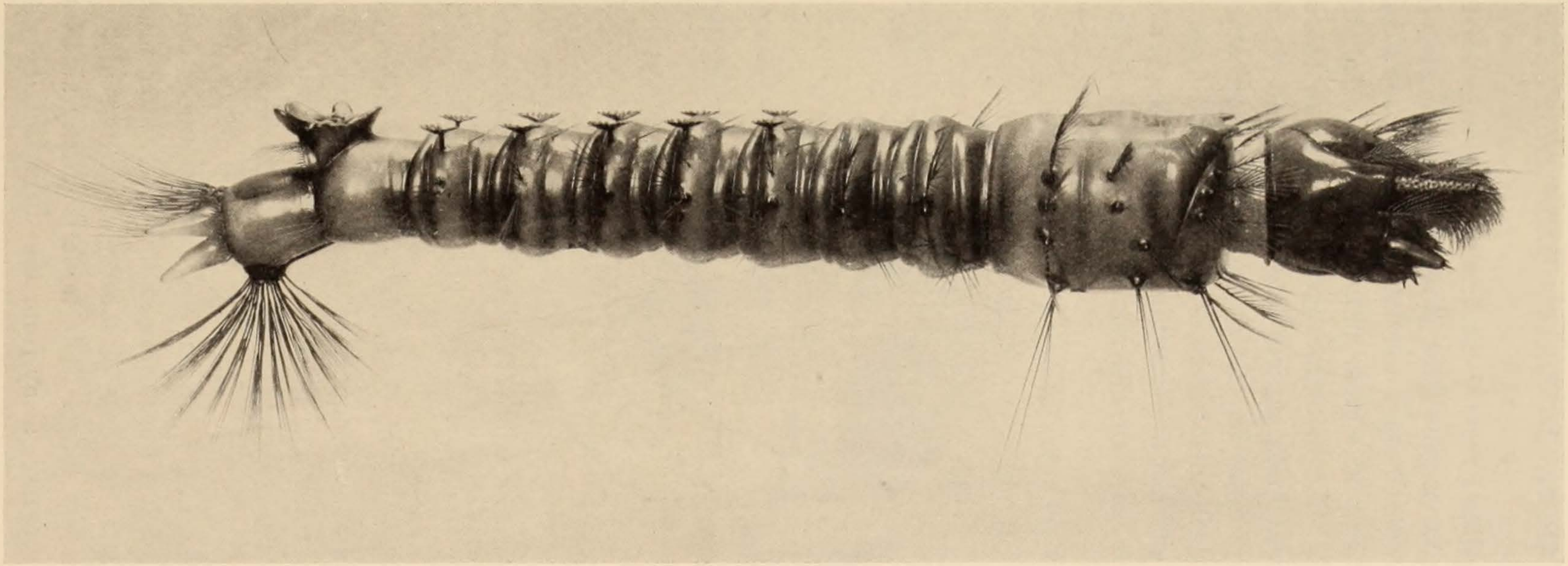


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FIG. 8. THE LARVA OF THE MALARIA MOSQUITO (*Anopheles maculipennis* Meigen).

Photograph of the model (× 75) in the American Museum. Magnification of the figure about 20 diameters.

hatched larva the latter regions can hardly be distinguished from each other, but as the larva grows the three fused segments of which the thorax consists become enlarged and flattened. Legs are absent, but both thorax and abdomen bear a great number of symmetrically placed pairs of branched feather-like hairs, arranged in a manner characteristic of the species. These hairs project laterally and aid in maintaining equilibrium, but they undoubtedly serve other purposes too, being also organs of touch and possibly of respiration. Similar, but smaller, hairs are found on the back of the head, and many very small, simpler hairs are distributed over the whole body, particu-

Appendages

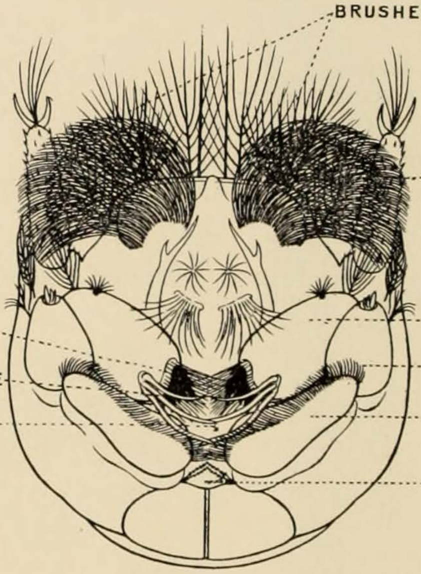


FIG. 9. HEAD OF ANOPHELES LARVA, SHOWING MOUTH-PARTS.

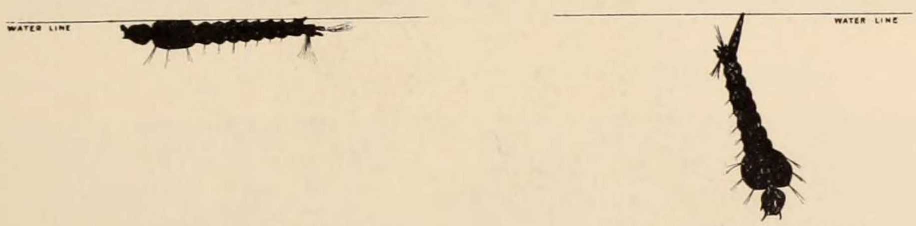
Ventral view. Magnification 45 diameters.

larly along the back and sides. On the back of the abdomen are five or six pairs of dark-brown palmate structures, which float on the surface of the water, when the larva is at rest, and aid in maintaining the horizontal position of the body which is characteristic of larvæ of the genus Anopheles.

The next to the last segment bears on its upper side the short "siphon," which reaches the surface of the water, when the larva floats in its usual position. In the siphon are the openings of the two main tracheæ, or respiratory tubes. The larva is strictly air-breathing and does not normally remain away from the surface of the water, except when disturbed, and then only for a short time. That the larva must have air in order to live makes possible its destruction by means of a film of oil spread on the surface of the water. The oil, acting mechanically, closes the openings in the respiratory siphon and causes the larvæ to die from suffocation. If oil is poured on the surface of an aquarium in which the larvæ are kept, they may be seen, after an instant's contact with the film, in frantic contortions, as they strive to free themselves from the oil, lashing the end of the abdomen about and even desperately biting the tip of the siphon.

Effect of Oil

The last segment of the abdomen has terminally two pairs of bristles and four elongated sac-like appendages with very thin walls, the "blood-gills." On its under side it bears a large fan-like arrangement of branched hairs which seems to serve as a keel or rudder.



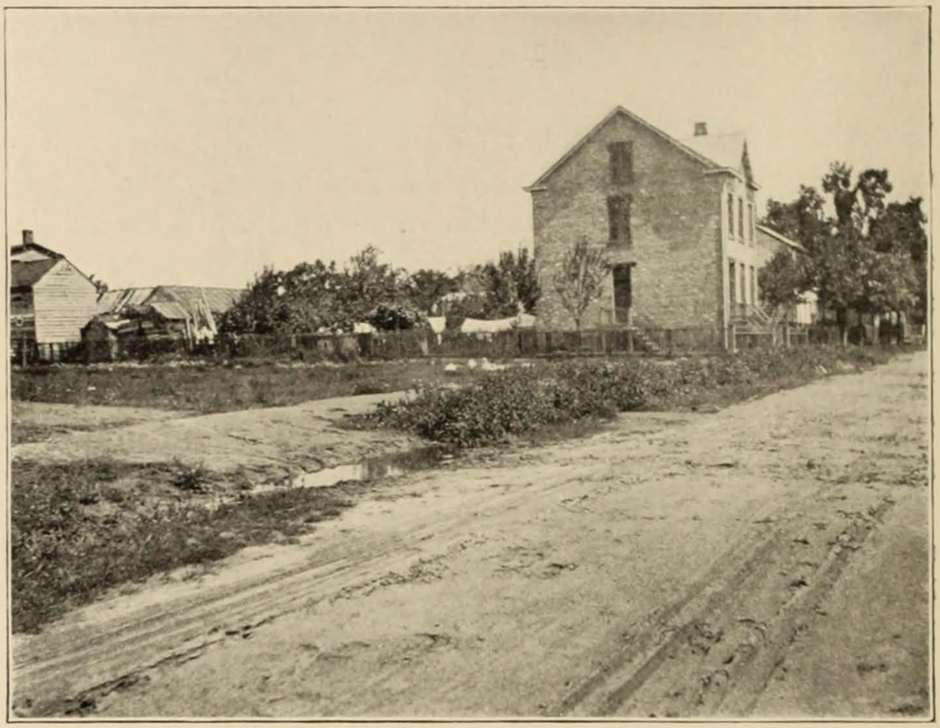
THE MALARIAL MOSQUITO LARVA
ITS USUAL POSITION IS HORIZONTAL AND AT THE SURFACE OF THE WATER.

THE COMMON WRIGGLER
ITS USUAL POSITION IS OBLIQUE, AND THE TIP OF THE SIPHON ALONE REACHES THE WATER.

FIG. 10. CHARACTERISTIC POSITION OF LARVÆ OF MALARIA AND COMMON MOSQUITO.

The head of the mature larva is large and rounded and is brown in color. It is united to the thorax by a membranous neck which allows considerable freedom of movement. Its upper surface is characteristically marked by dark-brown spots and bears rows of branched hairs. On the sides of the head are the antennæ extending forward, and behind these are the eyes. In front, on the under side and over-hung by the elongated anterior portion of the head, is the mouth, which is surrounded by a formidable armature (Fig. 9). Overhanging the mouth-parts and at the most anterior part of the head are two moustache-like brushes. Below these and behind them are two mandibles which move laterally and bear strong spine-like teeth for crushing food. On either side of the mandibles project the cylindrical maxillary palps, and below the mandibles are the flattened maxillæ beset with fine hairs. Below all of these mouth-parts is the small triangular so-called "lower lip."

Head of larva



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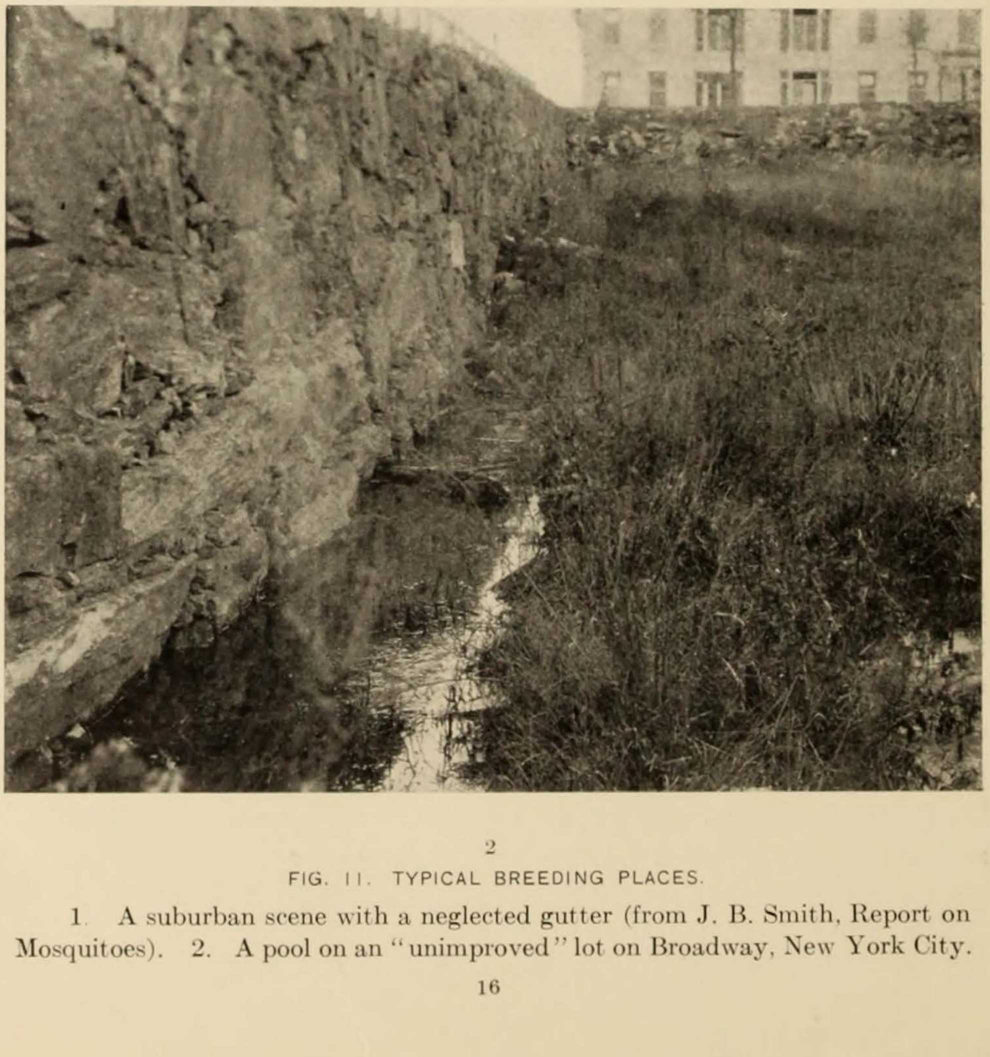

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FIG. 11. TYPICAL BREEDING PLACES.

