CATCH IT IF YOU CAN

EARTH matters
Studies For Our Global Future

introduction

Disease can move through a community in many different ways. A disease can be spread by both direct and indirect contact or be transmitted by a **disease vector**/vehicle such as an animal, insect (e.g. Zika virus, malaria), or food. A disease can also be airborne, like influenza or coronaviruses. Epidemics can either spread from a singular location to all who encounter it, such as by a contaminated water pump, or from person to person. The first is known as a **common source epidemic** (such as contaminated food) and the latter as a **propagated epidemic** (such as the common cold, COVID-19, or the Ebola virus). **Epidemiologists** study how and why diseases spread, attempting to trace the diffusion and initial infection point of a disease. This helps to contain diseases and prevent future outbreaks.

Propagated epidemics are infectious and have the potential to spread more rapidly in a densely populated area – the more people there are, the more likely it is that an infected individual will come into contact with others, thus passing the contagion. (In other words, the impact on a population of a propagated epidemic is **density dependent**.)

Ebola and COVID-19 are just two of many **zoonoses** (or zoonotic diseases) that have emerged in recent decades. Three-quarters of all new infections are zoonotic (jumping from animals to humans) and population growth and its related land and resource use, are driving this trend.

Vocabulary: common source epidemic, density dependent, disease vector, epidemiologist, pandemic, propagated epidemic, reproductive number (R_0), zoonosis

materials

Part 1

- Lab goggles and gloves
- Test tubes
- Plastic pipets
- Water
- Household ammonia
- Phenolphthalein solution (pH indicator)
- Student Worksheet

concept

Infectious diseases can spread quickly through a population. As humans have altered ecosystems around the globe, we have made ourselves more vulnerable to emerging zoonotic diseases.

objectives

Students will be able to:

- Model the spread of a “disease” and trace it through a population.
- Classify a disease as a common source or a propagated epidemic.
- Graph and analyze data on the Ebola virus outbreak in Sierra Leone.
- Describe how population density and economic factors can contribute to the spread of disease.
- Explain how human activities are accelerating the emergence of zoonotic diseases and making pandemics more likely.

subjects

Biology, Environmental Science (General and AP), AP Human Geography, Geography, Algebra, Health

skills

Lab preparation, deductive reasoning, graphing and analyzing data, interpreting line graphs, understanding cause and effect, listening comprehension, writing

method

Students mimic the spread of disease by exchanging liquids in test tubes in a hands-on simulation. They then graph and analyze data from the Ebola outbreak in Sierra Leone in 2014-2016, and watch and respond to short videos on the drivers of zoonoses and pandemics.

Part 2

- None

Part 3

- None

Part 1: Disease Detectives

procedure

1. Before class:

    a. Pour a small amount of water into all but one of the test tubes. (Prepare enough test tubes so that each student has one.)
    Note: You may want to prepare a few extra test tubes for demonstration purposes or in case some get spilled during the activity.
    b. Into the remaining test tube, pour the same amount of ammonia. It should appear to be the same as all of the other tubes.

2. Explain to students that they will be mimicking the spread of a disease among their class population.

3. Distribute the Student Worksheet and tell students that they should follow along and record information on their Worksheet as the simulation progresses.

4. Provide each student with lab goggles and gloves*, a prepared test tube and a pipet, and let them know one of the tubes is "infected" with the "disease." You may also want to point out that all of their tubes look the same. In other words, this "disease" is asymptomatic. Through analysis of the disease diffusion around the class, they will be trying to determine the initial infection point – which tube was the original source of the infection. Have students answer Question #1 on the Worksheet.

    *CAUTION: Ammonia and phenolphthalein can irritate the eyes and skin. Alert students to avoid spilling and warn them to NEVER drink what is in the test tube.

5. Wearing their goggles and gloves, direct students to use their pipets to exchange liquid from their tubes with *one* other person. This represents contact between two individuals. During an exchange, one student should use the pipet to put half of the liquid in his/her tube into a classmate's test tube. That person should then use the pipet to put the same amount back into the first person's test tube.

