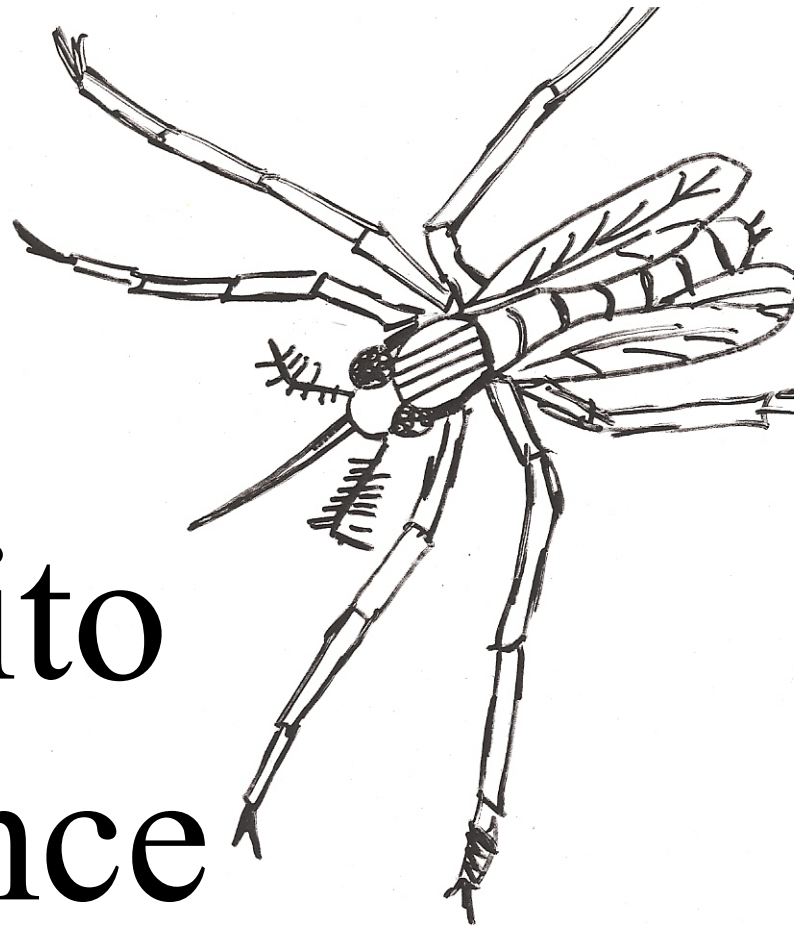


Mosquito Reference Manual



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Introduction

Insects (Class: Insecta) are highly diverse and arguably the most successful group of animals based on habitats that they occupy, numerous adaptations, and number of species. For example, insects live in almost every region of the world at high elevation, in freshwater, in the oceans, and deserts. Insects eat plants, prey on other animals, and can even feed on bodily fluids such as blood. You are probably familiar with ticks, fleas, and mosquitoes, all of which feed on us and our pets.

Mosquitoes, like all insects, have six legs, external articulating mouthparts, and three distinct body regions called tagma: the head, the thorax, and the abdomen. The mosquito family (Culicidae) belongs to the Order known as flies (Diptera), insects with only one set of wings. With their long thin bodies, wings, and proboscis, mosquitoes are readily distinguished from other flies (Fig 1). There are estimated to be over 3000 species of mosquitoes world wide, with hundreds of species in North America. This guide will help you to identify males and females of a couple of the most important species that are vectors for dengue and other viruses.

The mosquito genus *Culex*, and the genus *Aedes* are comprised of many related species. The species that this guide are most concerned with are *Culex pipiens*, common in the US and known for being a vector for the West Nile virus which causes febrile illness in Robins, Crows, Blue Jays and other birds, as well as in humans. Two species in the *Aedes* genus, *Aedes aegypti* and *Aedes albopictus* are present in the US, the latter being a recent invasive species from Asia (probably via a tire shipment). They are vectors for a number of viral illnesses including dengue fever.

The majority of mosquito species feed on plant nectar and on animal blood, but it is only the females that feed on blood to provide additional nutrition for their eggs. A female that has recently fed on blood will have a swollen abdomen (Fig 1).

Mosquitoes act as vectors for many human diseases including malaria, West Nile, yellow fever, encephalitis, and dengue. To understand a disease like dengue fever it is essential to understand the life cycle of the mosquito host the human host, and the virus, and also to understand the various environmental factors that can support disease transmission including potential epidemics and pandemics.

