**Title**

Graphing an Epidemic: West Africa Ebola Epidemic

**Overview**

In this activity, students will explore how the Ebola virus outbreak occurred in West Africa. They will start by defining some key terms related to disease prevalence and understanding the differences between the different types of data. Students will then graph prevalence, incidence and mortality data from the three major countries that were affected by the Ebola virus outbreak that were collected by the World Health Organization over a period of 2 years. Students are then asked to graph data as one large data set and then for each country separately (Version A) or to create graphs that answer a set of questions (Version B). After the data is graphed, students will explore the differences and similarities that occur between the different countries. Finally, students will be asked to hypothesize why these differences and similarities occur and why Ebola became an epidemic in these countries but not in the other 10 countries that reported cases.

**Key Concepts**

* Prevalence is the number of cases of a given disease in a time period. It gives an idea of the total number of people affected during an epidemic.
* Incidence is the number of new cases of a given disease in a time period. This differs from prevalence in that it isn’t a total number of everyone who has the disease, but the number who were recently diagnosed with the disease. It can show how transmission is increasing or decreasing over time.
* Mortality is the number of deaths caused by a given disease in a time period.
* An outbreak is when a disease that is not normally in a population appears.
* An epidemic is a disease that is occurring at a higher than normal prevalence in one area.
* A pandemic is a disease that is an epidemic on more than one continent.
* In countries not expecting a disease, it will often develop into an outbreak before public health can react. Once public health reacts, changes are often made to help mitigate the effects and transmission of the disease and provide education to the general public.

**Student Learning Targets**

The student should be able to define incidence, prevalence, and mortality rates and describe the differences between them.

The student should be able to graph data dealing with incidence, prevalence and mortality rates from various countries and interpret and compare the graphs.

The student should be able to make a hypothesis based on data given in a graph or table.

**Prior Knowledge**

Prior to starting this activity, students should have an introductory knowledge of viruses, viral transmission, and role of public health agencies.

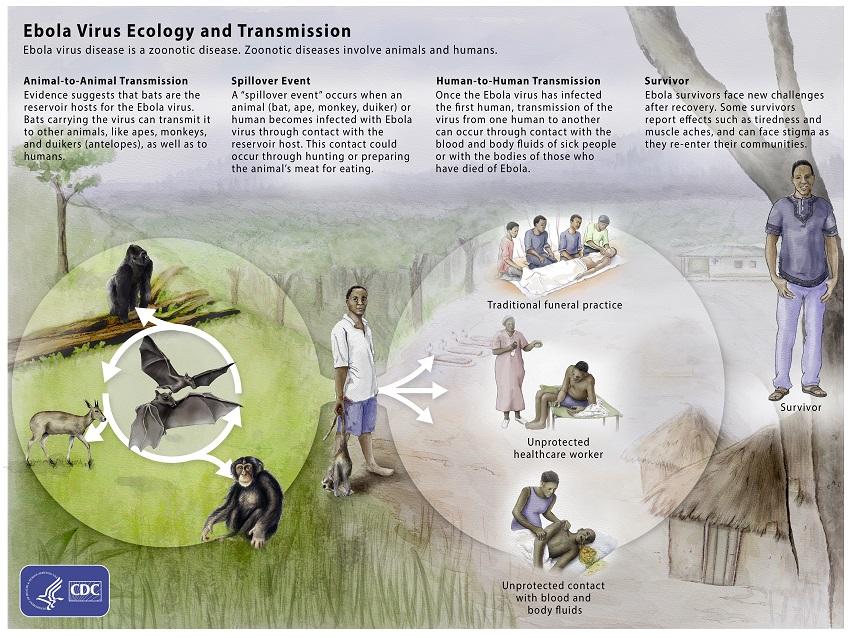
**Background**

Ebola virus disease or Ebola is caused by one of six viruses in the Ebola Virus genus, four of which causes disease in humans. It has a characteristic shape that resembles few other viruses. Primary symptoms of the disease are fever, aches and pains including a severe headache, weakness and fatigue, gastrointestinal symptoms, abdominal pain and hemorrhaging, bleeding or bruising. The disease has a high mortality rate and the current treatment is supportive care, although transfusing antibodies from survivors has shown to be useful. In December of 2019, the Food and Drug Administration approved the first Ebola Vaccine which provides protection against one strain, *Zaire ebolavirus* (CDC, 2019)



