

**LSU Health**  
SHREVEPORT

## RISK OF VECTOR-BORNE DISEASES FROM CLIMATE CHANGE

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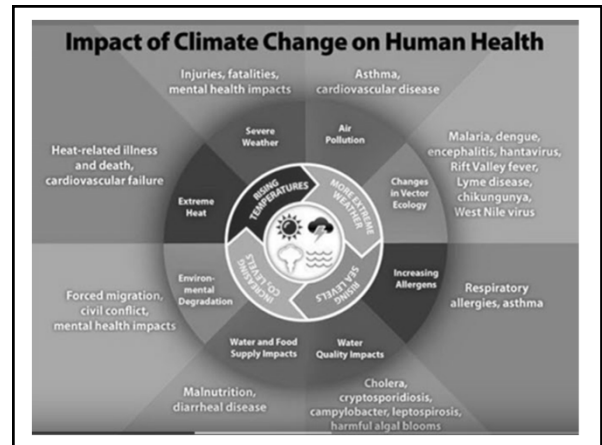
### OBJECTIVES

1. Describe the effects of climate change on vectorborne diseases
2. Discuss the new and most important vectorborne infections
3. Identify prevention and treatment strategies.

“CLIMATE CHANGE IS CONSIDERED ONE OF THE GREATEST THREATS TO HUMAN HEALTH BY THE WORLD HEALTH ORGANIZATION”

**a** CO<sub>2</sub> Concentration (ppm)

**b** Methane Concentration (ppm)



### TICK AND MOSQUITO INFECTIONS SPREADING RAPIDLY, C.D.C. FINDS

- Numbers tripled
- Warmer weather
- 2004-27K
- 2016-96K
- 643K illnesses

### IMPACT OF CLIMATE CHANGE

- 5.3% decrease in outdoor productivity
- 46% increase weather related disasters since 2000
- 9.4% increase in dengue since 1950

“...the most extreme precipitation events (those in the 99th percentile of intensity) have increased in every region of the contiguous states since the 1950s.”

National Climate Assessment, 2014

2017

- “Last year the United States suffered more than \$260 billion in direct damages from natural disasters—mainly from hurricanes Harvey, Irma, and Maria”
- “And there were also numerous wildfires, floods, and tornadoes. Data show that since 2000, approximately 99 percent of counties in the US have experienced significant damage from some type of natural disaster, with costs expected to increase significantly over coming years.”

### CLIMATE CHANGE AND VECTORS

- Mosquito-borne diseases worse during heat waves
  - Major outbreaks of West Nile virus in U.S. occurred during heatwaves
- ↑ temperatures make mosquitoes more infectious and infectious faster, promoting outbreaks
- Longer mosquito seasons and more regions
- ↑ temperatures expand the range of ticks further north and ↑ length of tick season
  - Increased Lyme in Canada

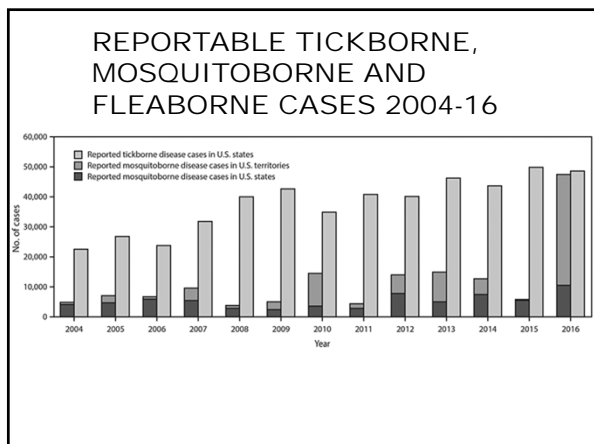
Did you know? Vector-borne diseases account for more than **17%** of all infectious diseases.

Caused by pathogens and parasites in human populations, vector-borne diseases cause more than **1 million** deaths annually.

