Anopheles

Anopheles are insects that are medically important because of their association with malaria, filariasis and arbovirus infections. There are nearly 500 recognised species of the *Anopheles* mosquito.The most important disease carried by *Anopheles* mosquitoes is malaria. Some *Anopheles* species are also vectors of filariasis, especially that caused by *Wuchereria bancrofti*, but some also transmit *Brugia malayi* and *Brugia timori*. A few species transmit arboviruses that are of minor medical importance.

External morphology

Eggs are laid singly and have air-filled ***floats*** that help them float on the water surface.

Larvae do not have a siphon and consequently lie ***parallel*** to the water surface. Dorsally a ***tergal plate*** and paired ***palmate hairs*** are present on most abdominal segments.

Pupal abdominal segments have numerous short setae, and segments 2–7 or 3–7 have in addition short peg-like spines which are absent in culicines.

Most, but not all, *Anopheles* have ***spotted wings***, that is the dark and pale scales are arranged in small blocks or areas on the veins. The number, length and arrangement of these dark and pale areas differ considerably in different species and provide useful characters for species identification.

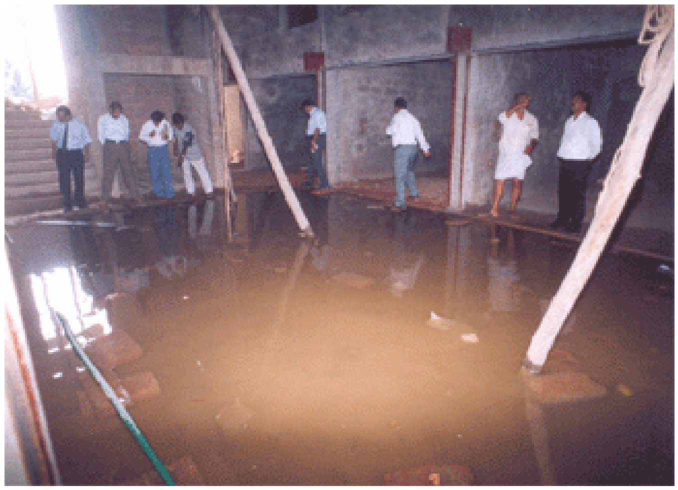
Lifecycle

The natural history of malaria involves cyclical infection of humans and female *Anopheles* mosquitoes. In humans, the parasites grow and multiply first in the liver cells and then in the red cells of the blood. In the blood, successive broods of parasites grow inside the red cells and destroy them, releasing daughter parasites ("merozoites") that continue the cycle by invading other red cells.

The blood stage parasites are those that cause the symptoms of malaria. When certain forms of blood stage parasites (gametocytes, which occur in male and female forms) are ingested during blood feeding by a female *Anopheles* mosquito, they mate in the gut of the mosquito and begin a cycle of growth and multiplication in the mosquito. After 10-18 days, a form of the parasite called a sporozoite migrates to the mosquito's salivary glands. When the *Anopheles* mosquito takes a blood meal on another human, anticoagulant saliva is injected together with the sporozoites, which migrate to the liver, thereby beginning a new cycle.

Thus the infected mosquito carries the disease from one human to another (acting as a “vector”), while infected humans transmit the parasite to the mosquito, In contrast to the human host, the mosquito vector does not suffer from the presence of the parasites.

Mosquito Control



Water logging at construction site

Mosquito control is an important component of malaria control strategy, although elimination of malaria in an area does not require the elimination of all Anopheles mosquitoes. In North America and Europe for example, although the vector Anopheles mosquitoes are still present, the parasite has been eliminated. Socio-economic improvements (e.g., houses with screened windows, air conditioning) combined with vector reduction efforts and effective treatment have led to the elimination of malaria without the complete elimination of the vectors. On the other, controlling these highly adapted, flying and hiding vectors is indeed a formidable task. Development of resistance to insecticides has compounded the problem. Ban on non-biodegradable and non-eco-friendly insecticides like DDT also may have contributed to the resurgence of malaria.