1. A suburban scene with a neglected gutter (from J. B. Smith, Report on Mosquitoes). 2. A pool on an "unimproved" lot on Broadway, New York City.

Anopheles larvæ exhibit a curious habit of suddenly twisting the head. The peculiar, almost audible "snap" or "click" with which the sudden turning is accomplished is very characteristic. On this account the name "head-turners" has been proposed for them.[1]

The larva feeds with its head turned so that the lower side, which bears the mouth, is directed upward. The moustache-like brushes, by rapidly sweeping the under side of the surface-film of the water, set up a current which carries food into the mouth. Small particles which become entangled in the brushes are combed out by stout curved hairs, three or four of which are borne on each mandible, the brushes bending back into the mouth for this purpose from time to time.

Manner of feeding

The food of the larva consists of the microscopic animals and plants which abound at the surface of the water. Little discrimination seems to be exercised in the choice of food, anything which is carried into the mouth, even sand grains, being sometimes voraciously swallowed. The intestine, which is practically a straight tube, may usually be seen in the rather transparent living animal, colored dark by its contents. The entire larva often appears green from ingested algæ.

Food of Larva

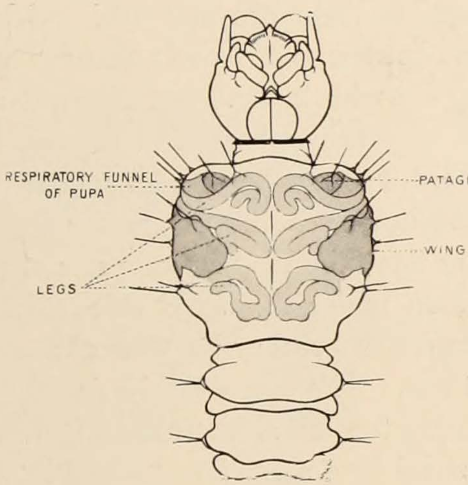


FIG. 12. MATURE LARVA OF ANOPHELES. Ventral surface. The figure shows clearly the formation of the thorax of the future insect within the larval thorax. Magnification, 13 diameters.

The Malaria Mosquito larva may be readily distinguished from the larva of the Culex Mosquito by the shortness of its siphon and its horizontal position in the water. The common "wrigglers" have elongated siphons and are always found hanging obliquely, or even vertically, head downward, the tip of the siphon only reaching the surface (Fig. 10).

The larvæ of certain mosquitoes are known to hibernate, and may remain throughout the winter frozen in the ice, coming to life when the ice melts in the spring. Professor Smith

Hibernation

[1] Minot, C. S. Notes on Anopheles. Boston Soc. Med. Sci. 1901.

gives an account of having repeatedly obtained certain mosquito larvæ in large quantities, by thawing out ice which had formed in the leaves of the pitcher plant (*Sarracenia*).[1] When pools in which the wrigglers live dry out, the larvæ usually perish in a short time. They are most likely to be found in small and undisturbed bodies of water, such as accumulate in little hollows between tufts of grass, in meadows, or in ditches where there is no perceptible flow (Fig. 11). Where there is any current in the water the larvæ are easily swept away, and those that occur in moving water are always found along the edges of the stream, where they are out of reach of the current. Cat-tail swamps are said to be practically free from mosquito larvæ, probably because of the usual presence in them of small fish. Such places as neglected tin cans or broken bottles, rain barrels, cisterns and deep wells may be swarming with larvæ. Dr. Howard mentions a case where the census of the inhabitants of a rain barrel was taken. In one month it yielded 36,369 mosquito eggs, larvæ and pupæ.[2]

Number

The duration of the larval stage is usually from seven to fourteen days. During this time the various parts of the adult insect are in process of formation under the larval skin (Fig. 12). In older larvæ the adult eye, for instance, may be seen as a crescentic dark mass lying near the larval eye. The legs and wings of the future "fly" may be seen forming within the larval thorax. The formation of adult structures is accompanied by destructive changes in the strictly larval internal organs and tissue. In due time, when this process has proceeded far enough, a T-shaped split occurs in the back of the larval skin and through this the insect emerges as a pupa.

The Pupa.

The pupa which escapes from the larval skin forms the next stage in the development of the insect (Figs. 13 and 14). It too is aquatic in habit and ordinarily leads a brief and comparatively quiet life. It does not feed. When at rest, it floats at the surface of the water, breathing through a pair of funnel-like tubes. It is, however, able to execute very rapid, though jerky, movements and

Habits of Pupa

[1] John B. Smith, N. J. State Agr. Exp. Station. Report on Mosquitoes, p. 346, 1905.

[2] L. O. Howard, Mosquitoes, p. 44.

darts downward instantly when disturbed. If confined in a glass vessel, it may be seen on such occasions to strike the bottom repeatedly, returning to the surface of the water by its own buoyancy as soon as its movements cease. The downward swimming is accomplished by a few vigorous strokes of the strongly curved abdomen, which bears at its tip a pair of "paddles," or "flippers," and is the only freely movable part of the body.

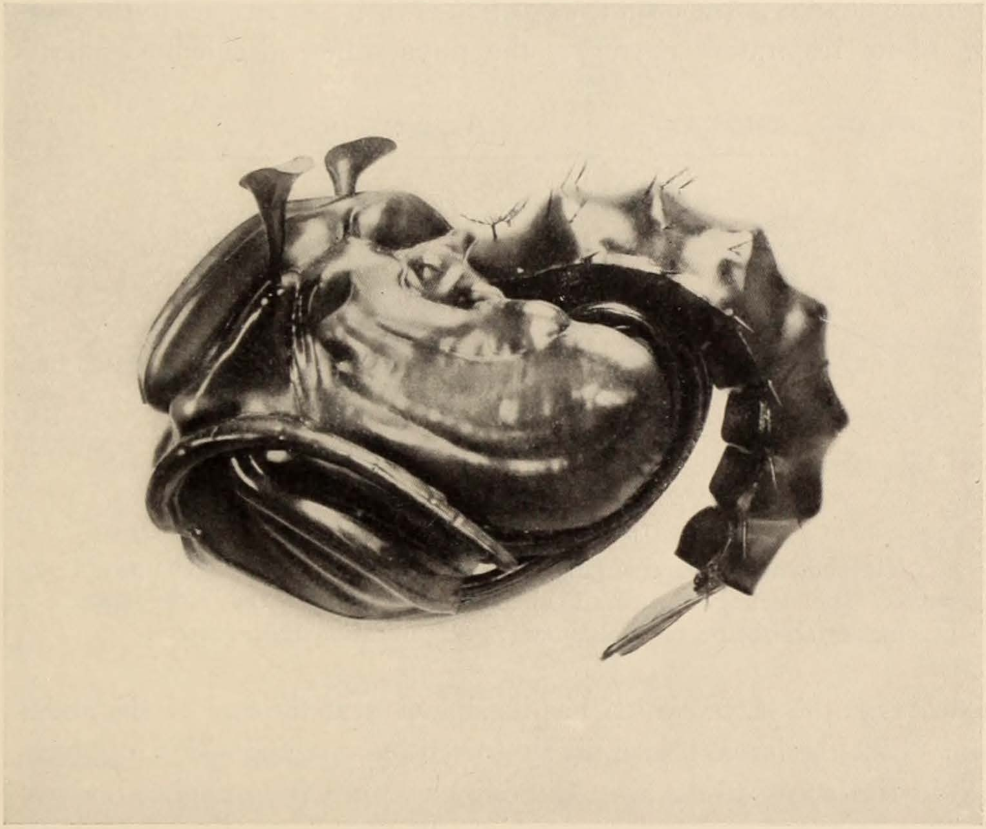


FIG. 13. THE PUPA OF THE MALARIA MOSQUITO. FEMALE.
Photograph of the model (× 75) in the American Museum. Magnification of the figure about 15 diameters.

Structure of Pupa

Under the transparent integument of the pupa may be seen outlined the body and appendages of the developing mosquito (Fig. 15). The head is drawn up against the anterior part of the thorax, giving the pupa its characteristic hunchbacked appearance. The strongly flexed abdomen curves downward and forward under the thorax. The elongated mouth-parts, the "proboscis" of the future fly, lie directed downward and backward in the median line, forming a "keel" just beneath the thorax. The legs are bent at the knee-joints and lie pressed against the thorax on each side, then they turn backward and terminate in S-shaped curves under the fore part of the abdomen. They are partly concealed by the wings, which hang, cramped in their wing-cases, closely pressed against the body on each side of the thorax. Arising from the anterior third of the thorax in front of the attachment of the wings, are the respiratory tubes terminating in funnel-like expansions which spread out on the surface of the water when the pupa is in the ordinary position of rest. In respect to the position of its respiratory openings, the pupa differs decidedly from its

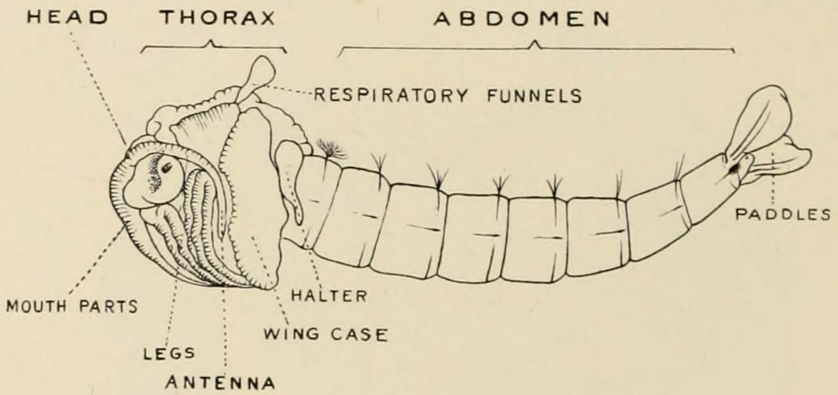


FIG. 14. THE YOUNG PUPA OF ANOPHELES.

The abdomen of the emerging pupa is straight or with a slight upward curve. The strong downward abdominal flexure of the older pupa becomes established a few hours later. Magnification 12 diameters.

predecessor, the larva, which has its siphon near the end of the abdomen. Like the larva, it is easily destroyed by anything which interferes with its free access to the air. Curving backward from the head, above the legs and in front of the wings, are the two antennæ. Below the origin of the antennæ lie the two palps, with sharply S-shaped flexures.

Duration of Pupal Life

The duration of the pupal stage is usually from two to four days, but it may, under unfavorable conditions of temperature, be prolonged to weeks. On the other hand, the threatening danger of a drought or the presence of a disagreeable substance in the water, such as the phinotas oil used for destroying mosquitoes, may very much hasten the emergence of the fly.

The pupa represents that period in the metamorphosis of the insect during which the internal changes begun in the larva, which are to result in the formation of the adult mosquito, are continued and completed. Under the pupa skin a new integument is secreted which becomes the final external covering of the fly. Its appendages, hairs and scales may be seen fully developed in late pupal stages like the one represented in the model as shown in Fig. 13.

