Introduction to Field Epidemiology and Outbreak Response

Michael E. DeWitt

2024-10-09

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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

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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 2024-10-09

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

6 Defining a case

One of the key aspects of an outbreak investigation is establishing the case definition.

7 Bioethics during an outbreak

Ethical considerations are vital during an outbreak in order to preserve the trust of the community

Part III

Vector capture

Many infectious diseases may be transmitted through a *vector*.

8 Mosquitos

Infections

- Malaria (*Plasmodium spp.*)
- Dengue
- Zika
- Chikungunya
- Mayaro
- Rift Valley

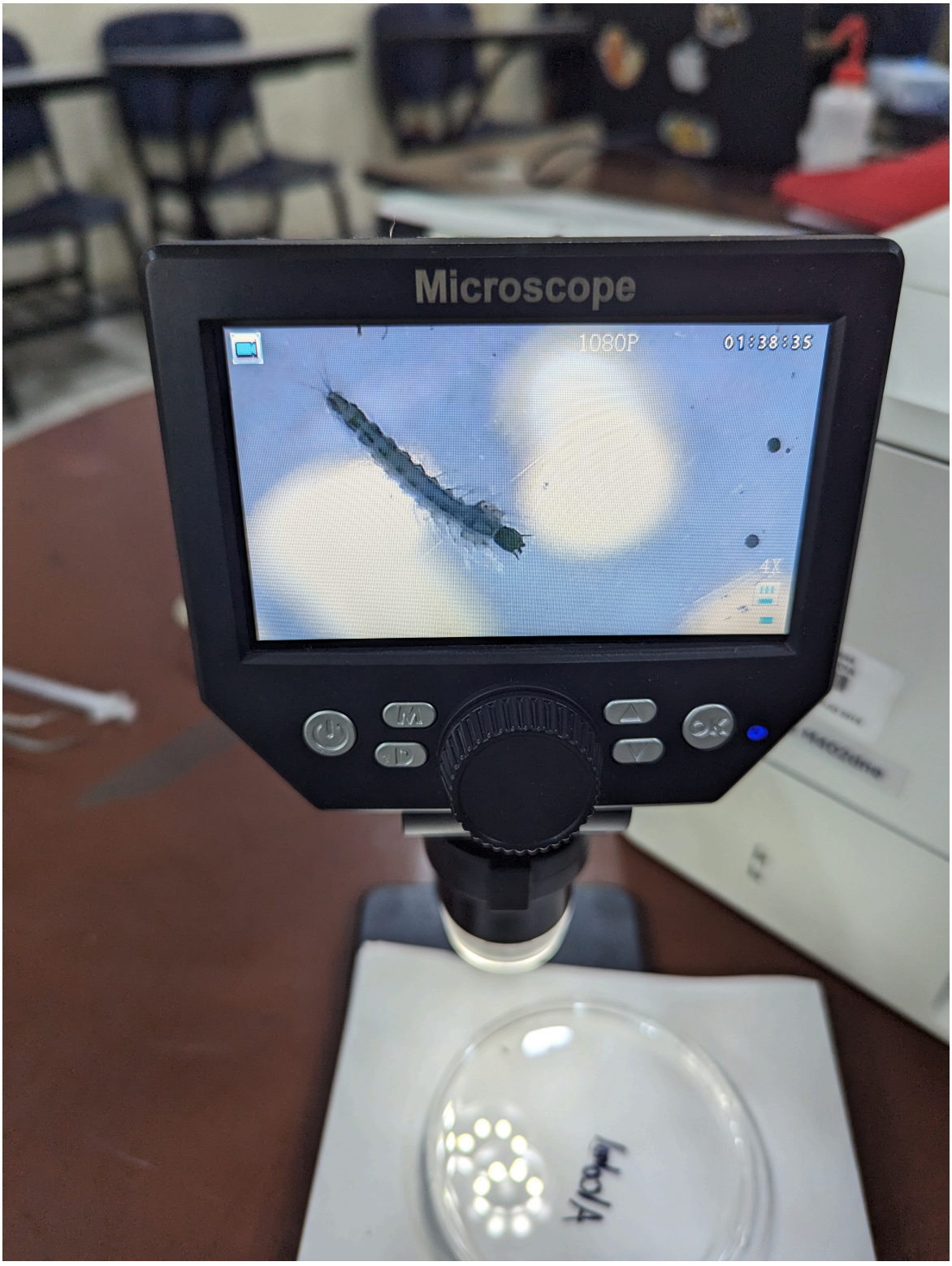

Figure 8.1: Anopheles mosquito larva magnified under a microscope

9 Ticks and mites

Infections

Tick-borne infections - Lyme disease (*Borrellia spp.*) - babesiosis - ehrlichiosis - Rocky Mountain Spotted Fever (*Rickettsia rickettsii*) - anaplasmosis - Southern Tick-Associated Rash Illness - Tick-Borne Relapsing Fever, and tularemia - Colorado tick fever - Powassan encephalitis - Q fever
Chiggers - Scrub typhus (*Orientia tsutsugamushi*)

Figure 9.1: Tick magnified under a microscope

10 Rodents and small mammals

Infections

- Hanta
- Leptospirosis

11 Bats

Infections

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

11.1 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.

