

The position assumed by *Anopheles* larvæ, however, is strikingly horizontal (Fig. 3373) and close to the surface. These larvæ have a small head, no siphon, and the respiratory orifices are almost level with the back. The head,

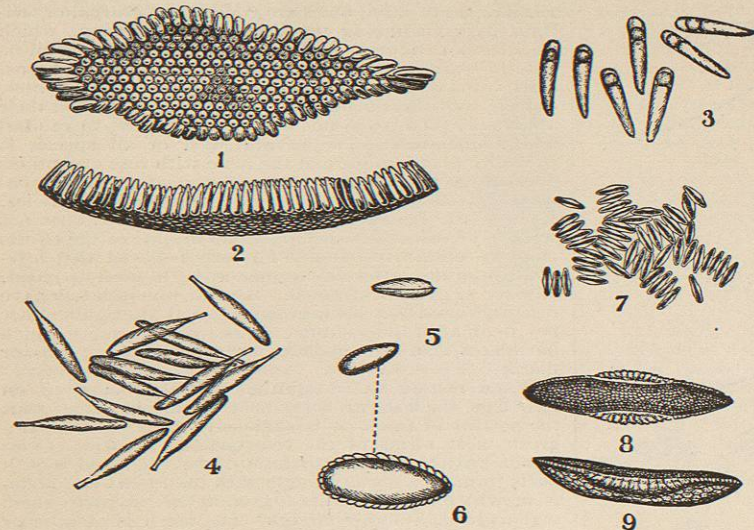


Fig. 3371.—Mosquito Eggs. 1, Egg mass of *Culex* seen from above; 2, same from the side (after Sambon); 3, separate *Culex* eggs; 4, eggs of *Panoplitæ* (after Daniels); 5, 6, eggs of *Stegomyia* (after Theobald); 7, group of *Anopheles* eggs floating; 8, 9, isolated eggs of *Anopheles maculipennis* to show floating organ. $\times 30$. (After Nuttall and Shipley.)

which is held barely below the surface, has been turned on the neck through a half-circle so that its lower aspect looks upward as it feeds on the floating debris. The pupæ (Fig. 3374, A and B) are also different for the different genera. In all, however, they float at the surface, taking no food but obtaining air through a curious auriculate respiratory siphon, until ready for the emergence of the perfect insect, which occurs through the back of the pupal thorax; the pupal skin floats at the surface as a rest for the adult before the latter starts on its initial flight. The process of breeding is retarded by colder weather, and the larvæ may even be frozen in masses of ice, and yet after thawing out regain their activity. Many, doubtless, regularly pass the winter in this way in higher latitudes.

Diseases Transmitted by Mosquitoes.—There no longer exists a reasonable doubt that malarial disease is transmitted by the agency of mosquitoes. The painstaking elucidation of the life cycle of the hæmatozoa of malaria has demonstrated the existence of a sexual phase in the life history which takes place in the body of the mosquito and alternates with asexual generation found in human blood. (For further detail on the life history of this organism and its relation to the disease see article on *Plasmodium malarie*.) When Manson had a number of *Anopheles*, which had bitten a patient suffering from tertian ague in Italy, brought to England and there permitted them to bite two healthy students, who at a suitable time thereafter came down with malarial fever and showed the characteristic parasites of tertian ague in the blood, all objection to the possibility of this method of transmission of the disease was eliminated. Thus far no one has been able to find any other method of transference save by operative interference, and to judge from the life history of other parasites which manifest alternation of generations in different hosts no other method is at all probable, as Giles has so forcibly and logically demonstrated. It would, however, be hazardous to maintain that the asexual generation, even of the so-called human malarial parasites, may not be found also in other verte-

brates. The immediate and abundant appearance of malaria among travellers in regions which have been depopulated or in which man is at best very rare, points indeed to the existence of another host for the asexual generation. On the other hand the sexual generation is known to inhabit only mosquitoes of the genus *Anopheles*, and experiments to infect various species of *Culex* and of other genera have thus far proved futile. All data thus far obtained show not only that, given *Anopheles*, the possibility of malaria exists, dependent to some extent no doubt upon other factors, but also that "no *Anopheles*, no malaria" is equally certain.

