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Mosquito 101

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Mosquito 101

Training Module 1: Basics of Mosquito biology, ecology, physiology, and behavior

By: Joanna Tyszko

University of Nebraska-Lincoln

MS Degree Project



Introduction

Mosquitoes are insects found throughout the world

Taxonomy:

Order: Diptera

Family: Culicidae (all mosquitoes)

Subfamily: Anophelinae (anophelines)

3 genera including *Anopheles*

Culicinae (culicines)

34 genera including *Aedes* and *Culex*

Toxorhynchitinae

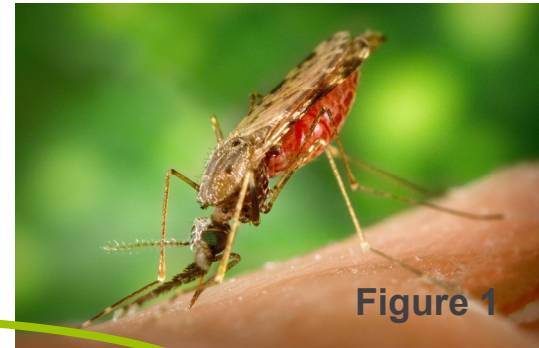


Figure 1



Figure 2

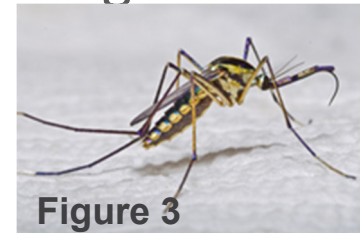


Figure 3



Life Cycle

- Mosquitoes are **holometabolous** insects
 - complete four life stages: **egg**, **larva**, **pupa**, and **adult**
 - Occupy 2 habitats:
 - Aquatic habitat in egg, larval and pupal stage
 - Terrestrial habitat in adult stage
- Mosquitoes lay eggs in or on the water or on a solid substrate that is likely to become inundated
 - Eggs hatch into larvae
 - ↳ Larvae undergo 4 stages – **instars**
 - ↳ Metamorphose into pupae

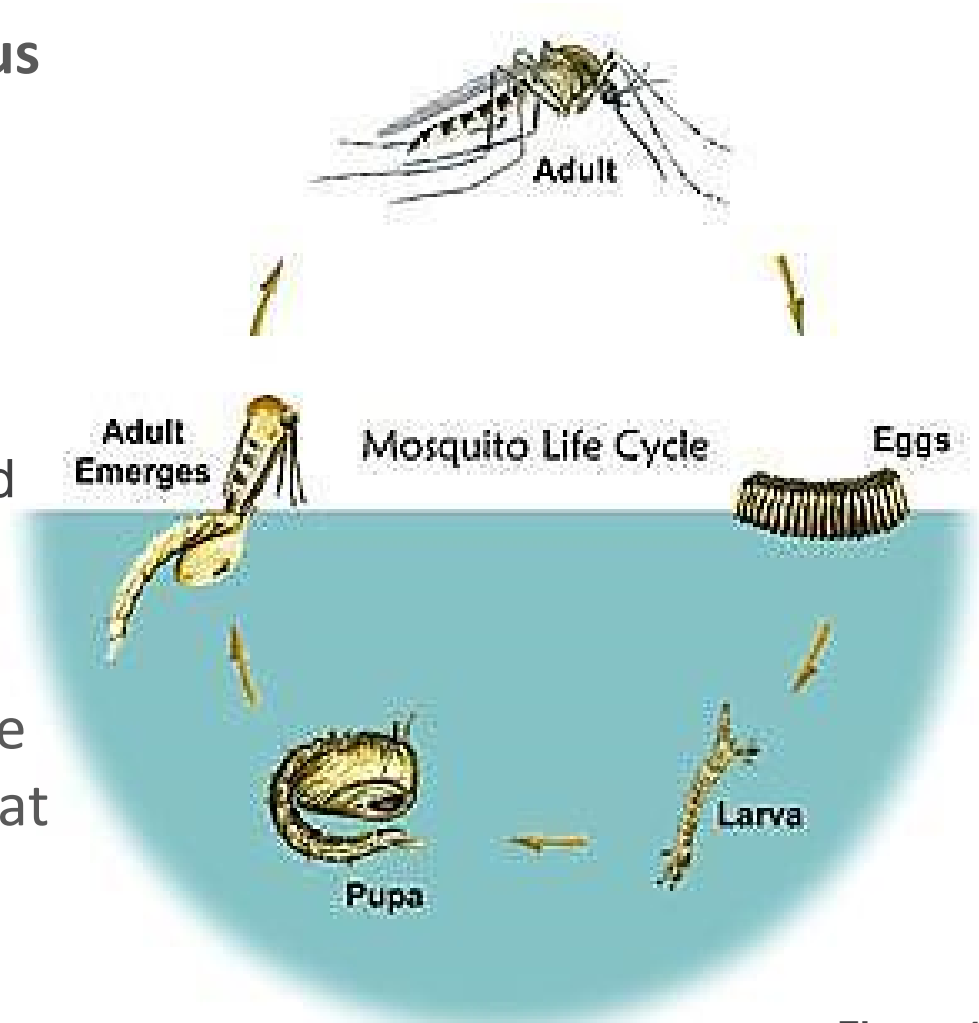


Figure 4

Eggs

- Elongate along the anterior-posterior axis
- Soft, flexible, and white → hardened, dark and waterproof
- Egg shell
 - Has rigidity and strength to provide mechanical support and protection
 - Permits gas exchange while minimizing water loss
- Number of eggs depends on:
 - Maternal body size, nutritional condition, and physiological age
 - Egg size
 - Volume and source of blood meal



Figure 5



Eggs

- Mosquito eggs must be exposed to water in order to hatch
- 3 different types of water in which mosquitoes breed:
 - Permanent Water
 - Flood Waters
 - Containers



Eggs

- Permanent water breeding mosquitoes
 - Cannot withstand drying out
 - Water must be a permanent or semi-permanent body of water
 - Eggs will typically hatch in about 24 hours
 - **Direct-Hatching Mosquitoes**
 - *Anopheles* and *Culex* species
 - Overwinter as pre-mated hibernating female mosquitoes
 - Females immediately search out a host and take a blood meal
 - Eggs laid in permanent water
 - Produce several generations spring through fall



Eggs

- Container breeding mosquitoes
 - Develop in a variety of water-holding containers
 - Tree holes, bromeliads, and bamboo trunks
 - Man-made objects: discarded tires, cans, flower pots, bird baths
 - Commonly found in backyards
 - Move mosquitoes out of their natural range
 - **Delayed-Hatching Mosquitoes**
 - *Aedes* species
 - Eggs need a desiccation period
 - Overwinter as eggs
 - Rains produce standing water that inundates eggs
 - Produce several generations spring through fall



Figure 6

Eggs

- Eggs hatch by splitting along a line over the head of the larva
- The split cap comes off and the larva escapes

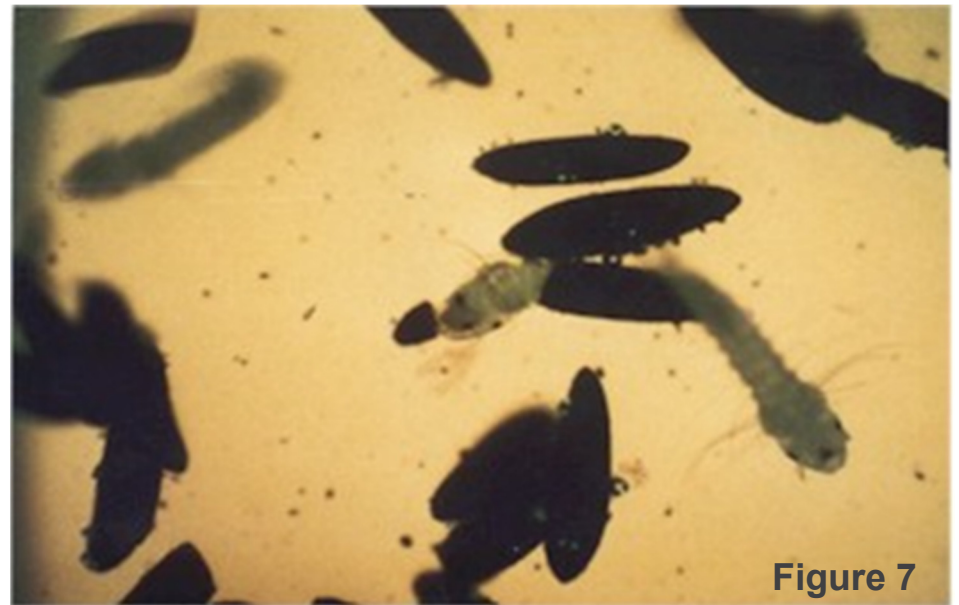


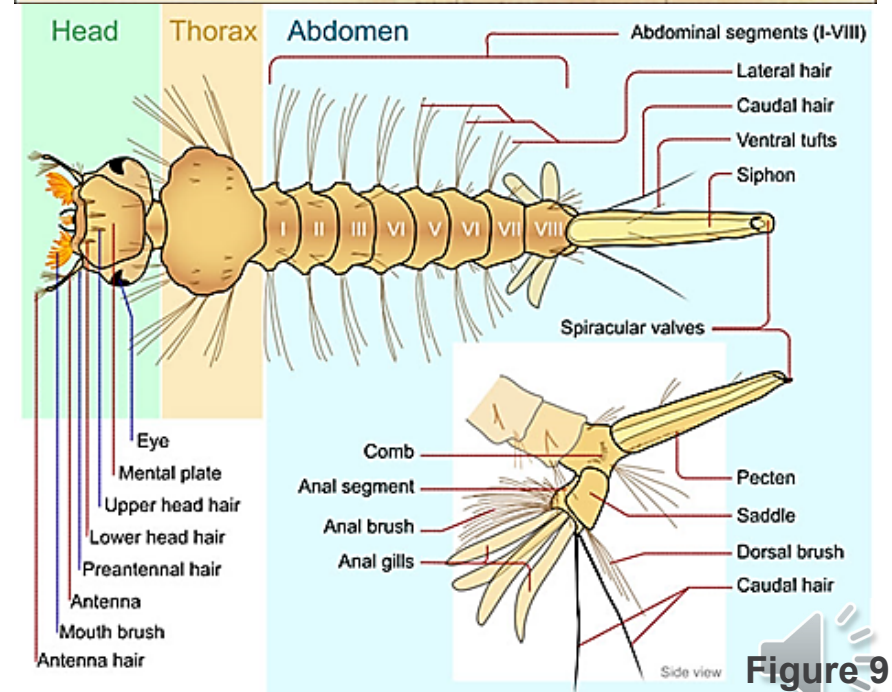
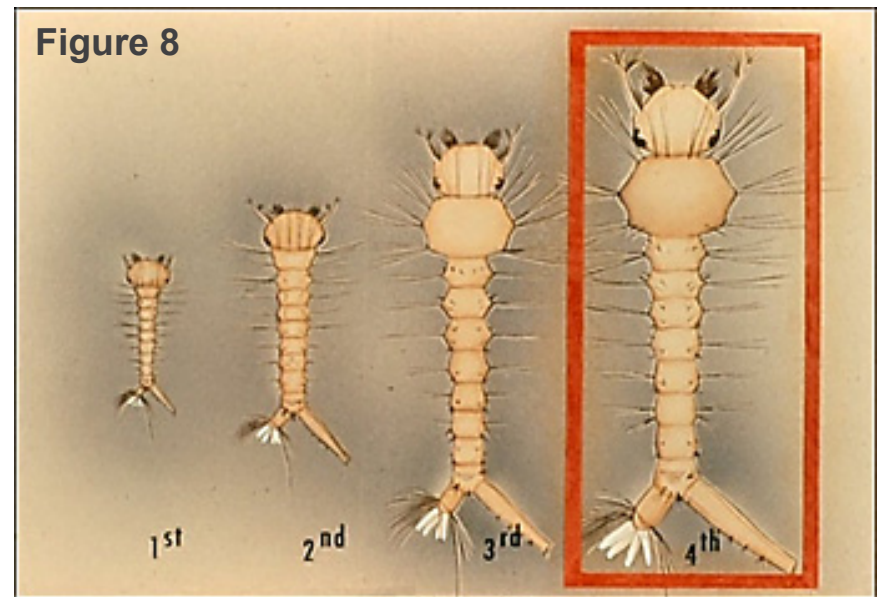
Figure 7

- Eggs laid in rafts are oriented with larvae head down so that hatching larvae can easily enter the water



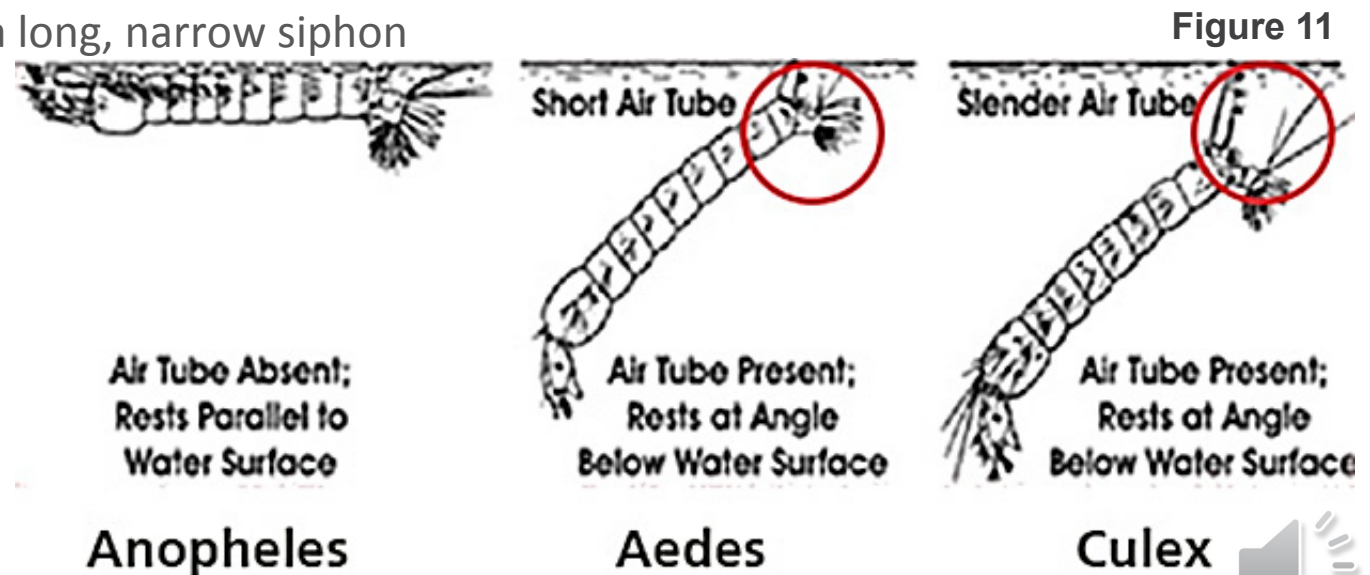
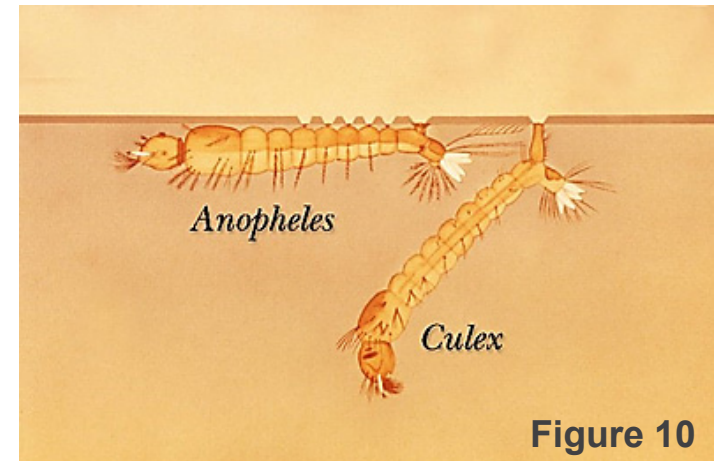
Larvae

- Pass through 4 **instars**
- Structure:
 - Well-developed head with mouth brushes used for feeding
 - Large thorax
 - 9 segmented abdomen
- Do not have legs
- **Filter feeders**
 - Collect food via mouth brushes
 - Generate water currents
 - Imbibe lots of water
- Males develop faster than females



Larvae

- Respiration by breaking water surface tension
 - Via **spiracles** located on the eighth abdominal segment (*Anopheles*)
 - Via a **siphon** located at the posterior end (*Aedes* and *Culex*)
- Anopheline larvae lack a siphon and lay parallel to the water surface
- *Aedes* and *Culex* rest with the body resting at an angle to the water surface
 - *Aedes* larvae have a short barrel-shaped siphon
 - *Culex* larvae have a long, narrow siphon



Larvae

- Extrinsic factors that affect rates of growth and development:
 - Temperature
 - Nutrition
 - Larval density
 - Water depth & salinity
- Larval habitats
 - Vary greatly and each species has a preferred water source
 - Shallow water
- Alarm response
 - Escape behavior done through diving
- Feed on organic debris and microorganisms suspended in water or found on the bottom of their aquatic habitat
- Grooming by working their mouthparts over accessible parts of the body surface



Pupae

- Aquatic
- Mobile
- Do not feed
- Structure
 - Cephalothorax
 - Respiratory trumpets
- Alarm response to escape danger
- Exceptional among insects due to their mobility