Mosquito Control Measures: Every step taken to control the mosquitoes has a cumulative effect and contributes immensely to control malaria. The eggs developing within the female mosquito need human blood for nourishment and so the female mosquito bites humans. By personal protection against mosquito bites, this blood meal can be denied, leading to reduction in mosquito eggs and hence mosquito population. Personal protection includes closure of windows and doors to prevent entry; protection of humans against mosquito bite by using bednets (insecticide treated) and mosquito repellent. Female mosquitoes lay the eggs on water collections where they develop further over a week into adult mosquitoes. By preventing water logging, destroying unwanted water collections and keeping the water containers closed, sources of egg laying (Source Reduction) can be denied and breeding of mosquitoes can be prevented. Further, different types of chemical (insecticides) or biological (Guppy or Gambusia fish or bacteria or fungii*)* larvicides can be used on such breeding grounds to kill the developing larvae and pupae. It is far easier to kill the non-flying forms of the mosquitoes than going after the adults that can fly a kilometer or more. The adult mosquitoes can live up to 4-10 weeks depending on the ambient temperature and humidity. Space sprays are used to instantly kill the adults and residual sprays, on their resting places such as walls, are used for residual mosquitocidal effect. But most of such insecticides have effects on the human beings as well as the environment and other life forms. The adult mosquitoes enter the human dwellings between 5 pm and 10 pm and early morning and hide in dark corners, to come out and bite human beings at night, mostly between 11pm-4am. The entry of the adult mosquitoes can be prevented by keeping the doors and windows closed between 5-10pm and early morning. Screening of all the windows and vents is a very easy and sure method of controlling the entry of adult mosquitoes. The hiding places of the mosquitoes, such as clothes hanging in the open, can be minimised. Personal protection by covering the body with clothes and use of mosquito nets and repellents will further help in preventing mosquito bites. All these in turn will deny the blood meal and development of eggs.

Source reduction

involves preventing development of mosquito larvae. The female mosquitoes need a blood meal from a vertebrate host to nourish their eggs. About 50-200 eggs are laid per oviposition on the surface of stagnant water and these eggs develop into adult mosquitoes in a span of about 5-14 days, passing through the stages of larvae and pupae. High humidity and ambient temperature between 20-30ºC provide ideal conditions for breeding of Anopheline mosquitoes. Common sites of breeding for *Anopheles* mosquitoes include rainwater pools and puddles, borrow pits, river bed pools, irrigation channels, seepages, rice fields, wells, pond margins, sluggish streams with sandy margins, hoof prints, tyre tracks etc. Water stagnation due to construction of dams, reforestation, shrimp farming, fish ponds etc., have also been identified as possible sites of *Anopheles* breeding. *An. stephensi* is a well adapted urban vector, being a container breeder, making use of man-made sites such as building-construction sites, wells, garden ponds, cisterns, overhead tanks, ground level cement tanks, water coolers, tyres, barrels and tins, intra-domestic containers etc. *Anopheles* breeding sites increase with rainfall and resultant water stagnation, ; however, some larvae and pupae may be washed away by heavy rainfall.

The best method of mosquito control is preventing the development of the eggs into adult mosquitoes, by reducing the sources of breeding. These anti larval measures are not only simple and cost effective, but also environment friendly.

a. Preventing egg laying: The easiest, cheapest and most environment-friendly method to control malaria is by preventing the mosquito from laying eggs. This is done by avoiding or eliminating the clean water collections. As mentioned, most such collections are artificial, temporary and man made.

It is a common habit to throw the unutilized utensils, buckets, bottles, tyres etc., into the open. During the rains, water gets collected in these containers and provides ample breeding locations for the female anopheles mosquito.

