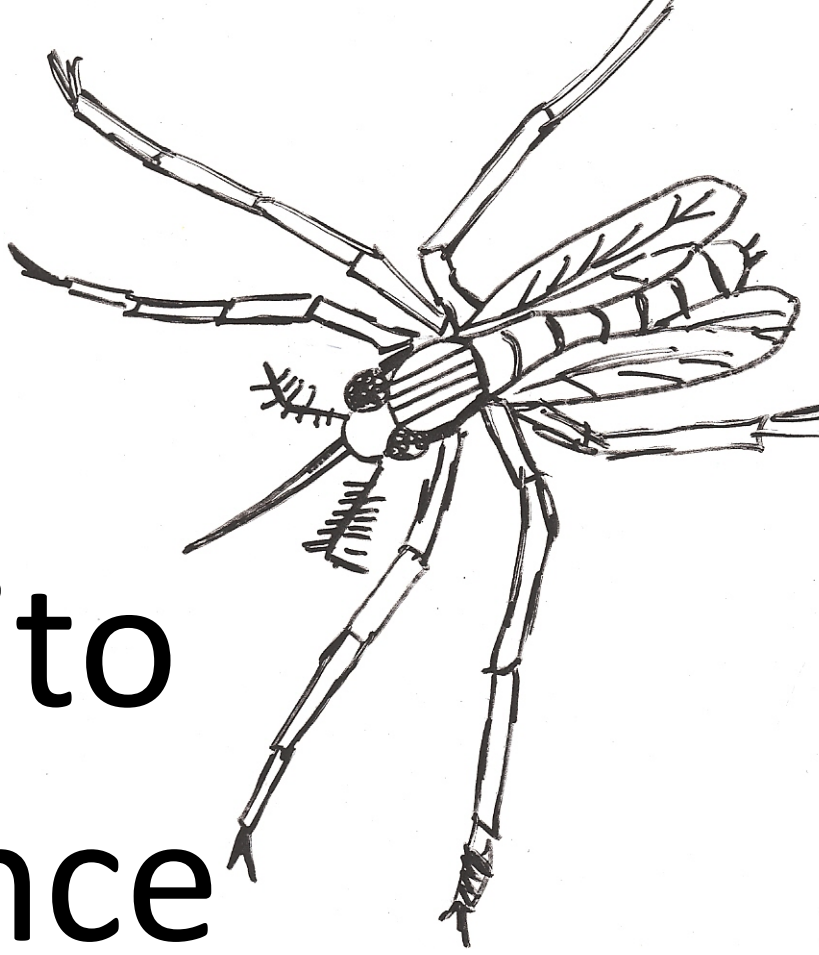

# Mosquito Reference Manual

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## Introduction

Insects (class Insecta) are highly diverse and one of the most successful groups of animals. They live in almost every region of the world: at high elevation, in freshwater, in oceans, and in deserts. They eat plants, prey on other animals, and can even feed on bodily fluids, such as blood.

The mosquito, like all insects, has six legs, external articulating mouthparts, and three distinct body regions called tagma: the head, the thorax, and the abdomen (Figure 1). The mosquito family (Culicidae) belongs to the order known as flies (Diptera), insects with only one set of wings. With a long, thin body, narrow wings, and a proboscis, the mosquito is easily distinguished from other flies. More than 3,000 mosquito species are found worldwide, including hundreds of species in North America.

Most mosquito species feed on plant nectar and animal blood. Only females, however, feed on blood, which provides additional nutrition for their eggs. A female that has recently fed on blood will have a swollen abdomen.

Mosquitoes are vectors for many human diseases, including malaria, West Nile, yellow fever, encephalitis, and dengue. One common species in the United States, *Culex pipiens,* is a vector for the West Nile virus. The virus causes febrile illness—that is, an illness marked by the sudden onset of fever—in robins, crows, blue jays, and other birds, as well as in humans. Two species in the *Aedes* genus, *Aedes aegypti* and *Aedes albopictus,* also present in the United States (*A. albopictus* is a recent invasive species from Asia), are vectors for a number of viral illnesses, including dengue fever.

To control such diseases as dengue fever and West Nile, it is essential to understand the mosquito's life cycle, the hosts, and the virus. It is also important to understand the various environmental factors that can support disease transmission, including those factors that can lead to epidemics and pandemics.