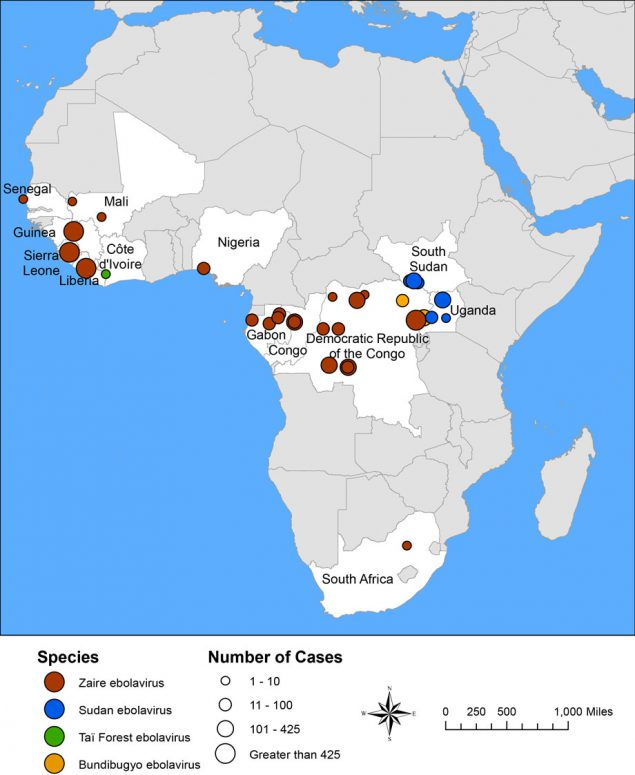
<https://www.cdc.gov/vhf/ebola/modules/flexslider/about-ebola-medium.jpg>

It is thought that one of the main ways an Ebola virus is transmitted initially in an infection is through the interaction of humans with an infected bat. Once an infected bat passes the virus onto humans (a spillover event), the virus can be transmitted from person to person through contact with blood and other body fluids of individuals with Ebola or individuals who have died from Ebola.



<https://www.cdc.gov/vhf/ebola/about.html>

The Ebola virus was first discovered in 1976 in the Democratic Republic of the Congo (formerly Zaire) near the Ebola River with a second outbreak that occurred shortly afterward in South Sudan. However, it should be noted that viral and epidemiologic data suggest that the Ebola virus probably existed long before these recorded outbreaks. Since 1976, there have been many Ebola outbreaks in Africa and the virus is considered to be endemic in central Africa especially in the Democratic Republic of the Congo.



<https://www.cdc.gov/vhf/ebola/history/distribution-map.html>

The 2014 West Africa Ebola Epidemic first case was traced to an 18-month old boy in a rural village of Guinea in December of 2013. It took over a month before an official medical alert was issued and it was not until March of 2014 that an outbreak would be declared after the virus had spread to Guinea’s overcrowded capital city. Due to an inadequate public health infrastructure and the fact that Ebola was not expected to be present in this part of Africa, the virus would easily spread to neighboring Liberia and Sierra Leone. By July, the virus would be in the overcrowded capitals of both countries. The large number of cases in this outbreak is attributed to the crowded urban structure, the ease of human travel across borders, and conflicts between culture and infection control practices. The outbreak would eventually spread to 7 other countries on three continents (CDC). However, only in Guinea, Liberia and Sierra Leone was transmission considered to be widespread. Last cases of Ebola associated with this epidemic would be reported into 2016.

**Teaching Tips**

Prior to completing this activity, the instructor may want to have students watch the video Spillover (a PBS, Tangled Bank production, instructors can get a free copy from HHMI) that describes the Ebola, Nipah and Zika spillover events.

In addition, HHMI’s viral explorer can be used to further study virus characteristics.

There are two versions of this activity. Version A is intended for a group of students who do not have a lot of experience creating graphs and directs the students to make specific graphs, while Version B is intended for students who are comfortable with this and is more inquiry-based.

1. In Version A: I recommend that the instructor split students into at least three groups and assign each group one country to graph. Each group can then send a member of their group to share their information with a different group until each group has the information on all three countries.
2. In Version B: The instructor may want to have each group create a set of graphs and then compare.

Both Versions have the same introductory information and differ only in the student directions for the graphs.