In the cities, the other sites for mosquito breeding are the water tanks. Shortage of water supply in large cities makes it necessary to have these tanks in virtually every building. Overhead tanks, sump tanks, storage tanks, ornamental tanks etc. are often left uncovered and this provides scope for mosquito breeding. Also, it is common to find puddles of water everywhere during the rainy season. This is the reason why malarial transmission is at its peak during the monsoon.

There is abundant scope for water collection in and around the construction sites: water stored in tanks; the layer of water on the surface of the cement concrete (used for ‘curing’ the concrete and left as such for 3 weeks); puddles of water in and around the place of construction – all these provide scope for mosquito breeding. To add to the problem, construction workers tend to harbour the malarial parasite, due to frequent infections owing to their poor standards of living. Thus, construction sites not only provide for mosquito breeding but also supply the parasites. This is the reason why malaria tends to be more common in cities where construction activities are in full swing.

Tiled roof

The older houses have tiled roofs that are sloping. This helps easy drainage of water during rains, thus minimising water logging. In the recent years, most new constructions have concrete roofs and terraces that tend to be flat and non-sloping. These roofs/terraces may not have proper drains for water-flow. As a result, water tends to collect on these rooftops during the rains and this provides ample scope for mosquito breeding. In addition, there are the natural collections of water like the wells, lakes, ponds, paddy fields, marshlands etc. where mosquito breeding occurs in abundance.

Therefore, unless these breeding sites (most of which are man-made and temporary) are taken care of, it is impossible to control mosquito breeding and hence malaria. And it is impossible to achieve this without the participation of the general public. Education of the people is thus very important for any meaningful action. The following measures are called for to minimize mosquito breeding and these measures require only a trifle of human efforts:

Flat terrace

- Do not throw utensils, vessels, buckets, tyres, bottles, tender coconut shells etc. in the open. They should be either destroyed or buried or at least kept inverted so that water cannot collect in them. All such things should be cleared during the rainy season.
- All tanks should be kept tightly closed. A black plastic sheet can be used for the purpose. Also, all tanks should be emptied, cleaned and allowed to dry for at least half an hour, once every week.
- Terraces and roofs should ideally have a slope, particularly in places where monsoon tends to be heavy. All such roofs/terraces should have adequate drainage for water. Any collection of water on these surfaces should be cleared at least once a week.
- At construction sites, all the care should be taken to avoid collection of water at one place for more than a week. The layer of water on the surface of the concrete, used for concrete curing, should be cleared at least once a week and allowed to dry for half an hour. All other puddles should be cleared regularly. Collections of water in the toilets and closets under construction should also be cleared. All tanks should be kept snugly closed. All labourers should be frequently checked for parasitemia and adequately treated. They should also be provided with mosquito nets.
- All unused wells and tanks should be closed or destroyed. Engine oil or kerosene has been used as a larvicidal on these collections. Another method to prevent egg laying on unused wells is by adding EPS polyesterene beads onto the surface of water. These beads are non-toxic, cheap and long lasting. They coat the water surface and prevent the mosquito from laying eggs.
- Wells that are being used and ornamental tanks can be treated with biological larvicides that do not harm the quality of drinking water. Also, these wells should be covered with either mosquito-proof nets or with plastic sheets.

How engineers can help in malaria control?

Public Health Engineering has lot to do with malaria control, especially by means of Source Reduction.

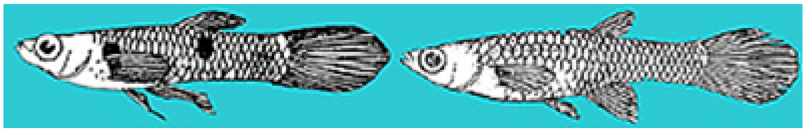
- Prevent water logging – Design the buildings with sloping roofs to aid easy drainage of rain water; provide drains in adequate numbers and sizes in buildings with flat roofs
- Prevent entry of insects – Screening of all windows and vents should be made mandatory. It is observed that this simple, common sense measure followed in every construction in the

U.S.A. has in a big way helped in control of all insects including mosquitoes and hence malaria.

