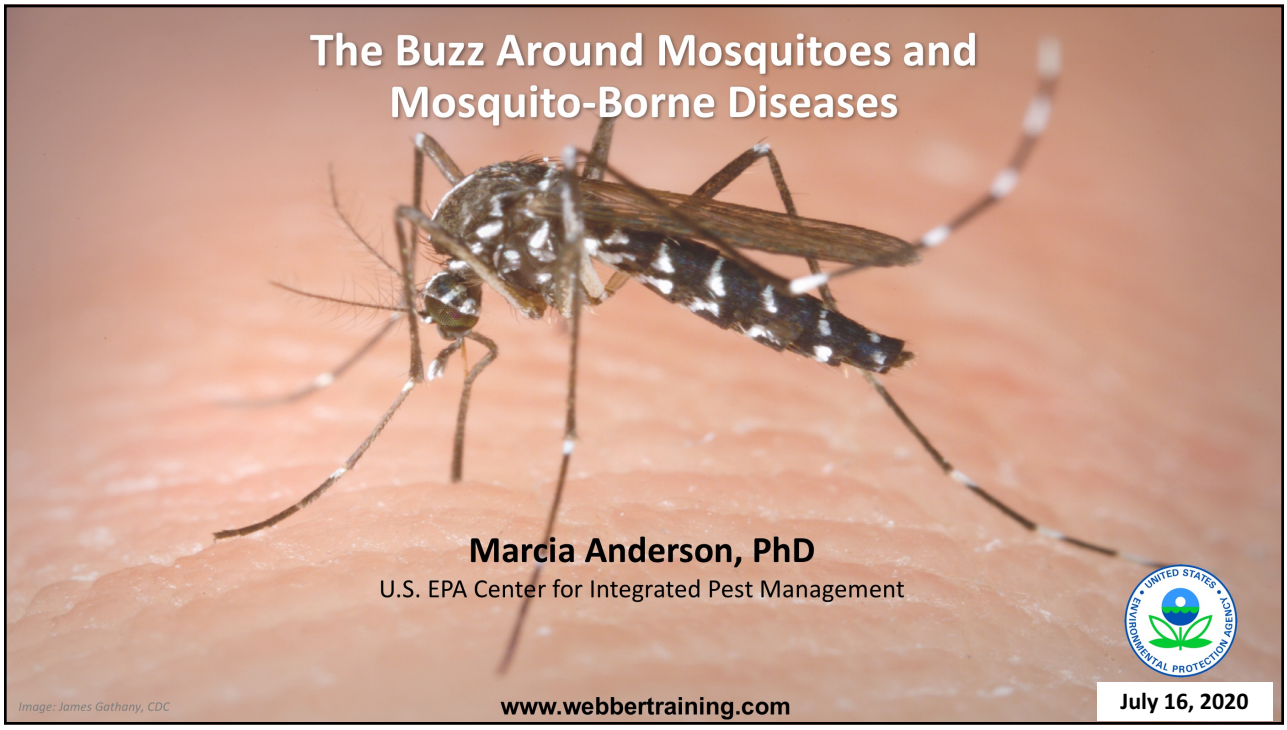

Learning Objectives

- Know how to identify mosquito types
- Recognize places where mosquitoes harbor
- Be acquainted with mosquito habits and habitats
- Be aware of what attracts mosquitoes
- Be able to provide common sense advice on controlling mosquitoes
- Learn about the latest mosquito management technologies
- Improve your community's mosquito management plan
- Know the importance of repellents

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Mosquitoes: Culicidae
Why We Care…

- 3,500 species worldwide
- Occur on every continent except Antarctica
- Most important arthropod affecting human and animal health
- Some have become *domesticated*

3

Basic Identification

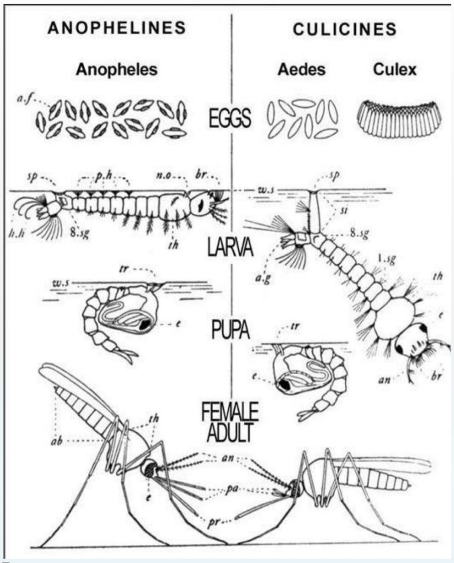
Anopheles
- Dark, four-spotted patterned wings
- Long slender palpi, nearly equaling the beak in length

Culex
- Dull brown medium-sized mosquito
- Females have very short palpi
- Lack bands on tarsi or proboscis

Aedes
- Females have dark body with leg spots
- Abdomen spots forming white chevrons

4

Top Three Disease-Transmitting Mosquitoes



Graphic: parasitology.informatic.uni-wuerzburg.de

- *Anopheles sp.*
  - malaria
- *Aedes sp.*
  - yellow fever, dengue fever, dengue hemorrhagic fever, zika, chikungunya
- *Culex sp.*
  - West Nile virus, St. Lewis and Japanese encephalitis, Eastern equine encephalitis, western equine encephalitis, lymphatic filariasis

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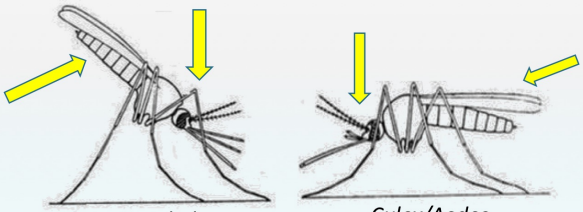
Adult Recognition

- Unlike mosquitoes of other genera, *Anopheles* rest with their heads pointed downward and their bodies slanted at a steep angle upward.
- *Culex and Aedes* hold their bodies parallel to the resting surface and keep the head and beak bent at an angle.