Additional activities or discussions that an instructor may want to incorporate after completion of this activity:

1. Discuss the economic impact of this outbreak, using the handouts available at

Center for Disease Control and Prevention. 2019. “Cost of Ebola Epidemic” March 8, 2019. <https://www.cdc.gov/vhf/ebola/history/2014-2016-outbreak/cost-of-ebola.html>

1. Discuss the economic differences between Sierra Leone, Liberia and Guinea with the rest of the world.

The Heritage Foundation. 2010. “2020 Index of Economic Freedom” <https://www.heritage.org/index/>

World Atlas, 2019. “World Atlas” Last Updated June 4th 2019. <https://www.worldatlas.com/webimage/countrys/af.htm>

<https://www.undp.org/content/dam/rba/docs/Reports/EVD%20Synthesis%20Report%2023Dec2014.pdf>

<https://www.amnh.org/learn-teach/curriculum-collections/politics-and-pathogens>

1. Discuss the public health system in each of the countries, how it may have led to the severity of the outbreak and what can be done to help improve it.

https://www.undp.org/content/dam/rba/docs/Reports/EVD%20Synthesis%20Report%2023Dec2014.pdf

<https://www.savethechildren.org.uk/content/dam/global/reports/health-and-nutrition/a-wake-up-call.pdf>

1. Discuss other outbreaks, like seasonal flu or Sars Cov2, how the same data can be graphed and presented to the general public. Data is available from other outbreaks is available on the Center for Disease Control (https://[www.cdc.gov](http://www.cdc.gov)) and World Health Organization websites (<https://www.who.int>).
2. Discuss how we can monitor diseases and how it is easy to stop an outbreak if you are looking for it.

<https://www.ted.com/talks/nathan_wolfe_the_jungle_search_for_viruses>

<https://p2.predict.global/predict-project>

Instructors should be prepared to address the students comments and answers to questions that relate to racism. For example, a student may wrongly assume that because the outbreak occurred in West Africa, that the color of the skin and / or ethnic background may be the reason why it occurred. Resources in the above teaching extensions may help address and educate the students on the problems that exist in this country.

**Answer Key for Both Versions**

**Understanding the terminology**

Before beginning to use the data set define the following terminology:

1. Prevalence: Total number of cases in a given time point, includes new and old cases
2. Incidence: Total number of new cases reported in a given time period
3. Mortality: Total number of deaths.
4. Epidemic: Higher incidence of a disease in a given area
5. Pandemic: Higher incidence of a disease on more than one continent

**Understanding the virus:**

Use the Center for Disease Control’s website on Ebola - <https://www.cdc.gov/vhf/ebola/symptoms/index.html>, to answer the following questions:

1. Give some characteristics of this virus, specifically, What does it look like? What type of genome does it have?

Ebola is a RNA virus that is helical in shape. It has a characteristic looping shape.

1. What are the signs and symptoms of Ebola?

Primary symptoms of the disease are fever, aches and pains including a severe headache, weakness and fatigue, gastrointestinal symptoms, abdominal pain and hemorrhaging, bleeding or bruising.

1. How many days after exposure do the signs and symptoms begin to appear?

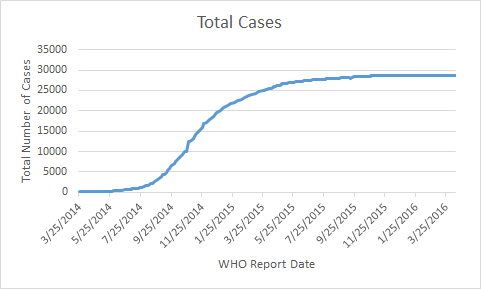
2 to 21 days

**Graphing the data**

The data set from the CDC originally contained data for mortality and prevalence. Incidence data was calculated by subtracting the total number of cases from the previous date’s total number of cases.