6. Have students record on their Worksheet the name of the student with whom they exchanged liquid.

7. Repeat this process twice, having all students exchange with a new partner each time and recording with whom they "came in contact" on their Worksheet (Question #2).

8. Have each student add a few drops of the phenolphthalein indicator solution to his or her test tube. If the liquid remains clear, this student has not been infected. If it turns pink, the student has the disease.

9. Infected students should write their names on the board, underline them, and write, in order, the names of the three people with whom they exchanged liquids. Have students answer Question #3 on their Worksheet.

10. Divide students into small groups of three or four. By examining the data on the board and using deductive reasoning, the groups should try to identify patient zero (the person who originally was contaminated) and record their answer on their Worksheet.

Note: You may want to mention to students that the best they will be able to do is narrow down to patient zero and patient zero's partner. In reality, we often do not know who patient zero is.

discussion questions

1. What did the following represent in our simulation:

Test tube?	*Human body*
Ammonia?	*Disease*
Liquid in tube?	*Bodily fluids*
Mixing liquids?	*Coming in contact with an infected person*
Clear indication?	*Uninfected person*
Pink indication?	*Infected person*

2. Some epidemics spread from a singular location (such as a contaminated water pump or food) to all who encounter it – this is known as a common source epidemic. Other epidemics spread from person to person contact and are known as a propagated epidemic (such as the common cold). Was the disease in this activity a common source or propagated epidemic? How do you know?

   This was a propagated epidemic because it was spread from person to person, rather than from a central source.

3. The spread of disease in our simulation was very rapid. Many people were infected in a few minutes. In real life, infections usually do not spread as rapidly. Why is the spread of infection slower in reality?

   Even with contact, you may not always transmit enough germs to start an infection every time. Also, if a person has contracted a pathogen in the past, their body will have an immunity to that particular pathogen and they may not become infected. Good hygiene, like hand washing, can also reduce the likelihood that a person will get sick after contact with an infected person.

4. The disease in this simulation was asymptomatic. All tubes looked the same throughout the activity and we couldn't tell who was infected (no one showed "symptoms" until the very end). What diseases might be similar to this?

   Any disease with a long incubation period (the time required for an infected person to show symptoms) could be represented by this simulation. An example is HIV. A person with HIV is capable of spreading the disease long before symptoms appear. In some diseases, like COVID-19, a significant portion of carriers can be completely asymptomatic.

5. Patient zero infected three people in the simulation. Epidemiologists calculate the **reproductive number (R_0)** of a new, contagious disease – that is, the average number that each infected person will go on to infect. In this simulation the R_0 is 3. The R_0 varies widely by disease outbreak. What do you think are some considerations for determining a disease's reproduction number?

There are several factors scientists take into account when calculating a new disease's R_0: length of time someone is infectious, contact rate (how many people that person might come in contact with), and how the disease is transmitted. Diseases with airborne transmission (like COVID-19) tend to have higher R_0 values than those transmitted through physical contact and bodily fluids.

6. Would infection spread faster or slower in areas that are densely populated? Why?

   In general, infection spreads faster in more crowded places because people tend to come in contact with others more often. In addition, infrastructure like sanitation may suffer in extremely densely populated areas, increasing the chances of contagion.

Part 2: The Spread of the Ebola Virus in Sierra Leone

Sierra Leone was one of the three hardest hit countries in the West African Ebola outbreak in 2014-2016. The other two most impacted countries were Guinea and Liberia, and all three experienced devastating loss of life during the two-year epidemic. While the Ebola virus had existed before, this was the largest outbreak of the disease since it was discovered in 1976.

Ebola is spread through bodily fluids or contact with an infected surface. A combination of factors, including limited public health services, cultural practices, and infection in densely population city centers contributed to the rapid spread of the disease.