Formation of the Adult

When the formation of the mosquito fly is complete, the pupa skin bursts along the middle of the back and the adult extricates itself from its floating case. At this "critical period," large numbers of mos-

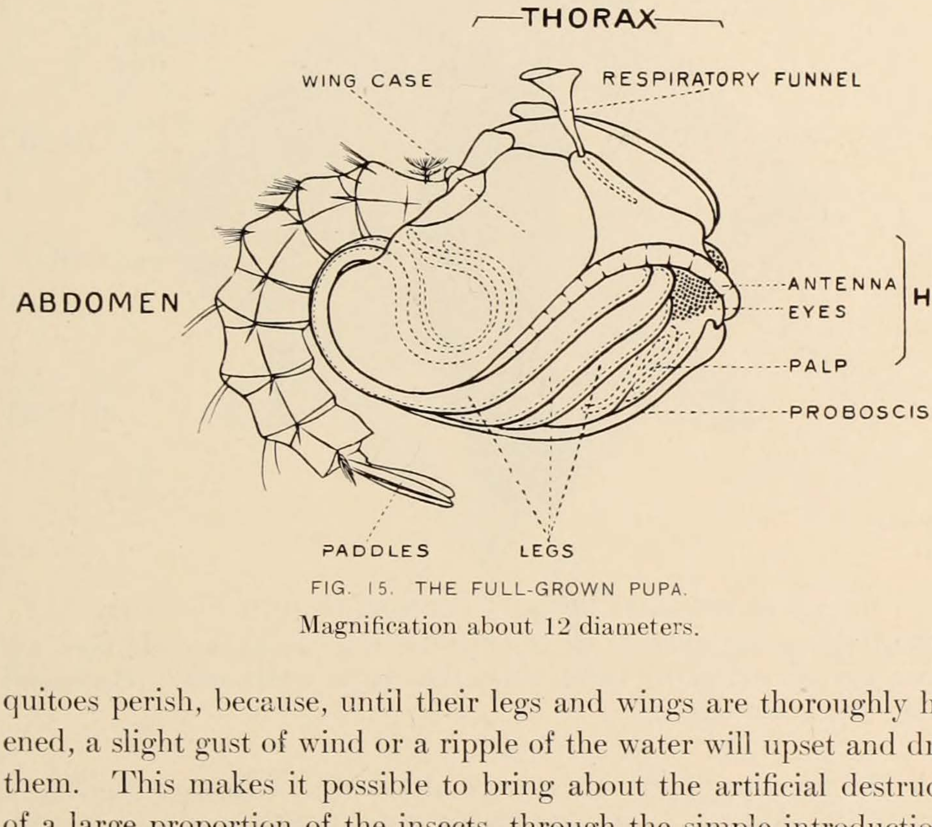


FIG. 15. THE FULL-GROWN PUPA.
Magnification about 12 diameters.

quitoes perish, because, until their legs and wings are thoroughly hardened, a slight gust of wind or a ripple of the water will upset and drown them. This makes it possible to bring about the artificial destruction of a large proportion of the insects, through the simple introduction of tidewater into mosquito-ridden marshes.

The Adult Mosquito.

The smallest of the local mosquitoes measures not more than 1.5 mm., while the largest, perhaps, the famous "Jersey mosquito" (*Psorophora ciliata*), called "Gallinippers" in the South, attains a length

Size

of 8 to 10 mm., — almost half an inch. The Malaria Mosquito is from 6 to 8 mm. long.

Body-covering

The body of the mosquito, like that of all other insects, is covered with a dense, though very thin, continuous layer of a hard substance, "chitin," secreted by the true, cellular skin, or hypodermis, which lies underneath it. The chitin not only affords protection to the body, but also gives support to the limbs and wing-veins and forms in fact an external skeleton, on the inner side of

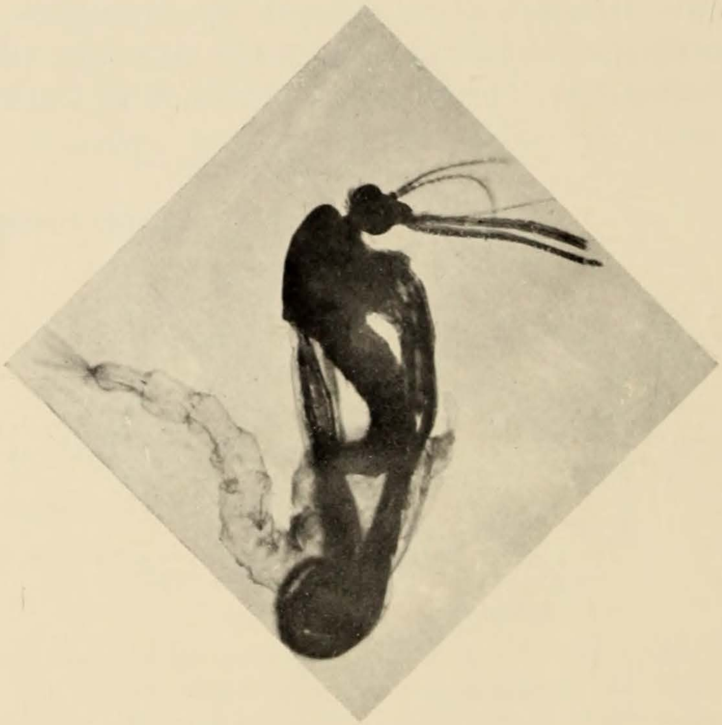


FIG. 16. AN ANOPHELES MOSQUITO EMERGING FROM ITS PUPA CASE.

Head, thorax and abdomen are free, but the wings are not entirely freed and the long legs are still partly coiled within their pupal integument. Photograph from life, greatly enlarged.

which the muscles of the insect are attached. Wherever rigidity is required, the chitinous coat is thickened, but elsewhere it remains thin to permit movement of the body segments.

Divisions of Body

Three main regions of the body may be easily distinguished, the small rounded head with its appendages, the relatively large thorax, and the elongated abdomen (Figs. 1 and 17). The head, which is connected with the body by means of a rather slender neck, bears the mouth-parts and special sense-organs. The thorax, which consists of three closely consolidated segments, bears the organs of locomotion, the legs, one on each segment, the wings on the middle segment and a pair of minute balancers on the third. The abdomen is distinctly segmented and consists of eight rings, but, except on the terminal segment, it bears no appendages. The almost spherical head is somewhat flattened in front.

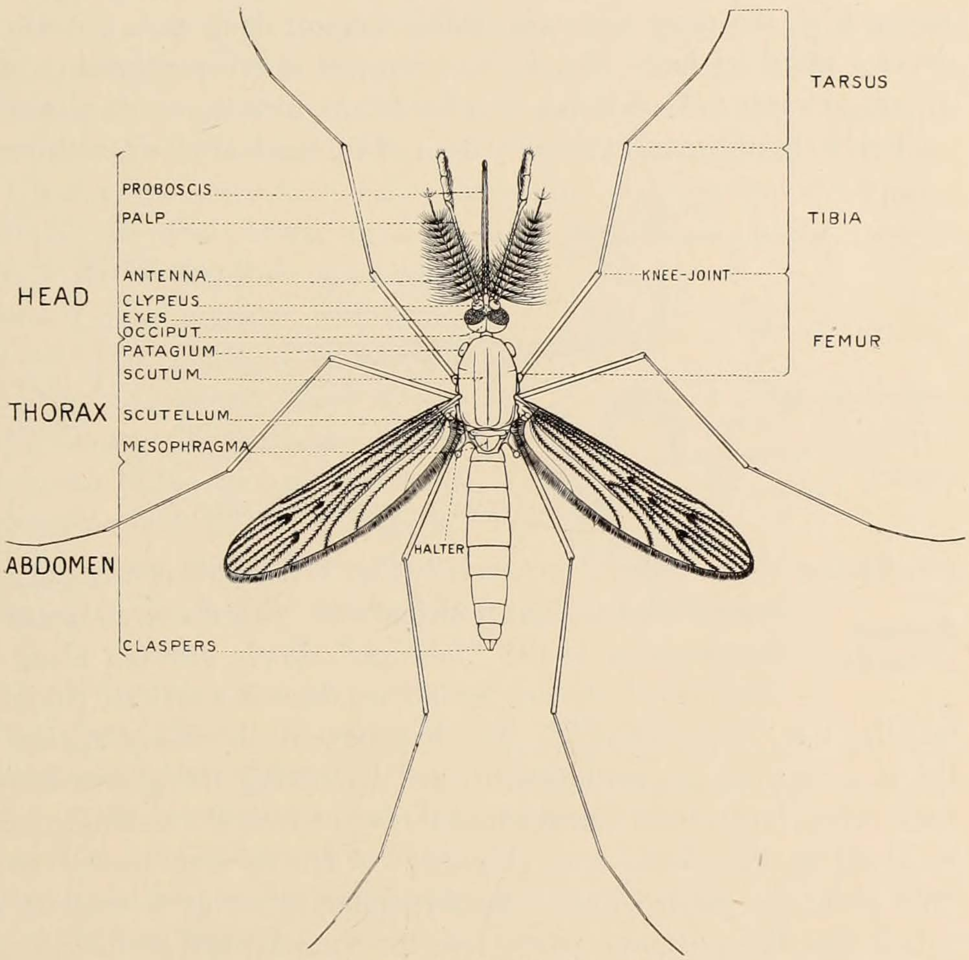


FIG. 17. MALARIA MOSQUITO. MALE.
Magnification 7 diameters.

Head

The anterior portion of the head is occupied by two large compound eyes, each composed of several thousand simple eyes or facets, regularly arranged and so closely crowded together that their outlines appear hexagonal. In such compound eyes each separate facet receives rays of light from only a single direction, but the great number of facets distributed over a spheroidal surface makes it possible for the mosquito to see in almost every direction.

Antennæ

In front of the eyes are the antennæ, two slender organs, with a central jointed axis of 15 or 16 segments, each bearing a whorl of fine hairs. The antennæ are organs of hearing, and by means of them the male is able to detect the presence of the female. If the "song" of a female mosquito be imitated with a tuning fork, the antennæ of the male mosquito, which support long and exceedingly delicate whorls of hairs (Fig. 1), that respond to every vibration of the air, may be seen to bend in the direction from which the sound proceeds.[1]

Below the antennæ, at the very front of the head, are the mouth-parts,

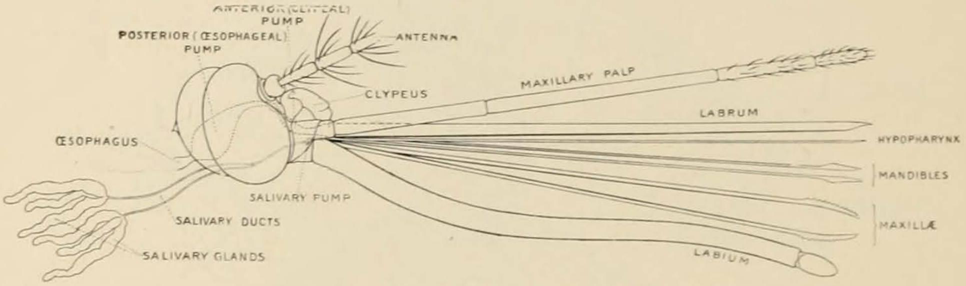


FIG. 18. HEAD OF FEMALE MALARIA MOSQUITO.

Proboscis of Female

constituting the so-called "proboscis" (Fig. 17). This consists of several members. The principal one, lying above all the other mouth-parts, is the "labrum," deeply grooved along its lower side.[2] Under the labrum there is a delicate chitinous lamella, the "hypopharynx." The hypopharynx is closely applied to the labrum along its entire extent, and by closing the groove therein from below, forms therewith the tube through which the mosquito sucks up blood or other liquid food (Fig. 19). A fine tubular channel which runs along the median line of the hypopharynx serves to conduct the poison that the mosquito pours into the wound when sucking blood. Along the sides and below the tube, composed of these two mouth-parts, there are two pairs of very slender chitinous rods, expanded at the ends into lancet-like blades set with fine teeth. One pair, the "mandibles," are exceedingly delicate; the other, the "maxillæ," are stouter and have

[1] Mayer, A. M. Researches in Acoustics. Am. Jour. Sci. and Arts. III, viii, p. 81. 1874.

[2] The "labrum" is undoubtedly a compound structure and properly is the "labrum-epipharynx."

larger teeth. These latter pairs of instruments enter the wound made by the point of the labrum, and with their saw-like blades, serve to brace the head while the "sucking-tube" is thrust forward. By a to-and-fro motion which alternates with that of the piercing tube, they are pushed into the tissues together with the tube, and their fine teeth undoubtedly also serve to lacerate the tissues in the wound and to produce an increased flow of blood at the point of the sucking-tube.

All these mouth-parts, *viz.*: the labrum, the hypopharynx, the mandibles and the maxillæ, form a very compact bundle which, when not in action, is almost entirely contained in a groove on the upper surface of the lower lip or "labium" (Fig. 19). This is attached below the base of the other mouth-parts. It is equal to them in length, but much larger than all the others taken together, and is flexible and forms a sheath which serves for their protection. Its outer surface is beset with scales. Of the whole bundle of mouth-parts only the labium and upper surface of the labrum are ordinarily visible. At the tip of the labium, two small pointed movable flaps, or "labellæ" are hinged (Figs. 18 and 26), which protect the points of all the mosquito's delicate surgical instruments, when these are not in use. The separation of these flaps exposes the points ready for instant action (Fig. 26). The female alone sucks blood. In the male the maxillæ are lacking, and the tip of the labrum is blunt and unfit for piercing.