**2,000+** Cases of West Nile Virus were reported in the U.S. last year.

VDCI

PROTECT PUBLIC HEALTH BY MANAGING VECTOR-BORNE DISEASES



### MOST COMMON VECTOR-BORNE DISEASES IN US

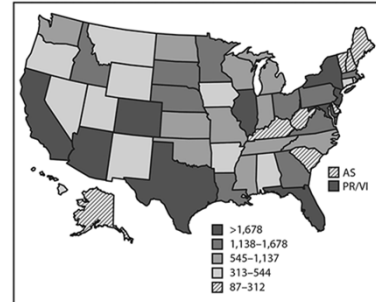
- West Nile Virus (WNV)
- Eastern equine encephalitis (EEE)
- Lyme disease
- Rocky Mountain spotted fever

### ASIAN LONG-HORNED TICK

- NJ in 11/17 now in Connecticut, Maryland, Pennsylvania, New York, North Carolina, Virginia, West Virginia and Arkansas
- 1st new in 50 yrs
- Carries virus in Asia



### MOSQUITOBORNE DISEASE 2004-16



### MOSQUITO-BORNE DISEASES IN US

- West Nile
- Several encephalitis viruses
  - EEE, JCV, SLE. etc
- New threats:
  - Zika
  - Dengue
  - Chikungunya

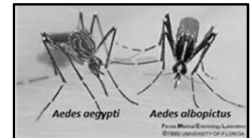
### MOSQUITOBORNE DISEASE 2004-16

- 4858 in 2004 to 47,461 in 2016
- Punctuated by epidemics
  - Dengue, chikungunya, Zika
  - Confined to territories—Puerto Rico
  - Travelers 90% in continental
  - Limited dengue in FL, TX, HI
  - Chikungunya and Zika in TX & FL
- WNV most common, dengue, Zika
- 1500 cases malaria

### MALARIA: THE LEADING MOSQUITOBORNE DISEASE HAS A HISTORY IN THE U.S.

- Leading cause of mosquito-borne deaths throughout the world
- Not until after 1950 that malaria was considered eliminated from the country
- Not currently a threat,
- *Anopheles quadrimaculatus* (Common Malaria Mosquito) distributed throughout the eastern United States
- Huge numbers in the southeastern states along the Gulf of Mexico

### AEDES AEGYPTI AND AEDES ALBOPICTUS



- *Ae. aegypti*--Most common mosquito transmitting viral diseases
  - Transmits dengue, chikungunya, yellow fever and Zika.
- *Ae. albopictus* also spreads all four diseases and West Nile Virus
- *Ae. aegypti* has high vectoral capacity--effective transmitter
- *Ae. albopictus*, Asian tiger mosquito, can live in more temperate (cooler) climates

## AE. AEGYPTI & AE. ALBOPICTUS

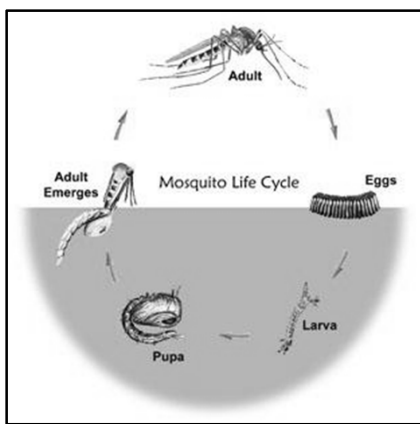
- *Ae. aegypti* lives in close proximity to people and their homes
- *Ae. albopictus* is less likely to live as close or spread disease—eggs survive in tires
- Both are more likely to be active and bite in the daytime



### Estimated Range of *Aedes aegypti* and *Aedes albopictus* in the United States

Estimated range of *Aedes aegypti* in the United States, 2016\*

Estimated range of *Aedes albopictus* in the United States, 2016\*

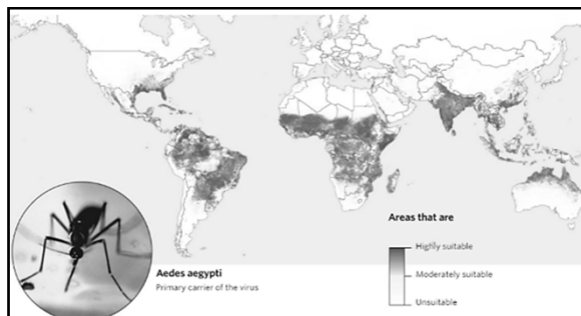


## ZIKA

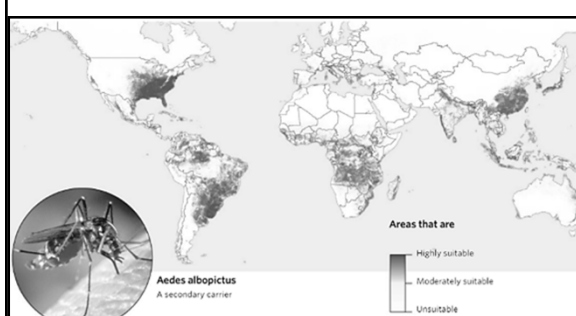


- Most asymptomatic
- Few days-week
- Rarely hospitalized
- Symptoms: fever, rash, conjunctivitis
- Severe birth defects if mother infected during pregnancy
- USZPIR monitors 7300 pregnancies