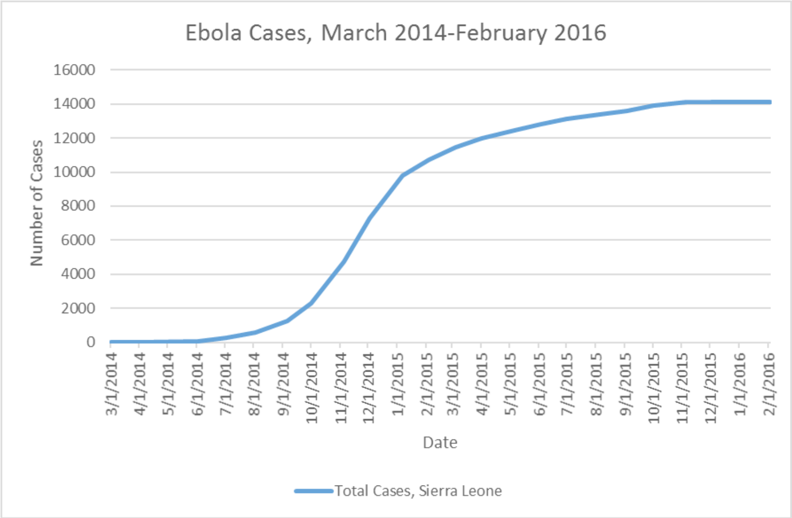
While scientists aren't completely certain of the source of the Ebola outbreak, they believe it was caused by a two-year old boy who was playing near a nest of infected bats in his village in Meliandou, Guinea. Many diseases emerge from animals. As population grows, people come into more frequent contact with natural ecosystems and the likelihood for animal-to-human disease transmission grows. Such zoonoses are on the rise.

procedure

1. Display a world map and have students locate Sierra Leone. Explain to students that beginning in 2014, there was an outbreak of the Ebola virus in Sierra Leone which killed nearly 4,000 people over a two-year period. Share with them the information in the Part 2 introduction above.

2. Using the data on their Worksheets, ask students to graph the transmission of the Ebola virus in Sierra Leone.

Answer to Student Worksheet



discussion questions

1. Why does the graph level off at the end? What does this represent?

   The leveling off of the graph represents no new cases being reported. This means that disease has been contained and is no longer rapidly spreading. According to the World Health Organization, Sierra Leone was declared "Ebola free" on November 7, 2015. This means that no new cases were reported for 42 days.

2. What factors might help contain on outbreak and cause the leveling off to occur?

   Answers may include: knowledge of doctors and the public about how to prevent the spread of disease, a strong system for quarantining infected people so that they don't infect others, doctors who are trained in how to care for patients and who have equipment to protect themselves from infection, a vaccine being created, etc.

3. What kind of growth does the beginning of your graph represent? Why does this make sense?

   The beginning of the graph shows a sharp increase, representing exponential growth. This makes sense because the number of infected people, the "base" of the growth, was continually growing.

4. Past outbreaks of Ebola have been seen mostly in rural areas in equatorial Africa. However in the West African outbreak, the capital cities of Sierra Leone, Guinea, and Liberia were epicenters of transmission. How do you think this impacted the spread of the disease?

   The disease spread much more rapidly than in past outbreaks, in part because it reached dense urban centers where there was more contact between infected and healthy people.

5. Once people contract a virus, their body builds up an immunity, preventing them from becoming infected again in the future. The Ebola virus had never existed in West Africa before the outbreak began in 2014. How might this have impacted the spread of the disease?

No one in the area had an immunity to the disease, so everyone who was infected became sick. However, once the disease had been around for some time, those who survived the infection were able to care for the sick without becoming ill again. Eventually, this fact helped to contain the spread of the disease.

6. There were 11 cases of the Ebola virus confirmed in the United States, but the virus was quickly contained. Why do you think transmission of the disease never escalated in the U.S.?

   In the U.S., we have a very robust health care system. The infected people were quarantined in sterile facilities and health workers were trained in how to care for these patients without exposing themselves to infection.