Proboscis of Male

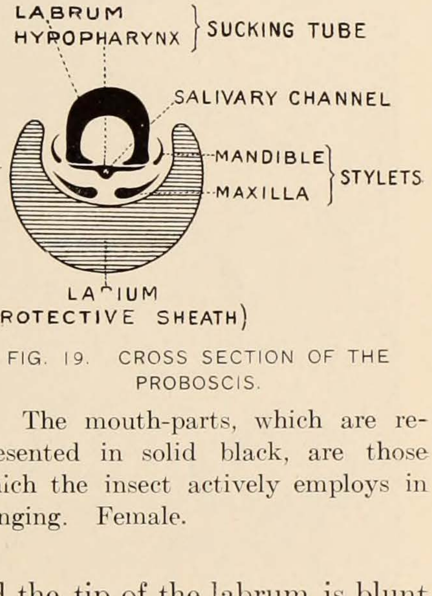


FIG. 19. CROSS SECTION OF THE PROBOSCIS.

The mouth-parts, which are represented in solid black, are those which the insect actively employs in stinging. Female.

The first, though somewhat erroneous, account of the mouth apparatus of the mosquito is contained in Swammerdam's "Bybel der Natuure" (1668) published in Holland in 1738. In 1739, the French scientist Réaumur published a description of the mosquitoes' manner of biting. His illustrations, here reproduced (Fig. 20), show well how the soft labrum is pushed away and flexed in biting, and how only the labellæ remain in contact with the stylets at the point of their entrance into the wound.

Manner of Stinging

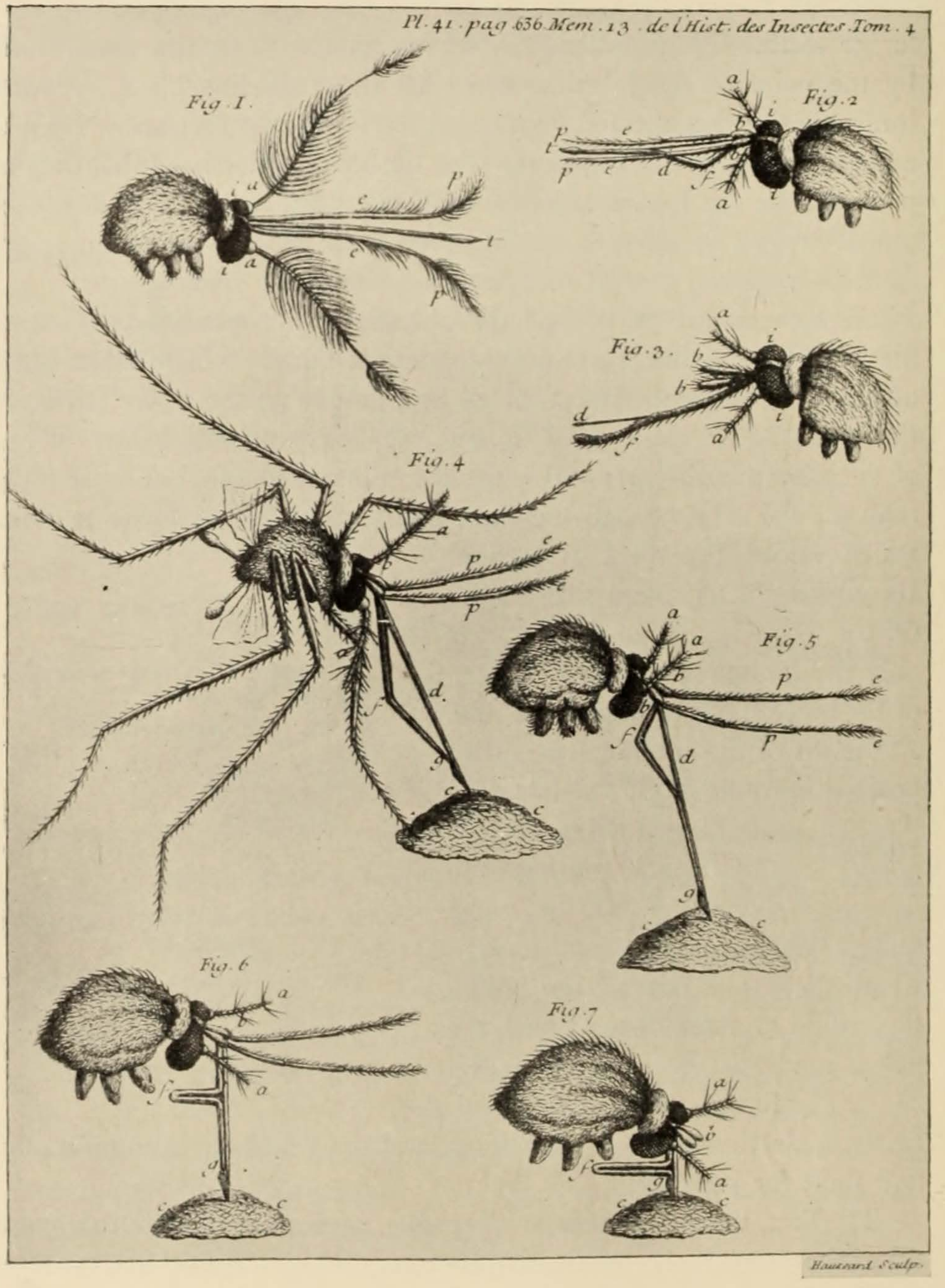


FIG. 20. HEAD AND THORAX OF THE MOSQUITO.

Fig. 1. Male. Figs. 2–7. Females, 4–7, in the act of stinging. Reproduction of a plate in Réaumur's Mémoires pour servir à l'histoire des Insects, 1739.

The Palps

On either side of the proboscis there are two long pointed appendages of the maxillæ, the maxillary palps, which serve as organs of touch. In the female Malaria Mosquito they are slender and of uniform thickness; in the male the terminal segment is enlarged and bears long hairs (Figs. 21 and 22). In both sexes of the Malaria Mosquito the palps are long, equal in length to the proboscis, and covered with fine scales. In the common Culex Mosquito, the palps of the female are short (Fig. 21), not more than half the length of the

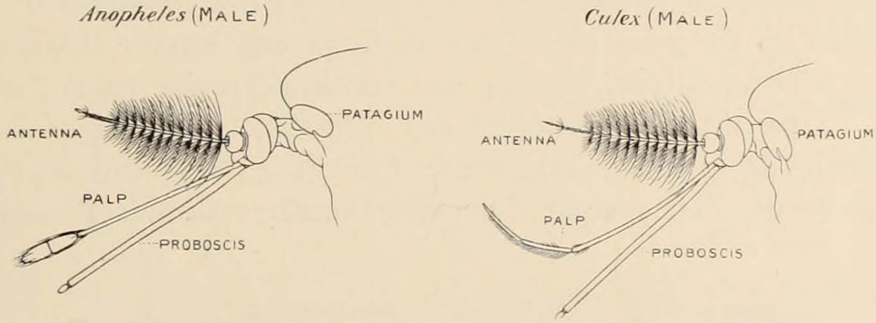


FIG. 21. THE MALARIA AND THE COMMON MOSQUITO. MALE.
Suggested by figures of Eysell, in Arch. für. Schiffs- u. Tropenhygiene.

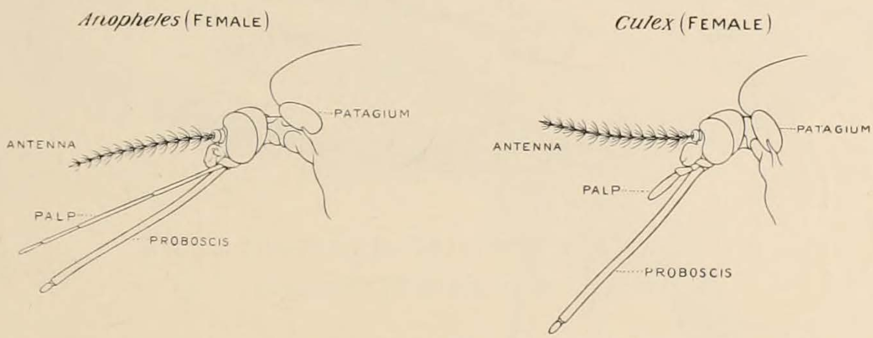


FIG. 22. THE MALARIA AND THE COMMON MOSQUITO. FEMALE.
Suggested by figures of Eysell, in Arch. für Schiffs- u. Tropenhygiene.

proboscis; those of the male are long, but their terminal segment is not enlarged, though set with long hairs (Fig. 22). This furnishes a ready means of distinguishing the Malaria Mosquito from the Culex.

The margin of the chitin bordering on the eyes, appears white or light gray in color. Just behind the light margin is a row of long hairs, which overhang the eyes, and in front a tuft of long hairs and scales overhang the space between the antennæ. The remainder of the head is covered with scales.

The slender and almost transparent neck connects the head with the second division of the body, — the thorax. This is greatly enlarged to accommodate the strong wing-muscles which it contains (Fig. 26). The middle segment, which bears the wings, exceeds the other in size and forms the entire dorsal portion of the thorax.

Wings

The delicate membranous wings are strengthened by ribs, or veins, closely beset with scales. The arrangement of scales varies in the different species of mosquitoes. The local Malaria Mosquito is distinguished by the presence of four dark spots in certain characteristic positions on its wings, and hence its specific name "maculipennis," or "spotted-winged" (Fig. 23). These spots are produced by the grouping of the scales of the wing veins into dense tufts at these points. The margin of the wing bears several rows of scales, long

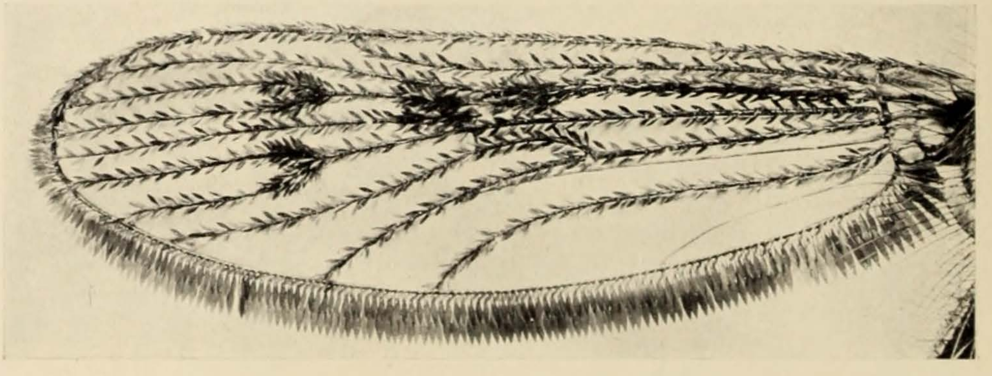


FIG. 23. WING OF ANOPHELES MACULIPENNIS MEIGEN.
Magnification about 20 diameters.

and slender scales alternating regularly with rows of shorter ones, producing a beautiful fringe.

A pair of small club-shaped organs, the "halteres," or balancers, on the third segment of the thorax, enables the insect to maintain its equilibrium, for without them it performs aimless evolutions in the air somewhat after the fashion of a tumbler-pigeon, and it cannot direct its flight. Similar organs are found in all Diptera and they represent a degenerated second pair of wings.