Anopheles



Anopheles *Culex/Aedes*

Images: majordifferences.com

Aedes

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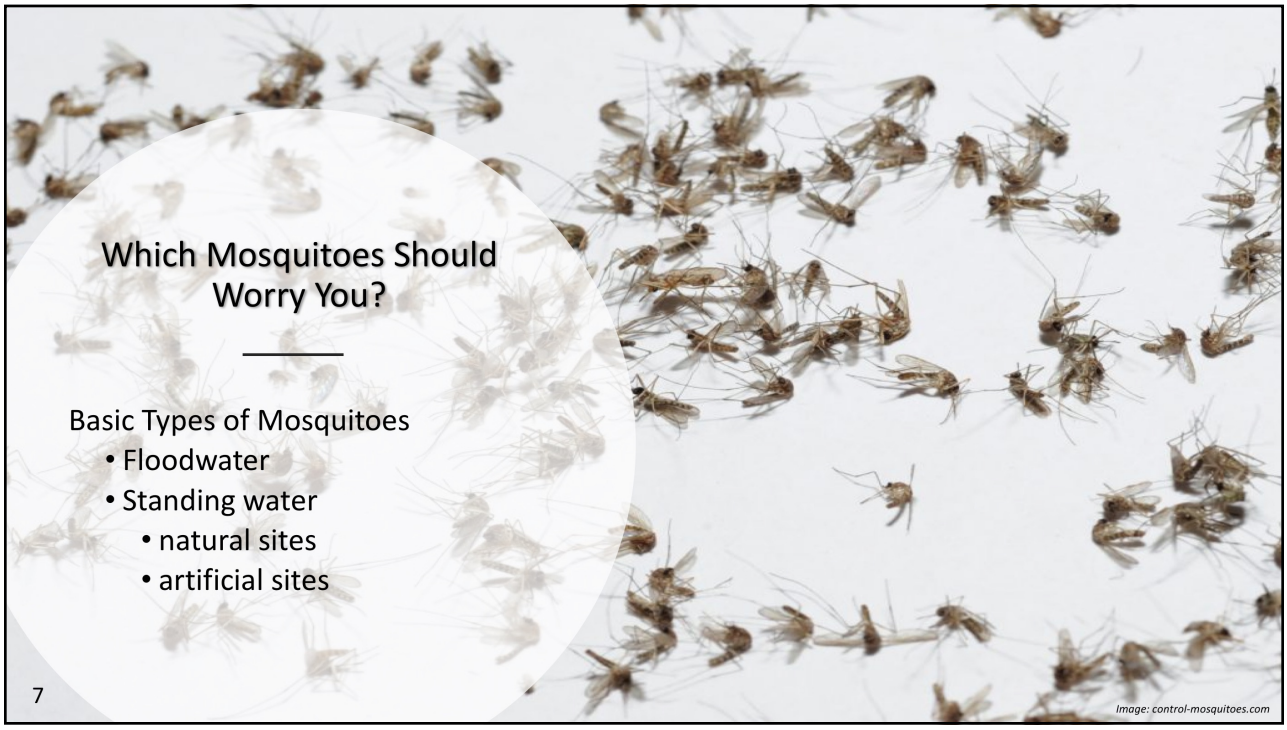
Which Mosquitoes Should Worry You?
Basic Types of Mosquitoes
• Floodwater
• Standing water
• natural sites
• artificial sites
7
Image: control-mosquitoes.com

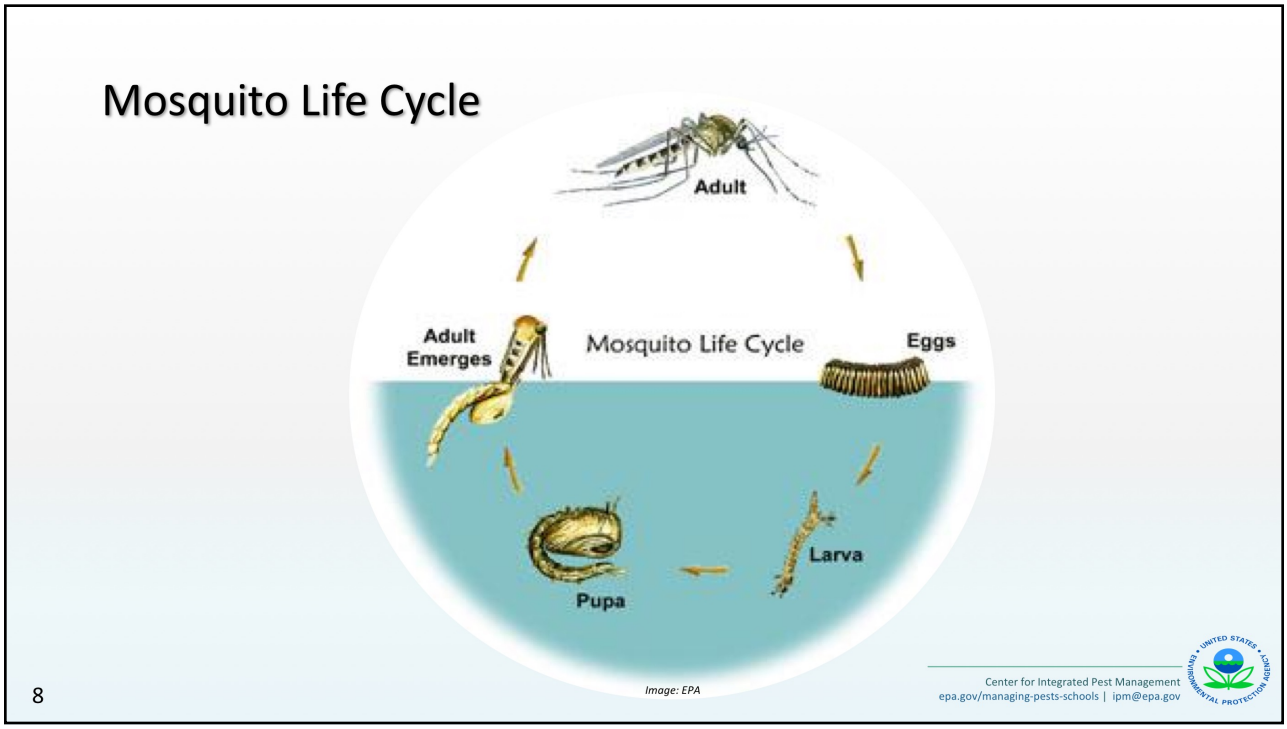
Mosquito Life Cycle
Adult
Adult Emerges
Mosquito Life Cycle
Eggs
Larva
Pupa
Image: EPA
8
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Image: M. Merchant Texas A&M