7. What social and economic factors in West Africa do you think might have allowed the Ebola virus to spread so rapidly?

   All three hardest hit countries are very poor and have minimal public health infrastructure – fewer doctors, nurses, and hospital beds and less access to medical equipment. Sierra Leone, Liberia and Guinea have a ratio of 2-8 doctors per 100,000 people as compared to the U.S. ratio of 260 doctors to every 100,000 people.[1] In addition, all three countries had recently emerged from civil war leaving not only their health system in shambles, but also their communication and transportation systems. This made it hard to report cases, communicate about prevention, and transport infected people to hospitals. The cultural practice of personally caring for the ill and burying the dead were also big factors in the rapid spread of the disease.

Part 3: Averting the Next Pandemic

procedure

Go over the following information with students before they begin Part 3 of the Student Worksheet.

- **Pandemics** are diseases that spread widely through many countries, and sometimes worldwide. Most originate with zoonotic transmission (pathogens that originate in animals before spilling over to humans).
- Early pandemics include the Black Death (bubonic plague) in the 14th century and smallpox, which decimated Indigenous populations in the Americas when Europeans brought it there in the 15th and 16th centuries.
- The deadliest pandemic in modern history was the Spanish flu (1918-1920), which infected 500 million people (about one-third of the world's population at that time) with the H1N1 virus and killed 20-50 million.
- Most recent pandemics, such as HIV/AIDS, SARS, Swine Flu, and COVID-19, are caused by zoonotic viruses. In fact, 70 percent of the new diseases that have emerged in human beings in recent decades are of animal origin, and these diseases are emerging with greater frequency than at any other time in human history.

Answers to Student Worksheet:

1. Why are zoonotic diseases on the rise? List some of the drivers.

   Zoonotic diseases are on the rise largely because of how humans have changed the Earth's physical landscape over the past century. Most of these changes have reduced and/or fragmented wildlife habitat, pushing wildlife into closer proximity to human settlements and to livestock. According the UN Environment Program, the seven drivers of zoonotic pandemics include: agricultural expansion and intensification, over-exploitation of wildlife, urbanization and industry, demand for animal protein, climate change, food supply chains, and global travel and transport.

2. Why has global land use accelerated over the past 100 years?

   Over the past 100 years, human population has quadrupled from 2 billion to 8 billion people. This growing population has required more land for agriculture, residential and industrial expansion, and a host of natural resources (timber, minerals, fuel, etc.). In addition to crops for human consumption, much of our agricultural land is used for grazing livestock and for growing crops to feed farm-raised livestock.

3. How were the wars in West Africa in the 1990s linked to the Ebola outbreak there in 2014-2016?

   Refugees leaving war-torn towns settled in forested areas and cleared land for agriculture and villages. This brought people into greater contact with the habitat for bats that carried the Ebola virus. The first person believed to be infected was a young child who was playing near a nest of infected bats.

4. How does the loss of biodiversity create new opportunities for diseases to spread? Provide an example.

   Some species are more effective carriers of certain pathogens, like viruses that can infect humans. The populations of these species can grow when they have fewer predators or other species competing for resources. One example is the spread of West Nile Virus in the U.S. Robins and crows are better carriers of the virus, and their populations have proliferated as other species' populations, like woodpeckers and rails, have been depleted, due to deforestation and habitat fragmentation. Another example in the U.S. is Lyme Disease, carried by white-footed mice and deer (and then the ticks that bite them). Deforestation and habitat fragmentation has depleted their predators (such as foxes), boosting the populations of Lyme-infested species that live close to people.

5. At the end of the Vox video, the narrator says that preventing future outbreaks might require us to "rethink our relationship with nature." What do you think he means by this? Provide examples of how changing this relationship could make pandemics less likely.

   Answers will vary. Students may refer to the drivers of pandemics (outlined in the InsideClimate News video). Rethinking our relationship with nature might encompass changes in how we eat and produce food, change the physical landscape and ecosystems for resources and technology, how our energy use affects the climate, and how our choices for meeting our needs and wants affect wildlife habitat and biodiversity.

assessment

Using their knowledge of how the Ebola virus spread in Sierra Leone, students list two limitations to the model that was used in Part 1 to show how disease spreads (e.g. the simulation doesn't account for immunity, there were no "symptoms" indicating that someone had the disease, everyone was *required* to interact with three people, etc.). Review Part 3 of the students' Worksheets to gauge their understanding of zoonoses.

