Introduction to Field Epidemiology and Outbreak Response

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Preface

The handbook evolved after my experience during the International Field Epidemiology program conducted during June 2024 in Lima and Tumbes, Peru.

Disclaimer

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Notice

This material is not indended to be and should not be considered a substitute for medical or other professional advice. Treatment for the conditions described in this material is highly dependent on the individual circumstances. While this material is designed to offer accurate information with respect to the subject matter covered and to be current as of the time it was written, research and knowledge about medical and health issues are constantly evolving, and dose schedules for medications and vaccines are being revised continually, with new side effects recognized and accounted for regularly. Readers must, therefore, always check the product information and data sheets provided by the manufacturers and the most recent codes of conduct and safety regulatioons. The the publisher and the authors make no representations or warranties to readers, express or implied, as to the accuracy or completeness of this material, including without limitations that they make no representations or warranties as to the accuracy of the drug dosages mentioned in this material. The authors and the publishers do not accept, and expressly disclaim, any responsibility for any liability, loss, or risk that may be claimed or incurred as a consequence of the use and/or application of any of the contents of this material.

1 Introduction

During an outbreak, the key mission is two-fold– save as many lives as possible and learn enough to stop the outbreak. Zoonoses are growing (Woolhouse and Gowtage-Sequeria 2005).

2 Before you go

One of the worst things to happen to a team investigating an outbreak is for a teammate to come down with an illness during the investigation. In the best case, everyone on the team has been vaccinated against the likely infections known for the region in which the outbreak occurs. Similarly, you may need to take prophylaxis for different pathogens before, during, and after your visit. It may also be good to have some common drugs in case a member of the team comes down with an illness. The best way to prepare for this is to visit a travel medicine clinic.

2.1 Travel medicine clinic

Travel medicine clinics are typically staffed by infectious disease physicians who can recommend different vaccines, prophylaxis, and counseling on what to do in case of emergencies. Visits to a travel medicine provider are typically covered by your insurance.

These providers will examine things like the Centers for Disease Control and Prevention (CDC)'s yellow book or other resources like Shoreland Travax. Based on the ongoing disease dynamics within the country, your will see three different categories for vaccination:

- **Recommended**
- **Generally not recommended**
- **Not recommended**

We can look at the CDC recommendations for Peru.

Table 2.1: Recommended vaccines for travelers to Peru retrieved from https://wwwnc.cdc.gov/travel/destinations/traveler/none/peru on 2025-01-27

Vaccines for disease	Recommendations	Clinical Guidance for Healthcare providers

Routine vaccines	Make sure you are up-to-date on all routine vaccines before every trip. Some of these vaccines includeChickenpox (Varicella) Diphtheria-Tetanus-Pertussis Flu (influenza) Measles-Mumps-Rubella (MMR) Polio Shingles	Immunization schedules
COVID-19	All eligible travelers should be up to date with their COVID-19 vaccines. Please see Your COVID-19 Vaccination for more information.	COVID-19 vaccine
Chikungunya	There has been evidence of chikungunya virus transmission in Peru within the last 5 years. Chikungunya vaccination may be considered for the following travelers:People aged 65 years or older, especially those with underlying medical conditions, who may spend at least 2 weeks (cumulative time) in indoor or outdoor areas where mosquitoes are present in Peru, OR People planning to stay in Peru for a cumulative period of 6 months or more	Chikungunya - CDC Yellow Book
Hepatitis A	Recommended for unvaccinated travelers one year old or older going to Peru.Infants 6 to 11 months old should also be vaccinated against Hepatitis A. The dose does not count toward the routine 2-dose series.Travelers allergic to a vaccine component should receive a single dose of immune globulin, which provides effective protection for up to 2 months depending on dosage given.Unvaccinated travelers who are over 40 years old, are immunocompromised, or have chronic medical conditions planning to depart to a risk area in less than 2 weeks should get the initial dose of vaccine and at the same appointment receive immune globulin.	Hepatitis A - CDC Yellow Book Dosing info - Hep A
Hepatitis B	Recommended for unvaccinated travelers younger than 60 years old traveling to Peru. Unvaccinated travelers 60 years and older may get vaccinated before traveling to Peru.	Hepatitis B - CDC Yellow Book Dosing info - Hep B