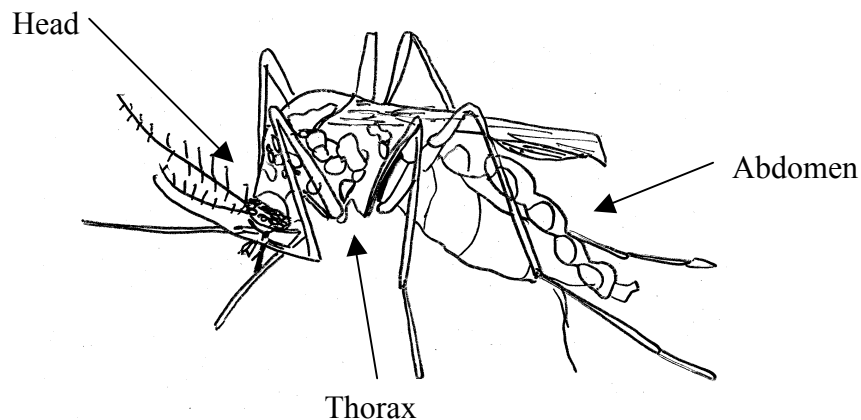


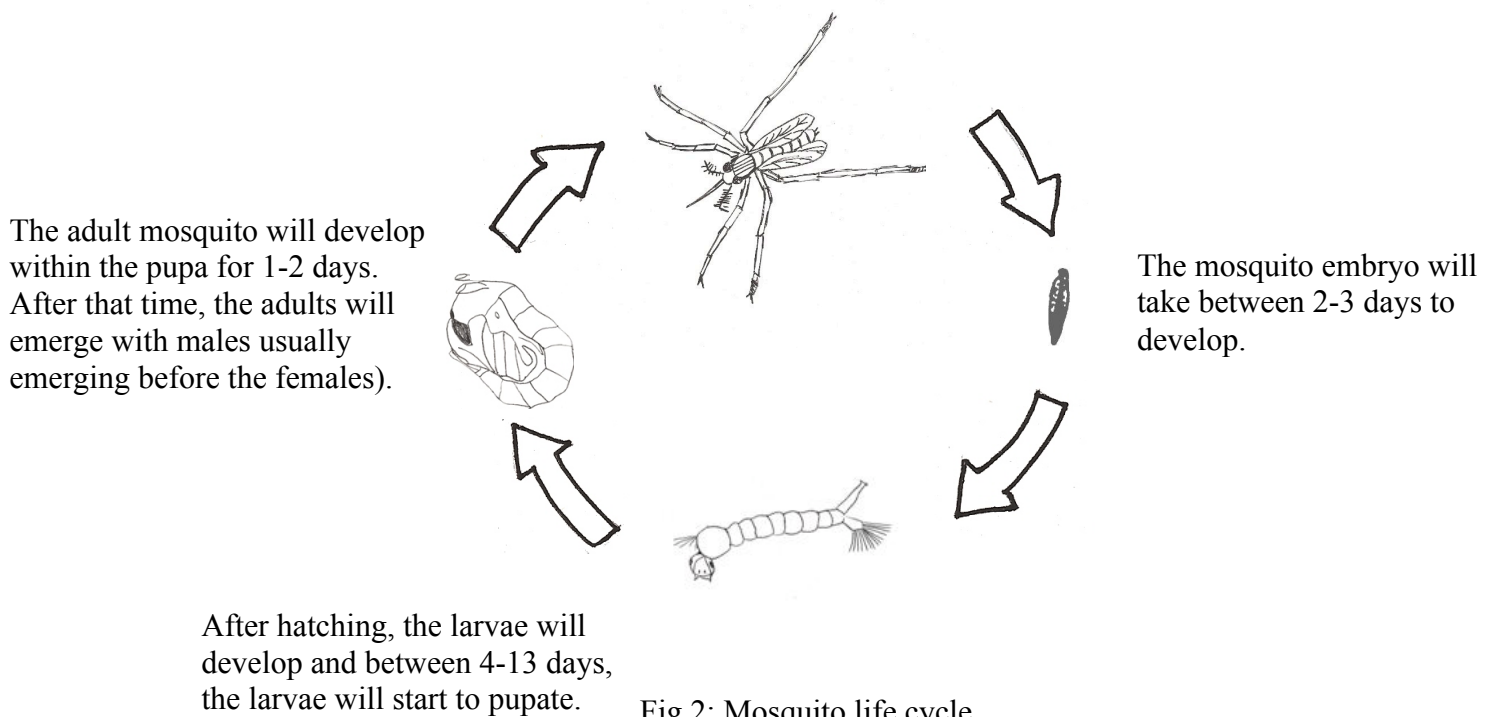
Fig 1: Blood feeding female *Aedes* sp. mosquito