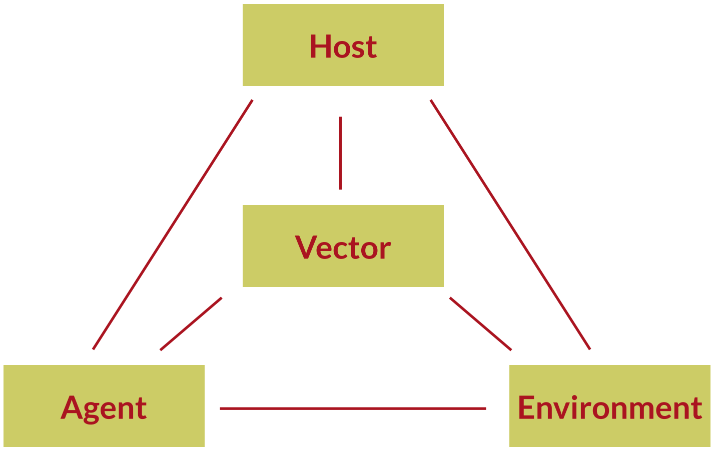
follow-up activities

1. Repeat the simulation but this time, have students add the phenolphthalein indicator between each round. This will make infected students appear "symptomatic." Discuss how the simulation changes once the disease is visible.

2. Students research the Zika outbreak of 2015-2016. They should determine:

   - Was the Zika outbreak a common source epidemic or a propagated epidemic?
   - What are the similarities and differences between the two viruses in terms of transmission, symptoms, and impact?
   - What are the similarities and differences between the two epidemics in terms of how cultural and economic factors impacted the spread of disease?

3. Introduce students to the Epidemiologic Triangle, a model that scientists use to understand the spread of infectious disease. The Triangle is made up of three parts: the agent, the host, and the environment. Epidemiologists attempt to break one side of the triangle in order to stop the spread of disease.



[1] World Health Organization. (2020). Global Health Observatory, Medical Doctors (per 10,000 population). https://www.who.int/data/gho/data/indicators/indicator-details/GHO/medical-doctors-(per-10-000-population)

CATCH IT IF YOU CAN | student worksheet

Name: ________________________________ **Date:** ______________

Part 1: Disease Detectives

1. How many students do you think will be infected at the end of this simulation?

   ____

2. Record the names of the three people you exchanged liquid with.

   1. ____

   2. ____

   3. ____

3. How many students in your class population were infected? ______________________

4. Using the data on the board, work in your small group to determine who you think patient zero was for this disease. Use the space below to show your work:

Part 2: The Spread of Ebola in Sierra Leone

1. Use the following data to graph the spread of the Ebola Virus from March 2014 through February 2016.

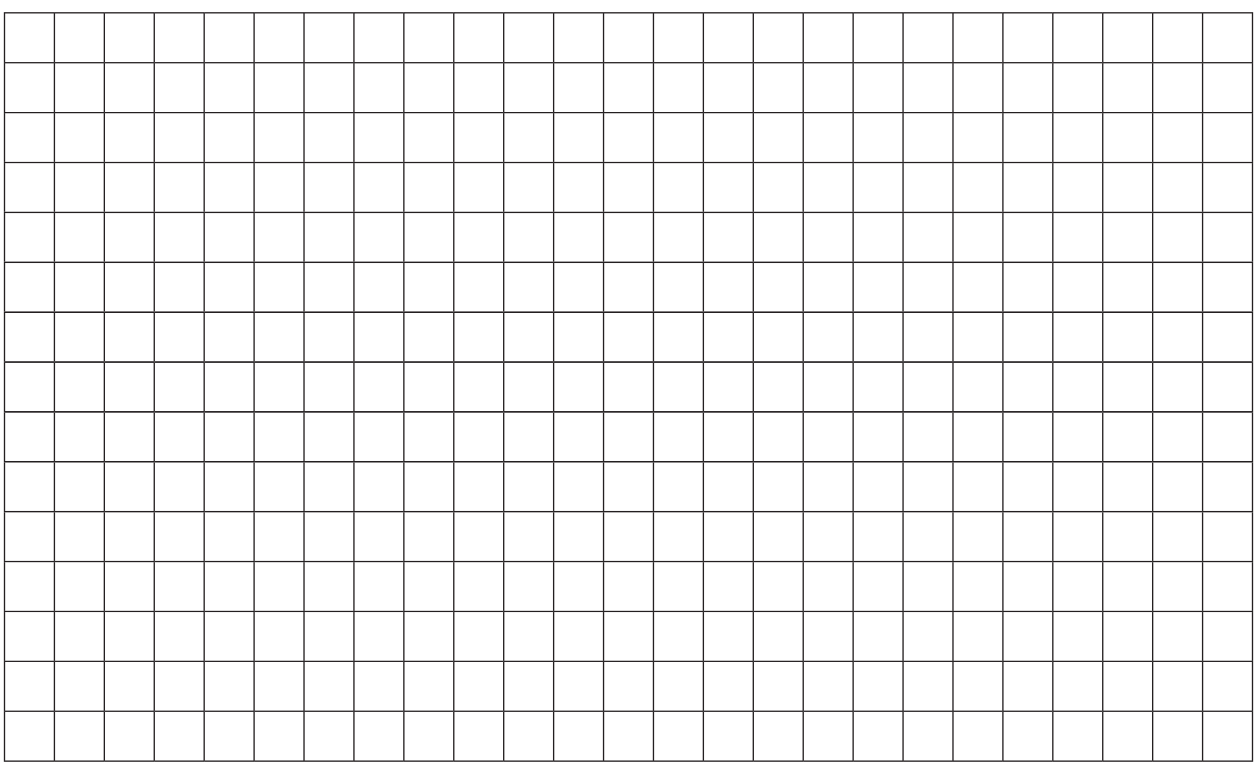
WHO report date	Total Cases, Sierra Leone
3/1/2014	0
4/1/2014	0
6/2/2014	50
7/2/2014	239
8/3/2014	574
9/6/2014	1,261
10/1/2014	2,304
11/5/2014	4,759
12/3/2014	7,312
1/7/2015	9,780
2/4/2015	10,740
3/4/2015	11,466

WHO report date	Total Cases, Sierra Leone
4/1/2015	11,974
5/6/2015	12,440
6/3/2015	12,827
7/1/2015	13,119
8/5/2015	13,406
9/3/2015	13,609
10/1/2015	13,911
11/5/2015	14,089
12/2/2015	14,122
1/6/2016	14,122
2/3/2016	14,124

Source: WHO

Ebola Cases, March 2014-February 2016

Number of Cases



Date

Part 3: Averting the Next Pandemic

Watch two short videos that explain the rise of zoonotic diseases and how human activities are contributing to this trend. Then answer the questions that follow.

"Zoonotic Diseases Like Covid-19 Are On the Rise" (4:35) from InsideClimate News (2020)
https://www.youtube.com/watch?v=pV2nFc2qUAA

"How humans are making pandemics more likely" (6:38) from Vox (2020)
https://www.youtube.com/watch?v=qp5CEclyk94

1. Why are zoonotic diseases on the rise? List some of the drivers.

2. Why has global land use accelerated over the past 100 years?

3. How were the wars in West Africa in the 1990s linked to the Ebola outbreak there in 2014-2016?

4. How does the loss of biodiversity create new opportunities for diseases to spread? Provide an example.

5. At the end of the Vox video, the narrator says that preventing future outbreak might require us to "rethink our relationship with nature." What do you think he means by this? Provide examples of how changing this relationship could make pandemics less likely.