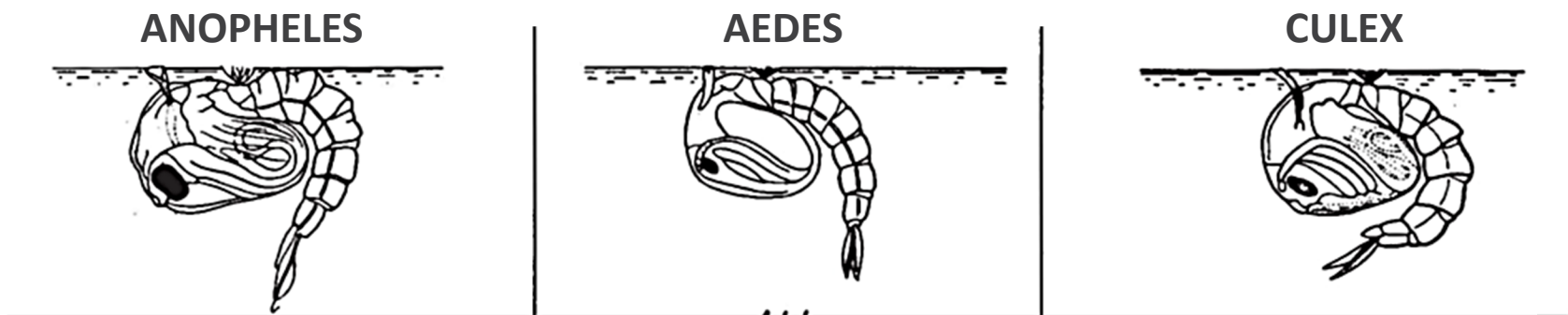
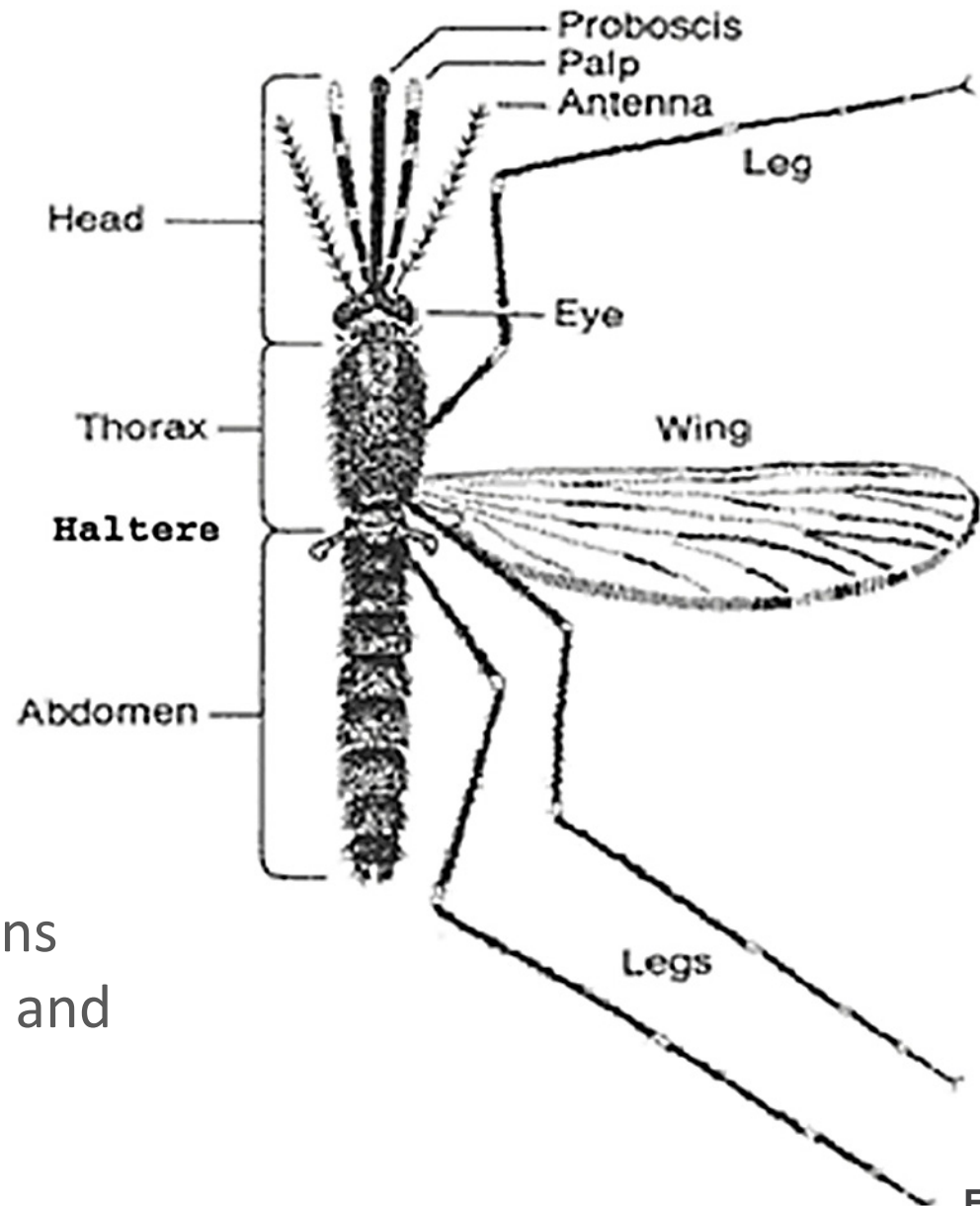


Figure 12

Adults

- Terrestrial
- Structure
 - Head
 - Thorax
 - Abdomen
 - Pair of wings
 - Pair of halteres
 - Antennae
 - Palps
- Biological activity patterns depend on temperature and light and dark cycles



Anatomy & Physiology

Head

- Feeding
- Sensing
 - Vision
 - Odor
 - Taste
- Structure
 - Eyes
 - Antennae
 - Proboscis
 - Maxillary palps

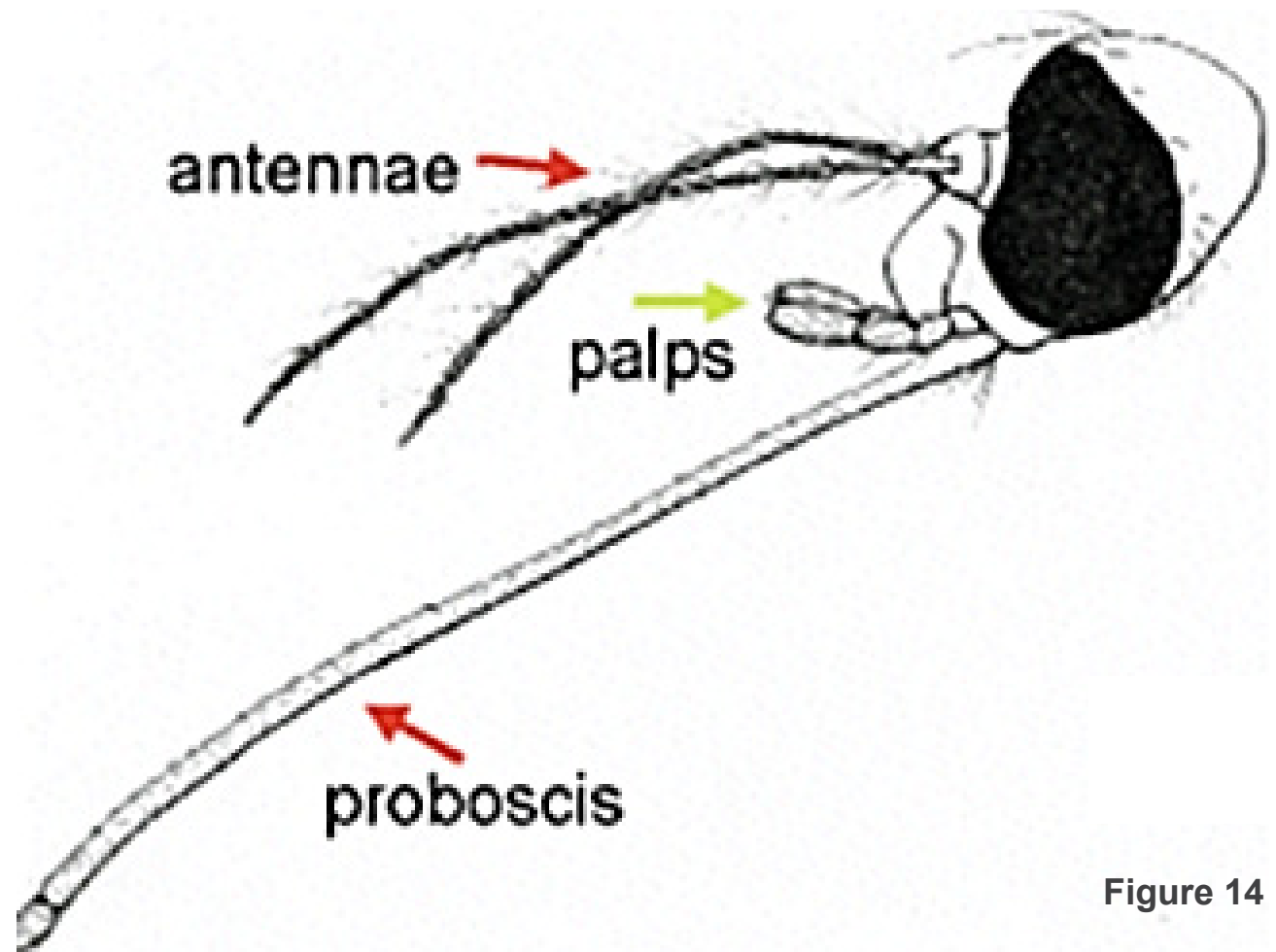


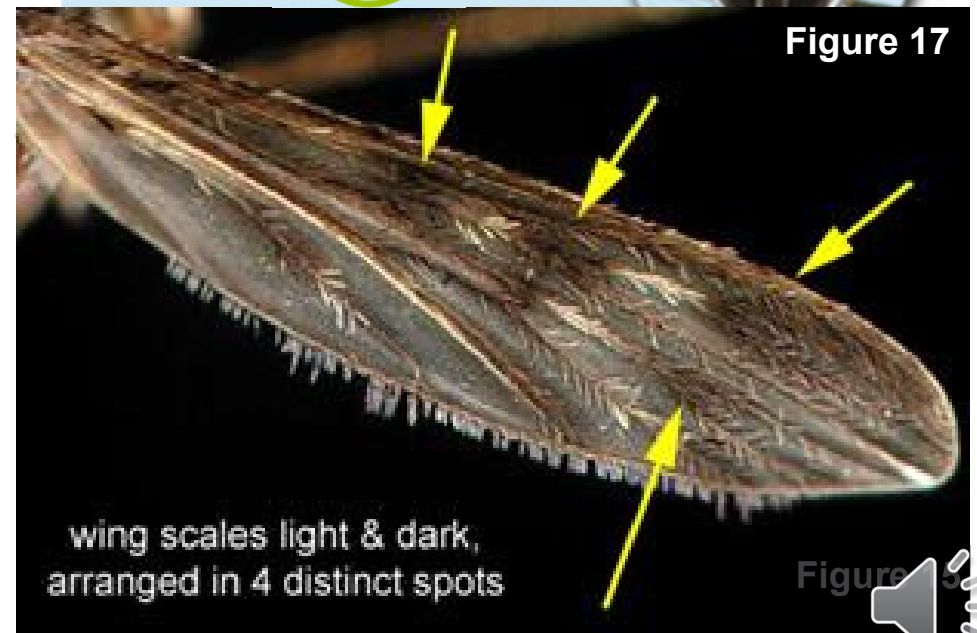
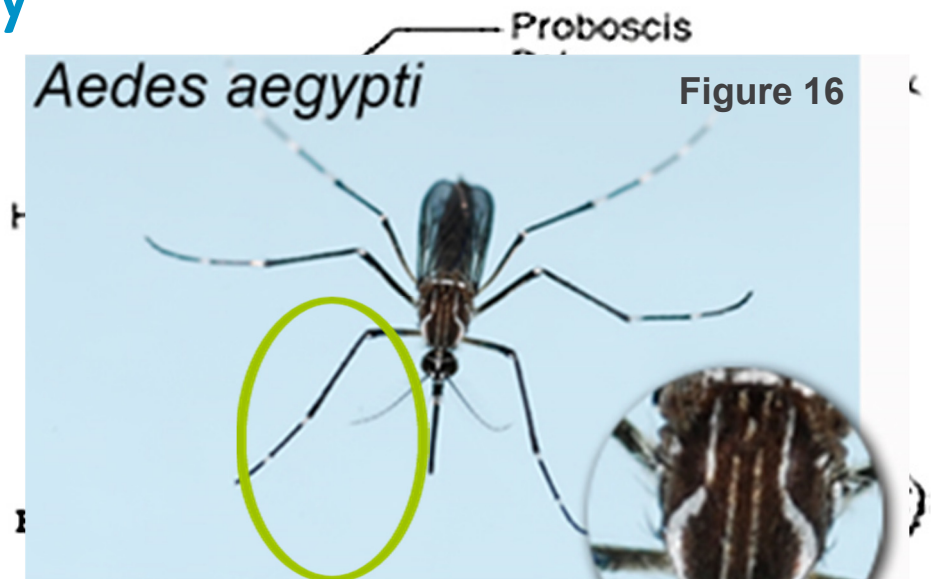
Figure 14



Anatomy & Physiology

Thorax

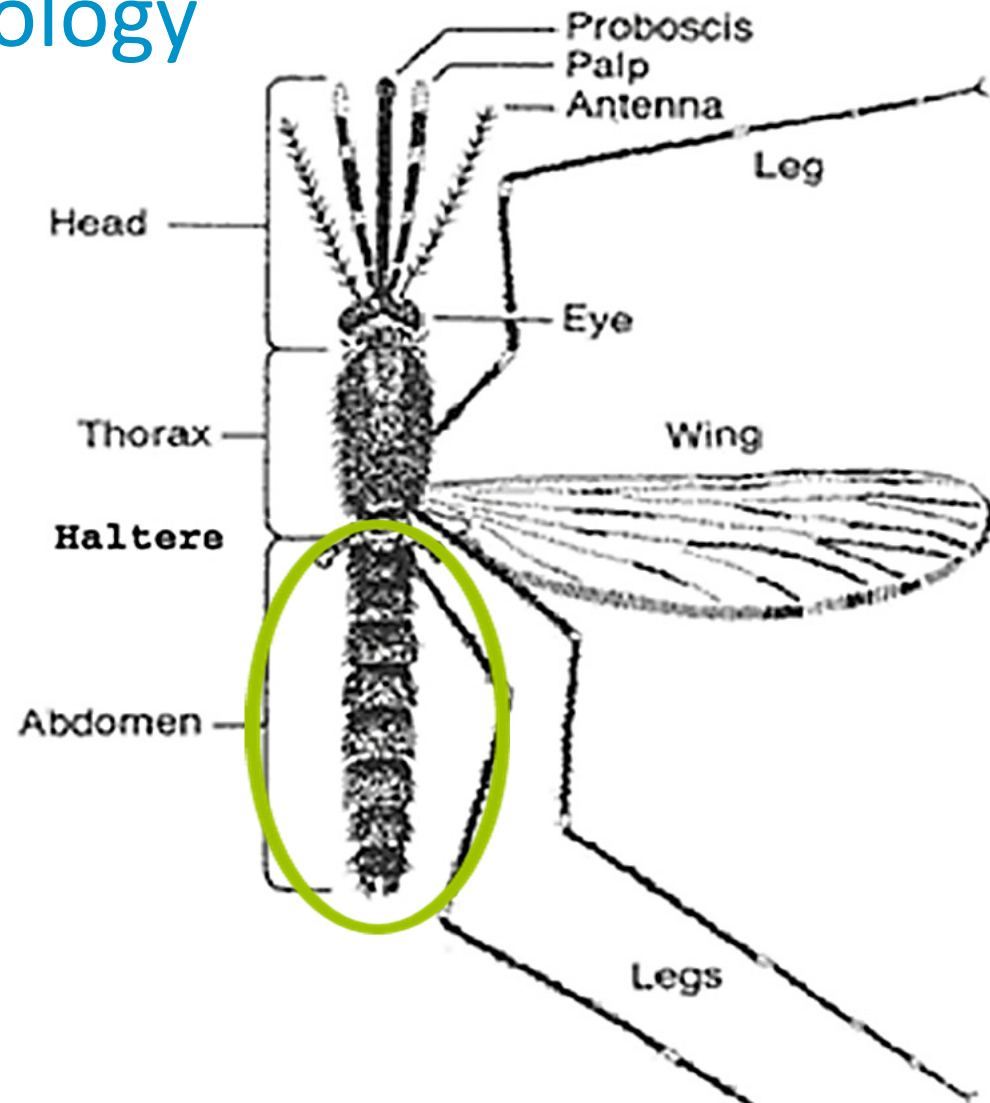
- Locomotion
- Structure
 - Three pairs of legs
 - Pair of wings
 - Pair of halteres
- Identification
 - Lyre or harp-shaped pattern on thorax of *Aedes aegypti*
 - 4 spots on wings of *Anopheles quadrimaculatus*