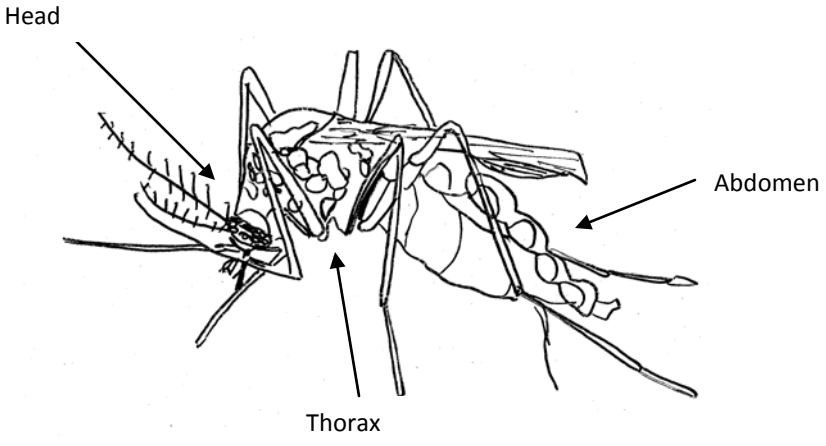


**Figure 1.** Female *Aedes* sp. mosquito.

## Mosquito Life Cycle

The mosquito has four life stages: egg, larva, pupa, and adult (Figure 2). The entire process of growth is known as complete metamorphosis. It begins when the newly emerged adult female mates with a male mosquito and searches for a blood meal. The nutrients in the digested blood form an egg yolk that provides nourishment for developing larvae. Some mosquito species can develop eggs without a blood meal by using proteins and hormones accumulated during the larval stage. These females are autogenous—that is, they can produce the necessary nutrients within their bodies.

When the eggs are mature, the female mosquito seeks water to lay her eggs, which are fertilized with the sperm that she has stored since mating. Eggs hatch into larvae. The larvae feed heavily and gradually pass through four stages called instars, during which they become progressively larger. The larvae eventually become pupae. During this stage, metamorphosis into the adult form occurs. Finally, the fully formed adult mosquito emerges from the pupal casing.

Mosquitoes are aquatic as eggs, larvae, and pupae, and they are terrestrial as adults. In their aquatic stages, mosquitoes live in streams, ponds, puddles, or any other place that has water. The standing rainwater trapped in collections of old tires is particularly good for breeding mosquitoes that prey on humans. A common control against mosquito repopulation is the removal of old tires and the draining of standing water to remove habitat space for developing larvae.

Adult mosquitoes can feed and reproduce for several weeks before dying. During this time, female mosquitoes feed on both blood and sugars. Male mosquitoes feed exclusively on nectar.