Mosquito Life Cycle

Insects have a hard outer exoskeleton that protects a soft inner body. They grow by forming a larger exoskeleton inside the existing one, then shedding the outer exoskeleton in a process called molting. Mosquito larvae, for example, molts four times to grow larger and become pupae. Mosquitoes have four life stages: egg, larva, pupa, and adult (Figure 2).

Mosquitoes are aquatic as larvae and pupae and are terrestrial as adults. As eggs, larvae, and pupae, 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, mosquito females will feed on blood. The nutrients in the digested blood will form a yolk that provides nourishment for developing larvae. *Aedes aegypti* males feed exclusively on nectar, while females feed nearly exclusively on blood.



Life Stages

Egg: A *Culex* sp. (ie. any species belonging to the genus *Culex*) female lays her eggs in clusters called rafts, which float on the top of the water (Fig 3 A); *Aedes* sp. females lay individual eggs (Fig 3 B).

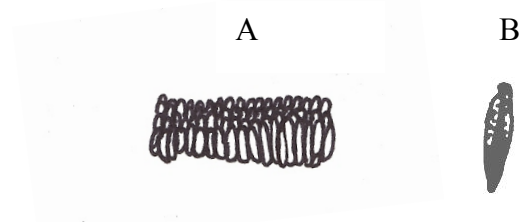


Figure 3: (A) *Culex* sp. egg raft and (B) *Aedes* sp. Egg

Larvae: Larvae, commonly known as wrigglers, hatch from eggs and live just under the surface of the water. They do not possess gills or any other way to obtain oxygen from the water, so wrigglers extend their siphon tube out of the water to take in atmospheric oxygen (Fig 4). The larvae feed mostly on plant and animal debris in the water; generally of low nutritional value thus emphasizing the importance of the nutrition provided by the blood-meal enriched yolk.

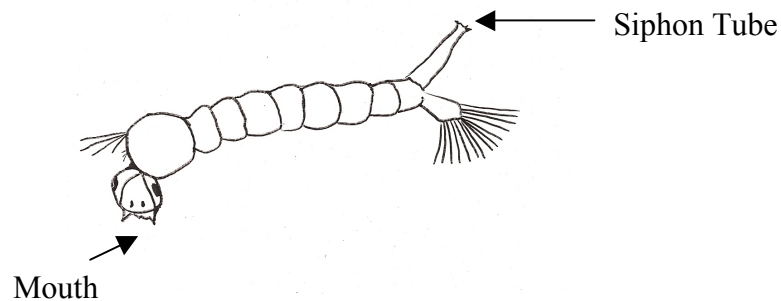


Figure 4: Mosquito larva

Pupae: Pupae, also known as tumblers, look like larvae rolled into a wheel with a hardened shell (Fig 5). The pupae, also live just below the surface of the water and use structures called trumpets to draw in atmospheric oxygen. Pupae do not eat.

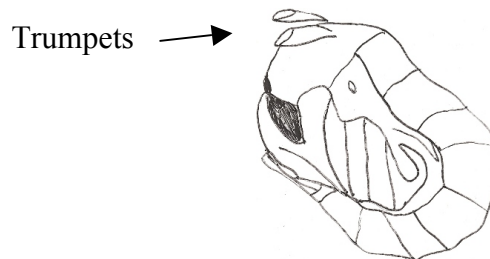


Figure 5: Mosquito pupa

Adults: The adult mosquito forms inside the shell of the pupae 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; while female mosquitoes have very small, fine hairs on their antennae (Figure 7). Males use their antennae to detect sounds from females that are mating cues. Both sexes use a specialized mouthpart called a proboscis to feed (Fig 6). The proboscis has a hard stylus inside it that allows female mosquitoes to pierce the skin of their host and suck the blood out. The salivary secretions of the mosquito can harbor pathogens that can be transferred to the host during feeding.