Malaria	CDC recommends that travelers going to certain areas of Peru take prescription medicine to prevent malaria. Depending on the medicine you take, you will need to start taking this medicine multiple days before your trip, as well as during and after your trip. Talk to your doctor about which malaria medication you should take.Find country-specific information about malaria.	Malaria - CDC Yellow Book Considerations when choosing a drug for malaria prophylaxis (CDC Yellow Book) Malaria information for Peru.
Measles	Cases of measles are on the rise worldwide. Travelers are at risk of measles if they have not been fully vaccinated at least two weeks prior to departure, or have not had measles in the past, and travel internationally to areas where measles is spreading.All international travelers should be fully vaccinated against measles with the measles-mumps-rubella (MMR) vaccine, including an early dose for infants 6–11 months, according to CDC's measles vaccination recommendations for international travel.	Measles (Rubeola) - CDC Yellow Book
Rabies	Dogs infected with rabies are sometimes found in Peru.Rabies is also commonly found in some terrestrial wildlife species and bats.If rabies exposures occur while in Peru, rabies vaccines may only be available in larger suburban/urban medical facilities.Rabies pre-exposure vaccination considerations include whether travelers 1) will be performing occupational or recreational activities that increase risk for exposure to potentially rabid animals and 2) might have difficulty getting prompt access to safe post-exposure prophylaxis.Please consult with a healthcare provider to determine whether you should receive pre-exposure vaccination before travel.For more information, see country rabies status assessments.	Rabies - CDC Yellow Book
Typhoid	Recommended for most travelers, especially those staying with friends or relatives or visiting smaller cities or rural areas.	Typhoid - CDC Yellow Book Dosing info - Typhoid

Yellow Fever	Recommended for travelers 9 months old going to areas <2,300 m (7,550 ft) elevation in the regions of Amazonas, Cusco, Huánuco, Junín, Loreto, Madre de Dios, Pasco, Puno, San Martín, and Ucayali, and designated areas of Ancash (far northeast), Apurímac (far north), Ayacucho (north and northeast), Cajamarca (north and east), Huancavelica (far north), La Libertad (east), and Piura (east). Generally not recommended for travel limited to the following areas west of the Andes: the regions of Lambayeque and Tumbes, and designated areas of Cajamarca (west-central), and Piura (west). Not recommended for travel limited to areas >2,300 m (7,550 ft) elevation, areas west of the Andes not listed above, the city of Lima (the capital), and the highland tourist areas (the city of Cusco, the Inca Trail, and Machu Picchu).	Yellow Fever - CDC Yellow Book

2.2 Packing for your travel

2.2.1 Prescription Medications

2.2.2 Medical supplies

2.2.3 Prevention

2.2.4 First Aid

2.2.5 Documentation

It is important that you have all of your documentation along with additional copies of your documentation.

Passport you should make sure that you have a valid passport with at least 6 months of time before it expires (at the time of your visit). Additionally, you should make several copies of the identification page of your passport. It is important that you do not have both the copies and your physical passport on you at the same time when traveling. Having paper copies of your passport on you while in the field can prevent your actual passport from being stolen.

Visas check with your embassy and relationship of your home country with the country you are visiting. For example, U.S. citizens visiting Peru can check the U.S. State Departments webpage. At the time of writing, you can stay without a visa for between 30 and 183 days. If you are not a U.S. citizen, it is essential that you contact your embassy and discuss what is required in order to enter the country (e.g., for Peru you can see some of those nationals that might require an additional visa application).

Copies of prescriptions for the medications that you are taking abroad. Some medicines might be illegal in the country you are visiting and therefore it is important that you have proper documentation for them prior to going. Additionally, if you are a physician bringing medications it is important that you claim these on entry if asked.

2.3 Travel insurance

It is important that you verify that you have international health insurance before you go. The United States government **does not** provide insurance and your domestic policy will likely not cover you when you are abroad. If you are attending the course, the university should help to arrange for international traveler's insurance (e.g., companies like GeoBlue among others). The CDC has more comphrehensive guides on their travel webpage.

2.4 Joining the Smart Traveler Enrollment Program

The U.S. State Department also

2.5 Fitness preparation

During field responses you will spend a lot of time on your feet in relatively warm conditions (i.e., 8-12 hours a day in the field). This is compounded by the fact that you will likely be in long pants, long sleeves, and hiking shoes or boots to protect yourself from insects. As such a base level of physical fitness and acclimation is recommended before you go. This might take the form of walking or running a few miles a day outdoors in the months leading up to your departure. You know your body better than anyone and some level of preparation goes a long way before you are in the field.

Part I

Organization

3 Incident Command

One of the most critical tasks during an outbreak is organizing the activities. Public health practictioners and experts are typically very interested in responding to an outbreak. This energy needs to be appropriately directed in order to reduce the risk that these efforts detract from oneanother.

4 Logistics

Logistics

Part II

Human epidemiology

Human epidemiology.

5 Ten Steps of a Field Investigation

The CDC Field Epidemiology Manual outlines 10 steps of a field investigation for an outbreak.

Source: Field Epi Manual

Step 1: Prepare for Field Work
Before beginning a field investigation, ensure all involved parties understand the purpose, roles, and responsibilities. Obtain necessary official approvals, including a formal invitation from an authorized official, and consult with laboratory colleagues about testing and safety protocols.

Step 2: Confirm the Diagnosis
Verification of the diagnosis ensures that the issue is properly identified and not a misdiagnosis. This can be achieved through interviews, clinical exams, medical records, and laboratory tests, and specimens should be preserved for later analysis.

Step 3: Determine the Existence of an Outbreak
Determine if an outbreak exists by comparing the number of cases to expected numbers, using historical data or surveillance records. This helps rule out pseudoepidemics caused by misdiagnosis or reporting issues.