## ZIKA AND AE. AEGYPTI



## ZIKA AND AE. ALBOPICTUS



### ZIKA VIRUS PERSISTS IN INFANTS' BRAIN AFTER BIRTH

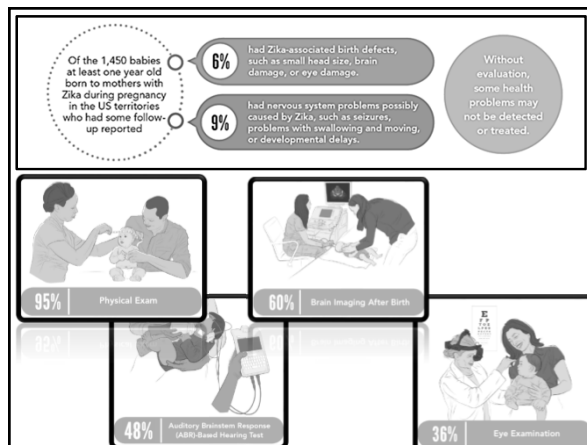
- Virus replicates in brains after birth
- Up to 7 mos
- Persists in placentas for months
- Infects Hofbauer cells in placenta
- These immune cells help transfer virus to fetus's brain
- Molecular testing (RT-PCR) detects virus replication and persistence
- Abnormalities persist after virus cleared

### CONGENITAL ZIKA SYNDROME



### 1 IN 7 BABIES EXPOSED TO ZIKA HAVE HEALTH PROBLEMS

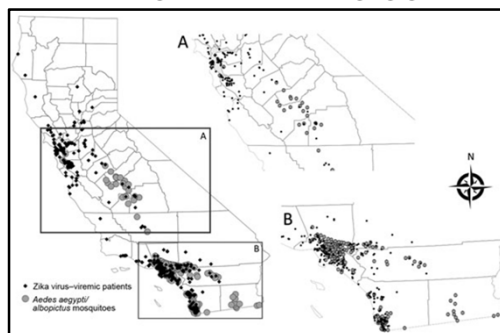
- 14% age 1 yr or older of 1450 babies
- Appear healthy at birth
- Eye or brain defect
- Neurodevelopment abnormality
  - Seizures, swallowing, moving, hearing, developmental delay
- 4800 pregnancies with Zika infection
- <https://youtu.be/j5zJ3Lm3frk>



### ZIKA UPDATE

- Local transmission study in CA 2015-17
- 588 travel-related cases—Mexico Central America
- 139 pregnant
- 10 congenital
- 8 STI
- *Ae. aegypti* mosquitoes spread to 124 locations--142% increase
- *Ae. albopictus* mosquitoes had spread to 53 locations—81% increase

### LOCATIONS OF VIREMIC PATIENTS AND *Aedes* spp.



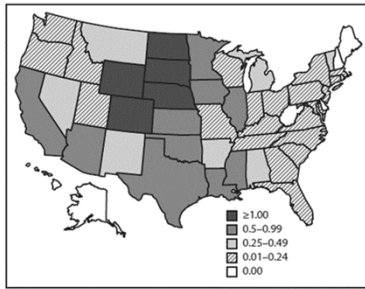
### UPDATED ZIKA GUIDELINES

- Men possibly exposed should wait 3 months instead of 6 to conceive
- Zika in semen declines substantially in 3 mo.
- Use condoms during entire pregnancy and pregnant women not travel
- Blood can also be screen in pools instead of individually
- Disease more than doubled 2004-16  
– 22,527 in 2004 to 48,610 in 2016

### ARBO VIRUSES UPDATE

- West Nile-2150 cases—61% neuroinvasive
- La Crosse—35 cases
- St. Louis encephalitis—8 cases
- Eastern Equine encephalitis—7 cases
- Sporadic disease and periodic outbreaks
- Most asymptomatic