Anatomy & Physiology

Abdomen

- Food digestion
 - Sugar
 - Blood
- Reproduction
 - Egg production
 - Sperm production
- Structure
 - 9 abdominal segments
 - Scales



Anatomy & Physiology

Females are
hematophagous

- Require proteins and iron from blood for egg production
- Blood meal taken from a variety of animals (hosts)
- Parasite transmission

Males do not need blood

- Mouthparts cannot penetrate the skin

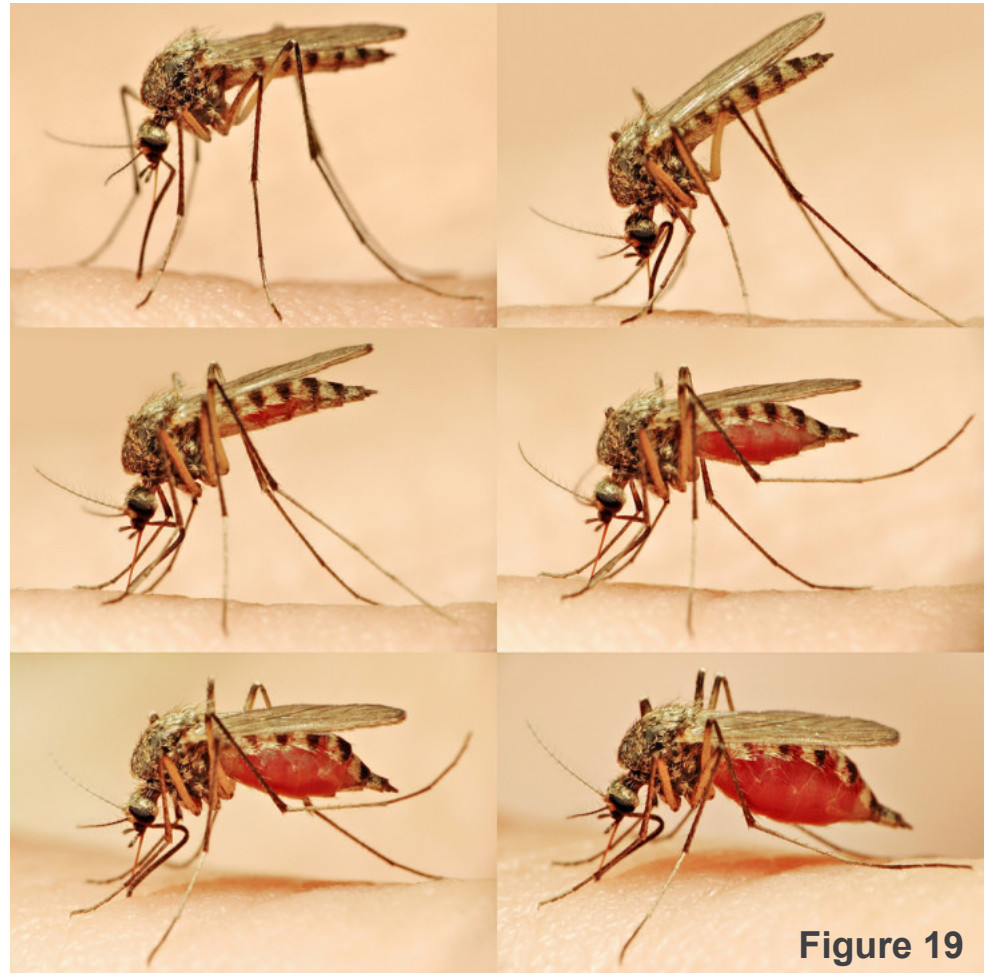


Figure 19



Anatomy & Physiology

Antennae

- Sense organs
 - In females
 - Host detection
 - Breeding site detection
 - In males
 - Organs of hearing /detecting conspecific females
- Structure
 - Females have thread-like antennae
 - Males have feathery antennae

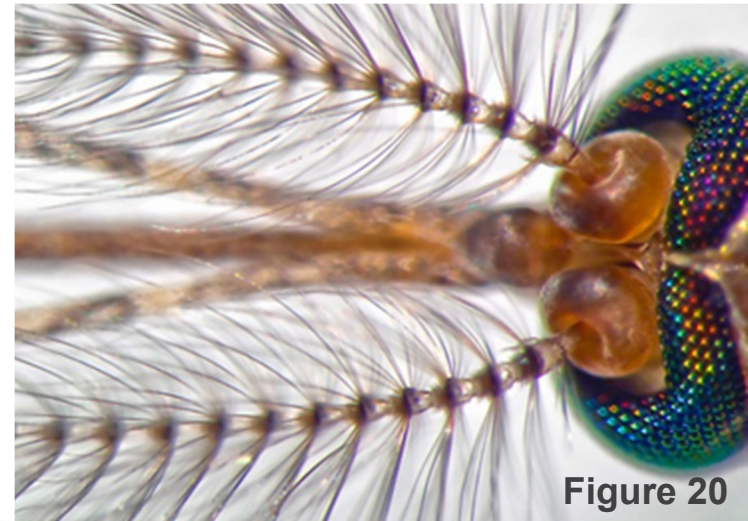


Figure 20

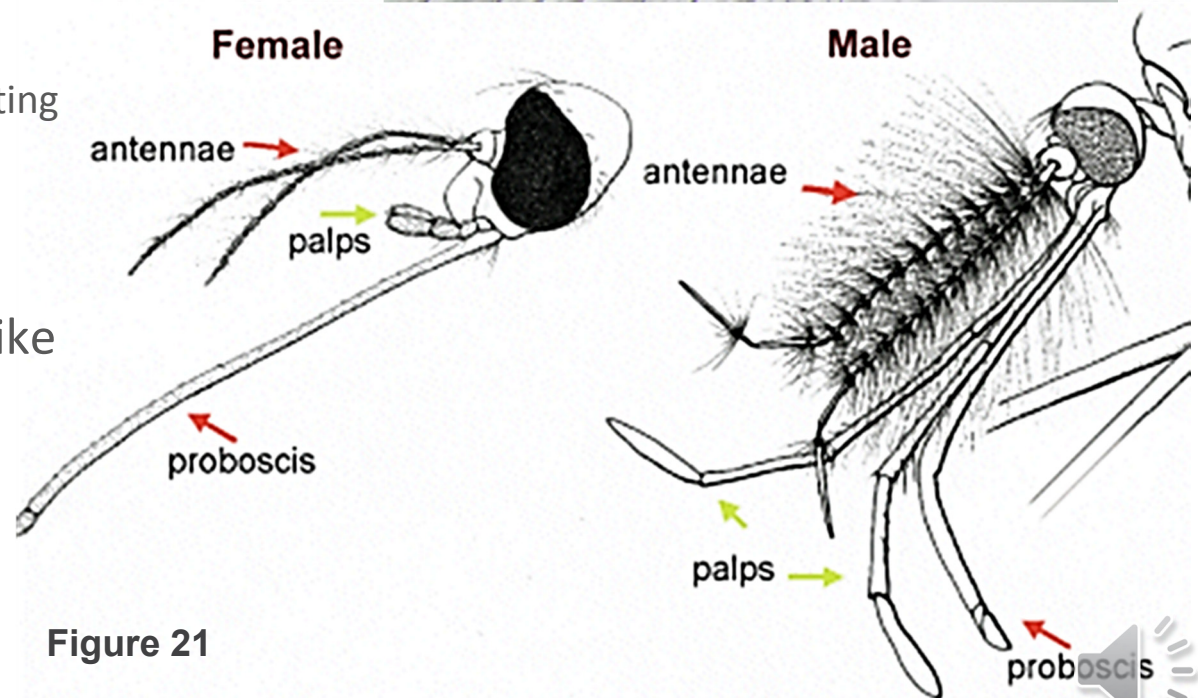


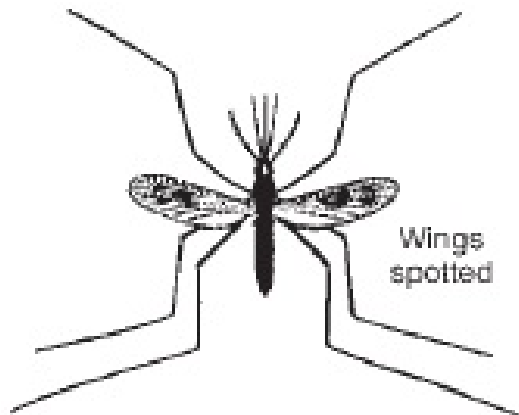
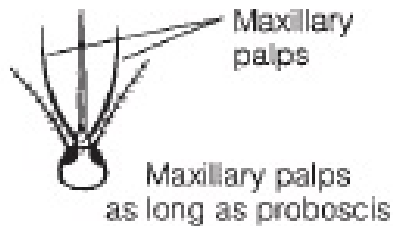
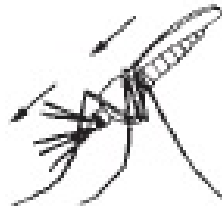
Figure 21

Anatomy & Physiology

ANOPHELES

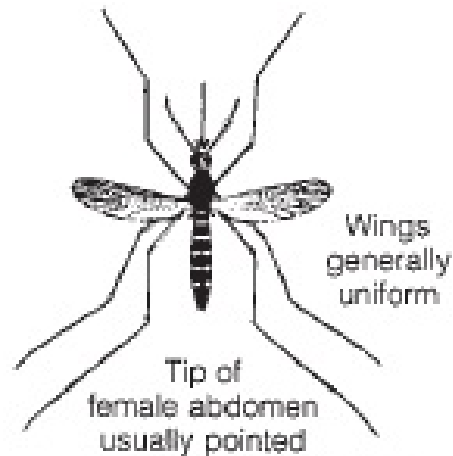
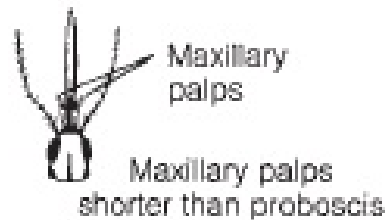
Adult

Proboscis and body in same straight line



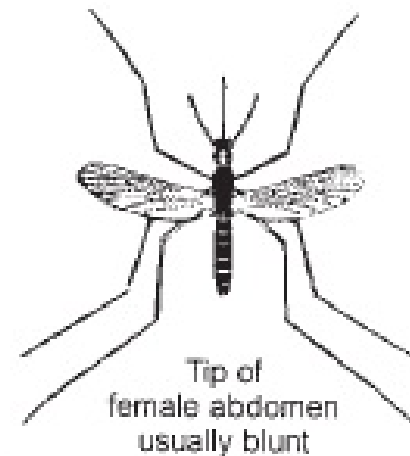
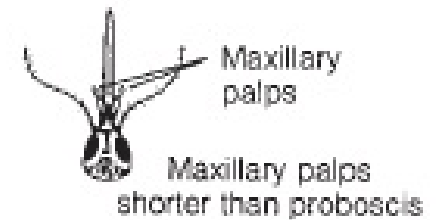
AEDES

Proboscis and body at an angle to one another



CULEX

Proboscis and body at an angle to one another



Anatomy & Physiology

- Mosquitoes navigate towards potential vertebrate hosts via chemical or physical cues
 - Expired breath
 - Skin secretions and their bacterial decomposition products
 - Flatus
 - Urine & feces
- Cues are carried by air movement and orient the insect towards host
 - CO₂ is main attractant
 - Mosquitoes also use lactic acid to find and identify a host
 - Mosquitoes see contrast between the host and the background
- Receptor cells sensitive to CO₂, lactic acid, and temperature must be stimulated simultaneously to evoke the blood feeding response



Anatomy & Physiology

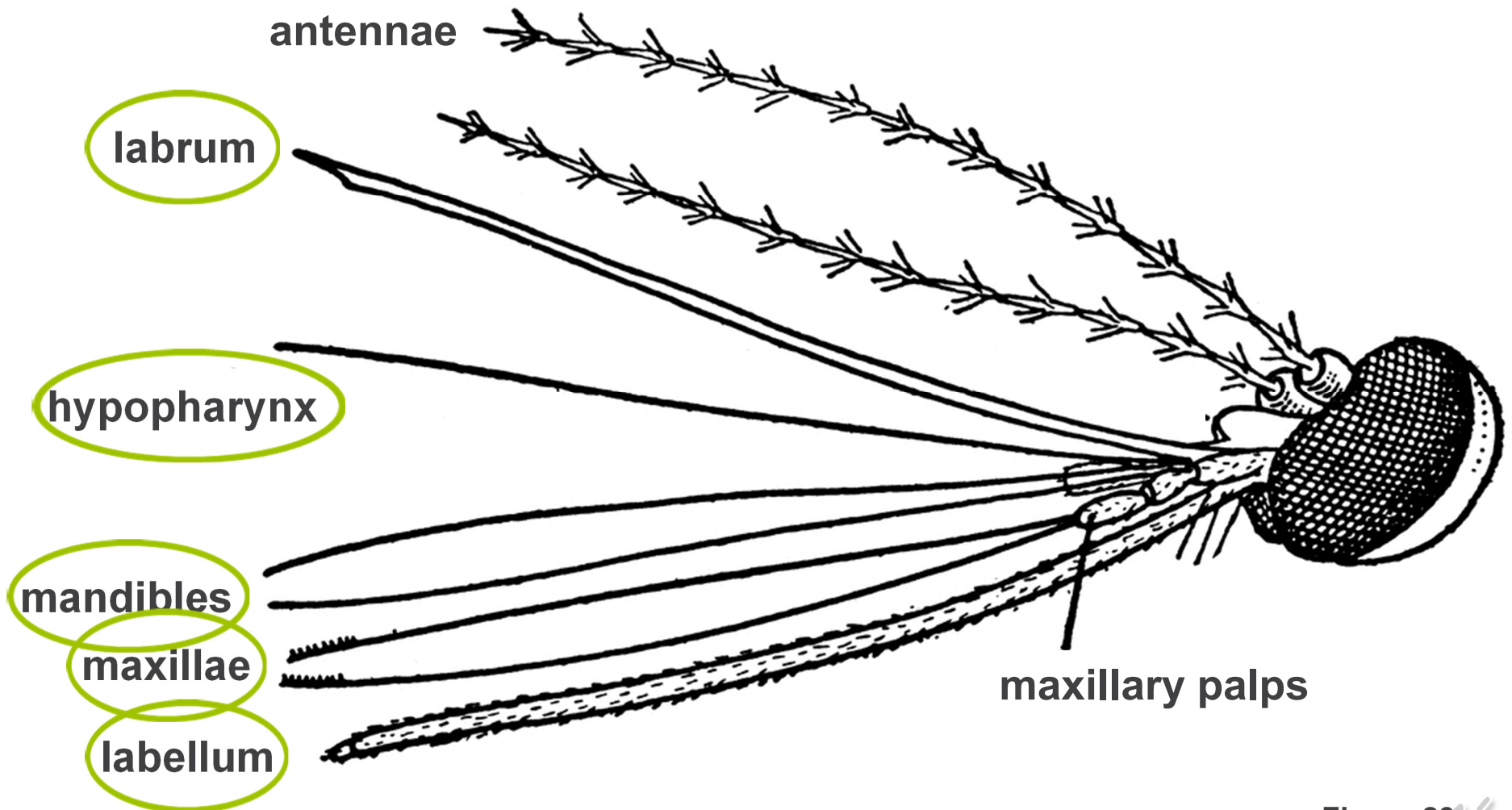


Figure 23

Anatomy & Physiology

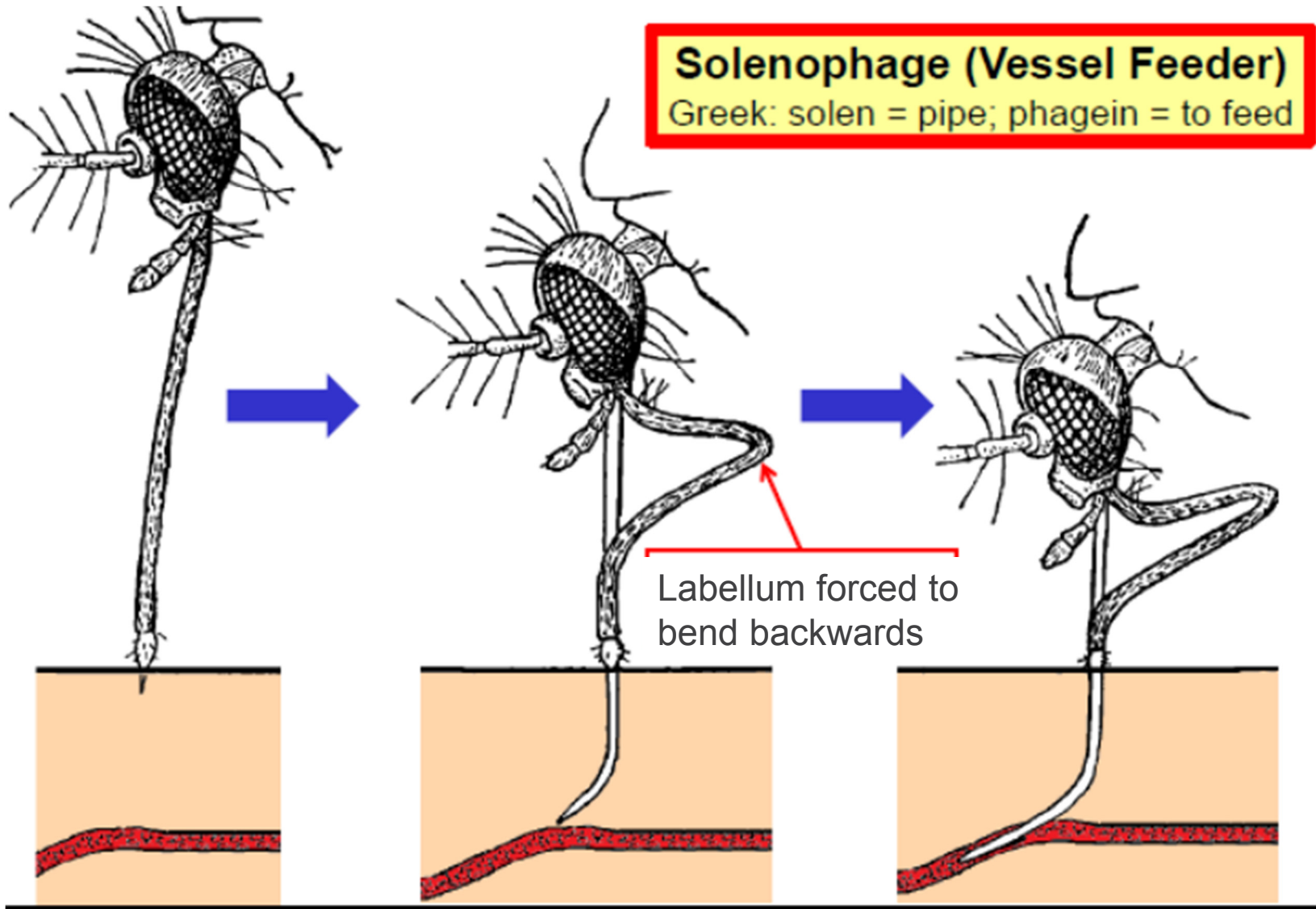


Figure 24



Anatomy & Physiology

- Adult mosquitoes eat plant nectars to obtain sugars for energy production and to support other metabolic functions
 - Sugars for flight fuel
- Mosquitoes store energy in the form of glycogen and lipids in the hemolymph, flight muscles, and fat body