The relation of the mosquito to elephantiasis (*q. v.*) and filariasis (see *Nematoda*) has been equally definitely established. Here the mosquito draws the embryo worms, still surrounded by a delicate embryonic membrane, with the blood into its stomach. The embryos bore their way thence into the muscles and after a brief stay wander out into the labium. As in malaria and yellow fever, there is here also a stage of incubation, but unlike the former it is not a period of reproduction for the parasites but merely for the growth of the larvæ which are ready to be transferred to the human host when the mosquito has digested its first meal and is ready for the second. In this case certain species both of *Culex*

and of *Anopheles* have been shown to afford proper environment for the development of the young worms. The recent brilliant discoveries of the Yellow Fever Commission have demonstrated that the mosquito serves as the intermediate host for the parasite of yellow fever, and that this parasite is transmitted after an interval of approximately twelve days to non-immune individuals by a mosquito that has fed on the blood of a yellow-fever patient. It is the more striking that this mode of propagation has been definitely determined since the specific cause of the disease is as yet undiscovered. The

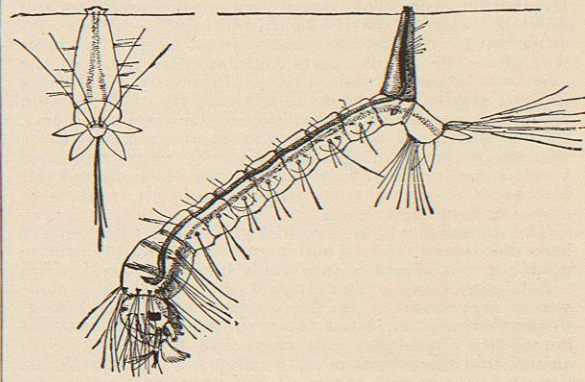


Fig. 3372.—*Culex pungens*. Larva in breathing position at surface of water. (After Howard, Bull. United States Dep. Ag.)

mosquito responsible for the transmission of yellow fever is *Stegomyia fuscicata*, although in all probability the culpability is shared by other species of the genus, if not by other genera.

Recently Blanchard has summarized forcibly arguments to show that leprosy also is transmitted by mosquitoes. An ailment exclusively human, caused by a bacillus which grows only so far as known in human tissue and which cannot be transmitted by mere contact, the

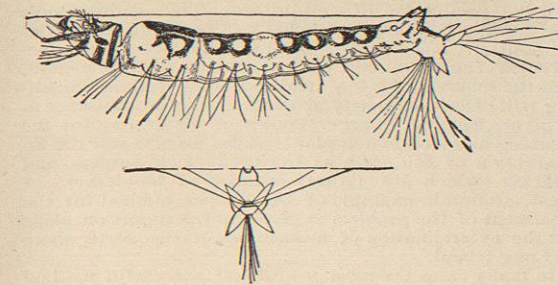


Fig. 3373.—*Anopheles maculipennis* Meig. Larva showing breathing position at surface of water. (After Howard, Bull. United States Dep. Ag.)

intervention of a biting insect appears indispensable that the bacilli may be brought into a favorable environment.

That the rôle is assumed by the mosquito rests only on conjectural and yet very probable grounds.

It has also been conjectured that tubercle bacilli are transmitted by mosquitoes, without positive evidence having been found for the view. While such unconfirmed suppositions must be regarded with suspicion, it is certain that in some instances bacteria are transmitted by mosquitoes. This is clearly shown by the observations of Giles on natives of India who had "applied for treatment on account of their faces being so swollen that they could scarcely open their eyes, and the fact that such cases are specially apt to occur among patients lying in a surgical ward makes it probable that the unusual effect of the bites in such cases is due to the mosquitoes having indulged in a previous feed from some wound secretion."

In this connection mention should be made of the annoyance caused by mosquitoes, of the irritation due to their bites, very noticeable in some persons, and of the limitation which these disturbances put upon the enjoyment and full utilization of the opportunities for invigorating outdoor existence which the warmer part of the year affords and the health of every individual demands. While trivial perhaps in the individual instance, it amounts in sum total to so much that for its remedy alone the severest measures against these pests should be advocated. When the loss of life and economic disturbance produced by yellow fever, and the still more serious but less striking since prolonged effects of malaria are taken into consideration, abundant reason exists for the immediate action of civilized communities to abate the mosquito nuisance. It must also be borne in mind that the casual introduction of a case of malaria, yellow fever, or elephantiasis into an otherwise healthy region gives conditions which may lead to the spread of the malady, if the place happens to be infested with the proper mosquito.

Dispersal of Mosquitoes.—The agency of mosquitoes in transmitting disease necessitates a consideration of the means which bring about the dispersal of the insects. In general, mosquitoes are home bred; and while this is true of *Culex* it is even more characteristic of *Anopheles*. Ross was able to find no case in which the distance from the infested house to the breeding-ground of this species was greater than one hundred and fifty yards. *Stegomyia* is said by Gorgas to be a very domestic mosquito, seldom leaving the immediate neighborhood of the place of its birth. The cause of a mosquito plague is then strictly local, although Smith thinks that swarms

of the salt-water mosquito, *Culex sollicitans*, may be carried twenty or even forty miles by a favorable wind. In most cases, however, it is clear that natural agents do not disperse them so widely. Howard has given numerous cases of their introduction into new regions by railway trains, and Grassi furnishes equally good evidence of their transportation by stage coaches.