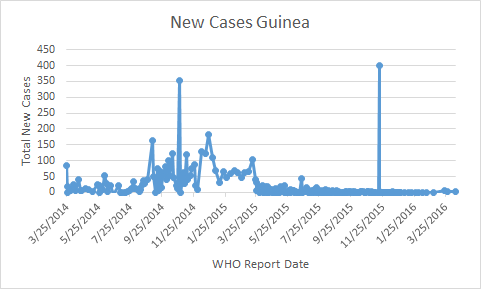
1. Using the combined data for all three countries make the following graphs:
2. Date versus Total Number of Cases (Prevalence)
3. Date versus Total Number of New Cases (Incidence)
4. Date versus Mortality

Example graph: (Graphs were made using Excel, but can be made in any graphing program that the instructor is familiar with and / or has access to)



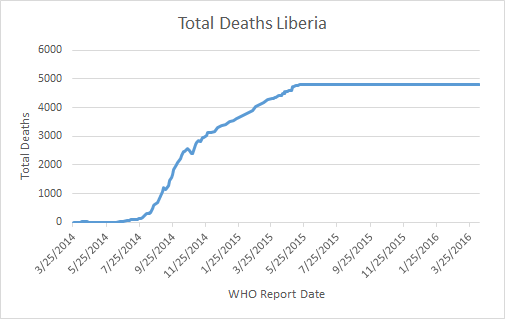
1. Using the data from Guinea make the following graphs:
2. Date versus Total Number of Cases (Prevalence)
3. Date versus Total Number of New Cases (Incidence)
4. Date versus Mortality

Example graph:



1. Using the data from Sierra Leone make the following graphs:
2. Date versus Total Number of Cases (Prevalence)
3. Date versus Total Number of New Cases (Incidence)
4. Date versus Mortality

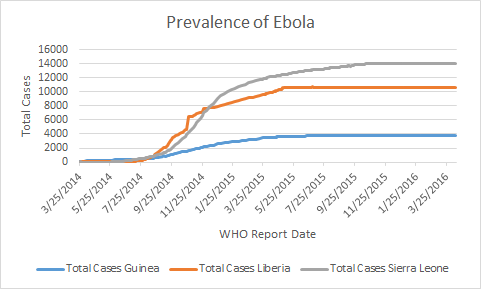
Example graph:



1. Using the data from Liberia make the following graphs:
2. Date versus Total Number of Cases (Prevalence)
3. Date versus Total Number of New Cases (Incidence)
4. Date versus Mortality

Example graph:

Possible graph for Version B



Comparison and Analysis of Graphs:

1. Using the data from all three countries, when was the outbreak the most severe? Does this time frame differ from country to country?

Using the graphs on prevalence, the students should notice that between July of 2014 and March of 2015, there is the largest increase in new cases.

They may also note that the curve starts to flatten out about the same time, but when comparing individual countries’ graphs, they may note that in Sierra Leone it has increased into July of 2015.

1. Compare graphs of prevalence and incidence. Do they give a different picture of the epidemic?

Students should note that while we see the sharpest curve of the prevalence also correlates with spikes in the incidence graphs.

The largest increases in prevalence correlates with spikes and large increases in numbers of new cases. When the number of new cases starts to decline, the prevalence curve flattens out.

1. In which country did the outbreak start? How does your graphs show this?

From the background material, we know that it started in Guinea. Students should be able to use either the prevalence graphs or the incidence graphs to indicate that when the data starts, there were already causes in Guinea.

1. In which country did it last the longest? How did you determine this?

Students could argue one of two possible countries.

Sierra Leone – Although they were the last country to have cases, their curve kept increasing (prevalence) and new cases were being reported consistently after the other countries did not have any causes.

Guinea – There is spike of cases in late November in 2015, which students could argue means that there are still cases occurring but maybe not being reported. Or this could indicate that the disease was brought back into the country from somewhere else or is a second wave of the disease.

1. Which country or countries had the last cases? Is this same country that had the longest disease outbreak?

Depending on how they answered question 4, this is either the same – Guinea had the last reported cases and the longest outbreak or Guinea was the last reported cases, but Sierra Leone have the longest outbreak.

1. Using the graphs from the individual countries, indicate the order that disease was first diagnosed in each country.
2. Guinea, Liberia, Sierra Leone or
3. Guinea, Sierra Leone and Liberia.

If students look carefully at the data, they will have the first answer. However, if they look at the graphs they may pick the second.

Students may either use incidence or prevalence data to show this.

1. Indicate on the graphs, your hypothesis for when the virus moved into a crowded city from the rural setting. Why do you think this is the case?

Students should mark the big increase in incidence numbers on their graphs. This would be in August and October of 2015. A large increase in numbers means that a larger amount of people were getting the disease during that time period and this would have exceeded the population of the small rural village in these countries.

1. Which country had the most deaths? What is your hypothesis for why this is the case?

Using the total deaths graphs, this is Liberia.