Step 4: Identify and Count Cases
Create a clear case definition and systematically search for all cases of the disease without including non-cases. This involves classifying cases based on symptoms, timing, and exposure settings and compiling the data into a structured format for analysis.

Step 5: Tabulate and Orient the Data in Terms of Time, Place, and Person
Organize the collected data into an epidemiologic description that focuses on time, place, and person. This includes creating epidemic curves, spot maps, and comparing groups to form initial hypotheses about the outbreak's cause and spread.

Step 6: Consider Whether Control Measures can be Implemented Now
Control measures can target either the source of the disease or susceptible individuals through interventions like treatment, isolation, vaccination, or prophylaxis. While typically implemented after confirming hypotheses, preliminary control measures can be initiated based on early information to prevent further spread.

Step 7: Develop and Test Hypotheses
Develop hypotheses about the cause, source, and mode of transmission of the outbreak based on various sources, including descriptive epidemiology and interviews. Testing these hypotheses

through analytic studies like cohort or case-control studies helps confirm risk factors and causal associations.

Step 9: Implement and Evaluate Control and Prevention Measures
The goal of an investigation is to implement and evaluate effective control measures to prevent further morbidity or mortality. Ongoing evaluation, including active surveillance, helps assess the effectiveness of these measures and guides necessary adjustments.

Step 10: Communicate Findings
Effective communication is essential throughout and after an outbreak investigation. Establishing a clear communications plan and a designated spokesperson ensures consistency in sharing findings with the public, stakeholders, and other relevant authorities, including through briefings and written reports.

6 Defining a case

One of the key aspects of an outbreak investigation is establishing the case definition. A case definition describes a set of standardized criteria to determine if an individual should be counted in the outbreak under investigation. The key components of a case definition are who (the individual), where (location), when (time frame), and what (symptoms, diagnostics).

6.1 CDC's Outbreak and Case Definition guide:

For detailed information on formulating a case definition and example case definitions, see the CDC's guidelines on developing a case definition:

7 Bioethics during an outbreak

Ethical considerations are vital during an outbreak in order to preserve the trust of the community. The World Health Organization has published a consensus statment on guidelines for establishing respectful partnerships with local communities and leaders while implementing evidence-based containment strategies.

7.1 Summarized WHO guidelines

WHO Consenses statement

1. Obligations of Governments and the International Community: Governments have a duty to prevent and respond to infectious disease outbreaks through improved health systems and public health activities and contribute to global surveillance and preparedness. These obligations extend beyond national borders, as infectious diseases can spread globally, and wealthier countries are have ethical obligations to assist poorer nations in enhancing their health capacities.

2. Involving the Local Community: Community engagement is crucial for building trust and social order during an outbreak. A community-centered approach involves inclusiveness, openness, transparency, and accountability, and ensures diverse perspectives are considered, with the media playing a key role in providing accurate, timely information.

3. Situations of Particular Vulnerability: Vulnerable individuals or groups face heightened risks during outbreaks, including difficulties accessing services, communication barriers, and the threat of stigmatization. Efforts should focus on addressing these challenges through targeted support, ensuring equitable access, and preventing discrimination or violence.

4. Allocating Scarce Resources: During outbreaks, resource allocation decisions must balance utility (maximizing benefits) and equity (fair distribution), with special attention to vulnerable populations.

5. Public Health Surveillance: Surveillance is critical for managing and preventing outbreaks, but it must be ethically managed to protect personal information and ensure transparency in its use. Ethical oversight should balance public health goals with individual rights and vulnerabilities.

6. Restrictions on Freedom of Movement: Restrictions like quarantine or travel bans should only be imposed when scientifically justified, using the least restrictive methods possible, and with humane conditions and support for those affected. They must be applied equitably, with opportunities for due process and transparency.

7. Obligations Related to Medical Interventions: Medical interventions during outbreaks must meet high standards, and individuals should have the right to refuse them, unless refusal poses significant public health risks. Any overridden refusals must be carefully justified, with due process and attention to individual and community impacts.

8. Research during Infectious Disease Outbreaks: Research during outbreaks is essential to inform public health responses and evaluate interventions, but it must be ethically conducted, respecting participants' rights and integrating with the broader outbreak response efforts. Ethical oversight, informed consent, local capacity-building, and transparent data sharing are critical to ensuring that research supports both immediate and long-term public health goals.

9. Emergency Use of Unproven Interventions Outside of Research: Offering unproven interventions outside of clinical trials is ethically acceptable during emergencies when no proven treatments are available, but it requires ethical oversight, informed consent, and transparent data sharing. Such interventions should be administered cautiously, with careful consideration of risks, benefits, and resource allocation.

10. Rapid Data Sharing: During infectious disease outbreaks, rapid data sharing is critical for understanding the disease, predicting its spread, and guiding public health responses. Ethical issues related to this include ensuring privacy, data confidentiality, and resolving disputes over data ownership, while supporting international cooperation for timely sharing.