Floodwater Mosquitoes

- Not important disease vectors in U.S. but are a source for *Aedes vexans*
- Adapted to short-lived pools of water
- Water need only stand 3-4 days for breeding
- Strong fliers (5-10 miles or more)

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Anopheles

- ~460 species
- 30–40 sp. transmit *Plasmodium* (human malaria) parasites
- *Anopheles gambiae* is one of the best known malaria vectors
- Transmit malaria from person-to-person but most prefer to feed on animals
- Can vector canine heartworm and the filariasis-causing *Wuchereria bancrofti*

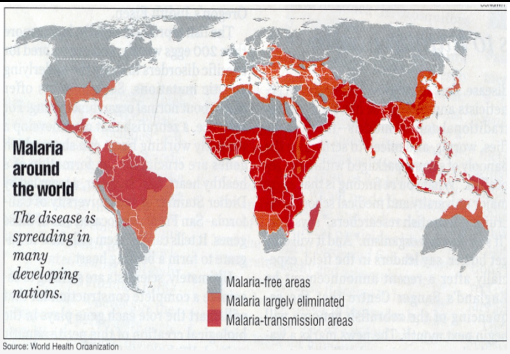

Image: James Gathany, CDC

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Anopheles

- Attracted to carbon dioxide
- Rest indoors and feed in the evening and early morning
- After feeding, they move outdoors to breed in standing water (clean or dirty)
- Control tactics involve pesticides, bed nets, window screens, and other exclusions

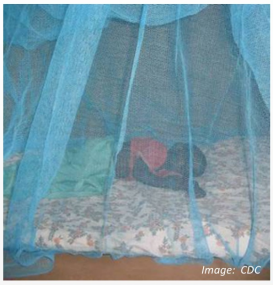
Image: CDC


Image: M. Anderson, EPA


Image: EPA/OPP


Image: EPA/OPP

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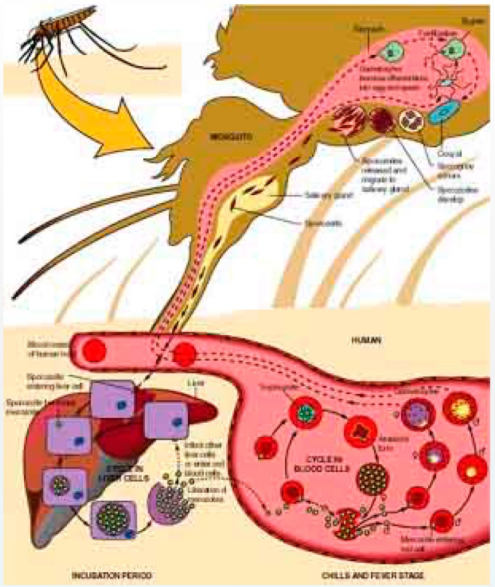
Malaria

- A mosquito bites an infected secondary host, picking up plasmodium parasite
- Replicates inside the mosquito
- 1 to 2 weeks
- Mosquito passes it on from the salivary gland as it feeds



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Major Standing Water Species

- *Aedes albopictus*
- *Aedes aegypti*
- *Culex quinquefasciatus*
- *Culex pipiens*
- *Culex tarsalis*

Culex tarsalis
Image: Joseph Berger, Bugwood.org

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Aedes sp.

- Indigenous to tropical and subtropical zones
- Spread by human activity to all continents except Antarctica
- 700+ species
- Several species transmit human diseases
- *Aedes*, comes from the Ancient Greek aēdēs, meaning unpleasant or odious
- *Aedes albopictus* is the most invasive mosquito worldwide

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Image: Muhammad Mahdi Karim, Wikimedia

Aedes albopictus

- *Aedes albopictus*, native to Asia,
- Widespread in the U.S. from Texas to Maine
- Evolved to withstand freezing climates
- Triggered into diapause* by shortened periods of sunlight
- Second-most common vector of dengue


Image: CDC

*Enables eggs to resist cold temperatures and delay hatching until spring.

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Dengue

- An important arboviral disease of humans
- Occurs in tropical and subtropical regions worldwide
- Thought to have spread as a result of:
  - ineffective vector control
  - ineffective disease surveillance
  - inadequate public health infrastructure
  - population growth
  - unplanned and uncontrolled urbanization
  - increased travel

Image: NRDC

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Dengue Vectors

Main vectors are domesticated mosquitoes:

- ***Aedes aegypti*** - breeds in urban environments in artificial containers that hold water
- ***Aedes albopictus*** - tolerates colder temperatures and also breeds in urban environments in artificial containers that hold water

Rainfall may be less important in urban areas as both species breed in small containers water in the absence of rain

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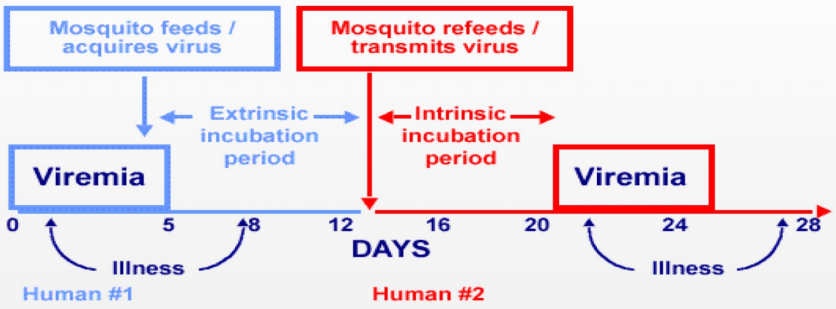
Disease Transmission



- A dengue-infected person has virus circulating in the blood stream (5 days).
- An uninfected female *Aedes* mosquito bites the person and ingests blood that contains dengue virus.
- The virus replicates in the mosquito (8-12 day incubation).
- The mosquito then bites (and transmits) the virus to every person it bites.
- The virus replicates in victims and produces symptoms.