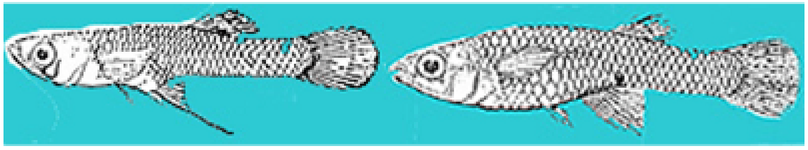
- Engineering skills are also called for in draining and flushing of water collections; deepening or filling of water logged areas; proper maintenance of water levels and intermittent irrigation in dams and canals and in changing salt content of water so as to make it unsuitable for mosquito breeding. Mosquitoes that breed in irrigation water can be controlled through careful water management.

b. Use of Larvicides: If the above mentioned measures are not adequate or difficult to achieve, then measures should be taken to destroy the larvae developing in the breeding sites. This can be done by either larvicidal chemicals or by biological larvicides like fish or bacteria.

i. Chemicals: Themiphos and Fenthion are the two commonly used larvicidal agents. Themiphos is used on potable water collections and Fenthion, being more toxic, is used on non-potable water collections. Oils may be applied to the water surface, suffocating the larvae and pupae. Most oils in use today are rapidly biodegraded. Insect growth regulators such as methroprene is specific to mosquitoes and can be applied in the same way as chemical insecticides.



Guppy Male and Female



Gambusia Male and Female

ii. Biological larvicides:

One of the safest and interesting methods in mosquito control is the use of biological agents that eat or destroy the larvae.

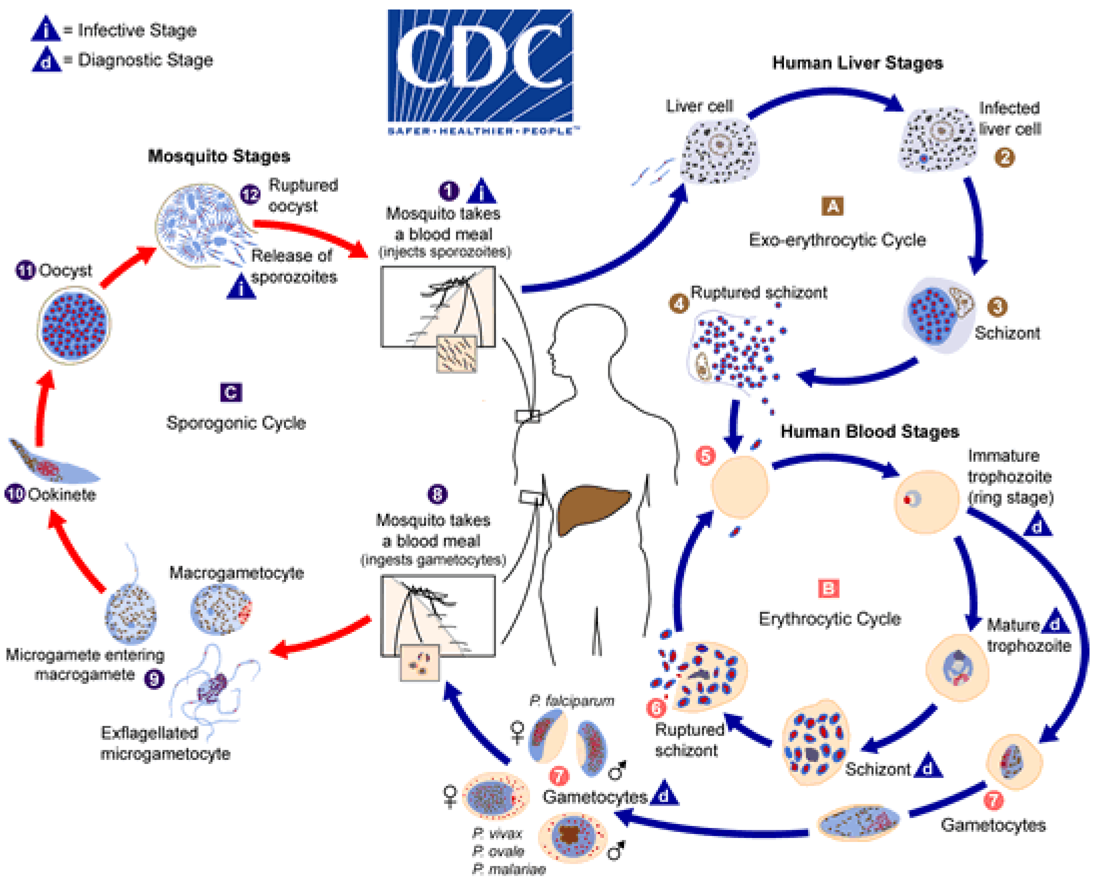
Eco-friendly larvivorous fish such as the top water minnow or mosquito fish (*Gambusia affinis*) or the common guppy (*Poecilia reticulate*) can be effectively used to control the mosquito population. These fish can be introduced into all collections of potable water like wells, tanks, ponds and lakes, particularly in rural and peri-urban areas and in freshwater bodies in rural areas.