You may have students ask if this is related to the population size of the country, indicating that the larger the population the more cases and more deaths (see extension activity in teaching notes).

1. In the following table, you have the final number of cases and the final number of deaths in each country. Calculate the mortality rate in each country and in the three countries combined:

Mortality Rate = (Number of Deaths / Number of Cases) x 100

|  |  |  |  |
| --- | --- | --- | --- |
| Country | Confirmed Cases | Deaths | Mortality Rate |
| Guinea | 3814 | 2544 | 67% |
| Sierra Leone | 10678 | 3956 | 37% |
| Liberia | 14124 | 4810 | 34% |
| All Three Countries Combined | 28616 | 11310 | 40% |

Which country had the highest mortality rate? Using your graphs, why do you think this was the reason?

The highest mortality rate was in Guinea. Using the graphs, we have already indicated that this was where the epidemic started.

Compare the % mortality with the graph of the number of deaths in each country. Does the % mortality tell the same story as the graph of the number of deaths? Which set of data gives you a better idea of how deadly a disease is in that population?

If you just looked at the graphs, students might think that that the biggest impact was in Liberia as there were more deaths (but there were also more cases). The % mortality rate tells you that people who contracted the disease in Guinea were more likely to die.

Why does % mortality give you a better idea of how deadly a disease is than the number of deaths?

The percent mortality gives you a better idea of the chance of dying from the disease in a specific country independent of the number of cases, while the number of deaths is expected to go up as more people contract the disease.

1. The outbreak spread to 7 other countries, including the United States. Here is the data from the CDC on the total numbers of cases in each of these countries.

|  |  |  |
| --- | --- | --- |
| Country | Confirmed Cases | Deaths |
| Italy | 1 | 0 |
| Mali | 7 | 6 |
| Nigeria | 19 | 8 |
| Senegal | 1 | 0 |
| Spain | 1 | 0 |
| United Kingdom | 1 | 0 |
| United States | 4 | 1 |

What is your hypothesis of why these countries did not have a widespread outbreak of Ebola?

Students may already have asked this question related to question 9. There are lots of possible hypotheses, some of which could include:

1. Guinea had the first cases and were not looking for it, so infection control methods were not in place and early cases may not have gotten the medical treatment they needed (especially in rural villages).
2. Stigma of getting Ebola may have prevented people from getting care early in the infection process, so they infected more family and friends.
3. There is better health care in these countries because these countries have recently had civil war or are also some of the poorer nations of the world (Also a possible extension of this activity).

Since some of the countries do not directly border Guinea, Sierra Leone and Liberia, How do you think that it arrived in these countries? Could other diseases travel around the world in the same manner?

Most likely someone who had been exposed but not showing signs of Ebola traveled by air, car or rail to these countries. Yes, this is possible in a lot of infectious diseases.

Calculate the percent mortality in each of the above countries. How do they compare with Guinea, Sierra Leone and Liberia? Is this a valid comparison? Why or Why not?

Students should note that in Mali there was an 85% mortality rate, Nigeria a 42% mortality rate, and the United States a 25% mortality rate. This is not a valid comparison because the number of confirmed cases is low.

The instructor may want to point out that the disease did not spread in these countries because these countries were already aware of Ebola’s presence in the region and that monitoring of individuals coming from specific countries was already occurring.

During this time period, in the United States, there was concern the few cases of Ebola would lead to an epidemic in the United States. Why do you think that this did not occur?

Some possible answers:

1. We were looking for it, monitoring individuals from infected countries.
2. Better health care and infection control methods at the start of the infection (isolation of patients)

**References**

Initial data obtained from: Center for Disease Control and Prevention, 2020, “Case Counts” Last updated Feb 19, 2020. <https://www.cdc.gov/vhf/ebola/history/2014-2016-outbreak/case-counts.html>

Center for Disease Control and Prevention. 2019. “What is Ebola Virus Disease” Last Updated November 5, 2019. <https://www.cdc.gov/vhf/ebola/about.html>

Center for Disease Control and Prevention. 2019. “2014-2016 Ebola Outbreak in West Africa” Last Updated March 8, 2019. <https://www.cdc.gov/vhf/ebola/history/2014-2016-outbreak/index.html>

Center for Disease Control and Prevention. 2019 “Signs and Symptoms” Last Updated November 5, 2019. <https://www.cdc.gov/vhf/ebola/symptoms/index.html>

**Credits**

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