Legs

Each of the segments of the thorax bears a pair of legs. Structurally these are simply hollow, jointed tubes of chitin containing the muscles by which they are flexed. Externally they are covered with scales, and in certain places they bear fine hairs. The legs are connected to the body by the "coxæ," or hip-joints, which are constructed so as to permit great freedom of movement (Fig. 26). Then follows in each leg, a small piece, the "trochanter," uniting the coxa with the leg proper. Each leg consists of seven pieces. The first is called

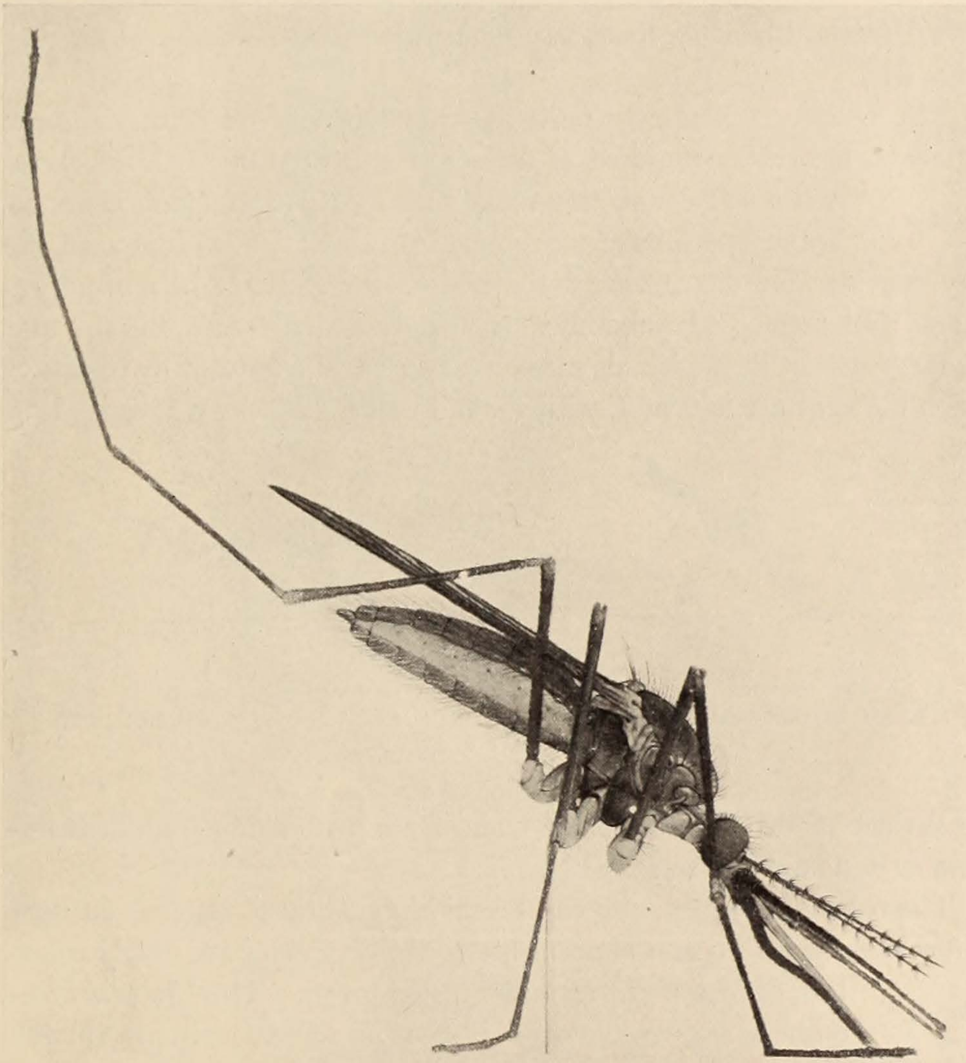
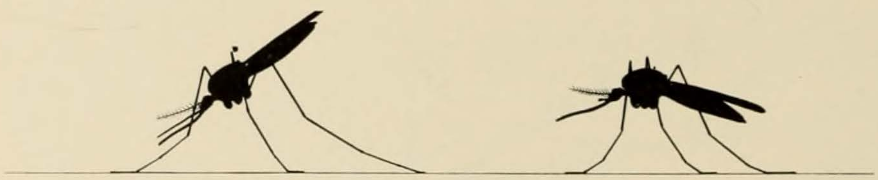


FIG. 24. FEMALE ANOPHELES IN CHARACTERISTIC STINGING POSTURE.
Photograph of the model (× 75) in the American Museum. Magnification of figure about 10 diameters.

the femur, the second is the tibia, then follow the tarsal joints, five in number, the last of which bears a pair of claws. In the male one of the claws of each foreleg is greatly enlarged. When the mosquito walks or rests, it supports itself on several of the tarsal joints. The legs of the third pair are, however, used very slightly in walking, but they serve continually as organs of touch, and in flight they help to balance the body and determine its inclination. They are often carried raised and curved forward over the body especially when the mosquito is stinging (Fig. 24).

Abdomen

The abdomen is closely united to the thorax. Its eight rings, or segments, are each composed of an upper and a lower shield of chitin and a soft connecting membrane. This soft "pleural membrane" permits of movements of respiration, as well as of the very considerable distension of the abdomen noticeable in mosquitoes after a full meal. The abdomen tapers gradually toward the tip, and the last segment in the female mosquito bears the ovipositor by means of which the eggs are laid and, with the aid of the hind legs, arranged on



Anopheles.
BODY AT AN ACUTE ANGLE TO THE SURFACE ON WHICH THE INSECT RESTS.

Culex
BODY PARALLEL TO THE SURFACE ON WHICH THE INSECT RESTS.

FIG. 25. CHARACTERISTIC POSITIONS OF THE MALARIA AND COMMON MOSQUITO WHEN AT REST.

the surface of the water. In the male, the last abdominal segment terminates in a pair of claspers (Fig. 17).

Color of Adult

The color of the mosquito can be said in general to range from light yellow to dark-brown and almost black. Some species are nearly colorless, or of a very transparent light green. The Malaria Mosquito is brown, the color increasing at first with age till the chitin becomes thickened. The thorax is dark brown above, with a light stripe in the middle and one on each side of the back. The sides of the thorax and the coxæ are light. The upper shields of the abdomen are dark brown, the lower ones lighter and more yellowish. The legs are dark brown above, sometimes with a purplish tinge, and are lighter below, with distinctly yellow spots at the knee-joints. The proboscis and palps appear very dark brown or purplish black. The back of the thorax and the entire abdomen, the soft membrane excepted, are covered with long, golden hairs.

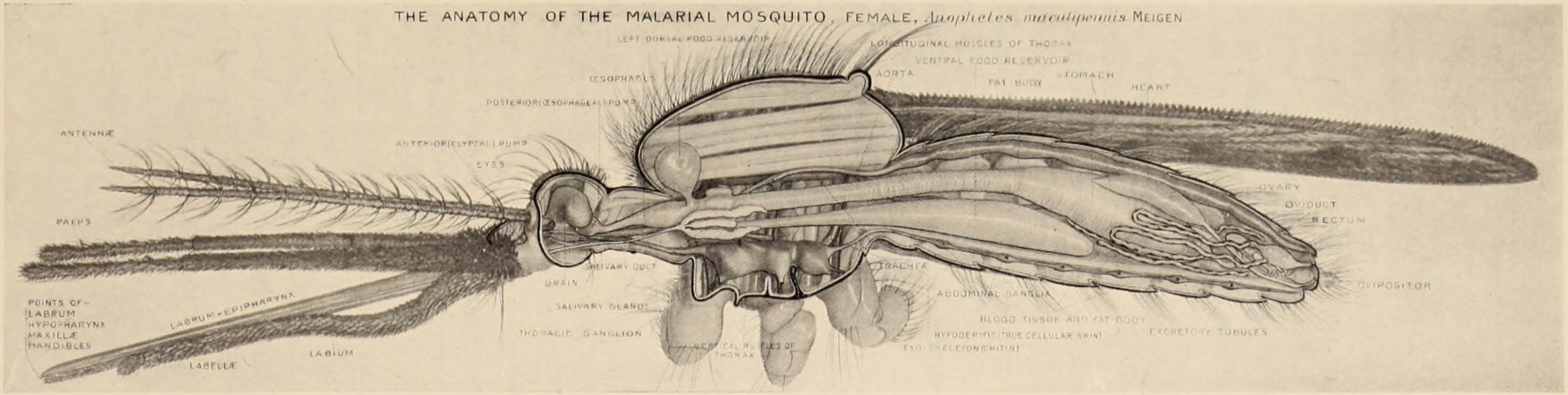


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FIG. 26. ANATOMY OF THE MALARIA MOSQUITO.

The figure represents a median section of a female. The mouthparts, the antennæ, the alimentary tract and the nervous and reproductive systems have been left entire. From a photograph of the left side of the model shown in Figure 24. Magnification 20 diameters.

The Internal Organs.

When the mosquito bites, blood is pumped up into the "sucking-tube" by two pumps (Fig. 18). The first and smaller pump lies just above the junction of the labrum with the head and forms a direct continuation with the tube. The second, larger and more efficient pump, lies further back in the head and is dilated by powerful muscles. In section it is triangular, with collapsed walls. When dilated by the muscles it fills with blood from the smaller pump and from the tube beyond. It is then allowed to collapse by its own elasticity, and the liquid is forced on into the œsophagus. This is in great part in the neck of the insect and gives off just beyond its entrance into the thorax, three food reservoirs, two small ones above, and a third elongated sac below, which reach far into the abdomen (Fig. 26). It is the blood stored in this reservoir, which in its greatly distended state may be seen through the thin pleural membrane, that gives to the mosquito the red color noticeable after a full meal. The stomach is a continuation of the œsophagus and is tubular, narrow in front but dilated into a sac behind. At its posterior end is a valve-like constriction just beyond which there open into the intestine five excretory tubules. After one or two rather sharp curves, the intestine is continued to the terminal end of the body.

Pumps

Food reservoirs

The nervous system of the mosquito (Fig. 26) consists of a chain of connected centers, or nerve ganglia. In the head several pairs of ganglia are fused to form the "brain," which supplies nerves to the eyes, antennæ, palps and mouth-parts. In the thorax, just above the origin of the legs, there is another large mass consisting of three pairs of fused ganglia which send nerves to the legs, wings and balancers. The nervous system is continued in the abdomen as a chain of small ganglia, six in number. In addition to this main nervous system a pair of small sympathetic ganglia lie on each side of the alimentary tube, in the anterior part of the thorax.

Nervous System

The large thorax is almost entirely filled with the great muscles of flight, consisting of two masses at right angles to each other (Fig. 26). Their alternate contractions change the shape of the thorax and indirectly serve to move the wings in flight. The wings are also controlled by smaller special wing-muscles. The muscles which move the abdominal segments during respiration lie for the most

Body Muscles

part directly on the hard chitinous pieces which compose the upper and lower shields of the abdomen.

Respiration

Respiration is carried on by means of a system of air-tubes, or tracheæ, which open to the exterior by two main openings on either side of the thorax, and by eight smaller ones in the soft membrane of the abdomen (Fig. 21). The tracheæ, by repeated branching, ramify throughout the entire body of the mosquito and supply the blood, as well as every organ and tissue, with air. Nearly filling all spaces between the muscles and the organs, are symmetrically arranged masses of a peculiar tissue, the blood-tissue or fat-body, which is especially well supplied with tracheæ.

Circulation

The circulation of the blood of the insect is maintained by the heart, which is a tubular organ lying directly under the upper chitin-shields of the abdomen (Fig. 22). It is continued forward in the thorax as a vessel, the "aorta," through which the blood is pumped to the head. This is the only blood vessel to be found in insects, and the blood circulates with the respiratory movements throughout the body in the interstices between the fat-tissue and the internal organs. Into the blood in the body cavity of the mosquito, the malarial spores which grow in its stomach-wall escape. Through the circulation of the blood the spores then find their way into the salivary or poison glands.

Poison Glands

These important little glands, which supply the irritating poison of the mosquito bite, lie within the anterior part of the thorax just beyond the neck (Fig. 26). The secretion from each three-lobed gland is conducted forward into the head by a fine tube, the salivary duct. In the head the two ducts join and the common duct empties into the salivary pump (Fig. 18). This, in connection with its continuation, the salivary channel in the hypopharynx, forms a practical syringe by which the poisonous saliva is automatically forced out at the point of the proboscis during the act of feeding. It has been thought that the saliva serves to prevent the clotting of the blood in the mosquito's sucking tube, but this, strangely enough, seems doubtful.[1] Its irritating effect is however well known, and it is, furthermore, with this salivary secretion that the malarial spores are injected into the human circulation.

[1] G. F. H. Nuttall and A. E. Shipley. Jour. of Hygiene, London, 1900, p. 195.

Malaria.

It was early observed that "malaria" was apt to be prevalent during damp and rainy seasons, and that it occurred principally in exactly such places as are now known to furnish ideal breeding grounds for the Malaria Mosquito. That new cases of malaria appeared at the time of year when the Malaria Mosquito abounded, was also recorded long before it was suspected that the insect was in any way connected with the malady; and one of the old medical writers, mentions as a characteristic of malarial seasons, that "gnats and flies are apt to be abundant."

Malarial Seasons

Asia is considered to have been the original home of malaria and from there it was introduced into Europe. In the fourth century B. C. it had become established in Greece, and since this time it has been endemic in Europe, particularly in the countries bordering on the Mediterranean. Its prevalence in Italy and Greece is historic. It is thought to have been an important factor in the decline of the nations of antiquity.[1]

Original Home of Malaria

Malaria was formerly considered to be a form of ague due to foul air, whence its name, which literally means "bad air." It was attributed to a sort of "miasma." Its true nature did not become known till 1880, when Laveran, a French military surgeon, working at the time in Algeria, discovered the malarial parasite in human blood. Some years later, Professor Manson of England, directed the attention of Major Ross of the Indian Service, to the mosquito as a possible carrier of malarial infection. It had at this time just been discovered that yellow fever was spread by mosquitoes, and Manson had previously, in 1879, found a Culex mosquito carrying the parasite of filarial disease. That the insect might play such a direct and extraordinary rôle as it does in the transmission of malaria, was, however, not suspected even by Manson. In 1897 Ross discovered the presence of the malarial organism in a mosquito of the genus *Anopheles*, and a little later, through the efforts, chiefly of Ross and the Italian, Grassi, the remarkable life-history of the parasite became known in its entirety.

Discovery of Malarial Parasite

[1] W. H. S. Jones. Malaria. A neglected factor in the history of Greece and Rome. London, 1907.

