Think Like a Scientist: Natural Selection in an Outbreak

hhmi | BioInteractive

Interactive Video Educator Materials

OVERVIEW

This interactive video explores how two scientists tracked the 2013 Ebola outbreak in West Africa. As students watch the video, they are prompted to answer questions that require them to predict steps in the research process and interpret data. Students also make connections to their own experiences and to other infectious diseases.

Videos can be used for teaching by stopping at appropriate time points and asking questions to cue student attention, encourage critical thinking, and make the students part of the story. This interactive video, which was created using BioInteractive's *Interactive Video Builder* tool, incorporates embedded questions at automatic pause points. Students can answer the questions directly in the interactive video or in the "Student Worksheet."

After finishing the video, students can review their answers and add to their explanations if their thinking has changed.

This document contains multiple resources for using the interactive video with students, including the following (use links to go directly to each section):

- teaching tips for how to use the video with students
- summaries and questions for each section of the video
- assessment guidance, including answers for the embedded questions

Additional information related to pedagogy and implementation can be found on this resource's webpage, including suggested audience, estimated time, and curriculum connections.

KEY CONCEPTS

- Microorganisms that cause infection, including viruses, accumulate mutations when they replicate. Some of these mutations can confer new abilities, like increased infectiveness or the ability to infect cells from a new species.
- The longer an outbreak lasts, the more a virus replicates, and the more opportunities it has to evolve new abilities.
- Microorganisms that cause infectious diseases do not discriminate between countries. For this reason, one of the ways to protect against infectious diseases is to ensure that everyone, in any country, has access to quality healthcare.
- Computational geneticists examine the genetic information of organisms across generations to determine how they evolved.

STUDENT LEARNING TARGETS

- Identify some of the factors that can fuel an infectious disease outbreak in humans.
- Explain how viruses evolve by natural selection during an epidemic.
- Describe how the evolution of viruses can be studied using their genetic information.
- Explain why outbreaks should be stopped as early as possible.

PRIOR KNOWLEDGE

Students should be familiar with:

- evolution by natural selection
- genetic material and impact of mutations
- the biology and replication of viruses

BACKGROUND

The 2013 Ebola outbreak in West Africa infected at least 28,000 people, making it the largest Ebola outbreak to date. In the years that it spread through the population, the virus mutated and became more infectious for humans.

In this case study, Lina Moses, a disease ecologist and epidemiologist, and Pardis Sabeti, a computational geneticist, share their experiences with the Ebola outbreak. Sabeti investigated the genetic changes and evolution of the virus across time. Moses investigated the ecological and societal factors that led to the spread of the infection. This case study helps students understand some of the factors that can cause an outbreak to occur and why it is important to curb the spread of infection as rapidly as possible.

TEACHING TIPS

- This video deals with a deadly infectious disease and includes images of graves. You may want students to know ahead of time that you will be covering this topic in class and encourage them to communicate with you if they have concerns about participating in this activity.
- Students can work on the questions individually or in small groups.
- There are multiple ways to show the interactive video and collect student responses.
  - You can project the interactive video to the whole class and have students answer questions in the "Student Worksheet," in a whole-class discussion, or by using polls.
  - Alternatively, students can work online and type responses into the answer boxes that appear during the interactive video.
- **The interactive video will not proceed until an answer is submitted.** You must type at least one letter into the answer box to continue.
  - If some questions do not fit the context of your course, you can direct students to skip those questions by typing "I am skipping this question." in the answer box.
- If students are answering questions within the interactive video, they will be prompted to submit their answers at the end of the video. They will have the opportunity to review and add further explanation to each answer if their thinking has changed.
  - Once they are done, they can download a report of their answers. The report can be saved as a PDF or printed. You can have students submit the PDF or screenshots/photos of the report.
- The original video without embedded questions is available under *Think Like a Scientist: Natural Selection in an Outbreak*.

SUMMARIES AND QUESTIONS

The interactive video has multiple sections. After each section, the video automatically pauses and prompts students to answer an **embedded question**. This document provides additional **extension questions** that do not appear in the video, which can be used for discussion prompts and written assessments.