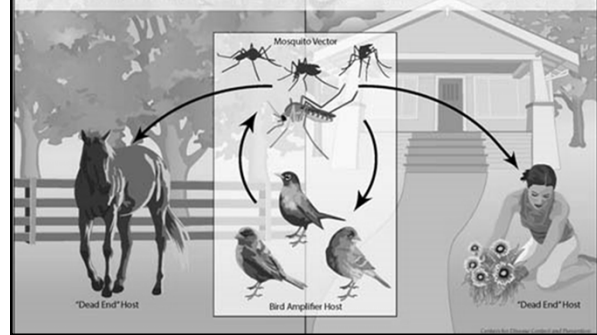
### WEST NILE VIRUS NEUROINVASIVE DISEASE 2016



### West Nile Virus Transmission Cycle

In nature, West Nile virus cycles between mosquitoes (especially *Culex* species) and birds. Some infected birds, can develop high levels of the virus in their bloodstream and mosquitoes can become infected by biting these infected birds. After about a week, infected mosquitoes can pass the virus to more birds when they bite.

Mosquitoes with West Nile virus also bite and infect people, horses and other mammals. However, humans, horses and other mammals are 'dead end' hosts. This means that they do not develop high levels of virus in their bloodstream, and cannot pass the virus on to other biting mosquitoes.



### WEST NILE VIRUS


- 63 species mosquitoes
- 330 species birds
- 85% of cases April to September
- 39,300 to 91,700 non-neuroinvasive disease cases expected to occur; however, only 840 (1%–2%) were reported
- 2018: Neuroinvasive 312/ Non-neuroinvasive 247 / Total cases 559 / Deaths 18 /

### DENGUE FEVER

#### Laboratory-Confirmed DHF in the Americas Prior to 1981 vs. 1981 - 2003

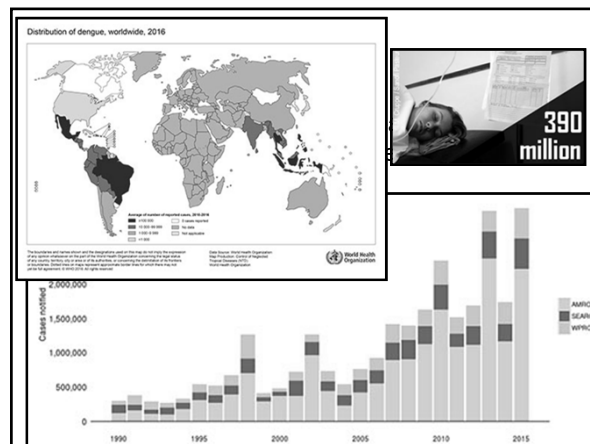


## DENGUE FEVER



**World Health Organization**

- 3.2 million cases in 2015
- Under-reported—50-100M
- Asia, Latin America, Africa
- Man or monkey to mosquito
- Severe dengue more likely with 2<sup>nd</sup> infection
  - Antibody dependent enhancement, cytokine storm, or cross reactive T cells
- US-- 35 [week ending 31 Aug 2018] / D? / 118 / 1 severe



## SEVERE DENGUE

- Follows symptomatic dengue after 1-2 days of defervescence
- Abdominal pain, vomiting, thrombocytopenia, breathing difficulties, and possibly severe bleeding
- 500,000 hospitalizations
- 2.5% die --usually children
- Convalescence over 4-7 days
- Vaccine developed—9-45 years in endemic areas

## US DENGUE OUTBREAKS WITH LOCAL TRANSMISSION

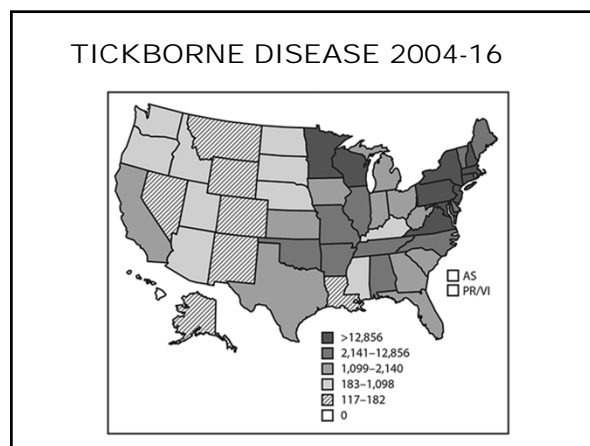
- 2009 and 2010 Key West
- 2013 Martin County FL
- Close proximity to Puerto Rico, C & S Am reintroduction
- 2015-16 Hawaii—181 cases
- Air conditioning, screened windows and indoor lifestyle protects from large outbreaks