Anatomy & Physiology

Digestive system – larvae

Alimentary canal of mosquito larvae

- Organ of digestion and food uptake, ionic and osmotic regulation, and excretion
- 3 regions:
 - Foregut
 - Filtering and swallowing bolus
 - Midgut
 - Digestion and absorption of digested products
 - Hindgut
 - Excretion and ionic and osmotic regulation
- Fat body – principal storage organ

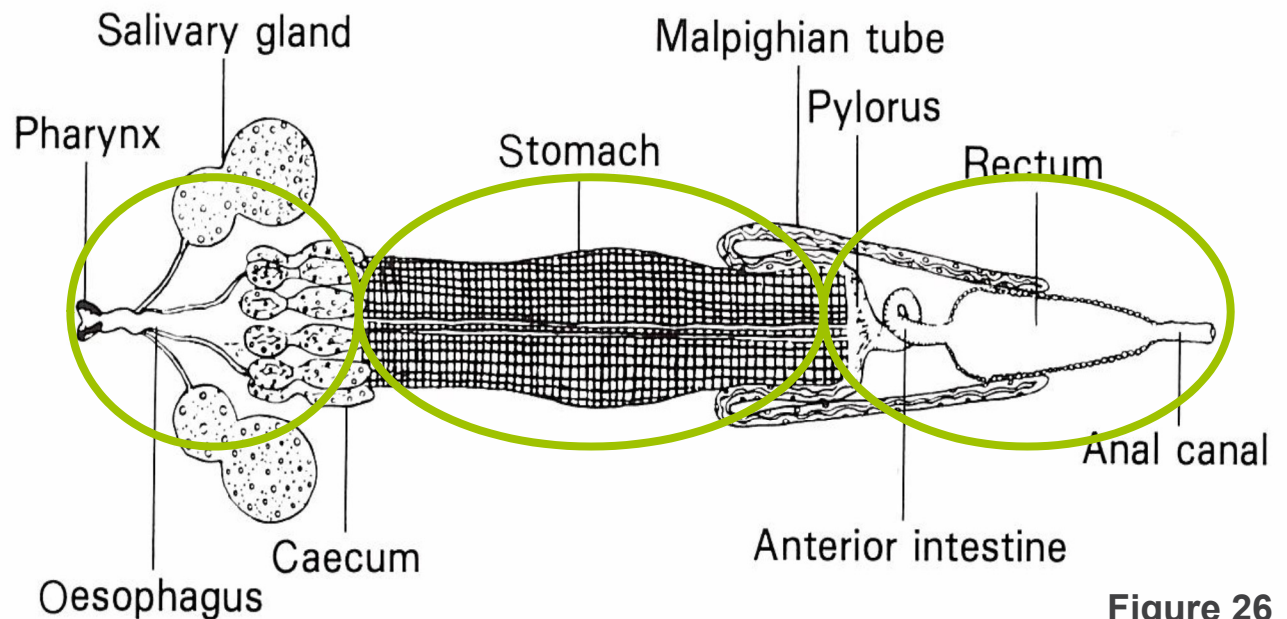


Figure 26



Anatomy & Physiology

Digestive system – adults

Alimentary canal of mosquito adults

- Structure

- Foregut
 - Crop
- Midgut
- Hindgut

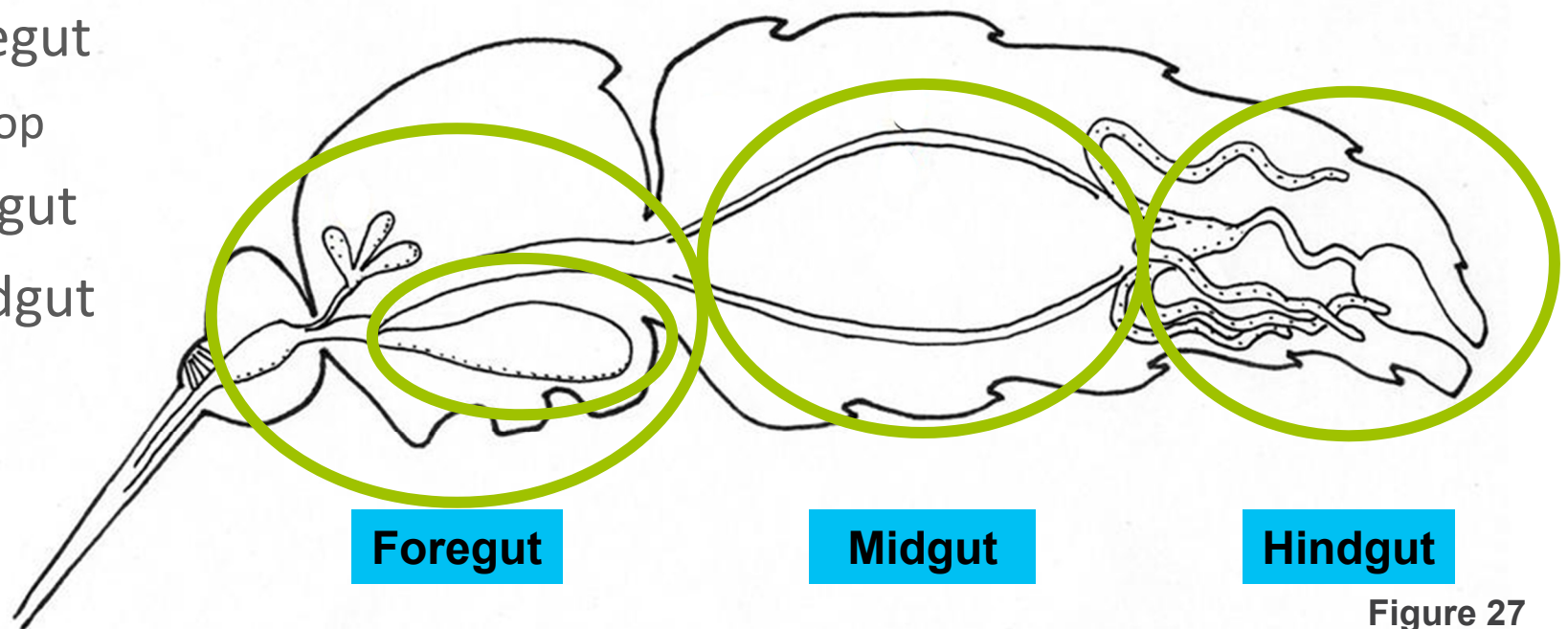


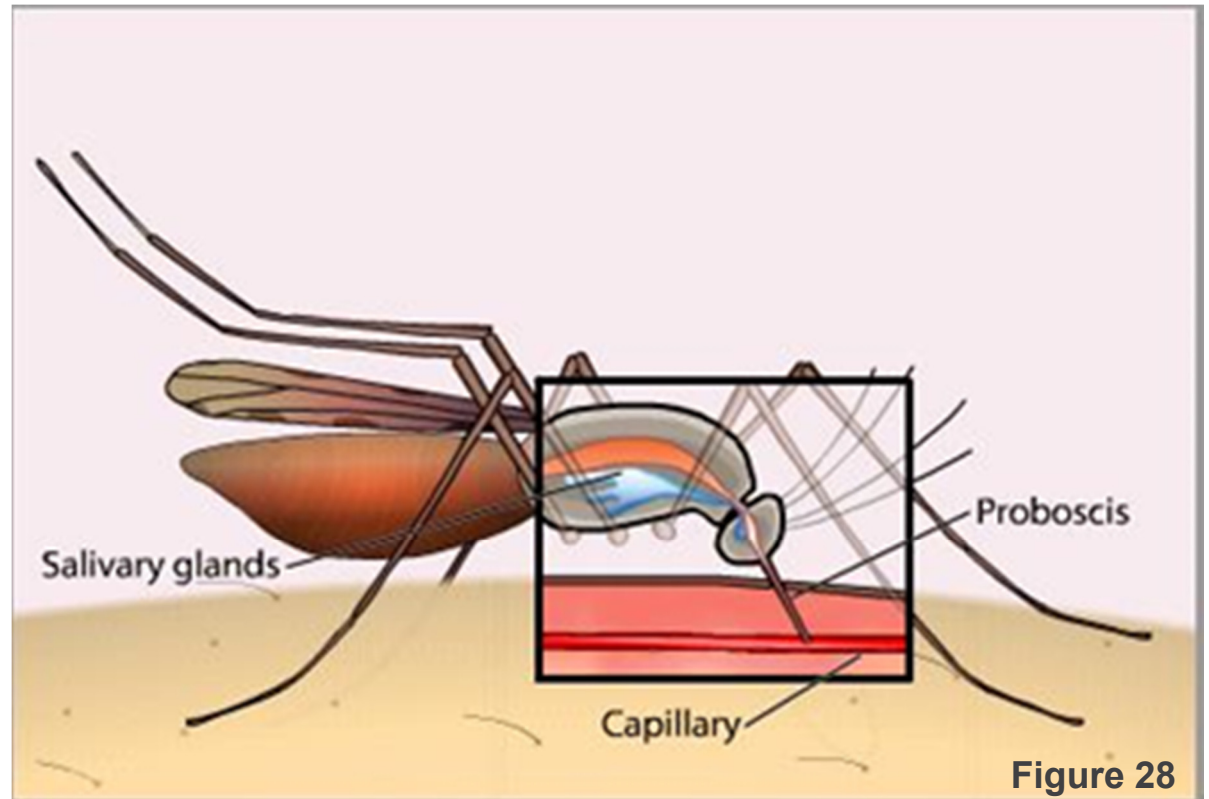
Figure 27



Anatomy & Physiology

Salivary glands

- Saliva
 - Discharge regulated by nervous and endocrine mechanisms
 - Prevents blood coagulation and host inflammation
- Located in thorax
 - Smaller in males



Anatomy & Physiology

Circulatory system

- Hemolymph
 - Circulates in the interior of arthropod body
 - Provides the tissues with nutrients and metabolic intermediates
 - Provides a medium for the transport of their chemical wastes
 - Distributes hormones throughout body
 - Provides defenses against parasites
- Dorsal vessel
 - Aorta
 - Heart
- Accessory pulsatile organs

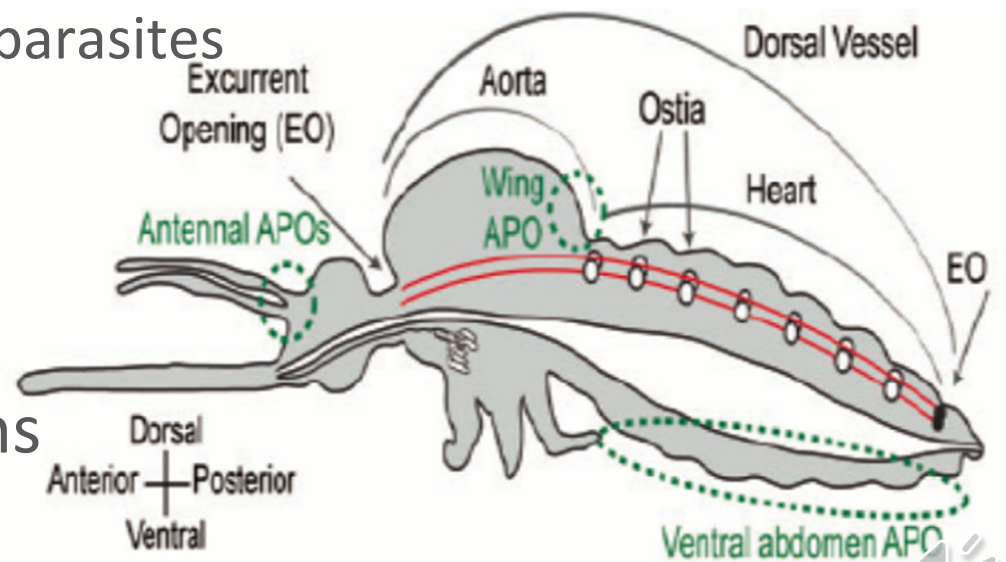


Figure 29

Anatomy & Physiology

Neuroendocrine system

- Neurosecretory cells
 - Within the central nervous system
 - Within paired endocrine complexes
 - Release hormones into the circulatory system
 - Axons extend to specific organs or tissues to deliver hormone

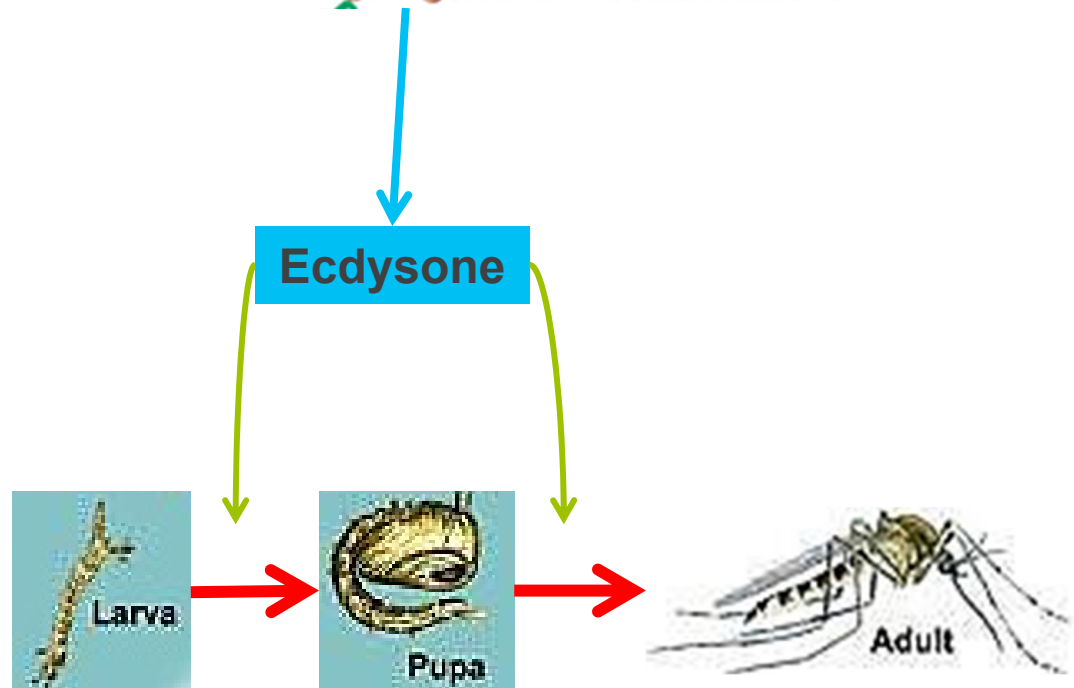
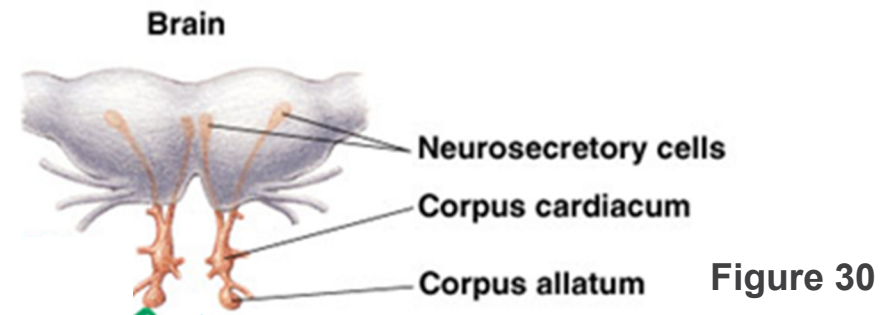