11. Long-Term Storage of Biological Specimens: The long-term storage of biological specimens offers valuable research opportunities but raises ethical concerns about confidentiality, informed consent, and community trust. Engaging local communities, ensuring proper governance, and implementing material transfer agreements are crucial for ethically managing the storage and sharing of biospecimens.

12. Addressing Sex- and Gender-Based Differences: Sex and gender influence the course and outcome of infectious disease outbreaks, affecting susceptibility, health care access, and interventions. Public health responses should include sex- and gender-sensitive surveillance, reproductive health services, inclusive research strategies, and tailored communication to address differential risks and needs.

13. Frontline Response Workers' Rights and Obligations: Frontline workers during infectious disease outbreaks have the right to protection, fair remuneration, and access to healthcare for themselves and their families. In return, society has an obligation to minimize risks, ensure adequate support, and help workers reintegrate post-outbreak, while considering the equity of risk distribution and potential consequences for non-participation.

14. Ethical Issues in Deploying Foreign Humanitarian Aid Workers: Foreign humanitarian aid organizations must coordinate with local officials, ensure that workers are adequately trained and informed, and provide necessary resources for safe and effective deployment. Aid workers also have ethical obligations to adhere to their roles, maintain infection control practices, and ensure the wellbeing of affected communities while considering the ethical challenges of working in crises.

Part III

Vectors and reservoirs

Many infectious diseases may be transmitted through a **vector.** A vector is an organism that acts as a carrier of an infectious agent between organisms of a different species (Wilson, 2017). Most commonly, vectors are arthropods, such as mosquitos or ticks. Vectors can serve as a purely mechanical transport between individuals or can serve as a necessary intermediate in the pathogens lifecycle.

A **reservoir** is the environment in which a pathogen population in maintained and could include humans, animals, and the environment (CDC, 2012). Many emerging pathogens have wildlife reservoirs, i.e. the pathogen circulates in a wild animal population normally with some risk of spillover to people. Pathogens that can be transmitted between vertebrate hosts and humans are considered **zoonoses.** Zoonotic diseases are often (but not always) transmitted by a vector.

8 Mosquitos

Infections

- Malaria (*Plasmodium spp.*)
- Dengue
- Zika
- Chikungunya
- Yellow fever
- Mayaro
- Rift Valley
- Lymphatic filariasis
- O'nyong'nyong virus
- West Nile Fever