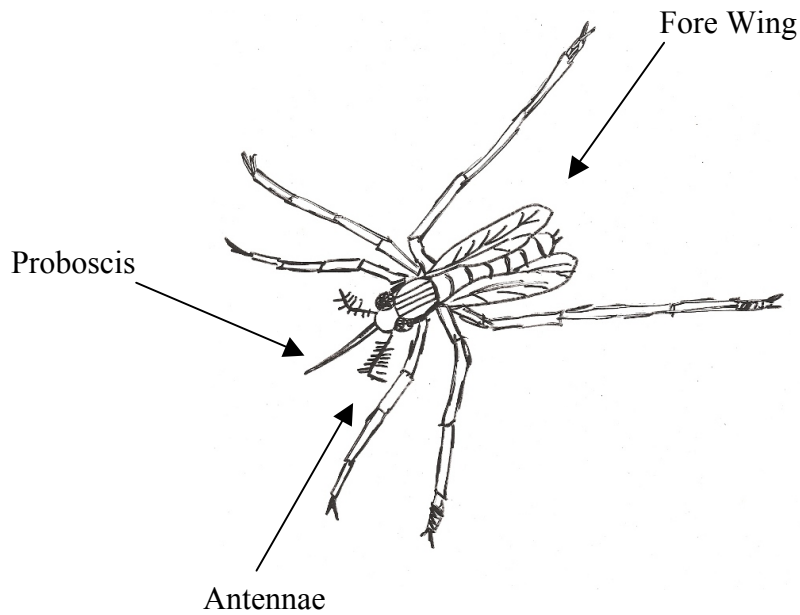


Figure 6: Adult female mosquito

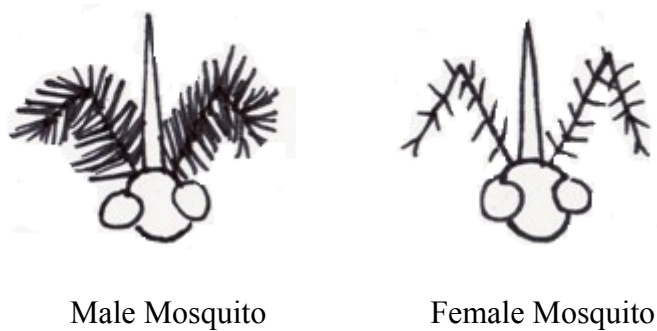


Figure 7: Heads of adult mosquitoes

Mosquitoes and Dengue Virus

Dengue virus (Family: Flaviviridae) causes a human disease affecting several million people every year. Dengue infections occur worldwide with highest prevalence in tropical and subtropical latitudes. The most common vectors are *Aedes aegypti* and *Aedes albopictus*, although other species in *Aedes* genus also carry the disease. The transmission cycle of Dengue virus is most commonly from infected mosquitoes, which constitute the year round virus repository, to humans and then back to mosquitoes (Figure 8). One can see how, as the infection rate climbs in a human population, the infection rate climbs in mosquitoes as well, in a feed forward cycle. This is in contrast to West Nile virus infections (see below) where birds and mosquitoes support the infection cycle, but humans—although infected—are not a viral repository for further infections.

There are four different serotypes of Dengue virus and it is possible to contract more than one type. Serotype refers to the viruses having slightly different antigens, and antibodies that recognize one serotype do not recognize another. Therefore, a person who has antibodies against one serotype of dengue virus may be protected against future infections by that serotype, but not from infection by other viral serotypes. In fact, due to a process called Antibody Dependent Enhancement (ADE), infection by a second serotype can lead to a person getting a much more severe disease called Dengue Shock Syndrome or Dengue hemorrhagic fever.

The best way to prevent dengue outbreaks is for individuals to avoid being bitten by infected mosquitoes. Keeping mosquitoes out of interior spaces can be achieved using screens and netting but 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 terms this means eliminating standing water, such as puddles, outdoor containers such as pots or barrels, and old tires (Figure 9). Although many people may think that insecticides are the most modern and effective means of mosquito control, from a public health and community control standpoint, eliminating standing water is both more effective and ecologically sound.