Figure 31

Anatomy & Physiology

Reproductive system

- **Terminalia** – posterior 3 abdominal segments and **genitalia** (external structures involved in copulation and oviposition)
- **Males**
 - Terminalia rotate 180°
 - **Claspers** – hold the female's genitalia and open the female's gonotreme during copulation
 - Semen
 - Secretions of the accessory gland with the spermatozoa
 - Transmitted to the female during copulation through the ejaculatory duct

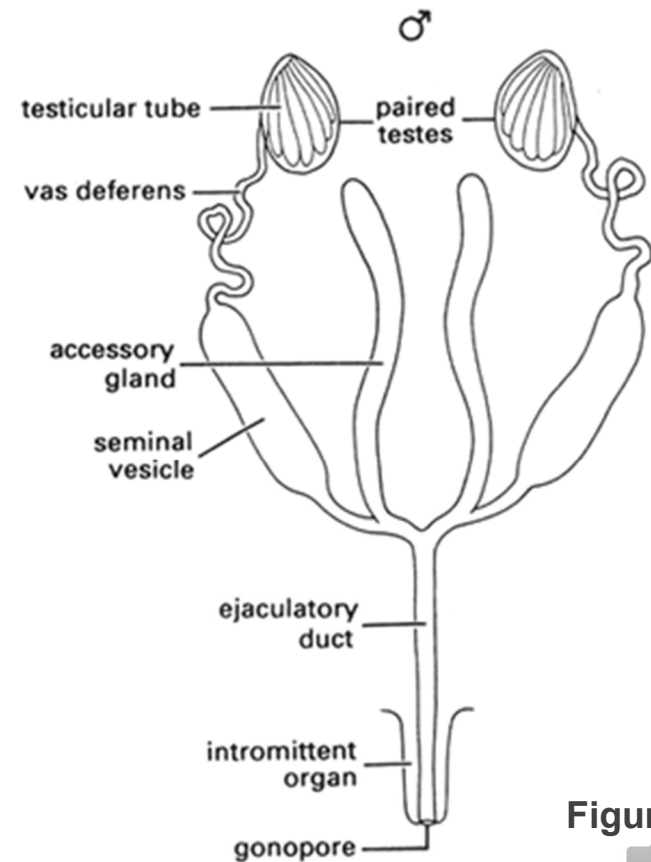


Figure 32

Anatomy & Physiology

Reproductive system

- Females

- 2 ovaries – each composed of ovarioles
- **Ovulation** – extrusion of mature oocytes from ovarian follicles into the calyces and oviducts
- **Spermathecae** – store spermatozoa after copulation until oviposition.
- **Oviposition**

- Full grown oocyte is surrounded by the **chorion** (egg shell)
- Sperm penetrate the oocyte through **micropyle**

- After oviposition the oocyte has transformed into an egg
- Female reproductive capacity is affected by nutrition in larval and adult stage

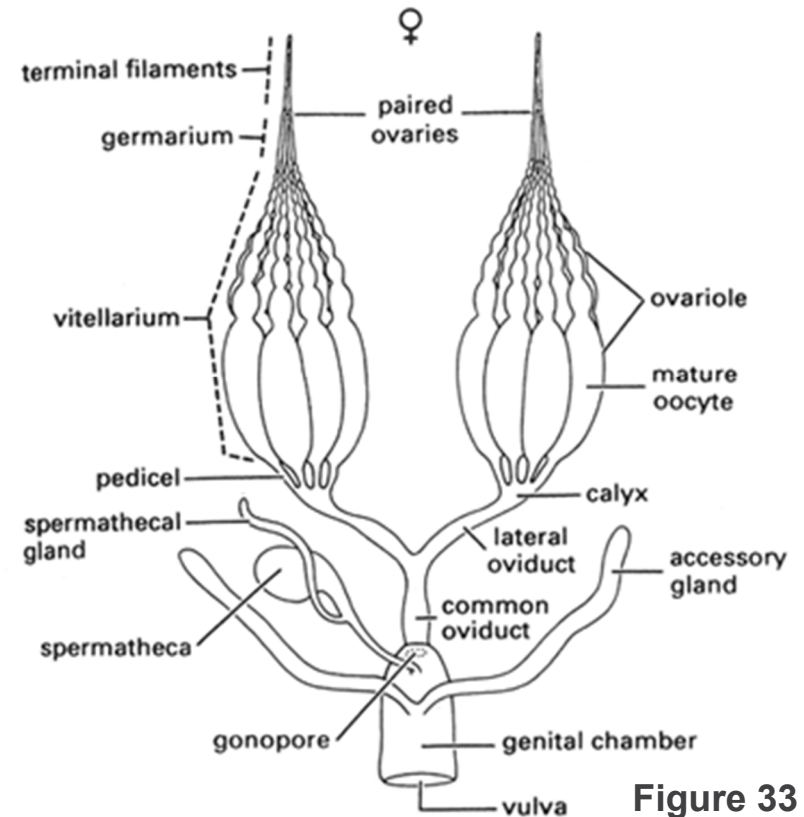


Figure 33

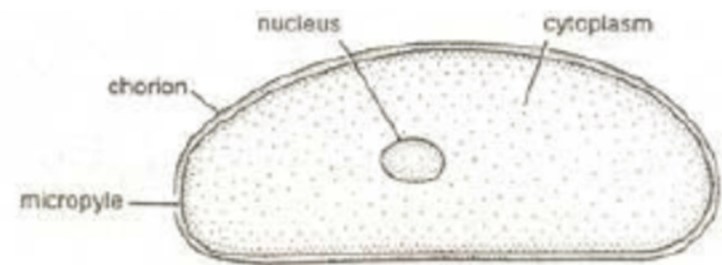


Figure 34



Adult behavior

- Behaviors are appropriate to a mosquito's sex, nutritional and reproductive requirements, and its needs for secure resting sites
 - Behavioral maturation due to interaction of hormones
 - Males require sugar from plant sources, mates, and resting sites
 - Females require sugar from plant sources, mates, resting sites, blood sources, and oviposition sites
 - **Gonotrophic cycle** – female passes through phases of host-finding and blood-feeding activity, relative inactivity during ovarian development, and pre-oviposition behavior followed by oviposition.
 - These sequences recur in a cyclic manner
- All mosquitoes show periods of activity and inactivity that are dependent on temperature, relative humidity, and light and dark cycles
 - Flight activity depends upon body temperature



Adult behavior

Feeding behaviors

- A mosquito is a vessel feeder or a **solenophage**
- Different species of mosquitoes have different host preferences
 - **Anthropophagic** mosquitoes prefer to feed on humans
 - **Zoophagic** mosquitoes prefer to feed on animals
- Female mosquito feed on a host in order to ingest enough blood to produce each batch of eggs
- After feeding, a female seeks a protected resting area in order to digest the blood and absorb the proteins necessary for egg development
 - State of engorgement



Figure 35

Adult behavior

Feeding behaviors

- Sugar feeding habits
 - Plant odors steer mosquitoes towards plant sugars
 - Mosquito tastes the sugar with its labella and tarsi
 - Imbibed nectar is passed to the crop
- Feeding habits
 - **Endophagic** – mosquitoes that enter homes to bite
 - **Exophagic** – mosquitoes that bite mostly outside
- Resting habits
 - **Endophilic** – mosquitoes that enter houses and rest on walls or furniture
 - **Exophilic** – mosquitoes that rest on plants, in holes, in trees or on the ground



Adult behavior

Sexual Behavior & Mating

- Males

- Become sexually responsive 12-36 hours after emergence
 - Terminalia have inverted
 - Antennae detect conspecific female wing beat frequency

- Females

- Non-receptive to males for the first 36-60 hours after eclosion
- Virgin females fly actively when males swarm and do not resist male sexual advances
- Once inseminated, females become refractory to further sexual intercourse and seek a host

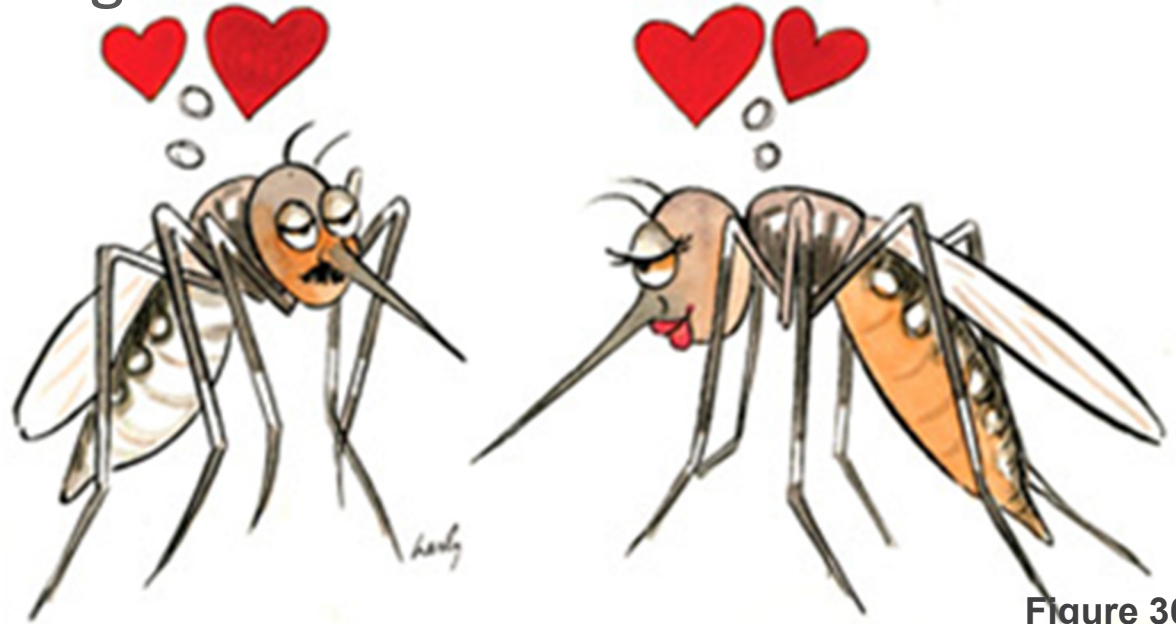


Figure 36



Adult behavior

Sexual Behavior & Mating

- Mating is initiated in flight
 - May end with the pair in flight or settled on vegetation or ground
 - Completed within seconds
- Mating involves sequences of behavior
 - Brings males and females into proximity
 - Permit short-distance location of the female by the male
 - Lead to engagement of the genitalia
- Different methods of assembly bring conspecific males and females together and prevents copulation between different species
 - In species that mate in flight, males fly towards a conspecific female when stimulated by her wingbeat frequency



Figure 37



Adult behavior

Oviposition behavior

- The antennae of females detect potential oviposition sites
- **Gravid** females oviposit during the first window of opportunity

- Behavioral events:

Ranging flight

↳ Orientation

↳ Encounter

↳ Acceptance

↳ Landing

↳ Surface evaluation

↳ Oviposition



Figure 38





End of Module 1

Quiz



Module 1 Quiz Questions

1. True or False: Mosquitoes are hemimetabolous insects.

Answer: False

2. Mosquitoes that take advantage of permanent waters or semi-permanent waters are called:

- a. Delayed-Hatching Mosquitoes
- b. Direct-Hatching Mosquitoes
- c. Flood Water Mosquitoes
- d. Artificial Container Mosquitoes

Answer: (B) Direct-Hatching Mosquitoes

3. True or False: The duration of larval growth and pupal stage are slightly shorter in males than in females

Answer: True

4. The principal extrinsic factors that affect larval growth and development rates are

- a. Temperature
- b. Nutrition
- c. Larval density
- d. A & B only
- e. All of the above

5. True or False: In mosquito pupae, the head and thorax are fused into a single region known as the mesothorax.

Answer: False

6. Which receptors must be stimulated at the same time to evoke the blood feeding response in female mosquitoes?

- a. Receptors for carbon dioxide, lactic acid, and temperature
- b. Receptors for carbon dioxide and temperature
- c. Receptors of sensilla on its tarsi and labella
- d. Receptors for carbon dioxide and lactic acid

Answer: (A) Receptors for carbon dioxide, lactic acid, and temperature

7. The posterior three abdominal segments of an adult mosquito and their external parts are referred to as:

- a. Claspers
- b. Genitalia
- c. Terminalia
- d. Ovipositor

Answer: (C) terminalia

8. After copulation, spermatozoa accumulate within the _____, where they remain until _____.

- a. Spermathecae, oviposition
- b. Accessory gland, oviposition
- c. Seminal vesicle, blood-feeding
- d. Chorion, blood-feeding

Answer: (A) Spermathecae, oviposition

9. True or False: The reproductive capacity of female mosquitoes is affected by their nutrition in the larval, pupal, and adult stages.

Answer: False

10. During a gonotrophic cycle a female passes through all the following phases except:

- a. host-finding
- b. blood-feeding
- c. pre-oviposition behavior
- d. increased flight activity
- e. oviposition

Answer: (D) increased flight activity

11. Mosquitoes that enter homes to bite are considered

- a. Exophagic
- b. Endophilic
- c. Endophagic
- d. Exophilic

Answer: (C) endophagic

12. True or False: The females of most mosquito species are non-receptive to males for the first 12-36 hours after emergence.

Answer: False

13. The _____ stores the ingested plant juices.

- a. Fat body
- b. Crop
- c. Midgut
- d. Hemolymph

Answer: (B) Crop

14. The proboscis includes all of the following parts except:

- a. Hypopharynx
- b. Maxillae
- c. Labellum
- d. Labrum
- e. Palps
- f. Mandibles

Answer: (E) Palps

15. True or False: The anophelines and culicines are filter feeders as they collect food by using their mouth brushes to filter the water for particles of yeast, bacteria, and other plant and animal matter.

Answer: True



Mosquito 101
Training Module 2:
Aedes aegypti

By: Joanna Tyszko

University of Nebraska-Lincoln

MS Degree Project



Aedes genus

- Eggs
 - Usually black and more or less ovoid
 - Eggshells have a mosaic appearance
 - Always laid singly just above the water line
 - Can withstand desiccation (Delayed-Hatching mosquitoes)
- Developmental sites
 - Transient ground pools
 - Flooded areas along overflowing streams
 - Inland and coastal flood plains
 - Rainwater catch basins
 - Container habitats

- Tree holes, wheel ruts, and discarded tires



Figure 1



Figure 2

Making communities around the world more livable, safe and comfortable.

Aedes genus

Larval characteristics:

- Short barrel-shaped siphon
- Larval body rests at an angle to the water surface

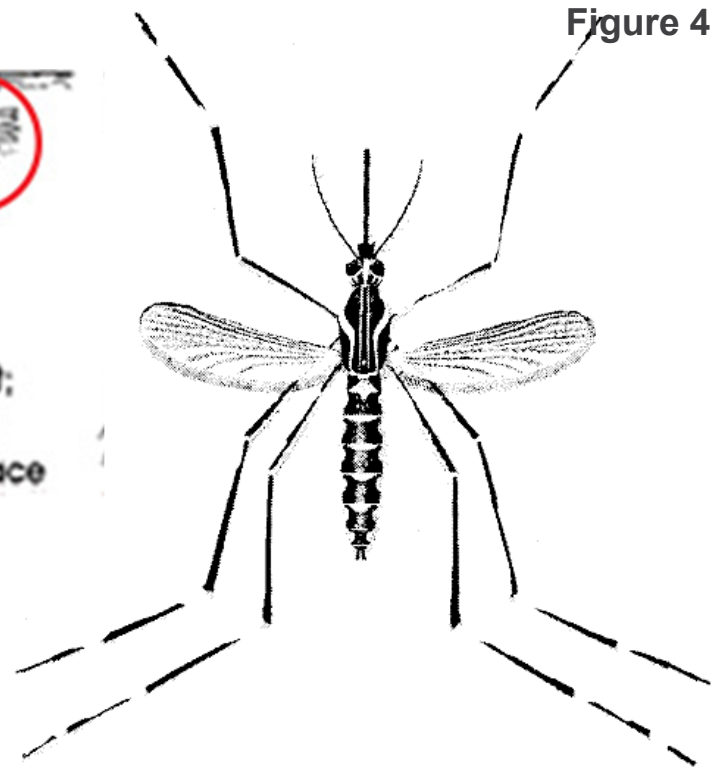
Adult characteristics:

- Thorax has patterns that are formed by black, white, and silvery scales
- Legs often have black and white rings
- Tip of the female's abdomen is usually pointed
- Palps are shorter than the proboscis
- Rest with their body horizontally and their proboscis at an angle and have a low crouching profile.