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The Risk of Explosive Epidemics

- Enhanced because of two other properties of the vector-virus relationship
- Dengue viruses multiply more rapidly in mosquitoes at high temperatures than at low ones
- The mosquito vector develops more rapidly at high temperatures
- This means a short viral incubation period in the mosquito and rapid mosquito population increase
- Can lead to rapid, sometimes explosive transmission in the human population

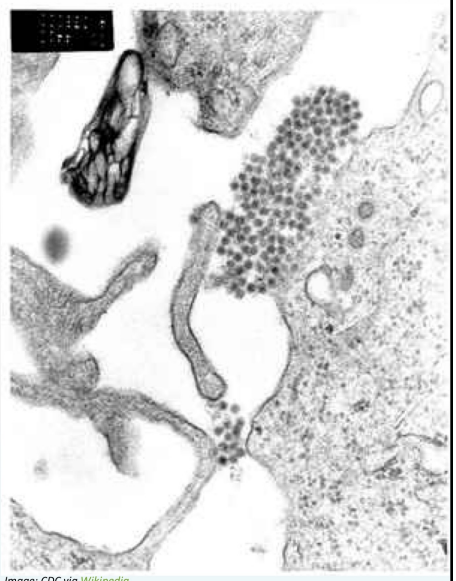

Image: CDC via Wikipedia

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Culex pipiens | C. quinquefasciatus | C. tarsalis

- Common in urban and suburban settings
- Prefer organically infused water in containers or standing water
- An indicator of polluted water
- Abundant where raw sewage leaks into subterranean drainage systems, catch basins and storm drains
- ***Culex pipiens***
  - Vectors St. Louis encephalitis and West Nile virus, Japanese encephalitis, and meningitis
  - Feed mostly on birds but will feed on humans
- ***Culex quinuefasciatus***
  - Southern house mosquito
- ***Culex tarsalis***
  - Associated with agricultural areas
  - Vectors West Nile, western equine encephalitis, and St. Louis encephalitis viruses

Image: CDC

House mosquitoes:
Culex pipiens (above) and
C. Quinquefasciatus (below)

Image: Stephen Doggett, Medical Entomology, Pathology West – ICPMR Westmead

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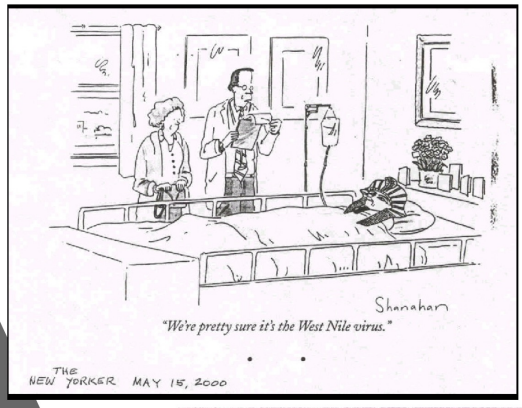
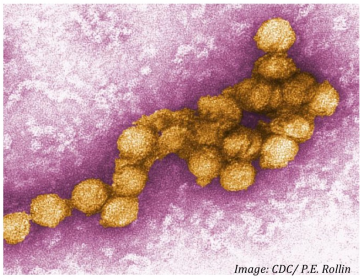
West Nile Virus

- An Old World flavivirus which is closely related to the Japanese encephalitis virus, endemic to eastern Asia
- Ornithophilic mosquitoes are the principal vectors of West Nile virus and birds of several species, are the major carrier

https://academic.oup.com/jme/pages/twenty-years-of-west-nile-virus-in-the-united-states





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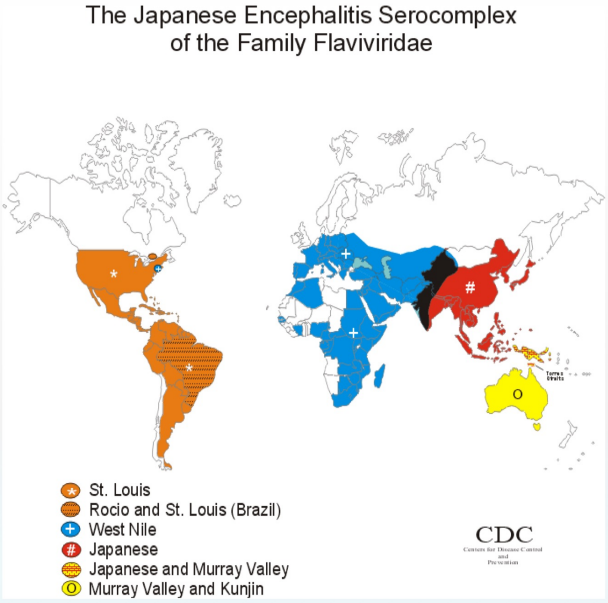
Viral Encephalitis

- Five major mosquito-transmitted encephalitis in the Americas
  - Eastern equine encephalitis
  - Western equine encephalitis
  - St. Louis encephalitis
  - Venezuelan equine encephalitis
  - La Crosse encephalitis
- Each type is caused by a different virus complex affecting the central nervous system
- Horses or humans may be infected



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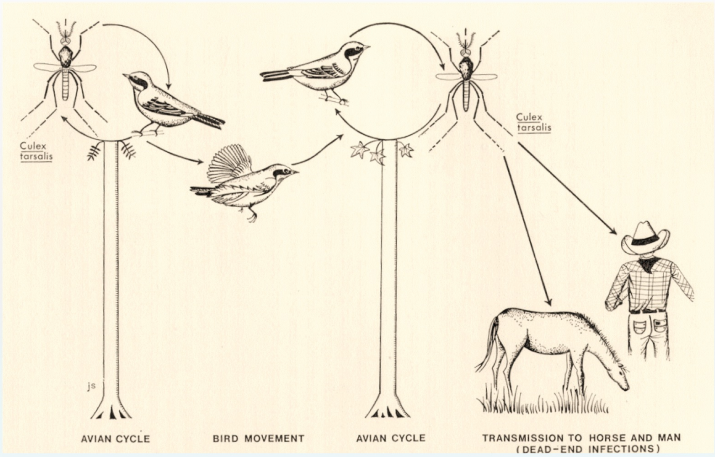
Encephalitis Disease Transmission

- *Culex* sp. are the main vectors transmitting the virus from birds, small mammals or rodents, to humans
- The virus can NOT be transmitted from person to person or from birds directly to people
- Birds that live near bodies of standing water, such as freshwater swamps, are susceptible to infection



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Mosquitoes and Diseases of Concern

Vector	Disease	Distribution
Aedes aegypti	yellow fever, zika, dengue fever, dengue hemorrhagic fever	Worldwide
Aedes albopictus	dengue fever, dengue hemorrhagic fever, chikungunya, zika	Worldwide
Aedes sierrensis	dog heartworm	Western/Southern U.S.
Aedes triseriatus	Eastern equine encephalitis, LaCrosse encephalitis	East/Central North America
Anopheles spp.	Human malaria (*Plasmodium*), numerous animal pathogens	Worldwide
Culex quinquefasciatus *C. pipiens*	West Nile virus, avian malaria, lymphatic filariasis, Western equine encephalomyelitis, St. Louis encephalitis, Eastern equine encephalitis	Worldwide

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How Do Mosquitoes Choose Their Feeding Targets?