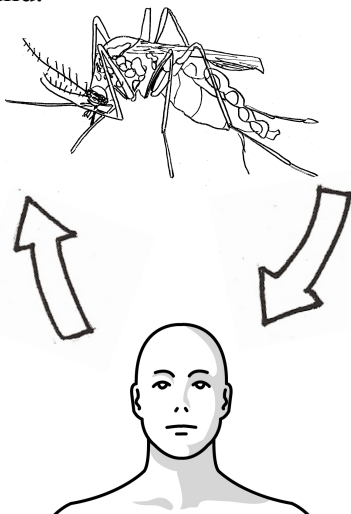


Figure 8: Dengue infection cycle

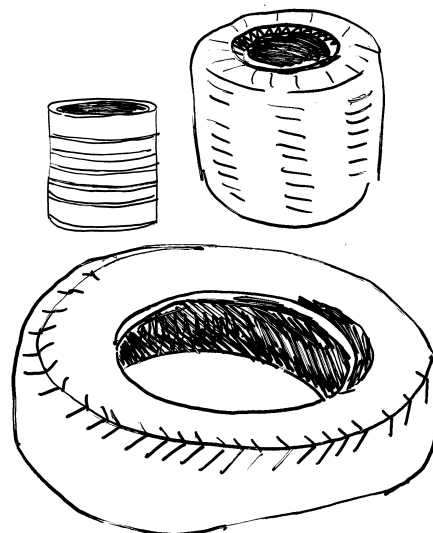


Figure 9: Common *Aedes* sp. larval habitats

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 (Fig 10). Most mammal hosts including humans do not in turn transmit the virus to mosquitoes.

Most people infected with West Nile virus will have no symptoms at all, or mild flu-like symptoms. However in a minority of cases, 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 polio-like syndrome affecting motor and sensory functions of the nervous system. NID can be fatal, more commonly among the elderly.

West Nile virus is a serious health threat to humans, but it also can cause extremely severe avian infections that can be devastating to bird populations. Several vaccines are currently being tested along with efficient means for delivering the vaccine to populations of humans, horses, and wild birds.

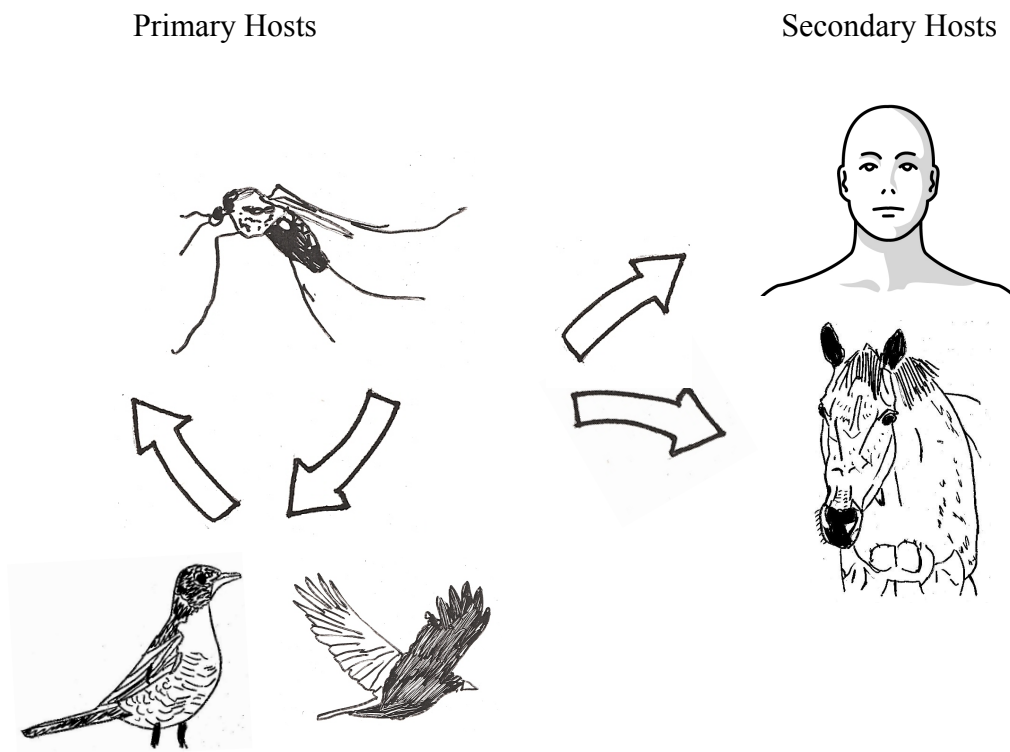


Figure 10: West Nile Virus infection cycle

Glossary

Aeropyle: Pore in an insect egg that allows gasses to flow between embryo and atmosphere

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 referred to as 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 history of an organism

Myalgia: Muscle pain or tenderness

Plumose: Antennae with many small plumes of hair; male mosquito antennae are plumose

Proboscis: Long, straw-like mouthpart that some insects use to access 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, i.e. 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, abdomen.

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