## TICKBORNE DISEASES

Eastern black-legged tick, *Ixodes scapularis*

Western black-legged tick, *Ixodes pacificus*

Relative size



TEXAS

- 23% carry *Rickettsia*, *Borrelia* & Ehrlichia
- 56% *Amblyomma americanum*



TICKBORNE

- Geographic range of *I. scapularis*—50% more counties in 2015 than 1996
- Lyme 82%—30,000/year
  - Under estimated—300,000

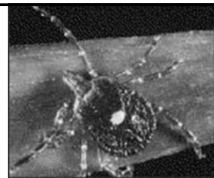
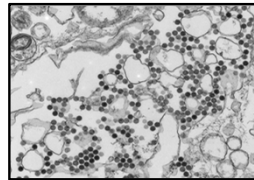
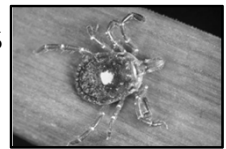


NEW EMERGING TICKBORNE DISEASES

- Heartland and Bourbon-RNA virus in Midwest
- *Rickettia parkeri* and *Rickettsia philipii* (364D)
- *Ehrlichia muris eauclairensis*

HEARTLAND VIRUS

- Midwest and South
- Fever, headache, fatigue, muscle aches and diarrhea
- >30 cases



*AMBLYOMMA AMERICANUM*



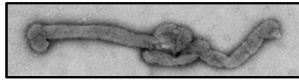
LONE STAR TICK

- Range and abundance ↑ over past 20-30 years
- Large numbers in Maine and as far west as central Texas and Oklahoma
- All life stages will feed on humans—aggressive
- Feed readily on dogs and cats
- Saliva can be irritating; redness and discomfort at a bite site does not necessarily indicate an infection



### BOURBON VIRUS

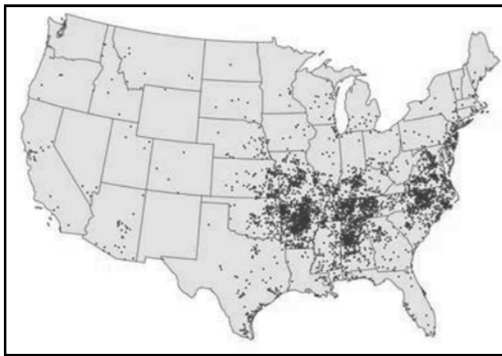
- Thogotovirus
- Midwest and South
- Discovered while studying Heartland using advance molecular detection (AMD)



### FIRST BOURBON CASE

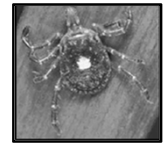
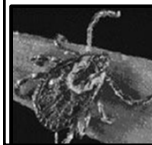
- Isolated from blood samples from a hospitalized male 2014
- Resident of Bourbon County, Kansas, USA
- >50 years of age and previously healthy
- Reported several tick bites and an engorged tick on his shoulder
- Nausea, weakness, and diarrhea, then fever, anorexia, chills, headache, myalgia, and arthralgia
- Day 4 after onset, hospitalized
- Papular rash on his trunk
- Leukopenia, lymphopenia, thrombocytopenia, hyponatremia, and increased liver enzymes
- Serologic assays for RMSF, tularemia, brucellosis, babesiosis, and Q fever negative, as were molecular tests for *Ehrlichia* spp. and *Anaplasma phagocytophilum* and blood smears for *Babesia*
- Died 11 days after symptom onset

### SPOTTED FEVER RICKETTSIOSIS



### ROCKY MOUNTAIN SPOTTED FEVER

- **Etiologic agent:** *Rickettsia rickettsii*
- **Vectors:**
  - *Dermacentor variabilis* (dog tick)
  - *D. andersoni* (wood tick)
  - *Amblyomma americanum* (lone star tick)

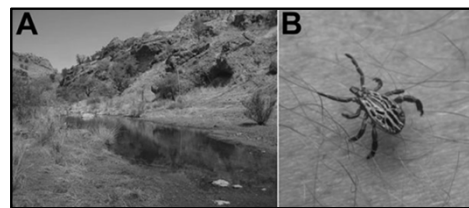


### *RICKETTSIA PARKERI*

- Febrile, eschar-associated illness
- Transmitted by *Amblyomma* ticks
- ≈40 cases reported since its recognition in 2004
- Gulf Coast tick (*Amblyomma maculatum*) is the principal vector
- Reported from Uruguay and Argentina