- Chemical, thermal, and motion sensors and sight
- Detect movement up to 10m away
- Attracted to heat/body warmth
- Sense exhalation of water vapor and CO_2
- Attuned to ammonia and lactic acid in concentrations
- Senses most attuned in humid conditions

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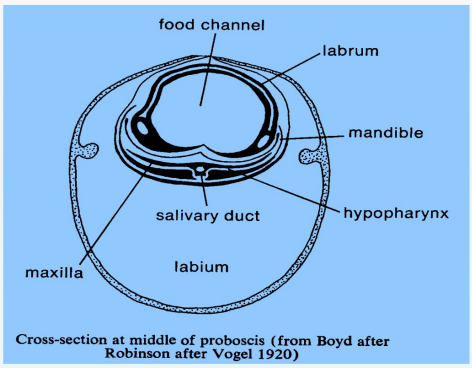
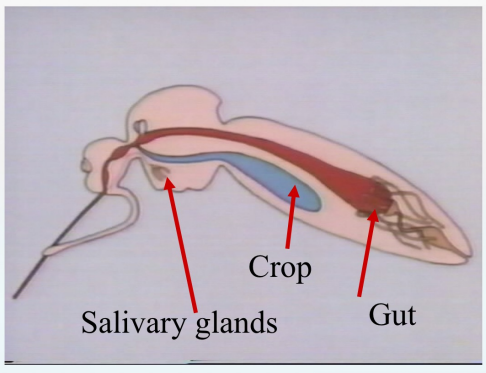
Size of a Mosquito Blood Meal

- Meal size directly related to the size of the mosquito
- Usually ~ 2 microliters



Cross-section at middle of proboscis (from Boyd after Robinson after Vogel 1920)



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Feeding Preferences: *Culex* & *Anopheles*

Culex

- Sunrise to sunset
- Peaks immediately following sunset and just before sunrise

Image: CDC, James Gathany

Anopheles

- Crepuscular (active at dusk or dawn) or nocturnal (active at night)
- Some feed indoors (endophagic) while others feed outdoors (exophagic)

Image: CDC, James Gathany

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Feeding Preferences: *Aedes*

- Aggressive biter, especially dawn and dusk
- Prefer shady areas, indoors, or when the weather is cloudy
- Bite more frequently in warm and humid weather
- Females are silent fliers
- Typically bite people around the ankles
- Only females require a blood meal necessary for making eggs
- After feeding, they seek a secure surface to rest, and not bite again for 3-4 days
- Require 2-3 blood meals before laying eggs

Aedes aegypti (left); *Aedes albopiticus* (right)

Image: Lolo from Tahiti, Flickr

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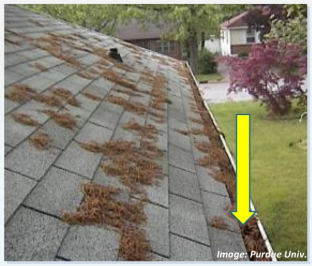
Recognizing Mosquito Breeding Sites



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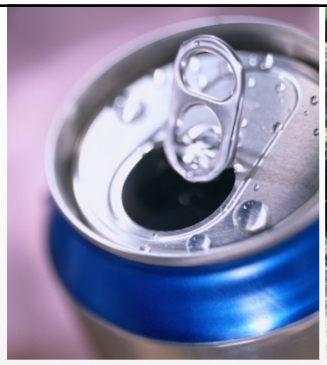


Images (top): EPA/OPP

Breeding Sites: *Aedes*

- Primarily man-made containers - cans, jars, cisterns, fountains, planters, plastic food containers, tires, and tarps
- Prefer clean water
- Need only 0.25 in (6.3 mm) of water - even bottle caps or puddles

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Breeding Sites: *Culex*

Image: CDC, Public Health Image Library

- Prefer standing water rich in decomposing organic material
  - dead leaves, grass clippings, and algae break down to produce an attractive organic infusion
- Flooded wooded areas, catch basins, storm sewers, cisterns, and floodwater pools

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Breeding Sites: Buildings

- Rain gutters
- Flat roofs
- Garbage cans and dumpsters
- Tarps

Image: Dan Lisenko, Manatee Co. School District

Image: M. Anderson, EPA

Image: M. Anderson, EPA

Image: M. Anderson, EPA

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What are these boys looking at?

- Toys and children's play equipment collect water providing an ideal nursery for mosquito larvae
- Drill holes for drainage

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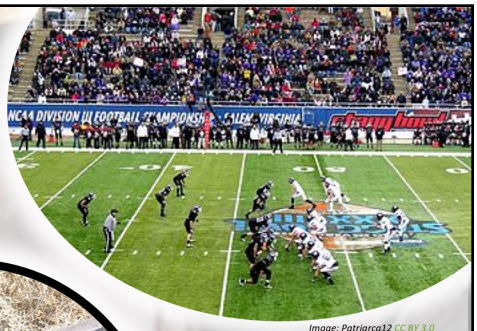
Breeding Sites:
Tires, Sports Equipment, and More…

- Tires are major breeding sites for *Aedes or Culex*
- Truck tires for football practice
- Drill holes to drain water
- Removal of abandoned tires from inhabited areas is imperative to mosquito vector control projects



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Breeding Sites:
Clogged / Damaged Stormwater Drainage Systems

- Standing water = prime larval habitat
- Problems occur with blocked drainage
- Long-standing puddles and potholes

Images : M Anderson EPA

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Breeding Sites: Agricultural

- Flooded fields
- Poor drainage and tire ruts
- Blocked irrigation ditches
- Drinking troughs and water holes

Images : EPA/OPP

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Breeding Sites:
Discarded Plastics

- Plastics are both a key breeding ground for mosquitoes and waste problem
- *Aedes aegypti* and *A. albopiticus* will breed in as little as a bottle cap of rainwater
- *Culex sp.* will breed in containers that have accumulated organic matter

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Breeding Sites:
Coastal Zone Habitats - Harbors, Dockyards and Shipyards

- Discarded plastic drink bottles, car tires, and other litter accumulate above the high tide line often obscured by vegetation
- In developed coastal areas, old piers, bulkheads, and fence lines capture and accumulate litter

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Breeding Sites: Natural Habitats

- Water-holding plants - Bromeliads and pitcher plants
- Tree holes

Anderson, M. 2018. Tree Care Industry Magazine 29:8

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How Do Cold-Adapted Mosquitoes Overwinter?