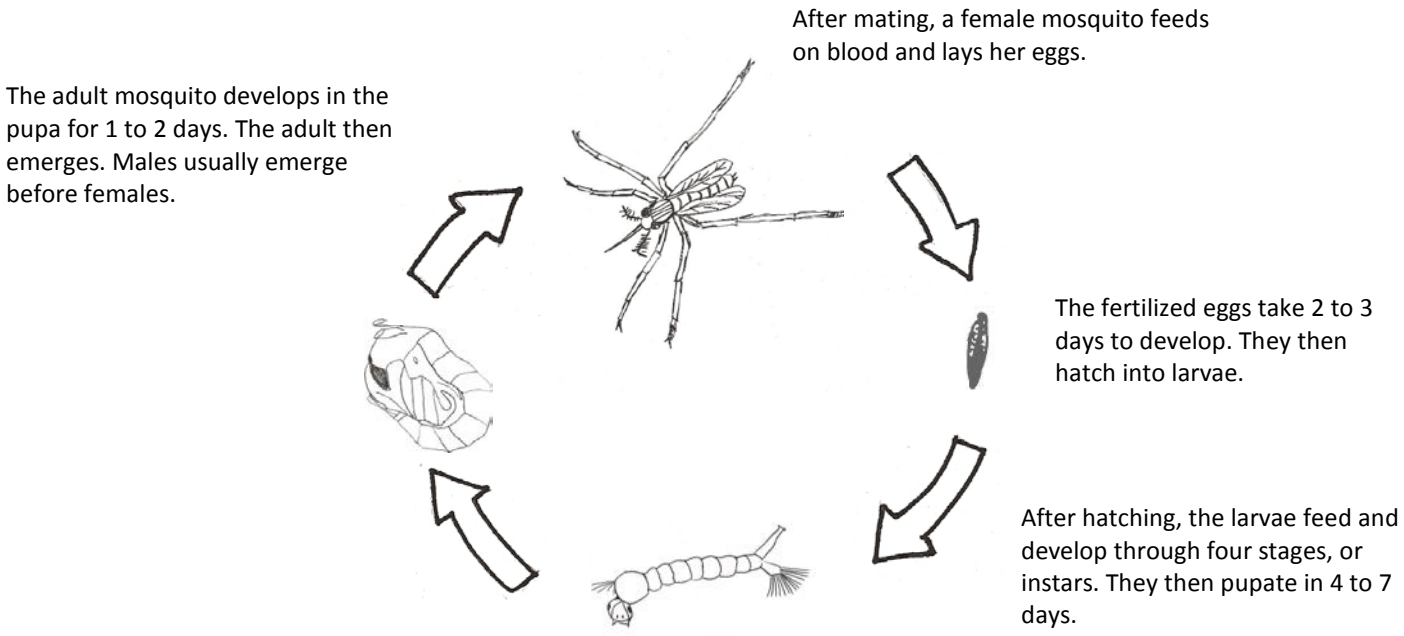


**Figure 2**. Mosquito life cycle.

## Life Stages

**Egg.** A *Culex* sp. (that is, any species belonging to the genus *Culex*) female lays her eggs in clusters called rafts, which float on the surface of the water (Figure 3*a*). *Aedes* sp. females lay individual eggs (Figure 3*b*).

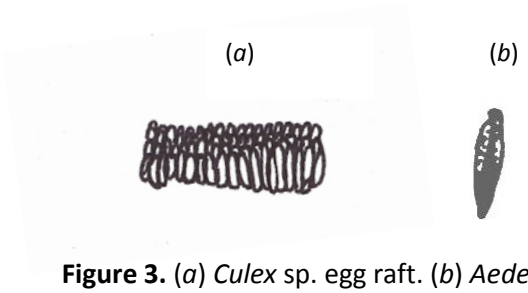


**Figure 3.** (*a*) *Culex* sp. egg raft. (*b*) *Aedes* sp. egg.

**Larva.** Larvae, commonly known as wrigglers, hatch from eggs and live just under the surface of the water. Because wrigglers do not have gills or any other way to obtain oxygen from the water, they extend a siphon tube out of the water to take in atmospheric oxygen (Figure 4). Larvae feed mostly on plant and animal debris in the water. This food is generally low in nutritional value. The nutrition provided by the blood-meal-enriched yolk is therefore important for development.

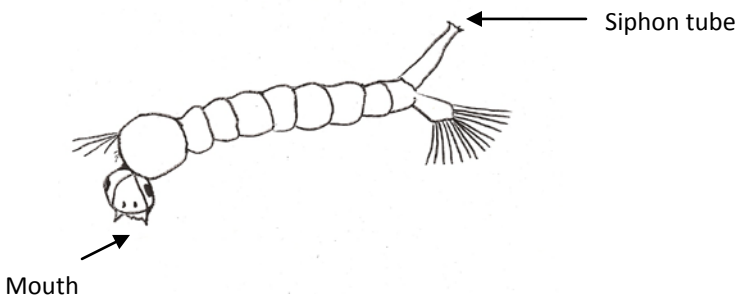


**Figure 4.** Mosquito larva.

**Pupa.** Pupae, also known as tumblers, look like a larva rolled into a wheel (Figure 5). They have a hardened shell. Like larvae, pupae live just below the surface of the water. They use structures called trumpets to draw in atmospheric oxygen. Pupae do not eat.

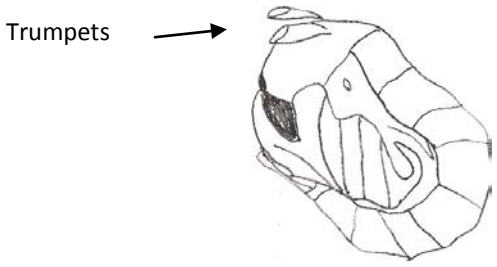


**Figure 5.** Mosquito pupa.

**Adult.** The adult mosquito forms inside the shell of the pupa during metamorphosis. When metamorphosis is complete, the adult emerges from the shell, dries its wings and exoskeleton, and takes flight. Male mosquitoes have bushy plumose antennae, and female mosquitoes have small, fine hairs on their antennae (Figure 6). Males use their antennae to detect mating sounds from females. Both sexes use a specialized mouthpart called a proboscis to feed (Figure 7). The proboscis has a hard stylus inside it that the female mosquito uses to pierce the skin of its host and suck out blood. The mosquito's salivary secretions can harbor pathogens that can be transferred to the host during feeding.