Below are summaries of the sections and their associated embedded/extension questions. Answers for the embedded questions are provided in the "Assessment Guidance" section.

Introduction (0:00)

Summary

Before the video begins, students are asked what they already know about the topic of this video. This serves to activate prior knowledge related to the content and prepare students for learning.

Embedded Question

Think about when several of your friends, family members, or other people around you were infected with a virus. How did you reduce your chance of getting infected or spreading the virus?

Extension Questions

- What do you know about Ebola?
- Several types of health professionals work to control outbreaks of infectious diseases like Ebola. List some of the professionals who might be involved.

Section 1 (0:00–0:57)

Summary

This video starts by describing how the Ebola outbreak started in Guinea, in West Africa, in 2013. It introduces two scientists who were involved in investigating the outbreak: Lina Moses, a disease ecologist and epidemiologist, and Pardis Sabeti, a computational geneticist. These scientists express concern that the virus was changing during the outbreak, making it an even larger health threat. They also explain that the outbreak originated when a bat encountered a human and transmitted the Ebola virus.

Embedded Question

Most viruses evolved to infect one type of host (for example, bats or primates). What factors might make transmission across different types of hosts more likely? Explain your reasoning.

Extension Questions

- An infectious disease that is passed from animals to humans is called a **zoonotic disease**. The Centers for Disease Control and Prevention (CDC) estimates that 60% of infectious diseases are zoonotic diseases. Name some zoonotic diseases that affect people in your region and the animal species they come from.
- Bats are often responsible for transmitting zoonotic viruses to humans. Why do you think that bats are a common carrier of viruses that can infect humans?
- New infectious diseases are on the rise. Hypothesize why that might be the case.

Section 2 (0:58–1:44)

Summary

The 2013 Ebola outbreak rapidly spread to the neighboring countries of Liberia and Sierra Leone. By the end of the outbreak, at least 28,000 people had been infected with the virus, of which 11,000 died. The virus spreads when an individual comes into contact with the bodily fluids of an infected individual. An infected person may develop a high fever, vomiting, diarrhea, bleeding, and a drop in blood pressure. These symptoms can lead to shock, organ failure, and death.

Embedded Question

It is important to stop an outbreak as quickly as possible to reduce the chances a virus will change. How does a virus change? How does the length of an outbreak affect whether the virus will change?

Extension Questions

- Since Ebola transmission requires direct contact with an infected person's bodily fluids, what might be effective ways of controlling the spread of infection?
- What might make it difficult to implement these control measures in any country?

Section 3 (1:45–3:03)

Summary

Sabeti explains that she uses computers to track the genomes of viruses across generations during an outbreak to monitor their evolution. Each time a virus replicates, it copies its genome. During this process, changes (mutations) in the virus's genome occur, which may impact the virus's biology. If a mutation is beneficial and increases the likelihood that a virus will spread, the mutation will become more prevalent in the virus population.

Embedded Question

Pardis Sabeti is a computational geneticist who studies viral evolution. What do you think an experiment looks like in her field? In your response, discuss the data she uses and how she tests hypotheses and analyzes results.

Extension Questions

- Sabeti mentions that some virus mutations result in traits that are beneficial to the virus, and some are detrimental. What sorts of traits might be beneficial? Conversely, what sorts of traits might be detrimental?
- For a trait to evolve by natural selection, these criteria must be met: the trait must have a genetic basis (must be able to pass on from parent to offspring), there must be variation in the trait in the population, and the trait must affect the organism's ability to survive and reproduce. How do these three factors apply to the evolution of viruses during an outbreak?
- Consider the following scenario: Scientists are monitoring the spread of two different viruses among students in two different environments. Virus A spreads through respiratory droplets, and Virus B spreads through the fecal-oral route. The first environment is a school building with air conditioning and shared public bathrooms. The second environment is an outdoor pool where students walk around barefoot in bathing suits and have snacks and drinks. Which virus will spread more quickly in which environment?