Culex pipiens


Aedes aegypti

- ***Culex sp.***
  - Adult females and build fat body by feeding on carbohydrates
  - Females find refuge in protected areas that stay above freezing
  - Metabolism slows and winter is spent in a state of torpor
- ***Aedes aegypti***
  - Eggs viable for over a year in a dry state
- ***Aedes albopictus***
  - Hibernates in the winter - can go into a state of diapause
  - Tolerates snow; highly adaptive

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Images: M. Merchant: Texas A&M

Mosquito Management:
SSLAP Approach

Surveillance

Source reduction

Larvicides to treat breeding sites

Adult mosquito control
- Truck-mounted ULV
- Aerial application

Public Education
- source reduction
- personal protection

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Integrated Mosquito Management

Image: CDC

- All integrated pest management plans focus on eliminating the source of pests by minimizing access to food, shelter, and water
- Integrated mosquito management practices include:
  - monitoring
  - sanitation
  - maintenance
  - biological controls
  - barriers
  - biorational controls
  - insecticides
  - EDUCATION

Image: EPA/OPP

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Monitoring: Collection Methods

Gravid Trap

CDC Storm Sewer Trap

CDC Aboveground Trap

Under-House Trap

BG Sentinel Trap

Images: CDC; Texas A&M; Howard Co. MCA

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Monitoring:
Right Trap, Right Place

Watch the EPA webinar:
www.youtube.com/watch?v=G0MLkfjkwnM&feature=youtu.be

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Biological Controls

- Non-chemical mosquito management
- Indigenous mosquito-eating fish, flatworms, turtles, nematodes, and copepods
- Add to water tanks, ponds, marshes, rice paddies, fountains, cisterns and drums
- Effective in managing *Aedes, Culex and Anopheles*
- Part of a long-term integrated mosquito management program

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Biological Controls: Fish

Does your community have open water or ponds?

Try Fish!

- Important predator of mosquito larvae
- Used worldwide

Gambusia about to eat a mosquito larva. *Image: CDC*

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Image: CDC/B. Partin, Jimmy Stewart


Image: USFWS/Katrina Mueller

Biological Controls: Fish (cont.)

- Both species are key part of integrated management strategies used by mosquito control agencies in the U.S.
- Mosquito fish are effective in eliminating mosquito populations in unused swimming pools, abandoned sewage, mine pits and permanently flooded stormwater facilities
- 3-spine sticklebacks prefer to feed on organisms living on pond bottom or in very shallow water

Mosquito Fish *(Gambusia affinis)*
3-Spine Stickleback *(Gasteroseus aculeatus)*

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Biological Controls: Fish (cont.)

- Introduced from tropical South America where it is native
- Provides good control of mosquitoes in highly polluted waters
- Unlike the mosquito fish, the guppy's ability to reproduce or control mosquitoes is not reduced by low levels of dissolved oxygen

Guppy
(*Poecilia reticulata)*

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Biological Controls: Fish in Rice Cultivation

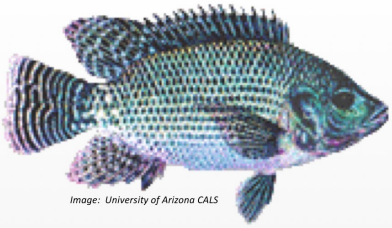

Image: University of Arizona CALS

- *Puntius* and tilapia are the fish found most useful in rice cultivation
- Adult tilapia stocked after rice transplantation kept test fields free of algae and weeds without the use of herbicides

Image: linetfreshfish.kbo.co.ke/products

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Image: Alan Wolf, Flickr CC 2.0.

Biological Controls: Tadpoles

Image: Russ Ottens, University of Georgia, Bugwood.org

- Few tadpoles (immature frogs) eat mosquito larvae but many compete with them for food
- Tadpoles effective as predators of mosquito larvae in North America:
  - *Scaphiopus hammondii* (spade-foot toad)
  - *Hyla cinerea* (green tree-frog)
  - *Hyla septentrionalis* (giant tree-frog)
- Tadpole predators of mosquito larvae in other parts of the world:
  - *Bufo viridis* (European green toad)
  - *Lechriodus fletcheri* (sandpaper frog)
  - *Rana tigrina* (Indian bullfrog)
  - *Anotheca spinos* (coronated tree frog)

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Biological Controls: Turtles

- Red-eared sliders (*Trachemys scripta*) were effective in controlling mosquito larvae in water storage tanks in Honduras
  - A single turtle placed in a water storage tank provided complete control of mosquito larvae
- In the U.S., turtles were introduced into an experimental enclosure of a roadside ditch in Louisiana for control of *Culex* larvae
  - Reduced larvae 99% within 5 weeks

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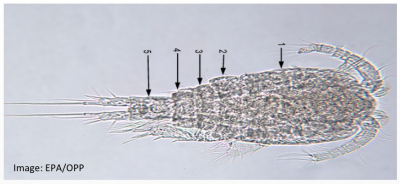
Biological Controls: Copepods



- Tiny crustaceans with an appetite for first instar mosquito larvae
- Most effective biological control than any other predatory invertebrate because of abundance
- Used successfully in Vietnam, Honduras, Brazil, French Polynesia, Australia, Puerto Rico and the U.S.
- Easy and inexpensive to mass produce

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Copepods: Uses

- Non-chemical vector management
- Biological mosquito control agents: cyclopoid copepods
- Can be added to water tanks, ponds, marshes, rice paddies, fountains, cisterns and metal drums
- Effective in treating Aedes, and Anopheles mosquitoes
- Part of long-term mosquito vector management programs

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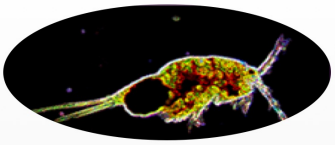
Copepods: Uses (cont.)