As the result of the laborious researches of these scientists, we now know that malaria is not communicated except by the Malaria Mosquito, that this is a member of the genus *Anopheles*, and that consequently, malaria does not exist in any locality in the absence of mosquitoes of this genus. While it is highly probable that all of the forty or more species of the genus, distributed over almost the entire world, may carry malaria, ability to harbor and transmit the malarial parasites has been actually proven of only about half the number. The majority of the species known to be malarial occur in India. The only European or North American member of the genus which stands at present positively convicted of carrying the disease, is the one figured and described in this paper, *Anopheles maculipennis* Meigen. That other mosquitoes, for instance, the common Culex, of which so many species exist everywhere, are as likely as Anopheles to imbibe malarial blood is unquestionable, but in all mosquitoes, except certain Anopheles, the human malarial parasites seem to perish in the alimentary tract of the insect, or the spores are perhaps destroyed by the more acid secretion of the salivary glands.

Malaria and Anopheles

The malarial organisms are unicellular animals, "protozoa," of the class Sporozoa, all members of which are parasitic. The members of the order to which they belong, the *Hæmosporidiida*, are parasitic in the blood of higher animals and resemble the malarial organisms in their life-history. Thus, there is a parasite of "bird malaria" found in pigeons, crows and bluejays, *Halteridium*, transmitted by a Culex mosquito; and another, *Proteosoma*, which lives in the blood of sparrows and is also carried from one bird to another by a mosquito.

When a malaria-infected mosquito bites, the poison or saliva which is injected into the wound carries into the human circulation some minute needle-like or elongated spindle-shaped bodies. These are the malarial spores (Fig. 32, S). Once in the human circulation, each spore, of which there may be half a hundred, enters a red blood corpuscle (Fig. 27, A, B), loses its characteristic form and becomes a minute, rounded, amœboid parasite. After its entrance, this measures one fifth to one fourth of the diameter of the blood cell; but, nourished by the contents of the corpuscle, it grows rapidly (Fig. 27, C, D). The blood corpuscle in which it lives, loses its circular outline, becomes enlarged, and, in a short time, is nearly filled by the growing parasite (Fig. 27, E). At the same time the nucleus of

The Malarial Spores in the Blood

the malarial amœbule divides, till six to sixteen daughter nuclei may be seen (Fig. 27, E). By the time this nuclear division is complete, almost the entire original contents of the red corpuscle have disappeared, little remaining of it but the thin cell-membrane, filled with the enlarged parasitic mass. At last the wall of the corpuscle bursts, and the parasite is liberated (Fig. 27, H). Its protoplasm has by this time divided into as many parts as there are nuclei, and each resulting part forms a new spore, which in its turn, enters a red blood corpuscle (Fig. 27, A). The same process of growth at the expense of the blood cells is then repeated, and new spores are formed by division, accompanied by the destruction of an

Asexual Multiplication of the Parasites

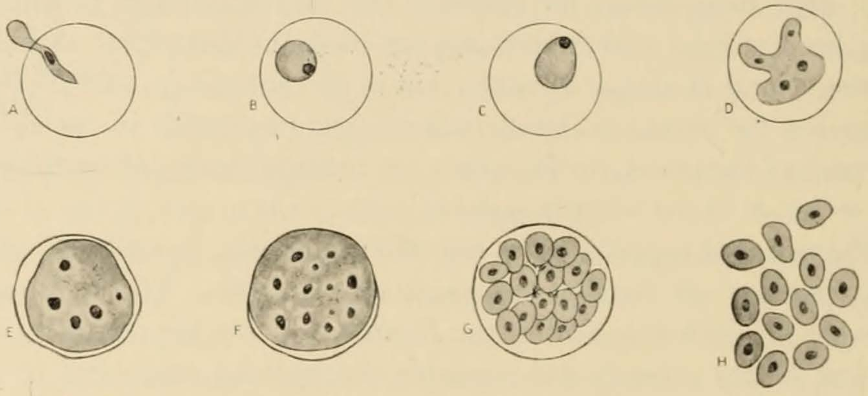

FIG. 27. THE MALARIAL PARASITE. (TERTIAN.) ASEXUAL CYCLE IN THE HUMAN BLOOD.

A. Malarial spore entering a blood corpuscle (schematic). B. C. Malarial parasite in the blood corpuscle. D. Enlarged, amœboid parasite. E. Growth and division of the parasite. H. The malarial blood-spores liberated by the bursting of the blood corpuscle. Magnification 1600 diameters. After Ruge.

ever increasing number of red blood cells. This process of multiplication, which constitutes the asexual cycle in the life of the malarial parasite, may go on for a considerable period, till the blood is filled with billions of minute organisms. In time, however, certain of the spores, after entering fresh corpuscles, do not divide, but they develop into forms of the parasite which, if taken up by a Malaria Mosquito, will conjugate and reproduce sexually (Fig. 28).

These new forms, which are approximately spherical in shape, are of two kinds (Fig. 29, A): larger (A) female (egg) cells, and somewhat smaller (A 2), male cells. The latter give rise to long filamentous sperms when removed from the human circulation. In the mosquito's stomach these sperms fertilize the female cells, a single sperm uniting with each (Fig. 29, B), and as many as five hundred of these fertilized egg cells have been found in the stomach of a single mosquito. The fertilized egg-cell becomes elongated and pointed at one end (Fig. 29, C), and finally works its way into the stomach-wall of the insect (Fig. 30), where the embryo-cells grow and, in fifteen to twenty days, produce large cysts (Fig. 32, C) each of which is filled with thousands of new needle-shaped spores. These cysts, which are on the outer wall of the stomach (Fig. 31), ultimately burst and the hosts of contained spores (Fig. 32, C, S) are set free in the body cavity and, consequently, in the blood of the mosquito. Some of them find their way into the salivary glands (Fig. 32, G) and then into the salivary ducts, whence, at the insect's next meal, they are again injected with the saliva into the blood of another human individual. In this manner malarial infection is handed on from subject to subject.

Sexual forms of the Parasite

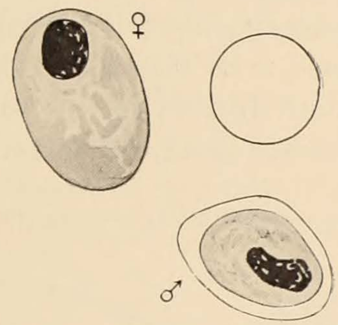

FIG. 28. NORMAL BLOOD CORPUSCLE AND MALE (♂) AND FEMALE (♀) REPRODUCTIVE FORMS OF THE MALARIAL ORGANISM.

Magnification 1600 diameters, after Ruge.

Malarial infection by the "Mosquito bite"

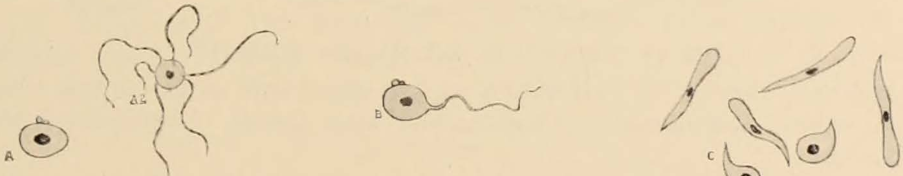

FIG. 29. THE REPRODUCTIVE FORMS OF THE MALARIAL ORGANISM IN THE MOSQUITO'S STOMACH.

(After Schaudinn and R. Koch.)

A. Female, or egg cell. A 2. Male cell giving off sperms. B. Fertilization of the egg-cell. C. The fertilized egg-cell. Magnification 375 diameters.

Forms of Malaria

Three varieties of malaria are distinguished: "tertian," where the fever and chills recur every forty-eight hours; "quartan," where they are separated by an interval of seventy-two hours, and, lastly and most dangerous of all, the irregular "tropical" malaria, the mild local form of which is known as "æstivo-autumnal." The intervals which separate the paroxysms correspond in length to the duration of the process of spore-formation in the blood cells, the chills marking the liberation of the spores (sporulation). The parasites which produce the three different forms of malaria are considered to be separate species, distinguished chiefly by a difference in the time required for the completion of their cycle of development in the human blood. In this connection it is of interest that immunity against

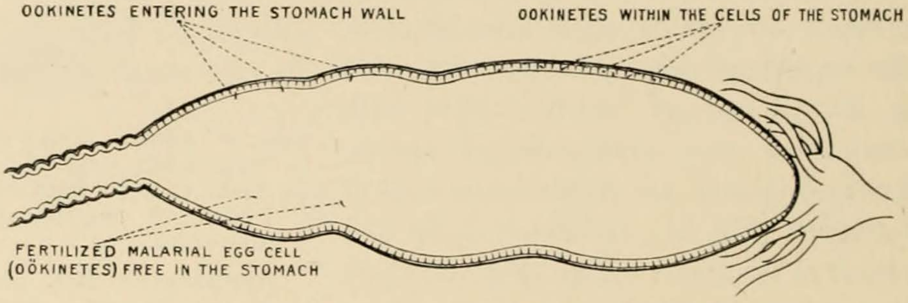

FIG. 30. STOMACH OF THE MALARIA MOSQUITO.

Oökinetes are shown entering the stomach wall. Diagrammatic. Magnification about 30 diameters.

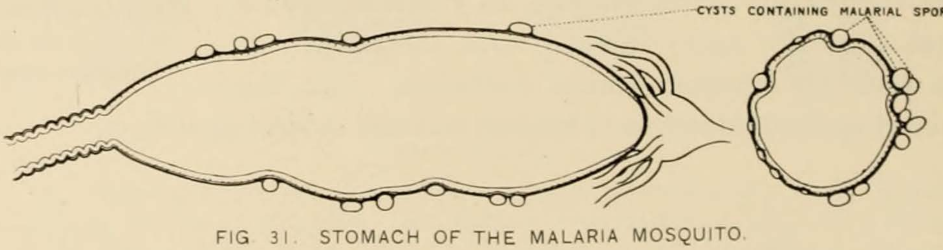

FIG. 31. STOMACH OF THE MALARIA MOSQUITO.

Malarial "Sporocysts" are shown on the outer wall of the organ. Longitudinal section diagrammatic. Cross section after Grassi. Magnification about 25 diameters.

one form of malarial organism has been found by Professor Koch not to insure immunity against the other two species. The parasite of the tropical variety differs from the others in respect to the appearance of the sexual forms, which are half-moon or crescent-shaped. It was these which were first found by Laveran, and they are termed the "half-moons of Laveran."

With the extermination of the mosquito of a malarial neighborhood the disease will, in time, disappear. Nuttall on the other hand describes districts in England from which malaria has disappeared, although the mosquitoes remain. This disappearance of malaria may have been brought about by a general use of quinine. Quinine, obtained from various species of trees of the genus *Cinchona,* growing at high altitudes particularly on the Andes and brought into use in Europe in the year 1640 by the Countess Chinchon, vice-queen of Peru, who had been cured of malaria by its use, is the only known specific against malaria. It will, if properly administered, destroy the parasites of tertian and quartan fever in a comparatively short time. The parasite of tropical fever, however, such as exists in its severest form in certain places on the West Coast of Africa, on the southernmost

Effect of quinine

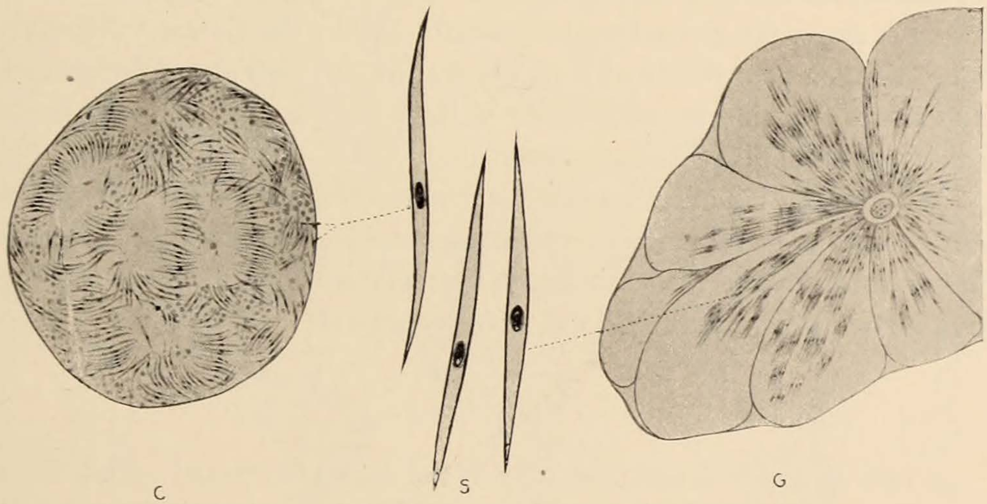

FIG. 32. THE MALARIAL SPORES IN THE MOSQUITO.