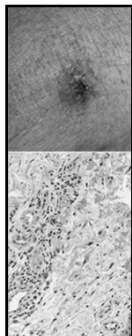
### *RICKETTSIA PARKERI*

- 1 confirmed and 1 probable case acquired in southern Arizona after bites from *Amblyomma triste* ticks



### ARIZONA CASE

- 49 y.o. male 2014
- Remove tick on arm <3 hrs
- 10 days later fever, headache, myalgia, and scalp tenderness
- Rash on trunk and feet
- Treated with doxycycline



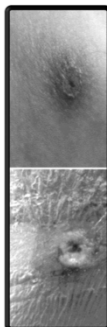
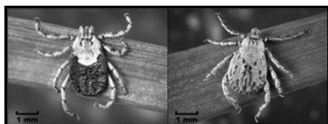
### RICKETTSIA PHILIPPI (364D)



- Pacific coast tick fever
- *Dermacentor occidentalis*
- Eschar, fever, headache
- 14 cases reported since 2008
- 15 of 37 CA counties

### RICKETTSIA PHILIPPI CASE

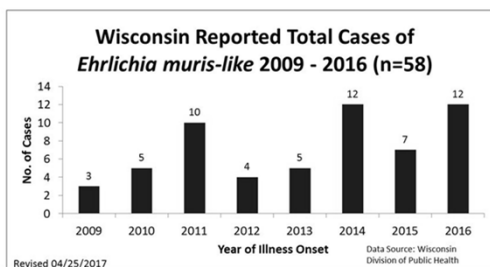
- 80 y.o. male rural N. CA
- Eschar on forearm
- No rash
- Milder than RMSF



### EHRlichiosis

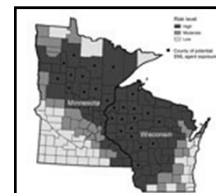


### EHRlichia muris EAUCLAIRENSIS



### EHRlichia muris EAUCLAIRENSIS

- 115 cases in upper Midwest
- *Ixodes scapularis*
- Similar to other ehrlichia
- No deaths reported



*EHRlichia muris*

- *Ixodes cookei* Wood Tick
- Northeastern United States, 2016–2017
- White-footed mouse



JAMESTOWN CANYON VIRUS

- Few cases reported (11-22 per year)
- Endemic throughout US
- Most asymptomatic
- 68% neuroinvasive
- Symptoms similar to WNV
- 15 cases in 2016 (MA, MN, WI)
  - 47% neuroinvasive
  - 0 deaths

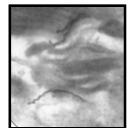
*BORRELIA MIYAMOTOI*

- 1st described in Russia
- Initially thought to cause a relapsing fever
- 1st described as meningoencephalitis in U.S.
- Transmitted by deer tick that transmits Lyme disease
- Can be severe--hospitalization with a sepsis-like presentation
- Febrile illness and confused with atypical Lyme disease (without a rash), ehrlichiosis, or anaplasmosis
- No commercial assays



*BORRELIA MAYONII*

- New Lyme disease in upper Midwestern US—6 cases in 90,000
- Fever and rash
- Erythema migrans or diffuse maculopapular rashes
- High loads of spirochetes in blood
- May or may not be detected in *B. burgdorferi* tests

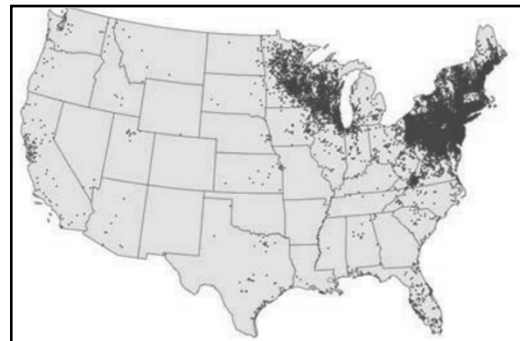


POWASSAN VIRUS

- North American tickborne encephalitis
- Death in 10-15%
- 50-70% long term sequelae
- 2006-16—99 cases