- Control mosquito larvae in salt marshes, roadside ditches and rice fields
- In rice fields, biological larvicides can be used in conjunction with cyclopoids
- Biological larvicides eliminate larvae too large for copepods to kill

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Copepods: Mass Distribution

- Water tanks and barrels
- Large copepod species (*Mesocyclops longisetus*) are effective for *Aedes aegypti* control in cisterns, 55-gallon drums, and other domestic containers
- *Mesocyclops longisetus* survive indefinitely in containers as long as they are well fed
- Copepods can be transported in small containers then transferred into larger containers

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Biological Controls: Flatworms

- Some flatworms (Platyhelminthes) can kill *Culex* and *Anopheles* larvae just by brushing against them
- When mosquito larvae brush against or touch the worms, the larvae immediately become paralyzed and die
- Rice fields, especially new fields, with abundant mosquitoes often lack flatworms
- Flatworms can be used in association with other biological controls to supplement other mosquito management tactics

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Biological Controls: Predatory Mosquitoes

- *Toxorhynchites* - a very large mosquito whose larvae prey on the larvae of other mosquitoes and similar prey
- Adults do not feed on blood
- Adults subsist on carbohydrate–rich materials, such as nectar, honeydew, saps and juices from damaged plants, refuse, and fruit
- *Toxorhynchites* introduced into an *Aedes*-infested area can lower mosquito-borne disease transmission

Image: Pennsylvania Department of Conservation and Natural Resources - Forestry, Bugwood.org

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Biological Controls: Environmental Precautions

- Follow local regulations when introducing any species
- Do not to introduce non-native fish into natural aquatic environments
- Remember that flooding can easily translocate fish from an isolated small pool, pond, or gulley into a larger water system

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Chemical Controls: Larvicides

- Chemicals that kill immature mosquitoes in the water include:
  - Oils
  - Monomolecular films
  - Insecticides
    - Bacterial insecticides
    - Insect growth inhibitors
    - Organophosphate insecticides

epa.gov/mosquitocontrol/controlling-mosquitoes-larval-stage

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Chemical Controls: Larvicides (Bacterial)

Bacillus thuringiensis israelensis
Bacillius sphaericus

- Bacteria that produce a toxin that kills mosquito larvae
- Bacterial spores, ingested by the mosquito larvae, are activated in the digestive tract and dissolve the lining and gut
- Most larvae die within 24 hours
- Not hazardous to humans, other animals, fish, and predacious insects
- Perfect for treating small areas – bird baths, garden pools and other potential mosquito breeding sites

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Chemical Controls: Adulticides

- Pesticides targeting adult mosquitoes
- Used to treat larval breeding sites that cannot be eliminated
- Applied when disease is present as determined by local health agency
  - Residual sprays to non-flowering vegetation
  - Doorways and building entry points
  - Area-wide (community) fogging programs

Image: M. Merchant, Texas A&M

epa.gov/safepestcontrol/search-registered-pesticide-products

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Chemical Controls: Residual Adulticides

- Backpack mist blowers distribute larger particle size (50-60 microns)
- Professional application leaves insecticide residues in mosquito resting sites
- Advantages
  - affordable
  - 3-4 week suppression
  - apply when needed
- Disadvantages
  - must avoid treating flowering plants
  - may harm some beneficial insects

Image: M. Merchant, Texas A&M

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Chemical Controls: Species Differences Impact Treatments

Culex
Resting sites 8–10 feet

Aedes
Resting sites typically close to the ground

Image: M. Merchant, Texas A&M

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Treat Entrances to Buildings

Image: rockychrysler, Flickr

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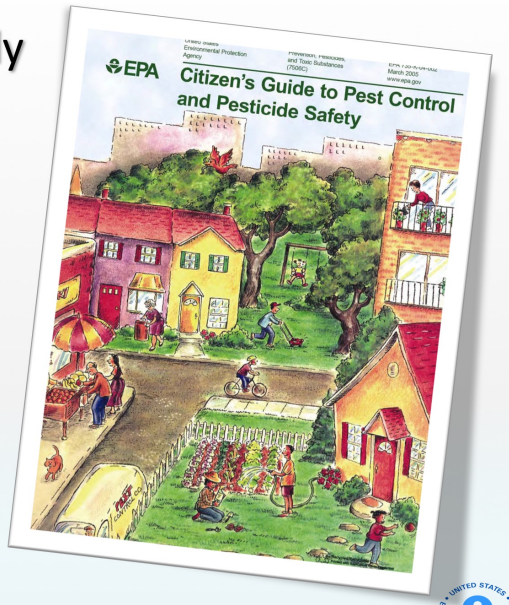
Use Pesticides Safely and Correctly

- Read the Label
- Choose the right product for the right pest
- Determine the right amount to use
- Correct mode of application
- Determine correct location for pesticides
- After applying a pesticide
- Storing pesticides safely
- Disposing of pesticides/ containers safely
- Reducing exposure to pesticides: dermal, air, water

See EPA's *Citizen's Guide to Pest Control and Pesticide Safety* at go.usa.gov/xdpYT



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Emerging Technologies for Mosquito Management

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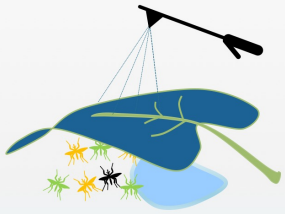
Aedes albopictus - Asian Tiger Mosquito

Challenge: Mosquito population management



- Reduction of breeding grounds by homeowners
- Neighborhood and home larvicide treatment
- Aerial applications and spray trucks: adulticides and larvicides