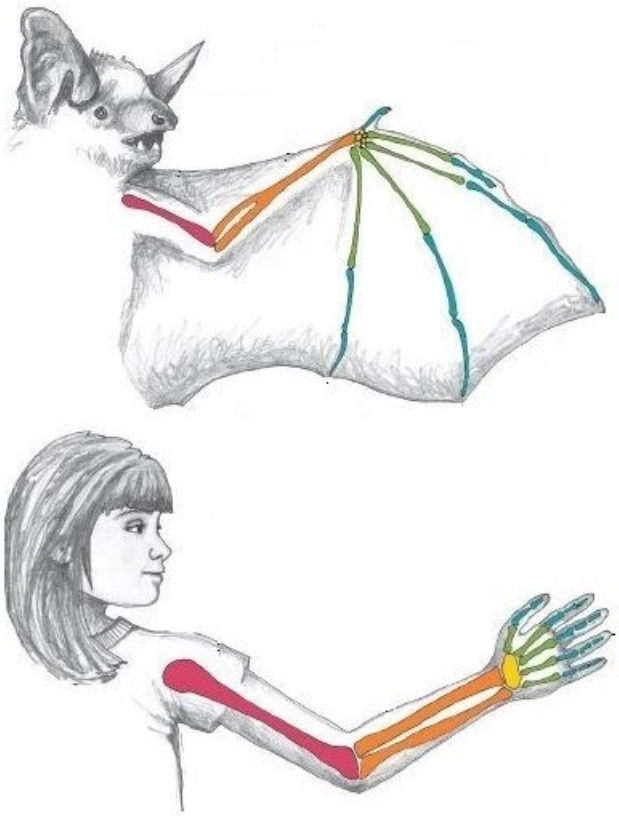

Figure 11.1: Mammalian forearm bone structure is remarkably conserved across species. Photo credit: National Park Service.

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.

11.2 Infectious diseases

11.2.1 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)

11.2.2 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)

11.2.3 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 11.2: Nipah and Hendra are both linked to Flying Fox bats dropping partially massicated fruit into animal enclosures. Photo credit: Johannes Giez.

11.2.4 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.

11.2.5 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)

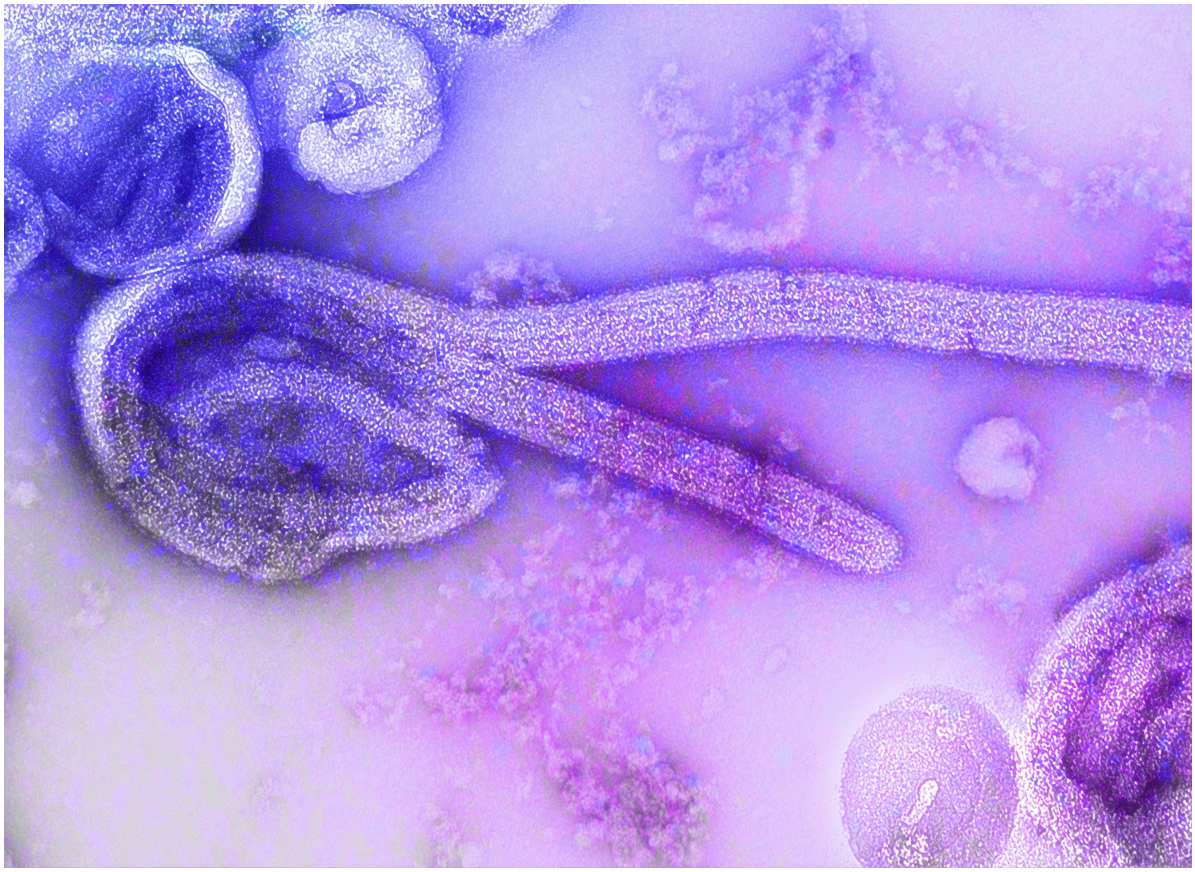

Figure 11.3: Filoviruses, including Ebolaviruses and Marburgviruses, have a distinctive filamentous struture. Pictured is an electron microscope image of an Ebolavirus. Photo credit: CDC.

11.2.6 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.

11.3 Study methods

11.3.1 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 11.4: 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 11.5: Harp trap. Photo credit: Rob and Stephanie Levy, cc-by-2.0.

- Hand capture

11.3.2 Recording

- acoustic surveys
- camera trap

Part IV

After action

12 Reporting

12.1 Situation Reports

12.2 After Action Reports

Part V

Conclusion

13 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