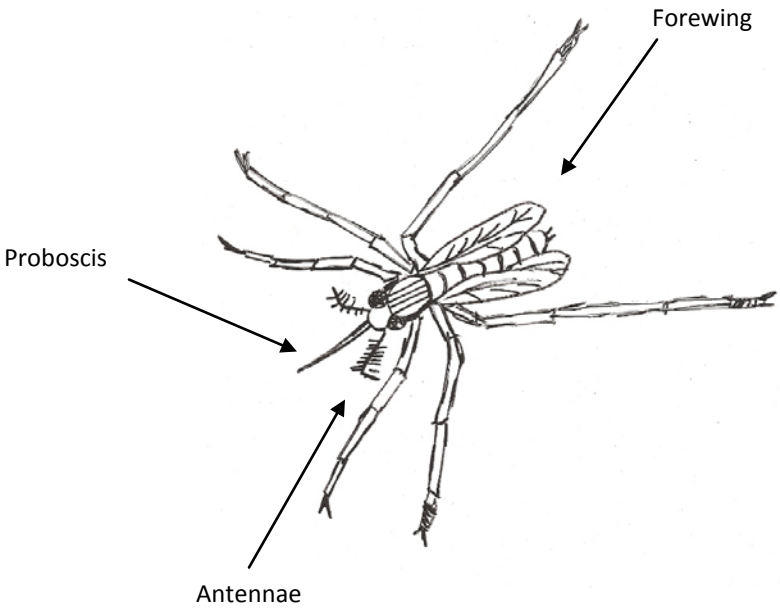


**Figure 7.** Adult female mosquito.

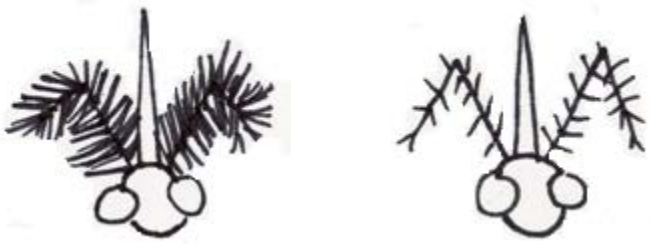


**Figure 6.** Heads of adult mosquitoes.

## Mosquitoes and Dengue Virus

Dengue virus (family Flaviviridae) infects as many as 100 million people annually. Dengue infections occur worldwide, but the highest prevalence is found in tropical and subtropical latitudes. The most common vectors are *Aedes aegypti* and *Aedes albopictus*, although other species in the *Aedes* genus also carry the virus. The transmission cycle of dengue virus is most commonly from infected mosquitoes to humans and then back to mosquitoes (Figure 8). As the infection rate climbs in a human population, the infection rate climbs in mosquitoes as well, leading to outbreak conditions. This is in contrast to West Nile virus infections (see next section), where birds are critical to the transmission cycle, and humans—although infected—are not a viral source for further infections.

The term *serotype* refers to variations within a species of virus, based on having slightly different surface antigens. There are four distinct serotypes of dengue virus, and it is possible to contract more than one of them. A person who has antibodies against one serotype of dengue virus may be protected against future infections by that serotype but not from infections by other viral serotypes. In fact, because of a process called antibody dependent enhancement (ADE), infection by a second serotype can lead to a severe disease called dengue hemorrhagic fever, which can progress to dengue shock syndrome.

The best way to prevent dengue outbreaks is for people to avoid being bitten by infected mosquitoes. Screens and netting can help keep mosquitoes out of interior spaces, but this method is challenging in climates and cultures where sealed indoor spaces are uncommon. Keeping mosquito populations down by eliminating breeding environments has been shown to be highly effective. In general, this approach involves removing standing water, such as puddles, and outdoor containers where water can collect, such as pots, barrels, and old tires. Some people may think that insecticides are the most modern and effective means of mosquito control. From a public health and community control standpoint, however, eliminating standing water is more effective and ecologically sound.

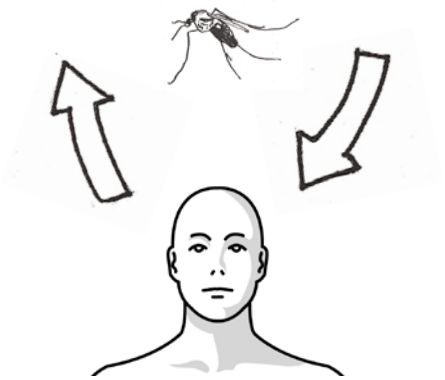

**Figure 8.** Dengue infection cycle.

## Mosquitoes and West Nile Virus

West Nile virus (family Flaviviridae) was first isolated in Uganda in 1937. The natural cycle of West Nile virus transmission occurs between birds and *Culex* species mosquitoes. Infected mosquitoes also transmit the virus to humans and other animals (Figure 9). Most mammal hosts, including humans, do not in turn transmit the virus to mosquitoes.