LYME DISEASE



### LYME DISEASE



- 300,000 cases estimated
- 35,000 diagnosed
- Ticks thriving—*Ixodes scapularis*
- More travel
- Lack of vaccine
- Fewer deer, less Lyme—87% less deer = 50% less tick infection & 80% less human cases

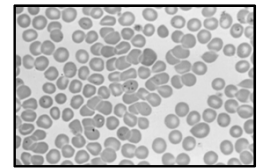
### ANAPLASMOSIS



### BABESIOSIS

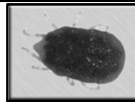


### BABESIOSIS



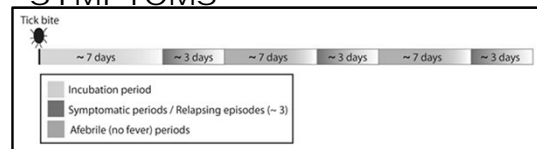
- Intraerythrocytic parasite
- *Babesia microti* transmitted by *I. scapularis*
- *B. divergens*—splenectomized Europe
- *B. duncani*—WA, CA
- Currently unnamed strain designated MO-1--Missouri

### TICK BORNE RELAPSING FEVER

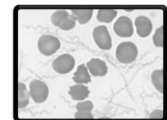


- *Ornithodoros hermsii* prefers coniferous forests at altitudes of 1500 to 8000 feet –14 western states
- Feeds on tree squirrels and chipmunks
- *O. turicatae*, found at lower altitudes in Southwest
  - cattle, rodents, pigs, snakes, tortoises, and possibly coyotes

### SYMPTOMS





- Fever lasting several days
- Interval without fever
- Episode of fever
- 1-4 times
- Body, muscle, joint and headache
- Nausea, vomiting, anorexia



# TOOLS FOR FIGHTING VECTORBORNE DISEASES AND PREVENTION

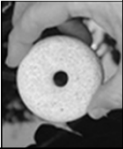
## PERSONAL PREVENTION OF MOSQUITO BITES

- Wear loose-fitting, long-sleeve, light-colored clothing
- Use an EPA-approved repellent

## PREVENTING MOSQUITOES

- Look around at items that can hold water
- If it can hold water for more than 4 days can be a potential breeding site
  - Plastic bottle cap
  - Tires
  - Gardening items & sporting equipment
  - Bird baths, clogged gutters, and low.





## KEEP MOSQUITOES OUT OF YOUR SEPTIC TANK



Mosquitoes in a septic tank      Repair broken septic tank covers      Cover ventilation pipes



## MOSQUITO TRAPS

- Light trap—small light and CO<sub>2</sub> emitter
- Gravid trap—stagnant water with a fan to blow mosquitoes into collection container
- BG Sentinel trap—tarp-like container with an attractant

## COUNTING AND REPORTING

- Identify species in area
- Mosquito-borne diseases
  - PCR

### KILLING MOSQUITOES



- Ultra low volume fogging machines
- Computers to aid customization with mission specific software
- Mobile mapping GPS



### PREVENTION OF MOSQUITO BITES

- Resistance to insecticides and larvicides
- 2 new agents in 2017
- New odors to attract and repel
  - ethyl pyruvate, food flavoring with a fruity flavor: found to reduce *Aedes aegypti* attraction
  - cyclopentanone, mint-smelling flavor and fragrance: powerful attractant for *Culex quinquefasciatus* mosquitoes

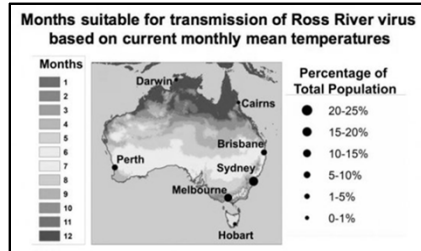
### ROBOTICS, GENE SEQUENCING, AND CLOUD COMPUTING TO DETECT DISEASES EARLY

- Robotic traps for collection



- Machine learning algorithms
- Analysis of DNA and RNA samples

### COMPUTER MODELING



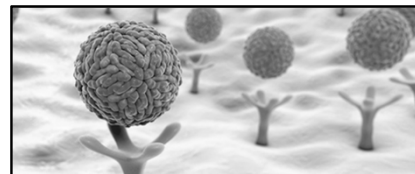
Build a model using laboratory data on traits : mosquito growth, survival, bite rate and infectiousness in response to different temperatures