Some observations have been made on the rôle of vessels in carrying mosquitoes from port to port. The insects probably are transported long distances in sheltered parts of the vessels and will breed in water barrels, and perhaps even in bilge water, during a voyage, thus furnishing a constant supply of adults. The emergence of mosquitoes from concealment on board ship would serve to explain the sudden outbreak of yellow fever at considerable intervals after leaving port. Ships coming into harbor have recorded swarms of mosquitoes carried out ten or even twenty miles by gentle off-shore winds. In this way vessels anchored at a considerable distance from infected ports, or even passing them without having had any direct communication, are subject to contamination with diseases transmitted by mosquitoes.

PROPHYLAXIS.—In view of the part played by the mosquito in the transmission of disease, it is fitting to inquire in the next place what means are available for the correction of the evil. A number of methods have been suggested which differ somewhat in applicability and efficacy, but all of which are valuable in certain cases. First may be mentioned the protection of individuals against the bite of the mosquito. This is accomplished by means of protecting the house with screens of mosquito netting or fine wire gauze in both doors and windows, or by screening beds with curtains of fine gauze, which completely shield the sleeper from the attack of the insect. In the case of persons engaged in outdoor employment it is necessary also to adopt some type of protection for the exposed parts of the body, such as wearing gloves on the hands and hoods or veils of netting over the face and neck.

The results of this practice are, that those in good health are not infected with the parasites carried by the mosquito, and on the other hand that sufferers from the disease do not give infection to the mosquitoes of the neighborhood. In the latter case it is imperative that such should not become sources of infection for the entire neighborhood, and the spread of the infection may be prevented by timely and perfect protection of the invalid from the attacks of mosquitoes. It is reasonable to require that all cases of malaria, as well as yellow fever and other infectious diseases, should be reported to

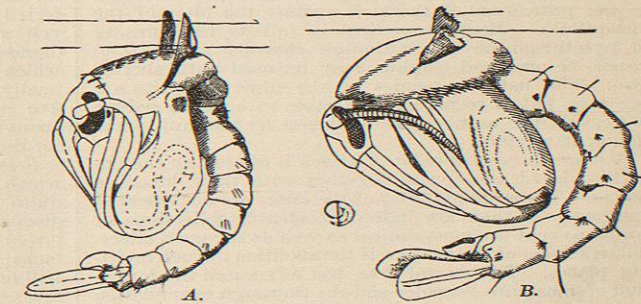


Fig. 3374.—Pupæ of A. *Culex pungens*. B. *Anopheles maculipennis*. (After Howard.)

the public health officer and that the isolation of the patient from mosquitoes be rigorously carried out, for otherwise the introduction of a single case may be the source of infection for an entire neighborhood. This has repeatedly been seen within recent times, as when, by the return of soldiers from the Spanish war, a previously unin-

fectured neighborhood has been infected with a veritable epidemic of malaria.

This method has been successfully employed among the railroad operatives in Italy by Celli and Grassi with results so pronounced that the latter has proclaimed the possibility of freeing Italy entirely from malaria within a short time and making the most dreaded regions into health resorts. Under protection from mosquitoes, house epidemics of malaria ceased and convalescence was as easy at home as with change of air. Outside of the protected houses hardly a person escaped the disease; within them hardly any one was infected. Such mechanical prophylaxis is of the greatest advantage, particularly to those whose employment compels them to remain in a badly infected region. But it is after all a temporary measure and unattainable for a large part of the population of the world and under the conditions of tropical climates.

As protection against the bite of the mosquito, use has also been made of their repugnance to strong odors with meagre success. The essential oils of lavender, citronella, and eucalyptus are effective, when rubbed on the skin, in discouraging the attacks of mosquitoes; but the greatest success has been attained with the formula: castor oil, $\frac{3}{4}$ i.; alcohol, $\frac{3}{4}$ i.; oil of lavender, $\frac{3}{4}$ i. As a remedy for the irritating effects of the bites so noticeable on some persons, glycerin, alcohol, and indigo have been recommended, but in my experience tincture of iodine is best where the location of the bite does not inhibit its use, and is successful in the worst cases.

It has also been suggested by Koch that the generous and universal use of quinine would destroy the malarial organisms and thus do away with the disease. It may be doubted whether even under governmental support such a method could be sufficiently generally applied, in spite of the prejudices of a considerable part of the population, in temperate regions at least, even to approximate the end sought. The use of quinine will always be in favor among the educated part of the population of malarial regions and with travellers who are called upon to penetrate fever-ridden territory. Its sale at cost under government authority is a wise measure for the sanitary improvement of general health in the tropical colonies. In temperate regions many cases of malaria are not recognized as such; and it should be noted, moreover, that while affecting a most important element of the mosquito problem, the proposed method does not offer any solution for the other factors concerned.