Section 4 (3:04–4:48)

Summary

Moses describes some of the characteristics of countries where the virus spread more quickly. For example, Sierra Leone was recovering from a civil war that destroyed 85% of its health clinics, and it has a high-density population and excellent roads. Sabeti describes how the healthcare system in Sierra Leone was overwhelmed during the 2013 Ebola outbreak. Only one hospital in the region was adequately set up to handle infections like Ebola, and it was not big enough for the size of the outbreak.

Embedded Question

The two scientists featured in this film, Lina Moses and Pardis Sabeti, describe nonviral factors that contributed to the outbreak. List two nonviral factors and explain how they contributed to the spread of the virus.

Extension Questions

- When describing the factors that contributed to the outbreak, why did Moses mention that West African countries have excellent roads?
- Moses lists some societal and demographic factors that fueled the Ebola outbreak. What additional societal characteristics can you think of? What characteristics where you live might promote the spread of infection?
- What measures might help control virus spread and reduce the number of deaths in a country?

Section 5 (4:49–5:41)

Summary

Sabeti describes how there was a mutation early in the Ebola outbreak that allowed the virus to infect new human hosts more easily. She says that the more a virus is allowed to spread, the more likely such evolution will occur.

Embedded Question
Unlike the flu, Ebola cannot spread through the air. However, early in the outbreak, a mutation in the Ebola virus helped it spread in people. Propose two additional characteristics that make viruses more likely to spread and cause an outbreak.

Section 6 (5:42–end)

Summary
This final section has students reflect on what they have learned from engaging in this video case study.

Embedded Question
How has your understanding of how viruses evolve changed? Phrase your answer using the following format: I used to think _____, and now I think _____.

How could you apply what you have learned to your own behavior to avoid getting sick from a virus? What are additional actions you can do to help others globally and in your community?

Extension Questions
- Sabeti says "to not assume that we need to completely eradicate [infectious microorganisms], but just to understand how to control them and how to respond when something gets out of control." What are some strategies to do that?
- How has your thinking about what it means to be a scientist changed?

ASSESSMENT GUIDANCE

Sample responses to the embedded questions are provided below. They include a lot more detail than what is expected in students' answers. The additional detail is meant to provide additional information that you may want to discuss with students. For additional extension questions, which could be used for discussion prompts or written assessments, refer to the "Summaries and Questions" section.

1. Think about when several of your friends, family members, or other people around you were infected with a virus. How did you reduce your chance of getting infected or spreading the virus?
   This question is meant to solicit existing knowledge ahead of the video, and student responses will vary.

   Students may bring up personal stories of common viruses like SARS-CoV-2, influenza, or chicken pox. They may also be aware of how these viruses spread. (For example, flu and SARS-CoV-2 are transmitted via respiratory droplets, and chicken pox through direct contact with skin.) They may describe ways they avoid infection, like wearing a mask or isolating infected people.

2. Most viruses evolved to infect one type of host (for example, birds or primates). What factors might make transmission across different types of hosts more likely? Explain your reasoning.
   Student answers will vary. Some of the responses may include:
   - ***Frequent and close contact between the animal host and humans (particularly if it includes the possibility of mixing bodily fluids, such as during hunting) may provide more opportunities for a virus with a human-adapted mutation to replicate in a human.***
   - ***Some animal species are more closely related to humans than others, making transmission from those animal species to humans easier for the virus and therefore more likely. (For example, a virus that typically infects a chimp may be more likely to be passed to humans than a virus that infects fish, because the proteins that make up a human are more similar to those of a chimp than a fish.)***

- ***If the virus can reproduce in an animal reservoir species (in which the virus does not cause illness, allowing the virus population to be maintained), it could then spread to humans when opportunities arise.***

3. It is important to stop an outbreak as quickly as possible to reduce the chances that a virus will change. How does a virus change? How does the length of an outbreak affect whether the virus will change?
   Students' answers will vary depending on their knowledge about viruses. They may mention that a virus changes as it spreads and replicates. Some students may mention that during replication, viruses may acquire changes to their genetic information (genomes). The longer an outbreak lasts, the more viruses will continue to replicate and possibly acquire changes in their genomes. Some of these changes may make the virus more infectious and/or deadly, escalating the outbreak.