Most people infected with West Nile virus will have either no symptoms at all or mild flu-like symptoms. In a small percentage of cases, however, West Nile infection can progress to neuroinvasive disease (NID). Symptoms of NID include swelling of the brain and its protective membranes, sometimes resulting in a syndrome that affects motor and sensory functions of the nervous system. Approximately 10% of NID cases are fatal, most often among the elderly.

West Nile virus is a serious health threat to humans, but it can also cause extremely severe avian infections that are devastating to bird populations. Several human vaccines are currently being tested. An equine vaccine has been in use since 2002, and selected species of endangered wild birds have also been vaccinated.

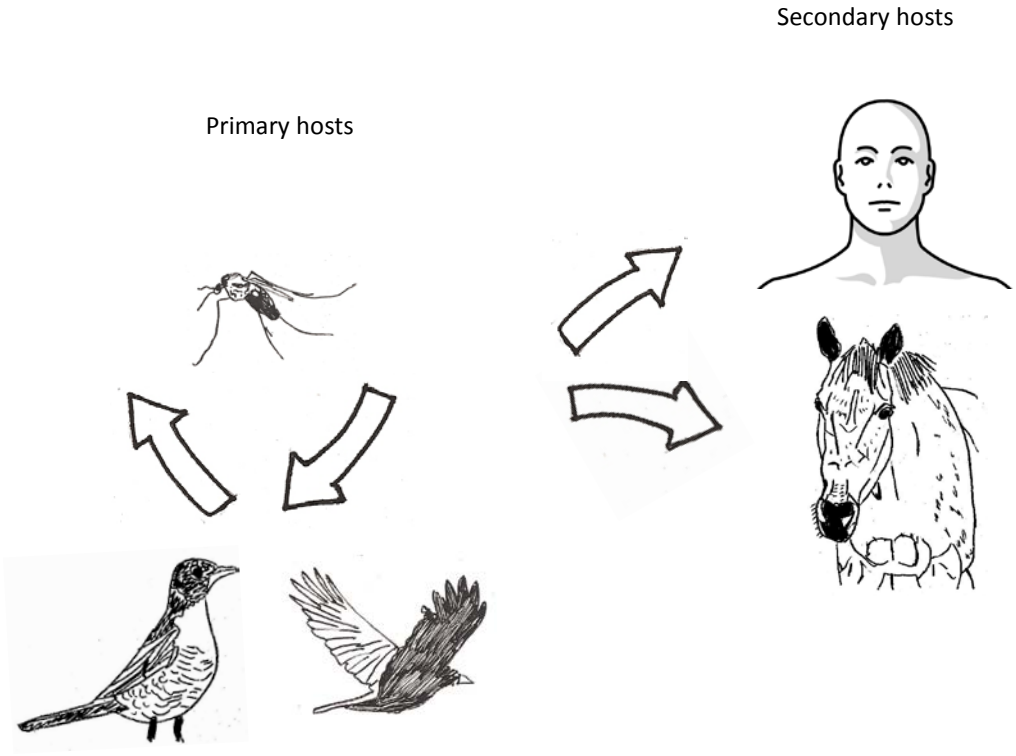


**Figure 9.** West Nile virus infection cycle.

## Glossary

**febrile illness.** An illness marked by the sudden onset of fever.

**hemorrhagic fever.** Viral infection that causes fever and internal bleeding (hemorrhaging), the deadly form of dengue infection. In the case of dengue, the most severe form of the illness is called dengue shock syndrome.

**host.** An organism that supports another organism living on or in its tissues.

**meningoencephalitis.** Inflammation of the brain and protective membranes.

**metamorphosis.** A profound change in form from one stage to the next in the life cycle of an organism.

**plumose.** Antennae with many small plumes of hair. Male mosquito antennae are plumose.

**proboscis.** Long, straw-like mouthpart that some insects use to feed on blood or nectar.

**serotype.** A specific type of a virus defined by the different antibodies that a vertebrate host will make in reaction to infection (e.g., dengue virus serotype).

**stylus.** Hard inside of proboscis that is used to puncture skin to get to blood or other fluid.

**tagma.** Major segments of arthropods. Insects have three tagma: head, thorax, and abdomen.

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