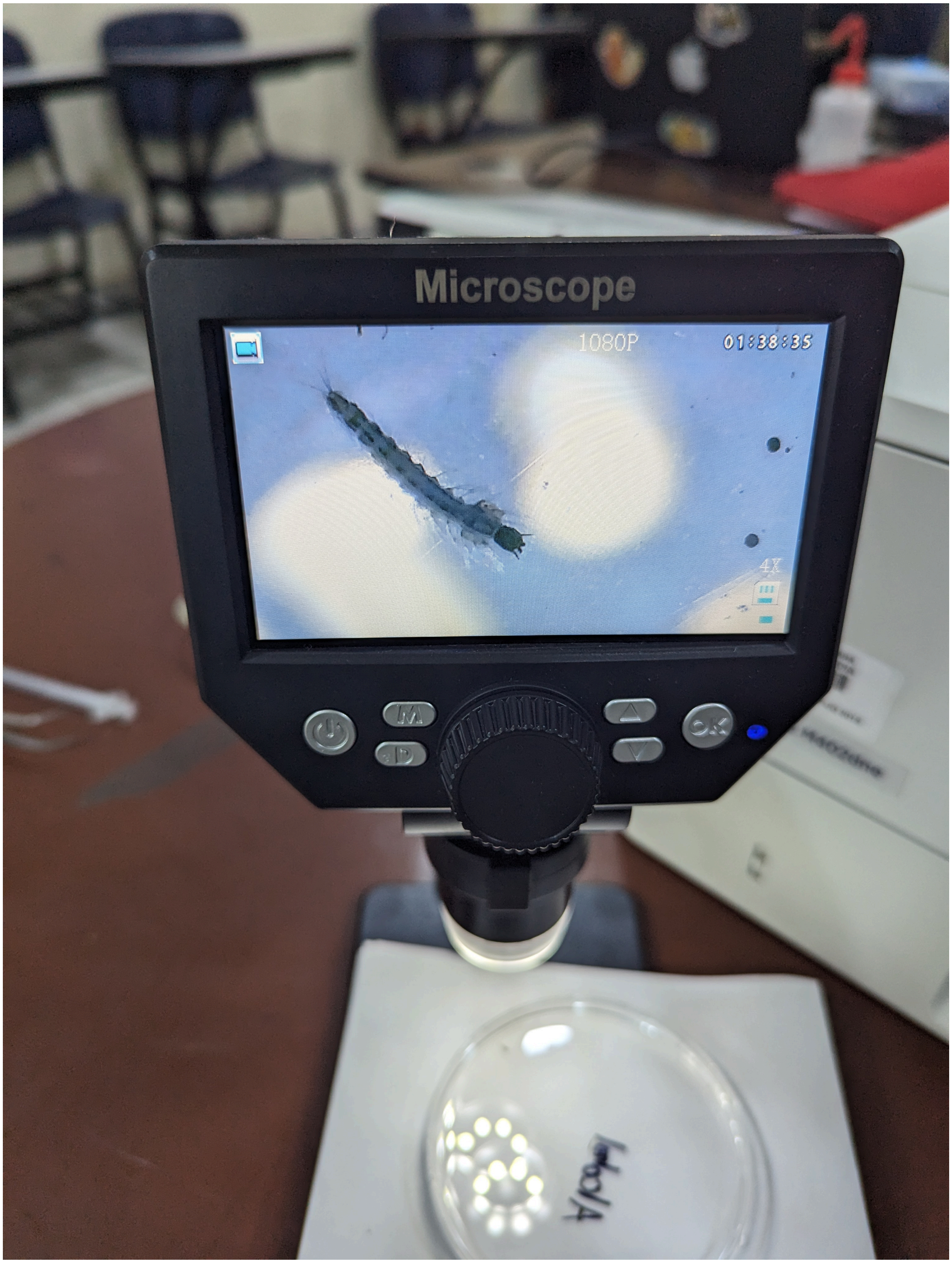

Figure 8.1: Anopheles mosquitoes larva magnified under a microscope

8.1 Biology

8.1.1 *Aedes*

Figure 8.2: *Aedes* spp. mosquitoes transmit a wide range of diseases: chikungunya, dengue, and Zika among others. Photo credit: NIAID.

8.1.2 *Anopheles*

Figure 8.3: *Anopheles* spp., primarily *A. gambiae* and *A. stephensi*, are the vectors of malaria. Photo credit: Jim Gathany.

8.1.3 *Culex*

Figure 8.4: *Culex* spp. mosquitoes transmit a wide range of diseases: West Nile viruse, St. Louis encephalitis, and Rift Valley Fever among others. Photo credit: NIAID.

8.2 Infectious diseases

8.2.1 Malaria

Pathogen: *Plasmodium sp.* unicellular protozoan, the greatest being attributable to *P. falciparum* and *P. vivex*
Vector: female *Anopheles sp.* mosquitos
Clinical manifestations: There is a varied incubation period from 7-30 days between bite of an infectious mosquito and onset of clinical symptoms. Disease can range from mild (fever, chills, headaches, malaise) to severe (seizures, shock, organ failure, DIC, severe anemia, pulmonary edema/ARDS).
Epidemiology:
Treatment/prevention:

8.2.2 Dengue

Pathogen: Dengue virus
Vector: female *Aedes sp.* mosquitoes, primarily *Aedes aegypti* but increased transmission by *Aedes albopictus.*
Clinical manifestations: Fever, joint pain, rash
Epidemiology:
Treatment/prevention:

8.2.3 Zika

Pathogen: Zika virus
Vector: *Aedes sp.* mosquitoes, primarily *Aedes aegypti*
Clinical manifestations: Fever, joint/muscle pain, rash, conjunctivitis, malaise, headache. Infection during pregnancy can lead to congenital malformations in the infant (congenital Zika syndrome)
Epidemiology:
Treatment/prevention:

8.2.4 Chickungunya

Pathogen:
Vector: *Aedes sp.* mosquitoes, primarily *Aedes aegypti* and *Aedes albopictus*
Clinical manifestations: fever, joint pain, muscle pain, headache, nausea, fatigue, rash
Epidemiology:
Treatment/prevention: Supportive care for clinical symptoms, one vaccine licensed in US

8.2.5 Mayaro

Pathogen: Mayaro virus **Vector:** *Haemagogus species* mosquitoes **Clinical manifestations:** Most commonly mild illness: fever, headache, muscle ache, chills, rash **Epidemiology:** **Treatment/prevention:** supportive care for clinical symptoms, prevention focused on limiting mosquito bites (no vaccine)

Figure 8.5: Mayaro virus has been found in Brazil, Bolivia, Colombia, Ecuador, French Guiana, Haiti, Peru, Suriname, Trinidad and Tobago, and Venezuela. Photo credit: CDC.

8.2.6 Rift Valley Fever

Pathogen:
Vector:
Clinical manifestations:
Epidemiology:
Treatment/prevention:

8.2.7 West Nile Virus

Pathogen:
Vector:
Clinical manifestations:
Epidemiology:
Treatment/prevention:

8.2.8 Lymphatic filariasis

Pathogen:
Vector:
Clinical manifestations:
Epidemiology:
Treatment/prevention:

8.2.9 O'nyong'nyong virus

Pathogen:
Vector:
Clinical manifestations:
Epidemiology:
Treatment/prevention:

8.2.10 West Nile Fever

Pathogen:
Vector:
Clinical manifestations:
Epidemiology:
Treatment/prevention:

8.3 Study methods

The CDC has published an overview of methods for mosquito surveillance:

9 Ticks

Infections

- Lyme disease (*Borrellia spp.*)
- Babesiosis
- Ehrlichiosis
- Rocky Mountain Spotted Fever (*Rickettsia rickettsii*)
- Anaplasmosis
- Southern Tick-Associated Rash Illness
- Tick-Borne Relapsing Fever
- Tularemia
- Colorado tick fever
- Powassan encephalitis
- Q fever

Figure 9.1: Tick magnified under a microscope

9.1 Biology

9.1.1 Common tick species and distributions

9.2 Infectious disease

9.2.1 Lyme disease (*Borrellia spp.*)

9.2.2 babesiosis

9.2.3 ehrlichiosis

9.2.4 Rocky Mountain Spotted Fever (*Rickettsia rickettsii*)

9.2.5 anaplasmosis

9.2.6 Southern Tick-Associated Rash Illness

9.2.7 Tick-Borne Relapsing Fever

9.2.8 Tularemia

9.2.9 Colorado tick fever

9.2.10 Powassan encephalitis

9.2.11 Q fever

9.3 Study Methods

10 Other arthropod vectors

Infections

Chiggers
- Scrub typhus (*Orientia tsutsugamushi*)

Biting midge
- Oropouche virus

Kissing bugs
- Chagas disease

Sand flies
- Leishmaniasis
- Oroya fever

10.1 Biology

10.2 Arachnids

10.2.1 Ticks

10.2.2 Mites

10.3 Insects

10.3.1 Mosquitos

10.3.2 Sand flies

10.3.3 Midges

10.3.4 Triatomines

10.4 Infectious disease

10.4.1 Scrub typhus (*Orientia tsutsugamushi*)

10.4.2 Oropouche virus

10.4.3 Chagas disease

10.4.4 Leishmaniasis

10.4.5 Oroya fever

10.5 Study Methods

11 Rodents and small mammals

Infections

- Hanta
- Leptospirosis

11.1 Biology

Figure 11.1: Field mouse, Photo credit: Nick Fewings

11.2 Infectious Diseases

Figure 11.2: Armadillos are the only mammal besides humans known to carry *Mycobacterium leprae*, the causative agent of leprosy, Photo credit: Lily Miller

11.3 Study Methods

12 Bats

Infections

- Rabies
- Nipah
- Hendra
- Coronaviruses (MERS, SARS, COVID)
- Ebola
- Marburg
- Histoplasma capsulatum

12.1 Biology

Bats are the only mammals capable of true flight. Found on all continents with the exception of Antarctica, there are over 1400 species of bats worldwide. Bat species exhibit enormous diversity, ranging in size from 2g to nearly 1.5kg. Most bat species eat either insects, fruit, or nector.

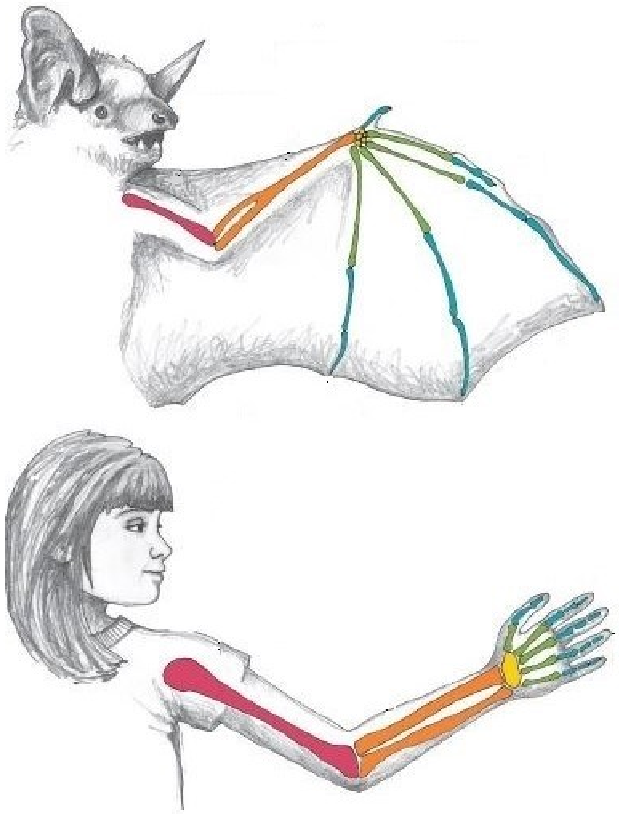

Figure 12.1: Mammalian forearm bone structure is remarkably conserved across species. Photo credit: National Park Service.

ℹ Fun fact

In addition to being the only mammals that can truly fly, and the unique sensory adaptations for echolocation, bats have several remarkable features. They live longer life-spans (up to 40 years!) than other species of a similar size and have enormous metabolic rates during flight. Fascinatingly, they carry a wide-range of human transmissible viruses, but rarely are affected clinically themselves. The unique immune and metabolic features that allow them to tolerate viruses and have marked longevity is an area of active research.