Figure 3



Figure 4



Resting Position Figure 6

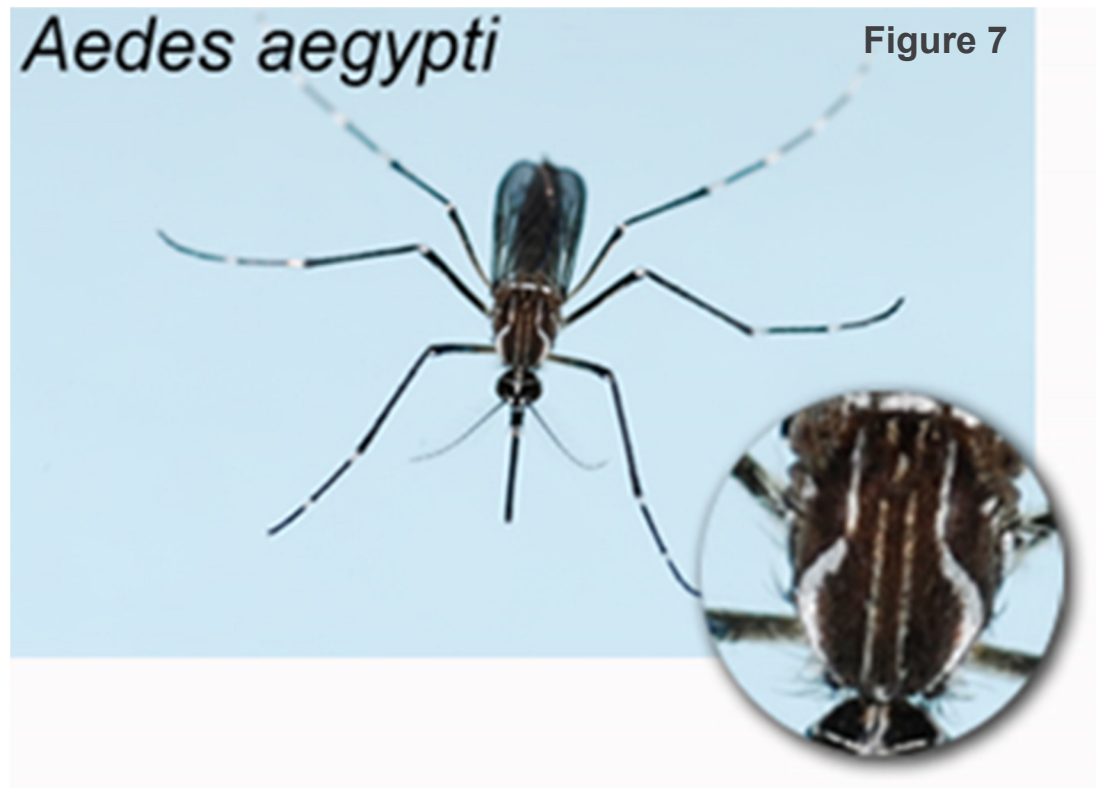


Figure 5



Aedes aegypti

- Small, dark mosquito with banded legs and white lyre shaped markings on thorax
- Bites primarily during the day and most active after sunrise and before sunset
- Can bite without being noticed because it approaches from behind
 - Bites on ankles and elbows
- Endophagic
- Anthropophagic



Aedes aegypti

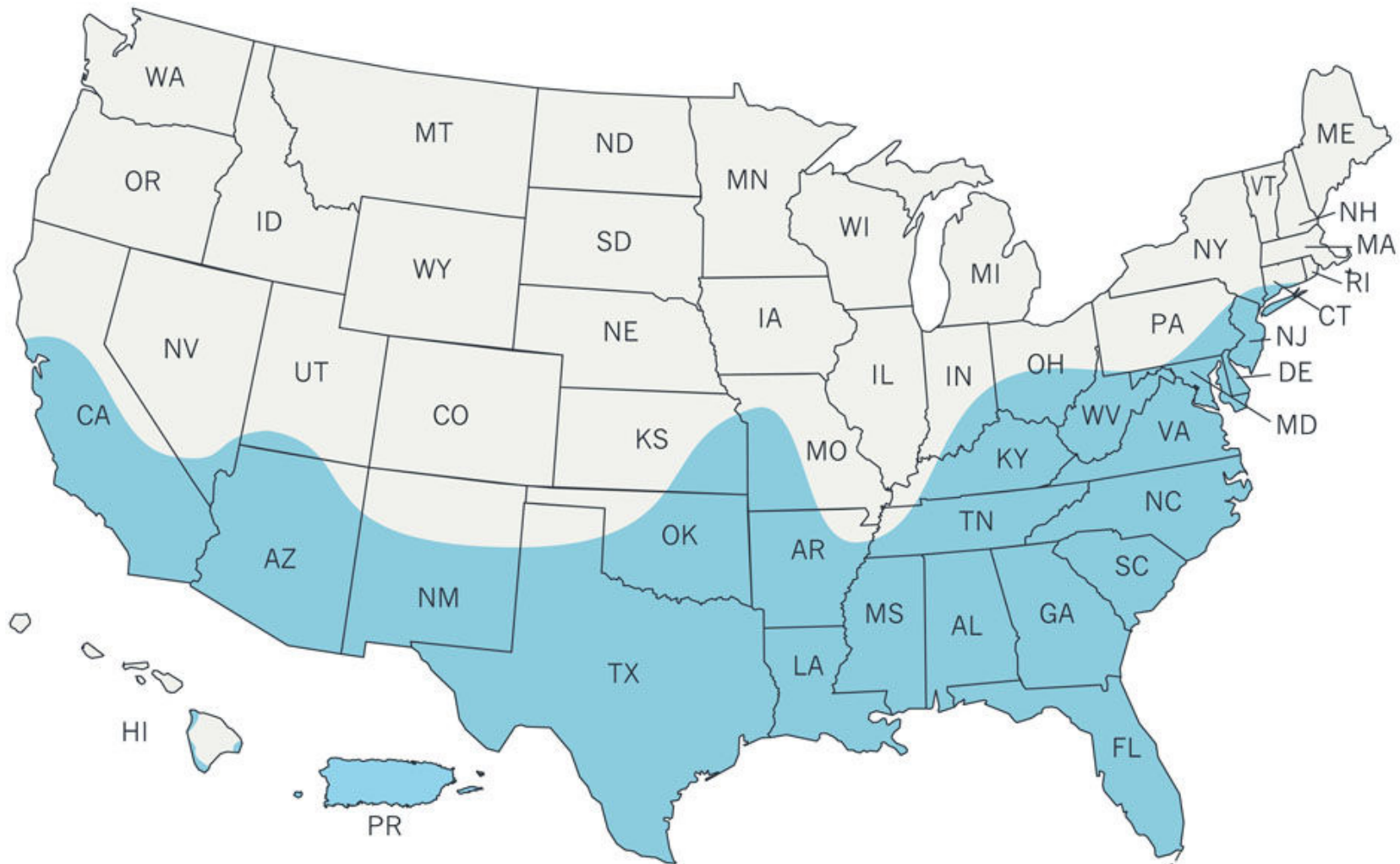


Figure 8



Aedes aegypti

- Common in areas lacking piped water systems
- Oviposition sites are in close proximity to households
- Lay eggs in natural and artificial containers
 - Prefers dark-colored containers located in the shade
 - Underground collections of water



Figure 9



Aedes aegypti

- Oviposition
 - About 3 days after blood feeding
 - Takes place during the day for several days

Aedes aegypti

It takes about 7-10 days for an egg to develop into an adult mosquito.

- Eggs
 - Laid just above the water line
 - Resistant to desiccation
 - Can survive for six months or more
 - When water inundates the eggs, the larvae hatch
- Larvae
 - Feed on small aquatic organisms by method of collecting-gathering
- After pupation, adults emerge

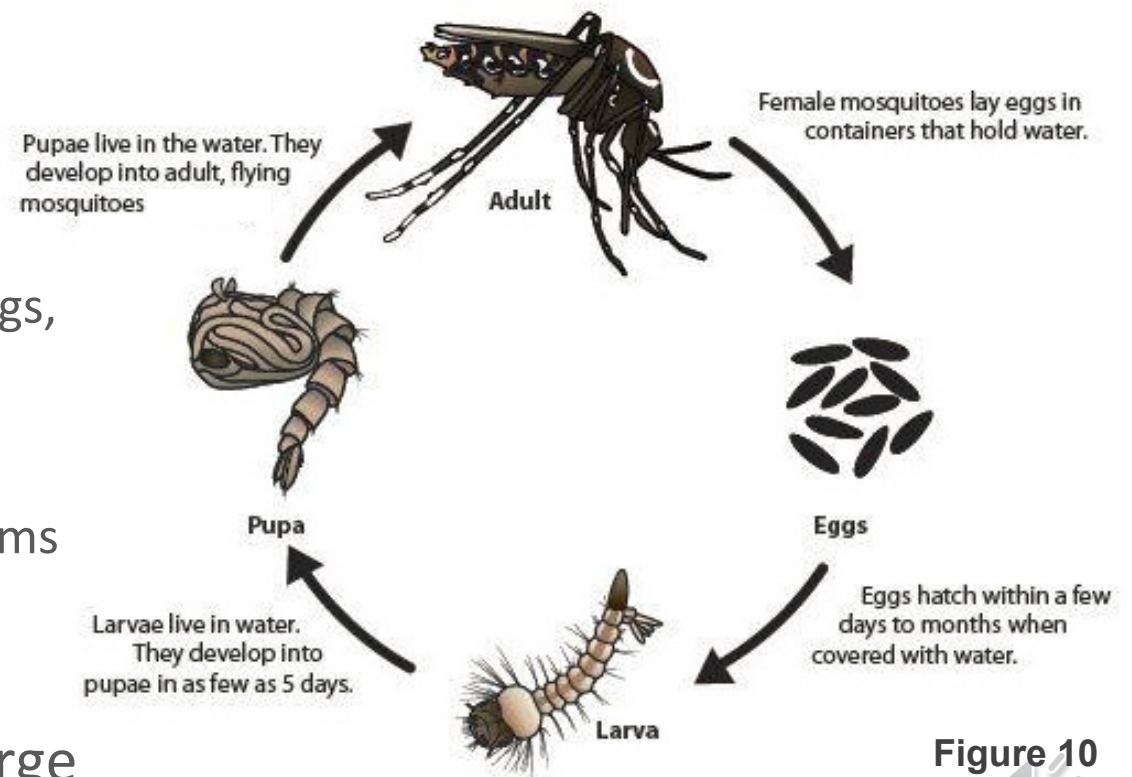


Figure 10

Aedes aegypti

- Mating
 - Initiated in flight with males pursuing females
 - Male seizes a flying female by his tarsi
 - Male reorients himself venter-to-venter with female
 - Male pushes the female's abdomen upward and flexes his abdomen to make genital contact
 - Coupling continues with the pair either in flight or settled on a surface until insemination occurs
- Females need to mate before blood feeding
- Blood feeding
 - Females stop feeding if disturbed
 - Feed on several persons during a single blood meal
- Efficient epidemic vector
 - Yellow fever, Dengue fever, Chikungunya, and Zika



Figure 11



Figure 12



Yellow Fever (YF)

- Arbovirus in the family *Flaviviridae*
- Zoonosis that is primarily a disease of forest monkeys
- Transmittable to humans
- Remains endemic in tropical regions of Africa and Latin America
 - approximately 900 million people at risk



Figure 13

- Often confused with malaria, typhoid, or other arboviruses
- Hemorrhagic disease with a 5-75% human mortality rate
- Vaccination is the most important preventive measure



Dengue virus (DENV)

- Flavivirus in family *Flaviviridae*
- 4 serotypes: DEN-1, DEN-2, DEN-3, and DEN-4
- In humans can take on several forms:
 - Dengue fever
 - Dengue hemorrhagic fever (DHF)
 - Dengue shock syndrome (DSS)
- 90% of infections are asymptomatic
- Infection with one DEN serotypes produces lifelong immunity against reinfection with that dengue serotype
 - No cross-protection against other three DENV serotypes
 - Antibody-dependent enhancement can lead to DHF and DSS
- *Aedes aegypti* acquire the dengue virus by biting viremic humans
 - After an extrinsic incubation period of 8–12 days
 - Infected mosquito can then transmit virus for the rest of its life
- Infections reported in over 100 countries
- The WHO estimates that 50 to 100 million infections occur yearly
- No therapeutics available and prevention is limited to vector control

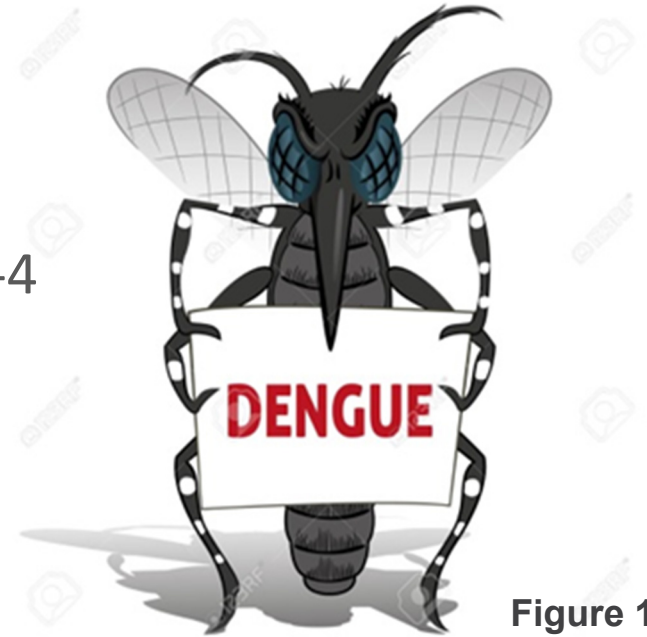


Figure 14



ZIKA Virus (ZIKV)

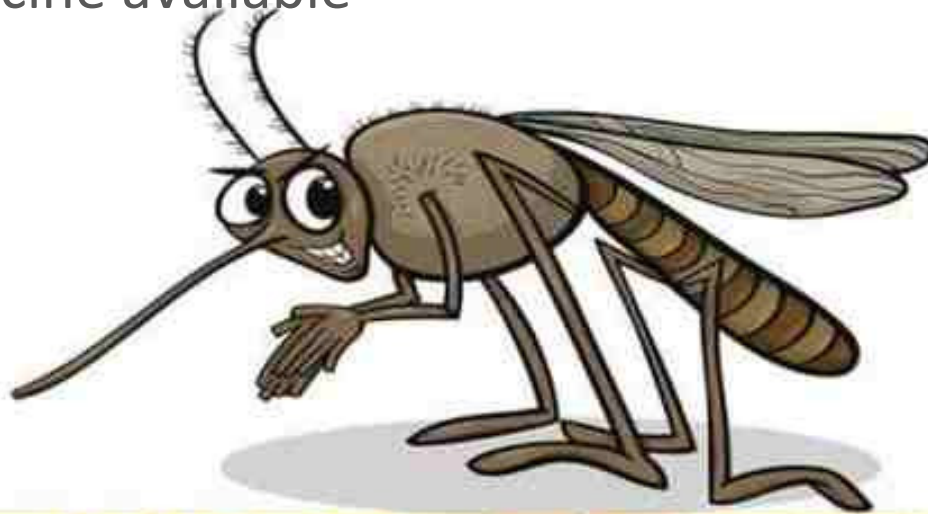
- Flavivirus
- Transmitted to people through the bite of an infected *Ae. aegypti* and *Ae. albopictus*
- An infected pregnant woman can pass the virus to her fetus
 - Causes microcephaly and other severe fetal brain defects
- Can also be passed through sexual intercourse from a person who has Zika to his or her partners
- Symptoms
 - Fever, rash, headache, joint pain, conjunctivitis, and muscle pain
- Zika virus usually remains in the blood of an infected person for about a week
- No medicine or vaccine available



Figure 15

Chikungunya Virus (CHIKV)

- Arbovirus that belongs to the family *Togaviridae*
- Occurs in Africa, south and southeast Asia
- Transmitted human-to-human by the bites of infected *Aedes*
 - Humans serve as the reservoir host during epidemic periods
- Symptoms usually begin 3–7 days after being bitten
 - Joint pain, fever, headache, muscle pain, joint swelling, or rash
- No vaccine or medicine available



Chikungunya



End of Module 2

Quiz



Module 2 Quiz Questions

1. *Aedes aegypti* are primarily
- Endophagic and zoophagic
 - Endophagic and anthropophagic
 - Exophagic and anthropophagic
 - Exophagic and zoophagic

Answer: (B) Endophagic and anthropophagic

2. *Aedes aegypti* can be identified by
- Lyre or harp-shaped markings on the thorax
 - Banded legs
 - Blunt tip of abdomen
 - All of the above
 - A & B only

Answer: (E) A & B only

3. True or False: *Aedes aegypti* are Direct Hatching Mosquitoes

Answer: False

4. True or False: Females need to mate before blood feeding.

Answer: True

5. *Aedes* larvae breathe through
- Spiracles on the 8th abdominal segment
 - Long barrel-shaped siphon
 - Short barrel-shaped siphon
 - Spiracles on the 9th abdominal segment

Answer: (C) Short barrel-shaped siphon

6. True or False: The tip of *Aedes* female's abdomen is usually pointed

Answer: True

7. True or False: *Aedes aegypti* is only found in tropical areas of the world.

Answer: False

8. True or False: *Aedes aegypti* are efficient epidemic vectors due to their nervous feeding habits

Answer: True

9. *Aedes aegypti* oviposition sites are found
- Near households
 - In areas lacking piped water systems
 - Light-colored containers located in the shade
 - A & B only
 - A & C only

Answer: (D) A & b only

10. True or False: Yellow Fever Virus, Dengue Fever Virus, ZIKA virus, and Chikungunya virus all belong to the family *Flaviviridae*.