The destruction of mosquitoes in the adult condition may be brought about by various means. In order to control yellow fever effectually this is essential as well as the protection of the sick against the bites of the mosquitoes. Most convenient of all is the burning of pyrethrum powder, although chlorine gas, formol vapor, chloral, and sulphur may be used with success also. The natural enemies of the adult mosquito are not rare, but it seems impracticable to hope to reduce noticeably the numbers of the insect by the multiplication of its enemies.

A more successful point of attack is offered by the immature larvæ and pupæ together with their breeding places. The large majority of the latter are not essential and many of them are indeed accidental collections of water, so that the most radical as well as the most effectual treatment of the subject is the abolition of such breeding places. To this end Ross has advocated the formation of mosquito brigades and the thorough examination and treatment of a region. This consists in the destruction of all unnecessary breeding spots and the regular treatment of necessary bodies of water so that they may not endanger general health by producing swarms of the insect. It is perfectly practicable in this manner to remove the sources of the infection and to reduce to the minimum limit the mosquitoes in any locality, since, as has already been mentioned, these insects are home bred and are rarely found at any considerable distance from their breeding places.

For a work of this character there are necessary: first, accurate knowledge regarding the location, number, and extent of the breeding places; second, capable treatment of the smaller localities that they may remain free of water even when it rains; and third, a scientific plan for handling the larger water areas that they may not serve for the production of mosquitoes. The smaller pools can usually be filled or drained by deepening the outlet without any considerable expense. The ease and effectiveness of such drainage work are entirely unappreciated, and the removal of a few small pools by draining or filling will often completely abate the mosquito nuisance in a given locality. Larger bodies of water require the cleaning away of marsh plants at the margin and the introduction of fish, such as the stickleback, sunfish, and goldfish, which are natural enemies of the larvæ. A most admirable example of the proper method for the treatment of the problem is given in the report on plans for the extermination of mosquitoes on the north shore of Long Island.

In many cases the most useful and successful method for the destruction of larval mosquitoes is the use of kerosene which has been advocated by Howard and has been successfully employed in many cases. The kerosene spreads over the surface and forms a film which smothers the larvæ and pupæ and catches the females as they come to deposit eggs. For the petrolization of a pool what is known as low-grade fuel oil which spreads rapidly and evaporates slowly is recommended and is best applied by pouring it on the surface of the water; spreading the oil through a spraying nozzle is less economical. Water treated with kerosene once a fortnight should be perfectly safe and the oil will not harm other animals than the aquatic insect larvæ.

The destruction of the mosquitoes and their breeding places has attracted much attention recently. The responsibility of the individual for the maintenance of his own property free from nuisance is thoroughly recognized and the breeding of mosquitoes will soon be included as a nuisance everywhere as it has been in several places, notably Havana, of which Ross speaks with admiration, commending "the straight-thinking Americans who quickly find a person who breeds mosquitoes." That campaigns against mosquitoes are not only reasonable but eminently successful has been abundantly proved by work in many localities in the United States under the direction of Howard and others, by the work of Young in Hong-Kong, of the United States army in Cuba, and most striking of all by the campaign of Gorgas in Havana. Within ninety days after the adoption of regulations providing for the effectual isolation of the sick and for the destruction of all mosquitoes present in the infected and the neighboring houses Havana was freed from yellow fever; and in spite of repeated introduction of the disease from without, the death rate from yellow fever, which had averaged four hundred and sixty-two annually for ten years previous, was reduced to a total of five in 1901, and for malaria the reduction was from about three hundred and fifty in 1900 to only twenty-six for the first four months of 1902.

Results.—Finally it is proper to call to mind the effects which will be produced by the extermination of the mosquito. These evidently depend upon the character of the diseases. Yellow fever consists of a single illness followed by greater or less immunity from subsequent attacks; consequently the extermination of the mosquito will bring about the immediate disappearance of the disease. This has been the case in Havana. Elephantiasis and malaria, however, are protracted diseases. The parasites remain alive for years after the time of introduction by a mosquito. Elephantiasis is a permanent disease, and in malaria relapses occur long after the removal of the effecting agent; hence after the disappearance of all mosquitoes in a locality those persons who were previously infected will continue to suffer from these two diseases, so that not much change may be found within a period of several years. And yet a single year's work in mosquito extermination in Havana reduced the mortality

from malaria in that city ninety-three per cent. within eighteen months.

In consideration of the enormous losses which Celli sums up for a single country in the positive assertion that "malaria costs Italy annually thousands of lives and incalculable treasure," and in view of the even greater losses of other countries, it is not too much to hope that extended action may soon be taken through governmental agency for the correction of the evil by the eradication of the mosquito.

Henry B. Ward.

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