Bacteria *such as Bacillus sphaericus* and *Bacillus thuringiensis var israelensis* are also effective larvicides. However, they need to be re-introduced every 15 days and their culture may need expertise.

Mermitid Nematod (*Romanomermis culicivorax*), Notonectid (Bug), Ambylospora (Protozoa), Coelomomyces (Fungus), Nuclear Polyhedrosis (Virus), and Cyclopoid copepods (Crustacean) are the other biological larvicides found to be effective.

A 'saline solution' from Kochi:

The Kochi Corporation in Kerala tried out a novel and cost effective method of reducing the mosquito population at the larvae stage itself. It has conducted experiments suggested by the retired National Institute of Oceanography (NIO) scientist, Dr. U.K. Gopalan, where the salinity of water in canals and stagnant pools is increased by adding sea water. The experiment was successful and mosquito larvae were found morbid in the canal portions where salinity was increased. When the salinity level reaches 30 parts per thousand or PPT (the normal percentage of salt in the sea), mosquito larvae cannot survive beyond 3 hours. Even at lower concentrations of 15 PPT, they are dead in 12 hours. And when the concentration is upped to 60 PPT, the larvae perish within the hour.



The malaria parasite life cycle involves two hosts. During a blood meal, a malaria-infected female *Anopheles* mosquito inoculates sporozoites into the human host ❶. Sporozoites infect liver cells ❷ and mature into schizonts ❸, which rupture and release merozoites ❹. (Of note, in *P. vivax* and *P. ovale* a dormant stage [hypnozoites] can persist in the liver (if untreated) and cause relapses by invading the bloodstream weeks, or even years later.) After this initial replication in the liver (exo-erythrocytic schizogony A), the parasites undergo asexual multiplication in the erythrocytes (erythrocytic schizogony B). Merozoites infect red blood cells ❺. The ring stage trophozoites mature into schizonts, which rupture releasing merozoites ❺. Some parasites differentiate into sexual erythrocytic stages (gametocytes) ❼. Blood stage parasites are responsible for the clinical manifestations of the disease. The gametocytes, male (microgametocytes) and female (macrogametocytes), are ingested by an *Anopheles* mosquito during a blood meal ❽. The parasites' multiplication in the mosquito is known as the sporogonic cycle C. While in the mosquito's stomach, the microgametes penetrate the macrogametes generating zygotes ❾. The zygotes in turn become motile and elongated (ookinetes) ❿ which invade the midgut wall of the mosquito where they develop into oocysts ⓫. The oocysts grow, rupture, and release sporozoites⓬, which make their way to the mosquito's salivary glands. Inoculation of the sporozoites ❶ into a new human host perpetuates the malaria life cycle.