C. A sporocyst with contained spores (× 400) (after Grassi). S. The liberated spores (× 3000). G. Section of the salivary gland of the mosquito, malarial spores lying in the cells and in the duct of the gland. (× 350) (after Grassi).

of the Philippine Islands and in the Malay Archipelago, is only slightly affected even by quinine, after the parasite has once begun to multiply in the blood. The sexual forms of the malarial organism are especially resistant and may, long after the destruction of all asexual parasites, take the place of these latter and by simple division give rise to new crops of spores. As a preventive the drug has, however, been found highly serviceable by those obliged to travel or to live in tropical malarial countries.

As an example of a local malarial epidemic may be mentioned an outbreak, described by Dr. W. N. Berkeley, which took place near Jerome

Park in the Borough of the Bronx, New York City, in 1900. A search revealed specimens of *Anopheles maculipennis* in every house and generally in the sleeping quarters wherever the disease occurred. In tropical climates, the natives, who often live in dark and poorly ventilated houses, are the chief sufferers, and we learn that, in India and Africa, from 20 to 100 per cent of the children of the native villages, are affected by malaria.[1] In the southern States of our own country malaria is a severe scourge among the negroes, and probably for the same reasons as in India.

Prevalence of Malaria

The Malaria Mosquito seldom rises even to the second story of a house, and it is a well known fact, that persons whose sleeping quarters are high above the ground are seldom attacked by the disease. Since the mosquito is a poor flyer and does not readily rise high above the ground, and since it avoids an abundance of light, its absence from the upper stories of a building is easily understood.

In general, high altitudes insure a freedom from the Malaria Mosquito and from malaria, but there are some notable exceptions, and malaria has been recorded as endemic in certain regions in India where the elevation is four to five thousand feet above sea-level.

Yellow Fever.

The rôle which mosquitoes play in the dissemination of yellow fever was discovered in 1881 by Dr. Finlay of Havana, and communicated by him in papers on the "Natural History of Yellow Fever" (1881–1886). A suspicion that some insects were concerned in the spreading of the disease had been expressed as early as 1848 by Nott, a physician of Mobile, Ala. Not much credence, however, was given to Finlay's discovery till it had been firmly established that malaria was transmitted by mosquitoes; and the real experimental proof of transmission by the mosquito was furnished by a commission of United States Army surgeons which was sent to Cuba by former Surgeon-General Sternberg for the purpose of carrying on investigations. The findings of the commission, which was in charge of Major Reed, U. S. A., positively demonstrated that yellow fever was communicated by the bite of a "Yellow Fever Mosquito" (*Stegomyia fasciata*

Mosquitoes and Yellow Fever

[1] Stephens and Christopher in Reports to the Malaria Committee of the Royal Society. Sixth series, March, 1902, p. 2, and elsewhere.

Fabricius) which must previously have fed on the blood of a yellow fever patient; that the fever could not possibly spread without the presence of a mosquito, and that simple contact with a yellow fever patient was not dangerous. To assure themselves of the correctness of their conclusions, members of the commission in the course of their investigations even went so far as to sleep for weeks in bed clothing soiled by yellow fever patients.

The organism which causes the yellow fever, has not, up to the present time, been found; but it is in every way probable that it will prove to be a

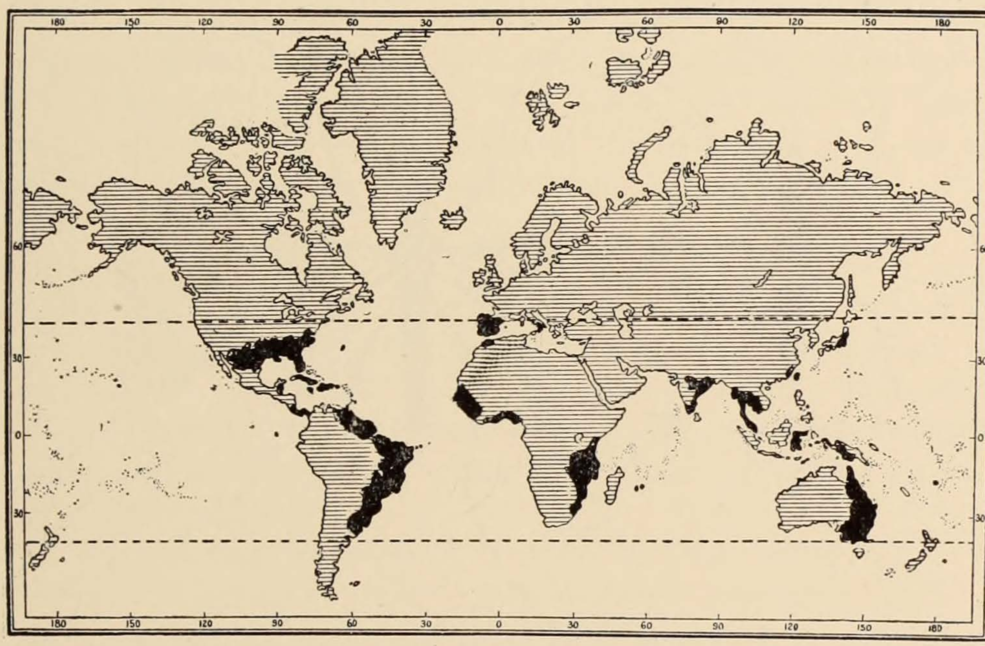

FIG. 33. THE DISTRIBUTION OF STEGOMYIA.
After Theobald.

blood parasite of the class Sporozoa, its life-history resembling in a general way that of the malarial organism. The period of incubation in man, *i. e.*, the period which must elapse between the bite of the infected mosquito and the beginning of the sickness, varies from forty-one hours to not more than six days. The period of its development in the mosquito was found by the commission to be twelve days or more. This fact is of very great importance in relation to quarantine measures, and makes it entirely possible to prevent the introduction of yellow fever into any port where it does not exist.

Period of Incubation

At the same time, the briefness of the period of incubation insures a practical freedom from yellow fever to places where the Yellow Fever Mosquito occurs, if they be distant but six days from an infected port. Hawaii is at present an example of such freedom from the disease, although the Stegomyia occurs there.

The Yellow Fever Mosquito is essentially tropical and sub-tropical. On the American continent its chief habitat is Central and South America

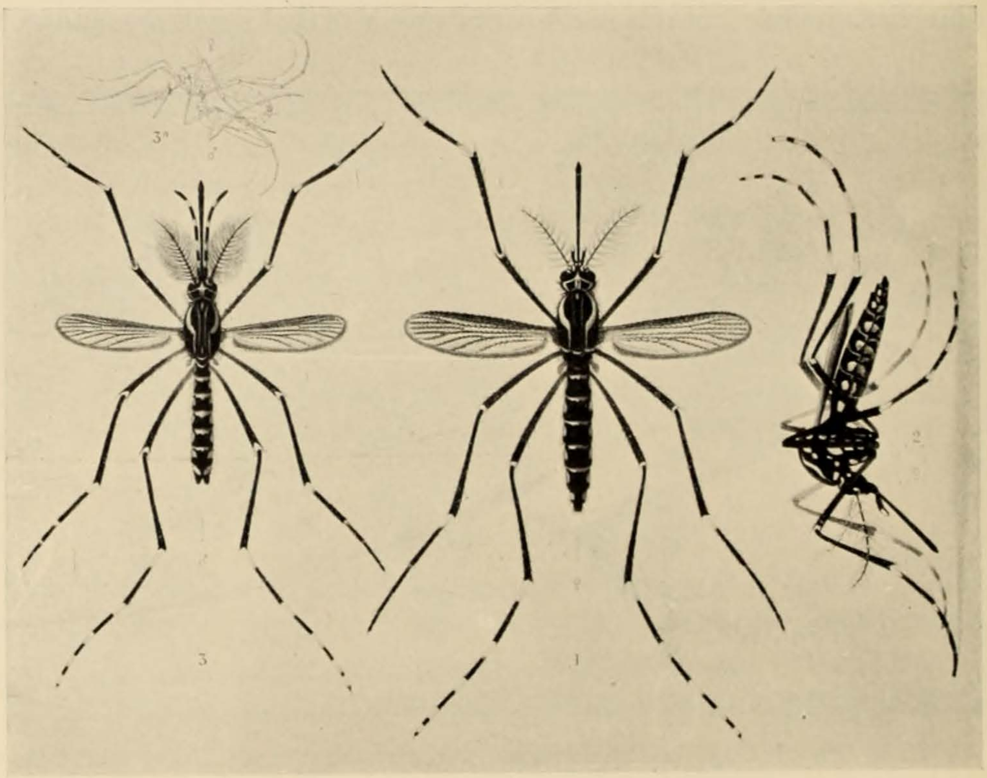

FIG. 34. THE YELLOW FEVER MOSQUITO (*Stegomyia fasciata* Fabricius).

1 and 2 females. 3 male. The figure shows well the banded abdomen, the markings on the thorax and the striped legs. (Magnification about 5 diameters.) From E. A. Goeldi: Os Mosquitos no Pará, 1905.

and the West Indian Islands. It is, however, found in the Southern States, as may be seen on the map, Fig. 33. According to Dr. Howard its life zone, over which it might well spread, includes practically all of the Southern States, as far north as Mason and Dixon's Line. Theobald, of the British Museum, puts its distribution between 48 degrees north and south latitude. That it may be carried

Distribution

far northward and under favorable conditions live, and perhaps breed, is shown by records of yellow fever epidemics in New York and Philadelphia in the early part of the past century. The success of the sanitary work done in Cuba under General Wood bears abundant witness to the effectiveness of measures for the extermination of Stegomyia mosquitoes, and of proper isolation of yellow fever patients from the insect by the simple means of mosquito netting.

The Yellow Fever Mosquito

The Yellow Fever Mosquito is known as a "day mosquito," and was formerly considered a species of Culex. The back of the thorax is marked by silvery stripes, the dark-brown or black sides of both thorax and abdomen are ornamented with conspicuous white spots, and each segment of the abdomen bears a white cross-stripe. The knee-spots of the black legs are white, and the tarsal joints are banded with white. These markings make the mosquito quite easy to recognize.

Insects as Carriers of Disease.

The whole question of the relation of insects to disease is a subject not only of significance to the medical world and of great interest to the naturalist, affording as it does a striking and most recent instance of the relation of medical science to natural history, but it has also become a matter of general and urgent sanitary importance, and as such demands an enlightened public appreciation.

Filarial disease

Many kinds of insects have been found to be instrumental in the spreading of disease, either by simply conveying disease germs from one place to another, or by actually harboring germs of parasites, which grow and multiply in the body of the insect till they are transferred by its bite to another animal or a human individual. This latter is the case not only in malaria and yellow fever, but also in many of the other most-dreaded diseases of man and beast, in which an insect has been found to serve as the intermediary host for a disease-producing organism. Our first knowledge of an instance of this kind was gained by the discovery in the proboscis of a species of a Culex mosquito by Professor Manson in India (1879) of the minute parasitic worm which produces the terrible filarial disease, or elephantiasis.[1] Since the time of Manson's discovery new instances of this

[1] The filarian worms find lodgment in the lymphatic vessels and by blocking the natural flow of the lymph at certain points cause enormous enlargement of parts of the body.

nature have continually come to light. The most notable recent

Sleeping Sickness

example is, perhaps, the African "sleeping sickness," caused by a protozoan blood parasite, *Trypanosoma*, of which many species causing severe, usually fatal affections have been found in the circulation not only of man and the domestic animals, but also of reptiles and fishes. The insect which serves as the intermediary host is the notorious "tsetse-fly." The fatal "tsetse-fly disease" and the "kalaazar" or "black water fever" are two stock diseases due to this organism. Cattle and horses used for travel are killed by them in a few days. The devastation due to these diseases has been so great that certain districts in South Africa have had to be abandoned by the inhabitants. A constant supply of the parasites is obtained by the flies from numerous wild animals which have in the course of time become immune to the disease. It has been suggested that the extinction of, for example, the horse on the American continent might probably have been due to the destructive agency of some disease-bearing insect.[1] The discovery at Florissant, Colorado (T. D. Cockerell, 1907), of a fossil tsetse-fly would seem to bear out this hypothesis.

Texas Fever

The well-known "Texas fever" or "red water fever" which has been introduced into many parts of the world and which has occasioned enormous losses to the cattle-breeders of the southwestern part of the United States is another example of a disease that has been conveyed by an insect, and caused by another type of protozoon, *Piroplasma*, parasitic in the blood. The insect in this case is the cattle tick (*Margaropus annulatus* Say). The list is growing, and the investigations which are now being carried on, particularly by the German and English Governments, may prove to be productive of important results.

The Bubonic Plague

English investigations in India and China have just brought to light the mode of transmission of the bacterial bubonic plague. It has been found that a minute flea, which normally lives on gray rats, carries the disease. When the rats die from the plague by thousands, the fleas find human victims and thus epidemics are produced.