12.2 Infectious diseases

12.2.1 Rabies

Rabies virus causes fatal neurological disease in all mammalian species. Transmitted through infectious saliva (generally through a bite from an infected animal), the virus is distributed in wildlife reservoirs globally. Approximately 59,000 humans die annually from rabies primarily in Africa and Asia; over 99% are attributable to bites from rabid dogs. Rabies is generally considered fatal with onset of clinical symptoms; the Milwaukee protocol can be attempted to rescue symptomatic humans but no treatment exists for animal species. Death generally occurs in most species within 10 days of clinical sign onset. Rabies is entirely vaccine preventable through vaccination; not only is pre-exposure vaccination effective, but due to the pathogenesis mechanism leading to a long (weeks to months) incubation period, post-exposure prophylaxis quickly after exposure is also effective in protecting against disease development. (REF WHO, 2018, Technical report)

Bats are a major wildlife reservoir for rabies in the Americas. Most human rabies cases in the United States are attributable to a bite from a rabid bat. Vampire bats in Central and South Americas are major transmitters of rabies, especially to livestock, because of their feeding habits: they bite their prey in order to lap up blood. (REF WHO, 2018, Technical report)

> **Fun fact**
>
> Bats generally tolerate most viruses without any clinical manifestations. Rabies is an exception - bats do get sick and die from rabies. However, though rabies is generally considered fatal, there are well-documented viral neutralizing antibodies in non-vaccinated bats, suggesting that some bats exposed to rabies will mount an immune response and survive. (REF Davis, 2012, 10.1089/vbz.2011.0674)

12.2.2 Nipah

Nipah virus is an emerging pathogen that can cause severe encephalitis with or without respiratory involvement and a reported fatality rate of up to 40-75%. Nipah virus was first recognized in Malaysia in 1998. The emergence of the virus demonstrates the complex interactions between people, animals, and the environment that characterizes One Health. Fruit trees planted in close proximity to pig farms attracted a fruit-eating bat species, "Flying Foxes," the wildlife reservoir of Nipah. The leading belief about Nipah emergence is that fruit dropped by the Flying Foxes into the pig enclosures were subsequently eaten by the pigs accompanied with Nipah exposure and infection. Infectious pigs could then transmit to humans who came into contact causing an outbreak. There have been subsequent Nipah outbreaks in Bangladesh, associated with date palm sap contaminated with Flying Fox saliva during the collection process. (REF Daszak, 2012, 10.1073/pnas.1201243109)

12.2.3 Hendra

Hendra virus is an emerging pathogen that can cause a range of clinical signs in humans and in horses from mild influenza-like syndromes to fatal respiratory and neurlogical disease. Similar to Nipah virus, Flying fox are the reservoir species for Hendra. Horses can become infected through exposure to Flying Fox bodily fluids, such as saliva on partially eaten fruit dropped into pastures. Though outbreaks have been rare, forward transmission to other horses and humans have been reported. The disease was first diagnosed in 1994. (REF Field, 2001, 10.1016/S1286-4579(01)01384-3)

Figure 12.2: Nipah and Hendra are both linked to Flying Fox bats dropping partially massicated fruit into animal enclosures. Photo credit: Johannes Giez.

12.2.4 Coronaviruses

Coronaviruses cause a range of diseases from common colds in humans to severe gastrointestinal disease in neonatal livestock. Coronaviruses are a large virus family that circulates in numerous animal opulations, including many bat species. Though bats generally are not affected clinically, spillover to other animals, ave historically caused catastrophic human epidemics. Three recent infamous coronavirus spillovers from bats into humans through an intermediary highlight the pandemic potential of these viruses: SARS, MERS, and COVID-19. All three of these syndromes are characterized by mild to severe respiratory disease.

SARS (severe acute respiratory syndrome) emerged in 2002 in the Guangdong Province in China. Characterized by large super-spreading events, the virus (SARS-CoV-1) spread to 29 countries and infected over 8000 people, killing over 900. (REF: Cherry, 2004. 10.1203/01.PDR.0000129184.87042.FC) Scientific research identified horseshoe bats as the wildlife reservoir; spillover to humans was mediated through the intermediary of palm civets from horseshoe bats. (REF: Lau, 2005. 0.1073/pnas.0506735102)

> **ℹ Fun fact**
>
> Interestingly, SARS was last diagnosed in 2004, and has since disappeared, with no new cases being detected in the last 20 years, a feat only achieved on purpose for 2 viruses through enormous coordinated vaccination efforts.

MERS (Middle-Eastern Respiratory Syndrome) was first recognized in Saudi Arabia in 2012. MERS-CoV is suspected to spillover to humans from contact with camelids, with camelids originally acquiring the virus from bats. (REF Corman, 2014, 10.1128/JVI.01498-14). Characterized by a high death rate (34.3%), MERS has caused nearly 2.5 thousand infections, largely in the Arabian penninsula. MERS-CoV continues to cause sporadic cases and local outbreaks. (REF: Memish, 2020, 10.1016/S0140-6736(19)33221-0)

COVID-19 (caused by SARS-CoV-2) origins are still under investigation, there is evidence that spillover occurred from horseshoe bats to raccoon dogs then humans in a wet market in Wuhan, China. (REF Looi 2024, 10.1136/bmj.q1578) Sustained human to human transmission expanded to a global scale by 2020 with the COVID-19 pandemic causing widespread infection and mortality.