Answer: False



Mosquito 101
Training Module 3:
Anopheles quadrimaculatus

By: Joanna Tyszko

University of Nebraska-Lincoln

MS Degree Project



Anopheles genus

- Eggs
 - Laid on the water surface
 - Cannot withstand desiccation (Direct-Hatching mosquitoes)
 - Laid singly
 - Boat-shaped and they have a pair of floats on the sides
- Larvae
 - Breathe through spiracles
 - Feed at water surface
 - Prefer clean water
- Pupae
 - Short and cone-shaped respiratory trumpets
 - Spines on abdominal segments

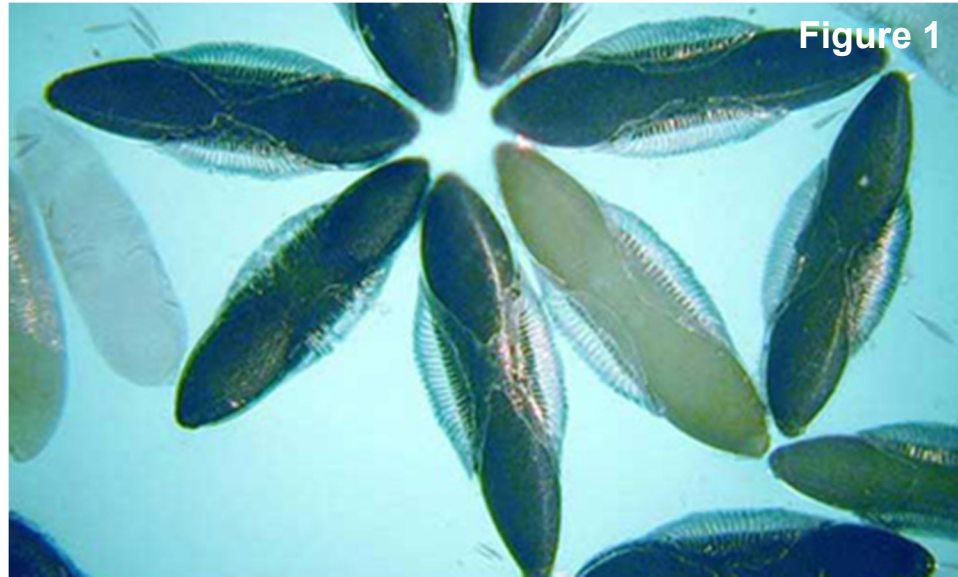


Figure 1



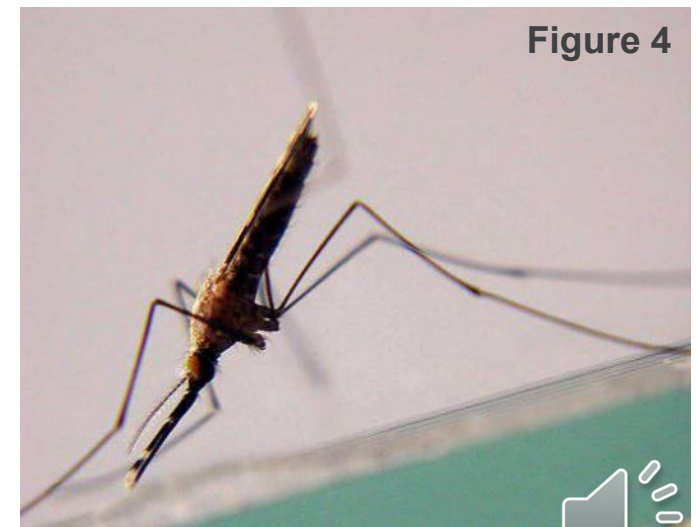
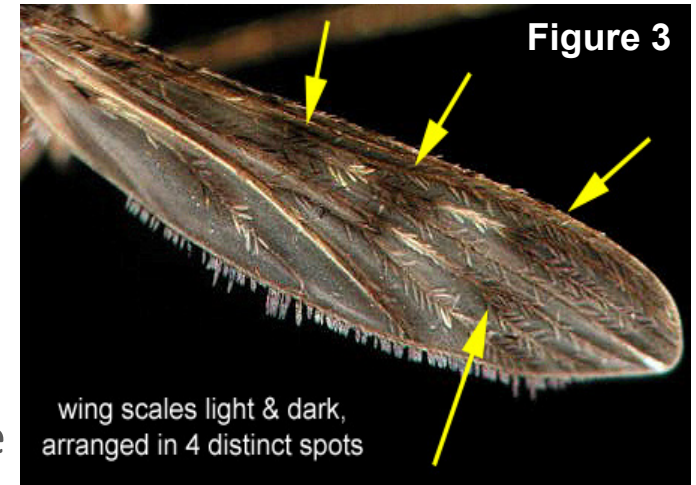
Figure 2



Anopheles genus

- Adults

- Dark and pale scales on wing veins
 - *An. quadrimaculatus* has 4 spots on each wing
- Palps are nearly as long as the proboscis and blackish with rings of pale scales
 - In the males the palps are club-shaped at the tip
- Rest with their bodies at an angle to the surface
- Mate in flight
 - Males hook legs with female and make genital contact
 - Form end-to-end position
 - Separate at completion of copulation



Making communities around the world more livable, safe and comfortable.

Anopheles genus

- Adults
 - Females mate only once
 - Females take first blood meal after mating
 - Bite at night
 - Fly quietly
 - Bite subtly
 - Bite near ground level
 - Can be carried by the wind away from larval sites
 - Rest inside transportation vehicles
 - Can be transported considerable distances



Figure 6

Anopheles quadrimaculatus

- Eastern Malaria Mosquito
 - Historically, the most important vector of malaria in the eastern US
- Active in the summer months
- Overwinter as fertilized females and stay in protected shelters such as barns, tree holes, and other dark protected areas
- The number of broods varies by region
 - 9 to 10 generations per year in the South
- Blood-feeding begins in the spring and ceases by November



Figure 7

Anopheles quadrimaculatus

- Oviposition and larval development occurs in clear, unpolluted, neutral or slightly alkaline water containing emergent vegetation
- Requires some light and some shade
- Eggs have floats and cannot survive desiccation
 - Hatch 2-3 days after oviposition
- Larvae feed by collecting-filtering
- Anthropophagic and zoophagic
- They feed at night with peak activity being shortly after dark



Figure 8

Anopheles quadrimaculatus



Anopheles quadrimaculatus

- Susceptible to infection with 4 species of malarial parasite:
 - *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium ovale* and *Plasmodium malariae*
 - *Plasmodium falciparum*, was endemic to the United States and still occurs in the western hemisphere
- Risks of importation and transmission of malaria are enhanced with the increase in immigration, global travel, and presence of anopheline vectors
- Also transmit the Cache Valley virus as well as the dog heart worm (*Dirofilaria immitis*)
- Considered a nuisance pest
 - Economical impact



Malaria

- Worldwide, the most widespread and prevalent of the vector borne infectious human diseases
- 1.6 billion people worldwide at risk of contracting malaria
 - Estimated 350 to 500 million annual cases of human malaria
- Drugs available for treatment along with continuous research
- 2 primary species in the United States capable of transmitting
 - *Anopheles quadrimaculatus* in the east
 - *Anopheles freeborni* in the west
- Caused by infection of red blood cells with protozoan parasites of the genus *Plasmodium*
 - Parasites are transmitted into humans by the feeding of female anopheline mosquitoes



Malaria

- 4 *Plasmodium* species that infect humans:
 - *P. falciparum*, *P. vivax*, *P. ovale*, and *P. malariae*
- *Anopheles* transmit the infectious stages of the parasite from human-to-human
 - The mosquito is the **definitive host**, also known as a **primary host**
 - The parasite reaches maturity and reproduces sexually
- The parasites complete the vertebrate host portion of their life cycle in humans
 - Humans are the intermediate host, or secondary host
 - The parasite reproduces asexually

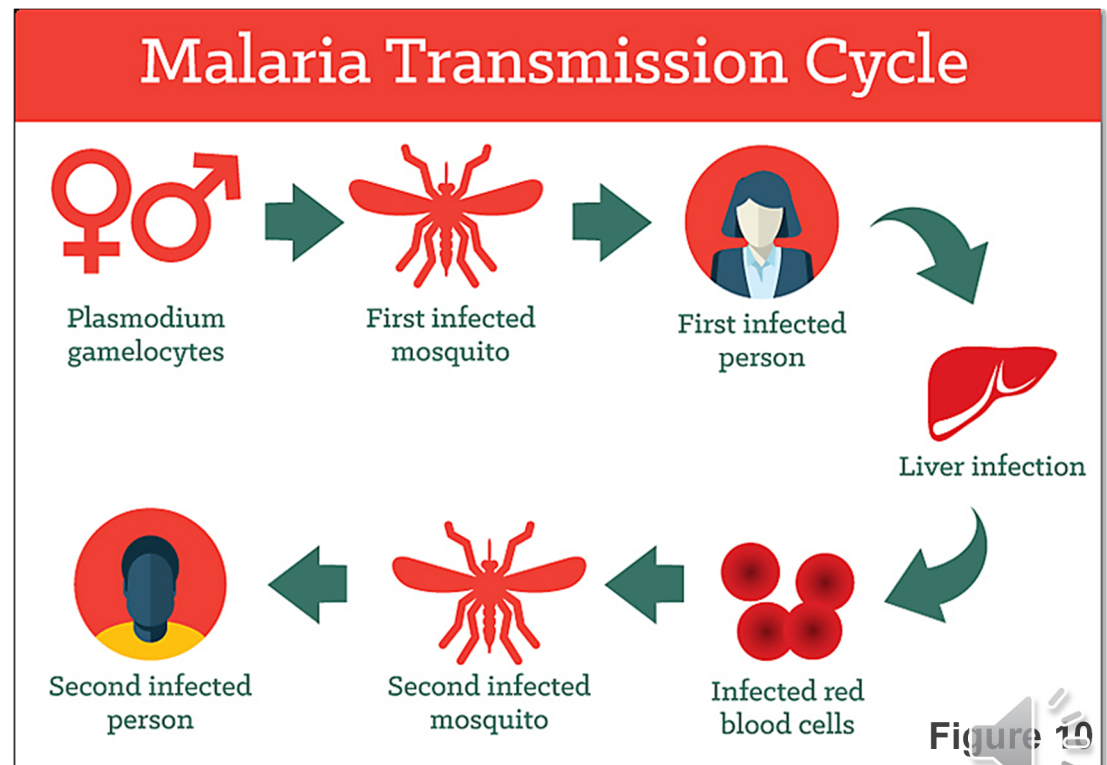


Figure 10

Cache Valley Virus (CVV)

- Mosquito-borne virus
 - family *Bunyaviridae*
- Geographically widespread in North America
 - circulates between mosquitoes and mammals
- Zoonosis that primarily effects sheep and goats and can cause severe illness in humans
- Neuroinvasive illness that is rarely diagnosed in North America
- No vaccine or known treatment available





End of Module 3

Quiz



Module 3 Quiz Questions

1. *Anopheles quadrimaculatus* are primarily

- a. Zoophagic
- b. Anthropophagic
- c. Daytime feeders
- d. Both A & B
- e. Both A & C
- f. Both B & C

Answer: (D) Both A and B

2. *Anopheles* larvae breathe through

- a. Spiracles on the 8th abdominal segment
- b. Long barrel-shaped siphon
- c. Short barrel-shaped siphon
- d. Spiracles on the 9th abdominal segment

Answer: (A) Spiracles on the 8th abdominal segment

3. True or False: *Anopheles quadrimaculatus* are Direct Hatching Mosquitoes

Answer: True

4. True or False: Human malaria is caused by infection of red blood cells with protozoan parasites of the genus *Plasmodium*

Answer: True

5. The most severe form of malaria, *Plasmodium* _____, was endemic to the United States and still occurs in the western hemisphere

- a. Vivax
- b. Falciparum
- c. Ovale
- d. Malariae

Answer: (B) Faciparum

6. True or False: Only mosquitoes belonging to the genus *Anopheles* transmit human malaria

Answer: True

7. True or False: *Anopheline* mosquito adults rest with their bodies at an angle to the surface

Answer: True

8. True or False: *Anopheles quadrimaculatus* is known as the Western Malaria Mosquito

Answer: False

9. *Anopheles* eggs are laid

- a. On moist surfaces above the water line
- b. Singly
- c. On the water surface

- d. In rafts
- e. A & B only
- f. A & D only
- g. B & C only
- h. C and D only

Answer: (G) B & C only

10. True or False: *Anopheles quadrimaculatus* oviposition sites and larval environments are highly polluted with organic matter.

Answer: False



Mosquito 101
Training Module 4:
Culex quinquefasciatus

By: Joanna Tyszko

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MS Degree Project



Culex genus

- Eggs
 - Brown
 - Long and cylindrical
 - Laid upright in rafts
 - 150-300 eggs
 - Held together by water surface tension
 - Rafts are dished
- Larvae
 - Siphon is long and narrow
 - resting at an angle to the water surface

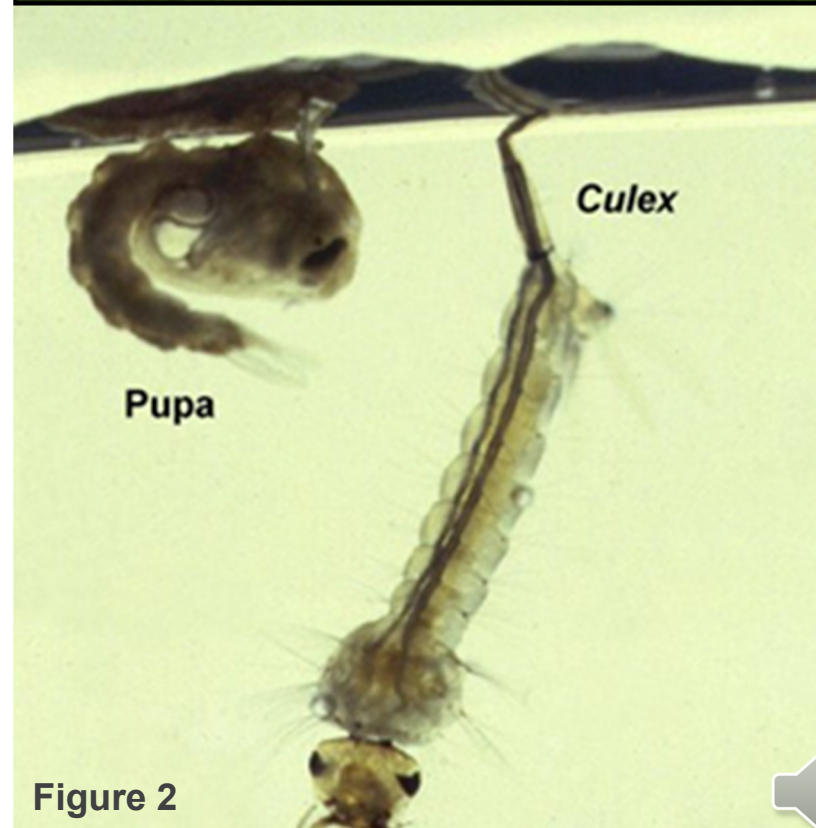


Figure 2



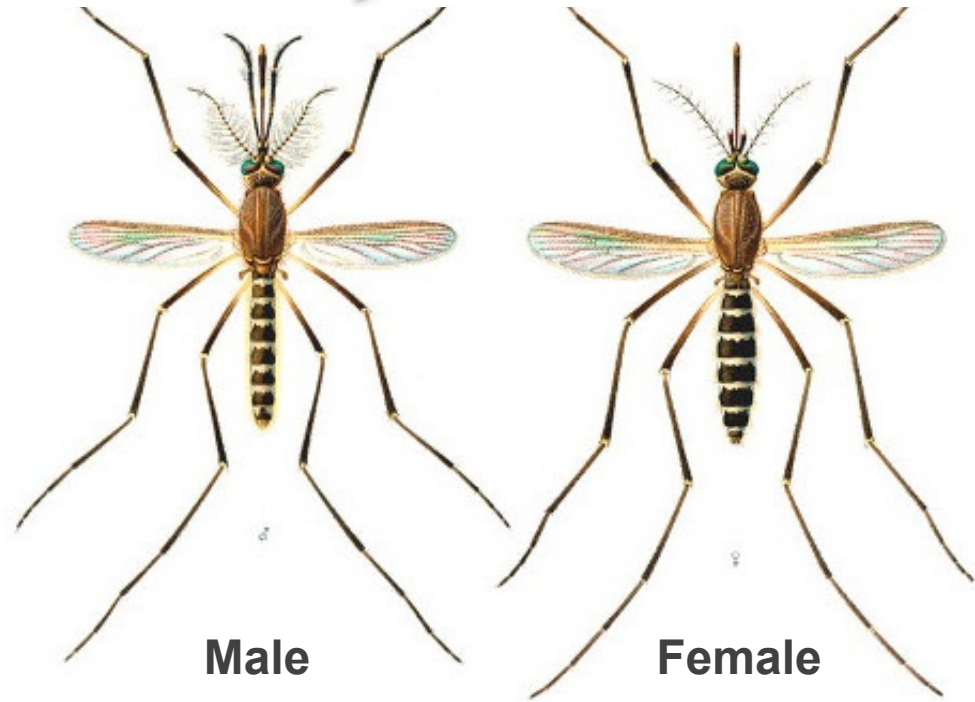
Culex genus

- Adults

- Thorax, legs, and wing veins are covered in brown scales
- Abdomen is covered in brown or blackish scales
- Lack of unique markings
- Palps are shorter than proboscis
 - Males palps are feathery
- Tip of the female's abdomen is usually blunt
- Rest with their body and proboscis in 2 different axes
- Have a high crouching profile