In connection with the subject of insects as carriers of disease, the ordinary house fly should not be forgotten, since it disseminates tuber-

[1] H. F. Osborn: The Causes of Extinction of Mammalia. The American Naturalist. Dec. 1906.

culosis, cholera and typhoid fever. The house-fly breeds in decaying matter, and its habits are so filthy, that even if for no other than esthetic reasons, it should be the first object of the general war on pestiferous insects, begun long ago by the agriculturists for economic reasons, but now become also a problem of sanitary importance for which communities and governments will be compelled to spend great sums of money.

The House-fly

Mosquito Extermination.

The study of disease-producing parasites and of the insects concerned in their transmission is not only indicating rational procedures for the extermination of the latter, but also, as in the case of yellow fever, furnishing a scientific basis for such quarantine and preventive measures as are at present carried out by the United States Government in Panama, and to some extent by modern nations everywhere. The far-reaching effect of such discoveries as those described above is difficult to estimate. The stimulus which they have given to research has already proved to be of vast moment. The practical results in tropical countries and colonizing nations will grow, as distant and hitherto almost uninhabitable parts of the world are opened up. In our own immediate neighborhood they have led to a campaign of extermination against the Malaria Mosquito, and indirectly have served to call public attention to the whole tribe of these insects, which, even though they may not all spread human diseases, nevertheless constitute a pernicious pest which renders large areas unfit for habitation. When we consider that within a radius of twenty-five miles of New York there exist two hundred square miles of marsh and swamp land,[1] the local mosquito problem alone will be seen to be far from insignificant. Such a campaign of extermination of mosquitoes as is now being waged in the State of New Jersey under the supervision of Professor Smith would have been considered before the time of the discoveries of Ross and Finlay, not only extravagant, but really insane.

Preventive and Quarantine Measures

The local Problem

When the problem of mosquito extermination on a large scale, first presented itself, it became, of course, necessary to devise effective means

[1] Felt: Mosquitoes of New York State, New York State Museum Bulletin 79, p. 244, 1901.

for its accomplishment. In the light of some knowledge of the habits and life-history of the mosquito, there was no difficulty in discovering that any extensive attempt to cope with the insects must be directed toward its destruction in the aquatic larval and pupal stages. A consideration of the "natural enemies" of the mosquito, which might be taken advantage of for the purpose, would seem to bear out such a decision, for in the case of the adult mosquito, these are practically confined to a few insectivorous birds which fly at dark, while the animals which prey on the larvæ are very numerous.

Practical Methods of Extermination

The systematic investigations of the subject, which have covered the ground very fully, make clear the practical measures that must be used, and the actual work which has been accomplished leaves no more room for any doubt that in civilized communities, mosquitoes may be, if not exterminated, at least reduced in number to a minimum. Professor Howard in his book, "Mosquitoes, How they live, etc.", (1901) gives an account of the work done at his instigation by the national and various local governments, up to that time. The "Report on Mosquitoes" (1905) of the New Jersey Agriculture Experiment Station, contains an account of Professor Smith's extensive investigations, which are put to the most practical use.

Natural Enemies of the Mosquito

Professor Smith finds that the larvæ are eaten by certain shore birds, like sand-pipers, and by other insects and their larvæ, such as the whirligig beetles (*Gyrinidæ*), water-scorpions (*Ranatra fusca*), and especially the larvæ of a diving beetle (*Dytiscus*), one of which was observed in confinement, to kill and eat 434 wrigglers in two days. Tadpoles are found to be practically worthless for the purpose. The most active enemies of the larvæ are small fishes of various kinds, such as minnows, "sunfish," the common "killifish" or "saltwater minnow," the "sheep-head minnow" and the "top minnow." One or more varieties of these or other small fishes, if introduced wherever there is a permanent body of water, will effectually keep mosquito larvæ from hatching. The fish must be carefully selected with reference to their preference in respect to environment, of which an account is to be found in the report mentioned above. The complete absence of larvæ in many places where they would naturally be expected, like cat-tail swamps, may undoubtedly be accounted for by the presence of some species of small fish.

Mosquitoes do not live in running water, and as a matter of fact, the greater number by far, hatch in places where fish could not possibly be maintained, hence other measures for extermination must be resorted to. The use of crude petroleum spread as a thin film on the surface has long been known to kill the larvæ and pupæ, but it is applicable only to small bodies of water, and it is not lasting in its effect. Poisoning of the water must naturally be restricted in its application, but it is effective, and of the agents tried, "phinotas oil" which is highly diffusible, is found to give much the best results. Cisterns, rain barrels and other receptacles in which mosquitoes are apt to breed in large numbers and in which poisoning of the water is not permissible, should be kept covered, while other mosquito-breeding collections of water in which fish cannot be used, should be treated by drainage or filling.

The Use of Oil

The saltwater marshes of New Jersey, which give rise to billions of insects that spread inland, are at present being drained by machine-dug ditches, and at comparatively small cost per square mile. In many cases, the simple introduction of tide-water into the low-lying shore districts, will bring about sufficient movement of the shallow stagnant water of the marshes to reduce greatly the numbers of mosquitoes that hatch.

Drainage

LITERATURE ON MOSQUITOES.

An old work "Micrographia Curiosa" by P. P. Bonnani, published in 1691, contains what is perhaps the first account of the mosquito and its life-history. A "Dissertation de Culice" by Johann Mathews Barth, dates from 1737; the "Bybel der Natuure" (1738) by the Dutch naturalist Swammerdam who evidently was not acquainted with any previous accounts of the mosquito, contains an excellent description of its metamorphoses, illustrated by plates, which surpass many of the illustrations of the insect published in more recent years. After the time of Linnæus the literature, of course, becomes more extensive, but no especially great attention was paid to the family Culicidæ till after the discovery of its disease-carrying propensities. The number of works dealing with the insects from a natural history point of view, is somewhat restricted, but papers treating of the medical aspects of the subject are exceedingly numerous.

Below are enumerated a few of the most important and easily accessible works on mosquitoes and on the subject of insects as carriers of disease. To all of these, as well as to many others, the writer is indebted for much of the information contained in this paper.

BERKELEY, W. N. Laboratory work with Mosquitoes. New York, 1902. A brief guide, introductory to microscopic work, particularly with salivary glands and the malarial organism.

CHRISTOPHERS, S. R., and STEPHENS, J. W. W. Reports to the Malaria Committee, Royal Society. London, 1900–1903. Brief Reports on Mosquitoes, in relation to Malaria in India, and the East Coast of Africa, also, a short description of the anatomy of the mosquito.

BLANCHARD, R. Les Moustiques. Histoire Naturelle et Médicale. 673 pp. Paris 1905. A comprehensive systematic work.

HOWARD, L. O. Mosquitoes. How they live, How they carry disease, How they are classified, How they may be destroyed. 241 pp. New York, 1901. An excellent popular account.

GILES, GEORGE M. A Handbook of the Gnats or Mosquitoes. Giving the Anatomy and Life-history of the *Culicidæ*, together with descriptions noted up to the present date. 530 pp. 1902.

NUTTALL, G. H. F. On the Rôle of Insects, Arachnids and Myriapods in the spread of Bacterial and Parasitic Diseases of Man and Animals. A critical and historical study. Johns Hopkins Hospital Reports, Vol. VIII, 154 pp. Baltimore, 1899–1900.

NUTTALL, G. H. F., and SHIPLEY, A. E. The Structure and Biology of Anopheles. The Journal of Hygiene, Cambridge and London. Vol. I. 1900.

Contains the results of their admirable and very complete technical study of the structure and biology of the malaria mosquito.

SMITH, JOHN B. Report of the New Jersey State Agricultural Experiment Station, upon the Mosquitoes occurring within the State, their Habits, Life-History, etc. Trenton, 1905.

A comprehensive and interesting report of Professor Smith's thorough investigation, from a practical as well as purely scientific point of view, of the natural history of the mosquito, and the methods which should be used in its extermination.

RUGE, REINHOLD. Einführung in das Studium der Malaria Krankheiten mit besonderer Berücksichtigung der Technic. 2te Auflage, Jena, 1906.

An excellent, clear exposition of scientific knowledge of malarial parasites and the clinical aspects of malaria, well illustrated.

THEOBALD, FRED V. A monograph of the Culicidæ or Mosquitoes of the World, mainly compiled from the collections received at the British Museum from various parts of the world, in connection with the investigation into the cause of malaria, conducted by the Colonial Office and the Royal Society. 4 Vols. London, 1903.

The only comprehensive and thorough, systematic account of the mosquitoes of the world.

No. 11.— THE MUSICAL INSTRUMENTS OF THE INCAS. By C. W. MEAD, Assistant in Archæology. July, 1903. *Price, 10 cents.*

No. 12.— THE COLLECTION OF FOSSIL VERTEBRATES. By W. D. MATTHEW, Ph. D., Associate Curator of Vertebrate Palæontology. October, 1903. *Price, 10 cents.*

No. 13.— A GENERAL GUIDE TO THE AMERICAN MUSEUM OF NATURAL HISTORY. January, 1904. *Out of print.*

No. 14.— BIRD'S NESTS AND EGGS. By FRANK M. CHAPMAN. Associate Curator of Mammalogy and Ornithology. April, 1904. *Reprinted,* February, 1905. *Price, 10 cents.*

No. 15.— PRIMITIVE ART. July, 1904. *Price, 15 cents.*

No. 16.— THE INSECT-GALLS OF THE VICINITY OF NEW YORK CITY. By WILLIAM BEUTENMÜLLER, Curator of Entomology. October, 1904. *Price, 15 cents.*

(*Reprinted from The American Museum Journal.*)

No. 17.— THE FOSSIL CARNIVORES, MARSUPIALS, AND SMALL MAMMALS IN THE AMERICAN MUSEUM OF NATURAL HISTORY. By W. D. MATTHEW, Ph. D., Associate Curator of Vertebrate Palæontology. January, 1905. *Price, 15 cents.*

No. 18.— THE MOUNTED SKELETON OF BRONTOSAURUS. By W. D. MATTHEW, Ph. D., Associate Curator of Vertebrate Palæontology. April, 1905. *Out of print.*

No. 19.— THE REPTILES OF THE VICINITY OF NEW YORK CITY. By RAYMOND L. DITMARS, Curator of Reptiles, New York Zoölogical Park. July, 1905. *Price, 15 cents.*

No. 20.— THE BATRACHIANS OF THE VICINITY OF NEW YORK CITY. By RAYMOND L. DITMARS, Curator of Reptiles, New York Zoölogical Park. October, 1905. *Price, 15 cents.*

No. 21.— THE DEVELOPMENT OF A MOLLUSK. By B. E. DAHLGREN, D. M. D. January, 1906. *Price, 10 cents.*

No. 22.— THE BIRDS OF THE VICINITY OF NEW YORK CITY. By FRANK M. CHAPMAN, Associate Curator of Mammalogy and Ornithology. April–July, 1906. *Price, 15 cents.*

No. 23.— THE SPONGE ALCOVE. By ROY W. MINER, Assistant Curator of Invertebrate Zoölogy. October, 1906. *Price, 10 cents.*

(*Published as a separate series.*)

No. 24.— PERUVIAN MUMMIES. By CHARLES W. MEAD, Department of Ethnology. March, 1907. *Price, 10 cents.*

No. 25.— PIONEERS OF AMERICAN SCIENCE. Memorials of the naturalists whose busts are in the Foyer of the Museum. April, 1907. Price, 15 *cents.*

No. 26.— THE METEORITES IN THE FOYER OF THE AMERICAN MUSEUM OF NATURAL HISTORY. By EDMUND OTIS HOVEY, Ph.D. Associate Curator of Geology. December, 1907. *Price 10 cents.*

No. 27.— THE MALARIA MOSQUITO. By B. E. DAHLGREN, D. M. D. Assistant Curator of Invertebrate Zoölogy. April, 1908. *Price, 15 cents.*

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No. 5.— NORTH AMERICAN RUMINANTS. By J. A. Allen, Ph. D. Curator of Mammalogy and Ornithology. March, 1902 *Revised edition,* February, 1904. *Price,* 10 *cents.*

No. 6.— THE ANCIENT BASKET MAKERS OF SOUTHEASTERN UTAH. By George H. Pepper, Assistant in Anthropology. April, 1902. *Price,* 10 *cents.*

No. 7.— THE BUTTERFLIES OF THE VICINITY OF NEW YORK CITY. By William Beutenmüller, Curator of Entomology. May, 1902. *Price,* 15 *cents.*

No. 8.— THE SEQUOIA. A Historical Review of Biological Science. By George H. Sherwood, A. M., Assistant Curator. November, 1902. *Price,* 10 *cents.*

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