### INFECTED WITH *WOLBACHIA* BACTERIA

- Sterile male *Aedes aegypti* mosquitoes infected with *Wolbachia* bacteria
- Releases millions of mosquitoes
- *Wolbachia* prevents females producing viable eggs
- Reduces populations by 80%

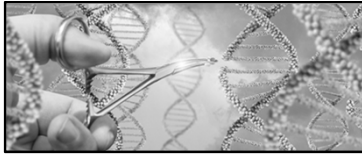
### MODIFICATION OF MOSQUITO GUT

- Targeting pathways needed for pathogens to infect cells lining gut
- Researching ways to block them



### KNOCKING OUT MOSQUITO GENES

- CRISPR/Cas9 to knock out FREP1 that enables *Plasmodium* to infect midgut
- Significantly reduces infection



### NEW ANTIMALARIALS

- Current treatment—1 or 2x daily for 3 days
- Resistant to both artemisinin and partner drugs, such as mefloquine and piperaquine
- Solve challenge of drug resistance
- Single exposure radical cure and prophylaxis
- Mass drug administration

### NEW ANTIMALARIALS

- Krintafei (tafenoquine)
  - FDA approved single dose
  - Kills *P. vivax* in the liver to prevent relapse
- Pyramax® Granules (pyronaridine-artesunate)
  - Uncomplicated malaria in infants 5-20 kg
  - Expanded to >20kg
  - Safe for redose up to 8 times in 2 years



### PREVENTION OF TICK BITES

- **Avoid wooded and brushy areas with high grass and leaf litter.**
- **Walk in the center of trails.**
- **Use repellents that contain 20 to 30% DEET (N, N-diethyl-m-toluamide) on exposed skin and clothing**



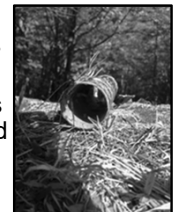
### PREVENTION OF TICK BITES

- **Permethrin on clothing--treat clothing and gear, such as boots, pants, socks and tents with products containing 0.5% permethrin**
  - Remains protective through several washings
  - Pre-treated clothing available and may be protective longer



### TICK TUBES

- Host-targeted devices
- Filled with cotton nesting materials laced with Permethrin
- Placed in mouse breeding habitats (e.g. stone walls, brush piles, wood piles)
- Mice place it in their nests
- Live ticks to detach and die
- Biodegradable and low risk for environmental contamination



## DEER TARGETED DEVICES



- 4-Poster Bait Stations—98%
- Central feed bin for baiting deer
- 2 application stations at either end
- Deer feed on the corn bait
- Device forces them to rub against applicator rollers which apply pesticide to the ears, neck, head, and shoulders
- [www.youtube.com/watch?v=l0nhdC5IPKU](http://www.youtube.com/watch?v=l0nhdC5IPKU)

## FIND AND REMOVE TICKS

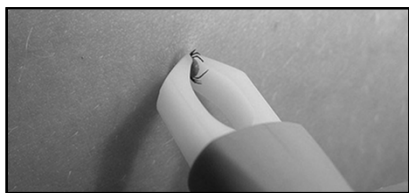
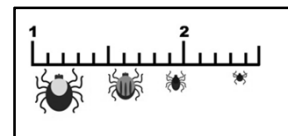
- **Bathe or shower as soon as possible (preferably within two hours) to wash off and find ticks**
- **Conduct a full-body tick check using a hand-held or full-length mirror**
- **Examine gear and pets**
- **Tumble clothes in a dryer on high heat for an hour**

## ANTIMICROBIAL PROPHYLAXIS

- Not recommended for any but Lyme
- Single dose doxycycline
  - Adults not pregnant
  - Children >8 yrs
- Tick *I. scapularis* and attached >36 hrs
- Lyme disease common in area

## FIND AND REMOVE TICKS

- **Parents should check children closely:**
  - Under the arms
  - In and around the ears
  - Inside the umbilicus
  - Behind the knees
  - Between their legs
  - Around the waist
  - In their hair



- **Use fine-tipped tweezers to grasp the tick as close to the skin's surface as possible**
- **Pull upward with steady, even pressure**
- **Don't twist or jerk the tick**

## HOW TO REMOVE A TICK

- **Thoroughly clean bite area and your hands with rubbing alcohol, iodine scrub, or soap and water**
- **Dispose of a live tick by submersing it in alcohol, placing it in a sealed bag/container, wrapping it tightly in tape, or flushing it down the toilet**
- **Never crush a tick with your fingers**