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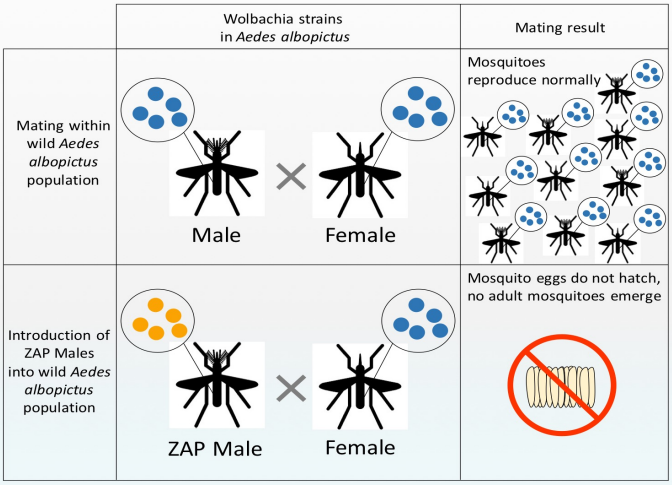
Images: istockphotos.com, CDC

Emerging Technologies: *Wolbachia*

Presence of *Wolbachia* prevents reproduction of *Aedes albopictus*

- Naturally-occurring bacterium
- Present in ~60% of insect species
- Non-biting males are released
- Mate with wild-type females
- Species-specific treatment
- No viable offspring through cytoplasmic incompatibility

Note: The U.S. has one active registration for the *Wolbachia* wPIP strain in *Aedes albopictus*



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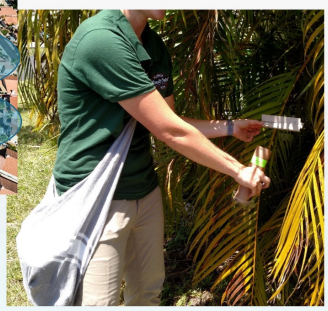
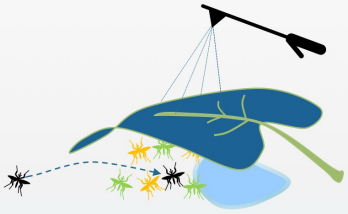
Aedes albopictus - Asian Tiger Mosquito

***Wolbachia*-carrying *Aedes albopictus* males seek out wild females**





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EPA Registered Repellents

- EPA-registered skin-applied insect repellents contain these active ingredients:
  - DEET
  - picaridin
  - IR3535
  - lemon oil of eucalyptus/para-menthane-diol
  - 2-undecanone
- Follow label instructions
- Treat gear with permethrin

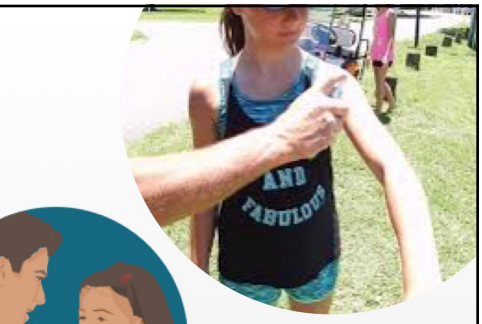

Image: EPA

EPA repellent website: epa.gov/insect-repellents

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Image: M. Merchant, Texas A&M

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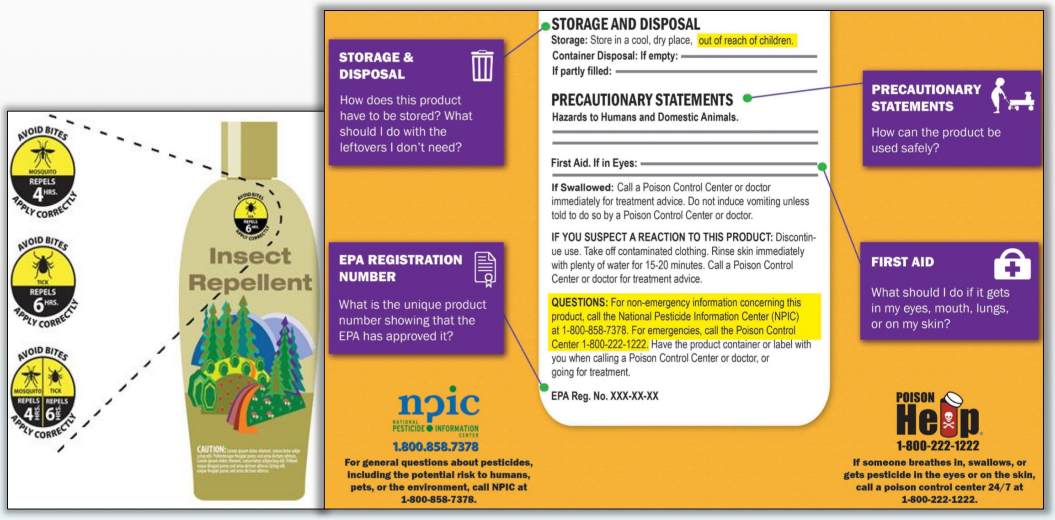
Repellents – Read the Label!



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Mosquito Resources

Cayman Islands mosquito crossing sign
Image: M. Anderson EPA

- *Success in Mosquito Control: An Integrated Approach (*EPA webpage) - go.usa.gov/xpd7h
- Entomological Society of America: *How Science is Turning Mosquitoes Against Themselves* - tinyurl.com/r3nq8la
- *Protecting Students from Mosquitoes and Zika Virus (*EPA Webinar) - tinyurl.com/whghkgx
- EPA Mosquito Webinars - go.usa.gov/xpd7z

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www.webbertraining.com/schedulep1.php	
July 23, 2020	IMPROVEMENT OF HOSPITAL ENVIRONMENTAL CLEANING AND DISINFECTION PRACTICES FOLLOWING AN EIGHT-MONTH OUTBREAK Speaker: **Corey Weisgerber** and **Terrence Shaw**, Regina General Hospital, Saskatchewan
August 6, 2020	CLEANING AND DISINFECTION IN THE ERA OF SARS-COV-2 Speaker: **Dr. Curtis Donskey**, Louis Stokes VA Medical Center, Cleveland, Ohio
August 13, 2020	AHEAD - A CONSOLIDATED FRAMEWORK FOR BEHAVIOURAL INFECTIOUS RISKS IN ACUTE CARE - PART 2 Speaker: **Prof. Hugo Sax** and **Dr. Lauren Clack**, University of Zurich Hospitals, Switzerland
August 18, 2020	*(FREE Teleclass)* POLIO ERADICATION IN INDIA AND TAKEAWAYS FOR OTHERS Speaker: **Dr. Ranga Reddy**, Infection Control Academy of India
August 26, 2020	*(FREE Teleclass)* HOSPITAL LAUNDRY AND C. DIFFICILE SPORE INACTIVATION

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