Figure 3



Male

Female

Figure 4

Culex genus

- Adults
 - Overwinter as mated females
 - Seek out oviposition site in spring
 - **Direct-hatching mosquitoes**
 - Water polluted with organic matter
 - Produce several generations in a year
- *Culex pipiens*
 - Most widely distributed mosquito in the world
 - Complex of 6 species including *Culex quinquefasciatus*



Figure 5



Culex quinquefasciatus

- Southern House Mosquito
- Found in urban, suburban and rural areas
- Breeds in habitats ranging from slightly polluted to very polluted with organic wastes
- Eggs are laid on top of water
- Larvae mature within two weeks
 - Feed by collecting-filtering

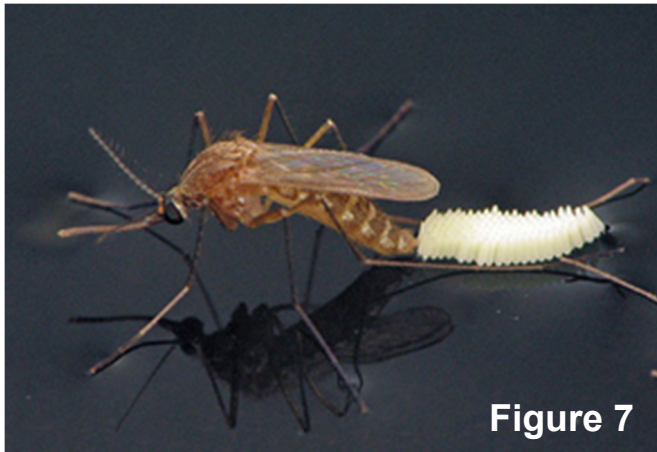


Figure 7



Figure 6

Culex quinquefasciatus

- Nighttime flyer
- Endophilic
- Opportunistic
 - Ornithophilic
- May travel up to 3/4 of a mile for blood meal
- Oviposit preferentially on water where eggs already have been laid
- Overwinters as adult mosquitoes



Culex quinquefasciatus



Culex quinquefasciatus

- Important vectors of human pathogens world-wide
 - West Nile Virus (WNV)
 - St. Louis encephalitis (SLE)
 - Human lymphatic filariasis



West Nile Virus (WNV)

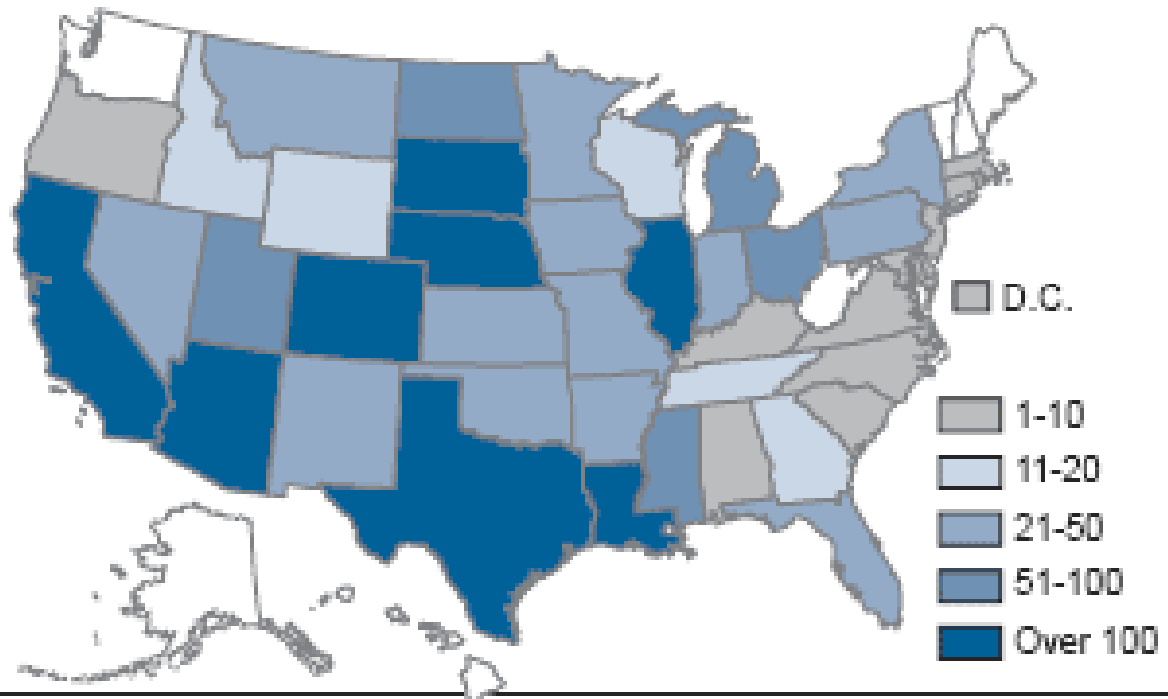
- Flavivirus
- First isolated in Uganda in 1937
- Introduction to North America in 1999 in New York
 - International travel of infected persons or import of infected birds
- 36,801 reported cases of WNV and 1,506 deaths in the US (1999 – 2012)



West Nile touched almost every state

The West Nile virus was reported in every state except Alaska and Hawaii last year. Five states reported no human cases.

2005 reported human cases of West Nile virus



SOURCE: Centers for Disease Control and Prevention

AP
Figure 10

Making communities around the world more livable, safe and comfortable.

West Nile Virus (WNV)

- Can infect a wide range of vertebrates
 - In humans it usually produces asymptomatic infection or mild febrile disease
- Amplified by continuous transmission between mosquito vectors and bird reservoir hosts
 - People, horses, and other mammals do not develop infectious-level viremias
 - Dead-end or incidental hosts
- No treatments available
 - In more severe cases
 - Neuroinvasive disease and paralysis
 - Hospitalization

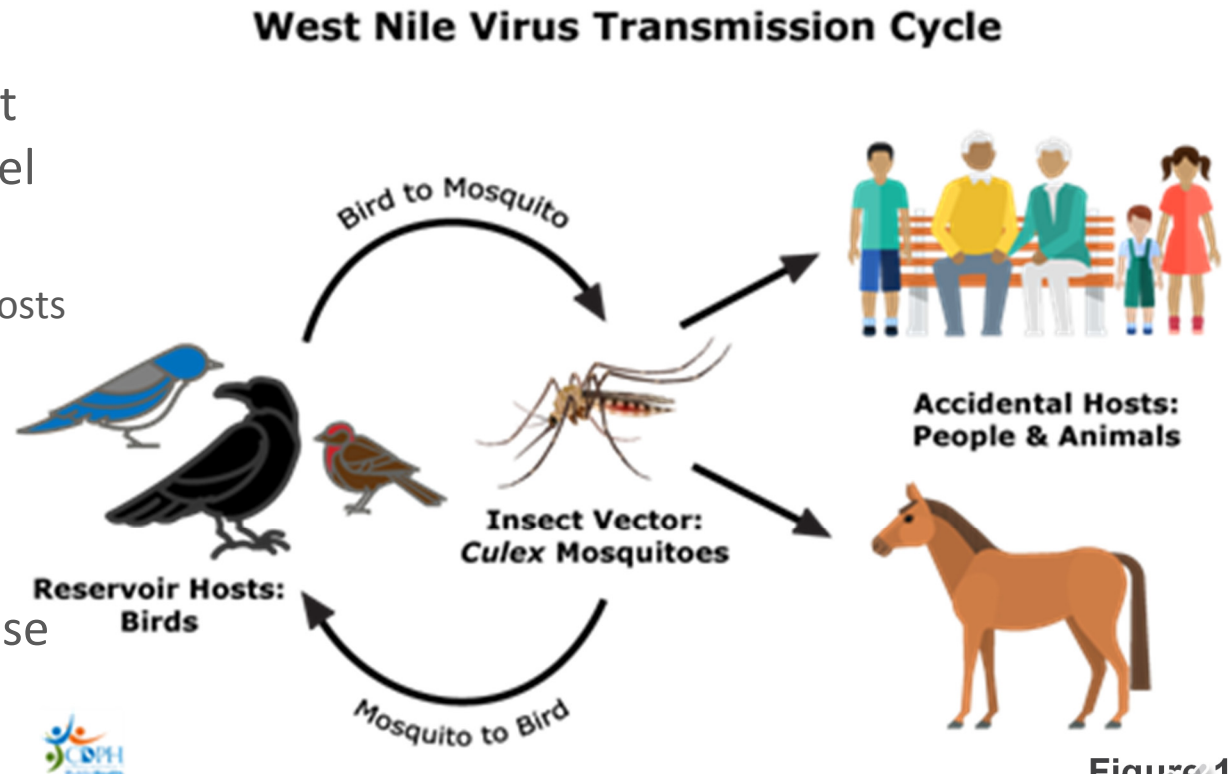


Figure 11

St. Louis Encephalitis (SLE)

- Leading cause of epidemic flaviviral encephalitis in US
- Distributed throughout the lower 48 states
- Illness ranges in severity
 - Simple febrile headache to meningoencephalitis
 - Overall case-fatality rate of 5-15%
- No treatments or vaccines available
- Maintained in a mosquito-bird-mosquito cycle
 - Wild birds are the primary vertebrate hosts
 - Humans and domestic mammals are dead-end hosts

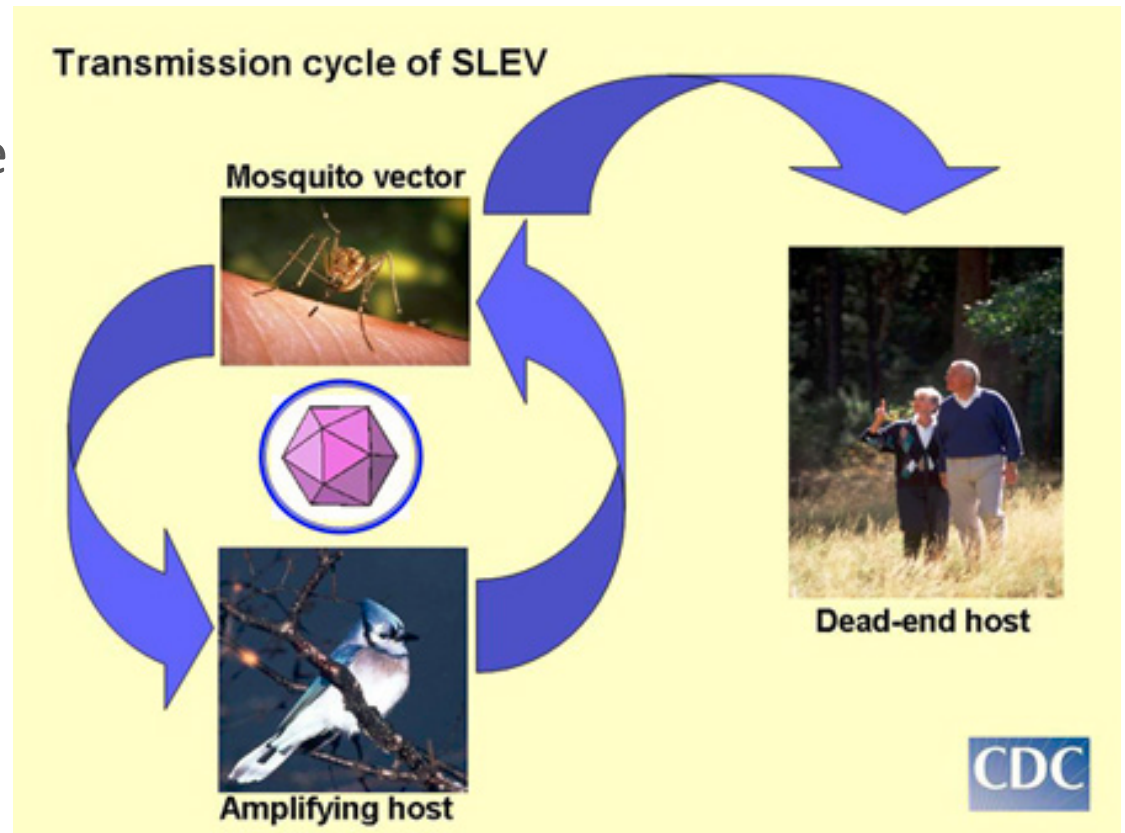
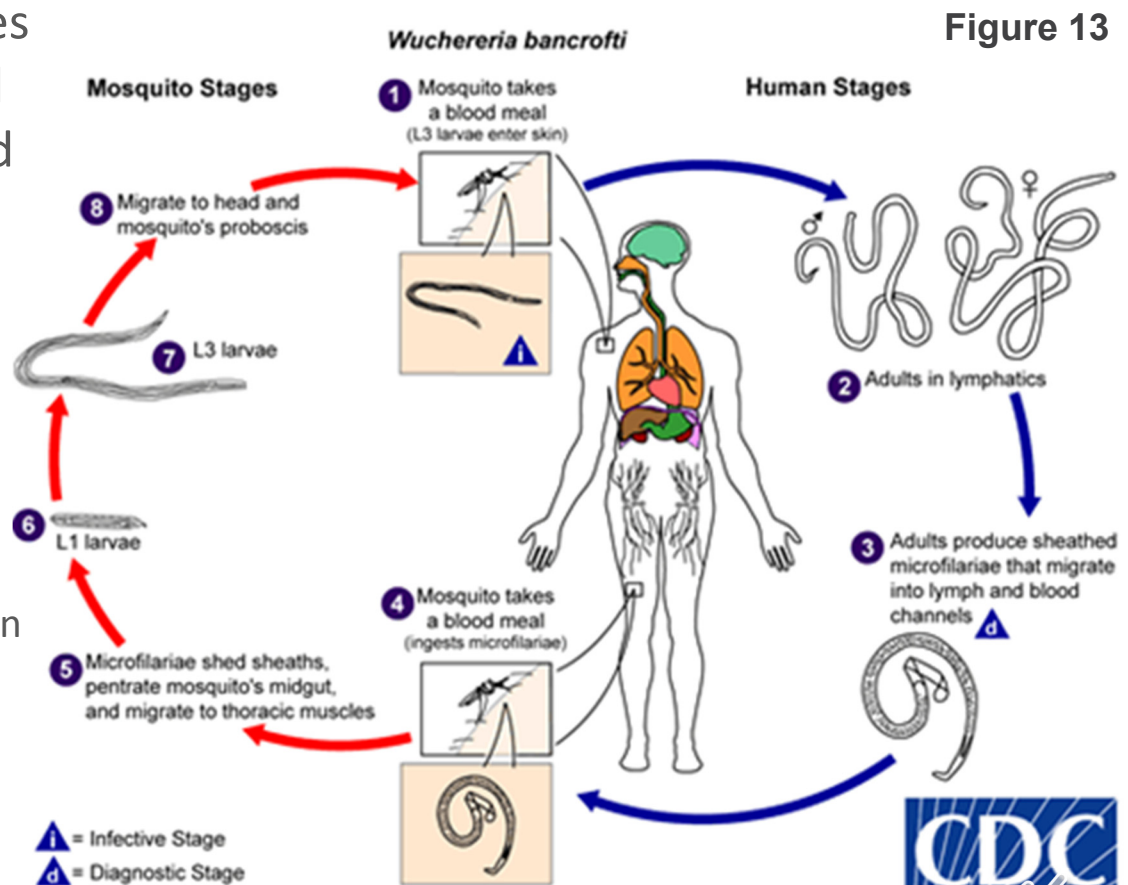


Figure 12



Human Lymphatic Filariasis

- Caused by nematodes in the family *Onchocercidae*
- Humans are the reservoirs for the filarial nematodes
 - During blood feeding parasites burst through the labium and crawl onto the host's skin and then move into the bite hole
- Over 900 million people at risk
 - 43 million people suffer from lymphedema
 - Accumulation of lymphatic fluids in the limbs, breast, scrotum, and vulva resulting in swelling and enlargement
 - Cause grotesque disfigurations





End of Module 4

Quiz



Module 4 Quiz Questions

1. *Culex quinquefasciatus* are primarily

- a. Ornithophilic
- b. Endophilic
- c. Opportunistic feeders
- d. Both A & B
- e. Both A & C
- f. Both B & C
- g. All of the above

Answer: (G) All of the above

2. *Culex* larvae breathe through

- a. Spiracles on the 8th abdominal segment
- b. Long narrow-shaped siphon
- c. Short barrel-shaped siphon
- d. Short narrow-shaped siphon

Answer: (B) Long narrow-shaped siphon

3. True or False: *Culex quinquefasciatus* are Direct Hatching Mosquitoes

Answer: True

4. True or False: *Culex quinquefasciatus* oviposit preferentially on water where eggs already have been laid

Answer: True

5. True or False: WNV is amplified during periods of adult mosquito blood-feeding by continuous transmission between mosquito vectors and human reservoir hosts.

Answer: False

6. True or False: With most forms of lymphatic filariasis, humans are the reservoirs for the filarial nematodes

Answer: True

7. True or False: *Culex quinquefasciatus* larvae rest with their bodies at an angle to the water surface

Answer: True

8. True or False: *Culex quinquefasciatus* is a complex made up of 6 species.

Answer: False

9. *Culex* eggs are laid

- a. On moist surfaces above the water line
- b. Singly
- c. On the water surface
- d. In rafts
- e. A & B only
- f. A & D only
- g. B & C only

h. C and D only

Answer: (H) C & D only

10. True or False: *Culex quinquefasciatus* oviposition sites and larval environments are highly polluted with organic matter.

Answer: True

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