12.2.5 Hemorrhagic fevers caused by filoviruses

Filoviruses, the pathogen family responsible for both Ebolavirus and Marburgvirus, are considered to primarily circulate among fruit bat reservoirs. Spillover to primates, including humans, can cause serious hemorrhagic fever.

Ebola was first recognized in the 1970's with several outbreaks occuring in the succeeding decades. Notably, in 2014, a large outbreak in West Africa was declared a Public Health emergency of International Concern by the WHO. More than 28,600 people were infected during the outbreak with a case mortality rate approaching 40%. The mortality of Ebolavirus without treatment reaches 90%. (REF Kalra, 2014, 10.4103/0974-777X.145247; CDC, 2024, Outbreak History)

Marburg virus disease presents clinically similar to Ebola with hemorrhagic fever and high case mortality (ranging from 24-88%). The disease was first recognized in Germany in the late 1960s. Rousettus bats are believed to be the main wildlife reservoir. (REF WHO, 2021, Factsheet)

Figure 12.3: Filoviruses, including Ebolaviruses and Marburgviruses, have a distinctive filamentous struture. Pictured is an electron microscope image of an Ebolavirus. Photo credit: CDC.

12.2.6 Histoplasmosis

Histoplasma capsulatum is a fungal pathogen that can be transmitted to humans and companion animals through inhalation of bat guano. Clinical manifestations include fever and respiratory disease.

12.3 Study methods

12.3.1 Capture

- Mist nets The most common method for capturing bats for wildlife studies is through mist nets. These nets are a very fine weave strung between two poles that is practically invisible to the eye and by echolocation. Used to capture both birds and bats, the animal flies into them and becomes entangled. The animals need to be promptly and expertly removed from the net in order to prevent injury.

Figure 12.4: Bat caught in mist net

- Harp traps capture bats as the are flying and then deposit them safely in the tarp slung underneath. There are many variations of the Harp trap often modified for specific species.

Figure 12.5: Harp trap. Photo credit: Rob and Stephanie Levy, cc-by-2.0.

- Hand capture

12.3.2 Recording

- acoustic surveys
- camera trap

Part IV

After action

13 Reporting

13.1 Situation Reports

13.2 After Action Reports

Part V

Conclusion

14 Conclusion

Importantly, field epidemiology requires a diverse team from a variety of skillsets in order to be sucessful.

References

Woolhouse, Mark E. J., and Sonya Gowtage-Sequeria. 2005. "Host Range and Emerging and Reemerging Pathogens." *Emerging Infectious Diseases* 11 (12). https://doi.org/10.3201/eid1112.050997.

A PPE

Personal protective equipment (PPE) is vital to protecting your staff and yourself during an outbreak investigation. Loss of personel to sickness and quarantine can disrupt ongoing outbreak response actions. Importantly, while supplies allow and until testing indicates otherwise, you should operate at higher levels of PPE. This may include the use of N-95 respirators with facial shields and gloves (i.e., mask, gowns, and glasses/goggles). Depending on the pathogen suspected and the transmission modality, higher levels of PPE may be required. For instance during outbreaks of Marburg and Ebola, higher levels of PPE are required including full protective suits, gloves, and PAPRs.

B Learning R

The basics of the R programming language

B.1 Learning the basics

- R for Data Science
- Hands on programming with R

B.2 Epidemiology focused

- The Epidemiologist R Handbook
- R for Epidemiology
- Introduction to R for Epidemiologists

B.3 Geospatial focused

- Geocomputation with R
- Spatial Data Science
- Geospatial Health Data
- R for Geospatial
-

C Diagnostics

C.1 Lateral Flow Assays

C.2 PCR

C.3 Immunochemistry

C.3.1 LAMP

C.3.2 ELISA

C.3.3 Western Blots

Glossary

CDC The United States Centers for Disease Control and Prevention.

DOD The United States Department of Defense

ELISA Enzyme-linked Immunosorbent Assay

Epidemic More cases of a particular disease or infection spread across a large geographic area.

GEIS Global Emerging Infection Surveillance

LAMP Loop-mediated isothermal amplification

Outbreak The occurance of more cases than expected in a particular geographic area, group of people or animals, over some period of time.

PCR Polymerization Chain Reaction. PCR approaches amplify DNA or cDNA (complement DNA from RNA sources).

Pseuoepidemic The phenomenon that describes when a series of cases have a pattern of reporting that mimics that of an epidemic or outbreak, but are the result of coincidence, changes in reporting practices, or some other artefact. This can result in the expense of resources (both people and materials) that this unnecessary highlighting the importance of conducting the diagnosis confirmation and verification of an outbreak.

PPE Personal Protective Equipment

WHO The World Health Organization