4. Pardis Sabeti is a computational geneticist who studies viral evolution. What do you think an experiment looks like in her field? In your response, discuss the data she uses and how she tests hypotheses and analyzes results.
   Student answers will vary, as they are being asked to guess based on the information provided so far.

   Since Sabeti is a computational geneticist who studies viral evolution, the data that she uses in her studies are viral genomes (or segments of them). To track the evolution of a virus over the course of an outbreak, as described in this video, she collects samples from multiple patients over different locations and times of the outbreak. The samples could be from saliva, blood, or other body fluids.

   She uses the samples to isolate the virus and sequence its genome. Then, she uses a software program to compare the genetic sequences of the viruses she is analyzing. By comparing their gene sequences (in particular, their mutations), the computer program builds models of the likely evolution of the virus.

   Students can experience a simplified version of this type of analysis in the BioInteractive card activity "Ebola: Disease Detectives," in which they manipulate partial DNA sequences of Ebola viruses during the 2013 outbreak and try to piece together how the virus evolved over time using the principle of parsimony.

5. The two scientists featured in this film, Lina Moses and Pardis Sabeti, describe nonviral factors that contributed to the outbreak. List two nonviral factors and explain how they contributed to the spread of the virus.
   Some of the factors mentioned in the film include:
   - ***Not enough hospitals to take in patients. This means that family members must take care of patients, allowing the virus to spread to other people. In addition, infected individuals who do not have access to hospital-level care may be more likely to die.***
   - ***High population density and good roads. This allows people to move rapidly, making it more likely for the virus to spread across the population.***
   - ***Too many patients, which overwhelms the healthcare system.***

   Students may also suggest a lack of equipment or supplies, unclear communication from health officials, a shortage of medicines or vaccines, etc.

6. Unlike the flu, Ebola cannot spread through the air. However, early in the outbreak, a mutation in the Ebola virus helped it spread in people. Propose two additional characteristics that make viruses more likely to spread and cause an outbreak.
   This question prepares students for the next section of the video on viral evolution. Student answers will vary. Some of the responses may include:

- ***The ability to recognize, bind, and enter a target cell more easily***
- ***The ability to infect multiple types of cells and/or hosts***
- ***A route of transmission that is a good match for the virus's environment. For example:***
  - ***A virus that transmits via respiratory droplets is more easily spread in indoor, enclosed environments.***
  - ***A virus that is transmitted through the fecal-oral route is more easily spread in places like a daycare or places that have a contaminated water supply.***
  - ***A virus that transmits via sexual fluids is more easily spread in a place where there is no sex education.***
  - ***A virus with any route of transmission is more easily spread in a place that does not have access to protective and disinfectant supplies.***
- ***The ability to survive the elements outside the host's body (e.g., drying, UV radiation, heat)***

All the factors listed above result from the virus's proteins (encoded by its genetic information) and are therefore subject to mutations and natural selection.

7. How has your understanding of how viruses evolve over time changed? Phrase your answer using the following format: I used to think _____, and now I think _____.

   How could you apply what you have learned to your own behavior to avoid getting sick from a virus? What are additional actions you can take to help others globally and in your community?
   Student answers will vary. For example:

   - ***Students might have thought that their risk of being infected with a virus was based only on what individual precautions they took. After the case study, they should understand that community-level health can impact the likelihood of infections.***
   - ***Students might have thought that all viruses spread equally well. After the case study, they should understand that there are many factors that influence the spread of an outbreak, including transmission route, hosts, and environment.***
   - ***Students might have thought that viruses evolve to be more deadly. After the case study, they should understand that, ultimately, it is a virus's ability to spread (not kill) that is selected for.***

   Students could apply this knowledge in multiple ways:
   - ***They could monitor regional health news, to stay aware of when infection rates in the area are high.***
   - ***They could take infection precautions more frequently, such as wearing masks in high-risk environments and using condoms during sex.***
   - ***They could volunteer at community health clinics.***
   - ***They could advocate for supporting human health on a global scale.***

CREDITS

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