Solving the Mystery of an Outbreak Using the One Health Concept

ABSTRACT
Zoonotic diseases pass between humans and other animals and are a major global health challenge. Lyme disease, SARS, swine flu, and Ebola are all examples of diseases spilling over to humans from other animals. Students may hear about these outbreaks in the news but learn very little about them in the classroom. We describe an activity designed to teach high school or college students about zoonotic disease outbreaks. This case-based lesson also introduces how habitat disruption can lead to far-reaching impacts on livestock and humans, often indirectly. Collaborative problem solving is used to explore the One Health concept and a real-world spillover event involving Hendra virus. Active learning using a “jigsaw” format to model the value of multiple stakeholders engages students in tracing the path of transmission for a pathogen. The scenario and class activity demonstrate how scientists and health professionals routinely work together to figure out the chain of transmission for a novel pathogen and use this information to limit the spread of disease.

Key Words: epidemic; pathogens; One Health; outbreak; zoonosis; spillover; transmission.

Case-based problem solving fosters critical thinking, builds community in the classroom, and provides an opportunity to model the scientific process while also introducing or reinforcing fundamental scientific concepts. This is especially valuable in science, where lectures and passive learning can dominate the classroom experience. Using cases that are current and that highlight the nature of science is time-consuming and may require more specialized knowledge, which can limit regular implementation of this pedagogical approach in the classroom (Allchin, 2013). While the term zoonosis may be unfamiliar to students, recent outbreaks of Ebola and Zika viruses have been highlighted in the media and are likely to be familiar. Complex disease cases that are relevant to humans offer a strong tool for motivating curiosity. Host–pathogen interactions are some of the most fundamental and fascinating interactions in ecology and are used as model systems to understand core concepts in ecology and evolution, including coevolution, population genetics, and community ecology (DiBlasi et al., 2018; Phillips et al., 2018).

The term pathogen refers to biological agents that cause disease. Pathogens can be bacteria, viruses, fungi, or protists. Larger organisms such as helminths, ticks, and fleas are typically called parasites and are generally treated in a manner that is separate from approaches used to control bacteria and viruses. Ticks and fleas can also be vectors for bacteria and viruses, such as Yersinia pestis (a bacterium vectored by fleas that causes plague) and Powassan virus (vectored by ticks). Parasitism is one of three interactions collectively known as symbiotic associations, the other two being mutualism and commensalism. Parasites and pathogens are often ignored as teaching tools in high school classrooms and introductory college biology courses (AAAS, 2011), even though these topics are genuinely interesting to students because of the “gross” factor. Giant worms, parasitic wasps, and leeches evoke comparisons to movies and conjure images of dense tropical jungles. New and less familiar diseases are becoming a problem for humans residing in locations that may be distant from the origins of a pathogen because of globalization, habitat encroachment, and a changing climate (Jones et al., 2008; Thompson, 2013).

Zoonoses are diseases transmitted from other animals to humans and pose a threat to human health. Most emerging and reemerging zoonotic diseases have occurred recently (Jones et al., 2008), leading scientists to study reasons why. Climate change, deforestation, and new interactions among species are all known to be major drivers of the emergence of these diseases. Anthrax and Zika virus are zoonotic, as are Middle Eastern respiratory syndrome (MERS) and severe acute respiratory syndrome (SARS). Avian (H5N1/H7N9) and swine influenza (H1N1) have recently infected humans, resulting in large outbreaks. In fact, all human influenza viruses are zoonotic in origin. Some of the most virulent human pathogens are zoonotic, such as Ebola virus, Marburg virus, and rabies. Vector-borne diseases (e.g., Lyme disease and plague) can also spill over from other animals into humans. When an outbreak of unknown origin occurs, it is up to doctors, veterinarians, health officials, and epidemiologists to identify the pathogen and trace the path of transmission in order to protect public health by stopping the spread of disease. Teamwork is required to piece together the chain of transmission. Once this information is
available, mitigation strategies can be put into place by local, regional, and global health organizations (Jones et al., 2008).

The One Health concept represents an integrated approach to studying human, animal, and environmental health in an effort to identify and solve urgent and complex health issues. A major goal of the initiative is to prevent health issues from arising by promoting interdisciplinary collaborations at local, regional, national, and international scales. The collaborative movement aims to bring together individuals from all aspects of health and environmental sciences. Zoonotic diseases are at the forefront of the One Health mission because they span the human–animal interface and are affected by environmental issues, such as deforestation and climate change (Thompson, 2013). One Health involves the cooperation of doctors, veterinarians, wildlife biologists, farmers, land developers, policymakers, and many other stakeholders (Atlas et al., 2010). Teaching the One Health approach to high school and college students is essential for successfully ushering in the next generation of health professionals, scientists, and policymakers.

Here, we describe an activity that can be readily adapted for high school and college science classes. This activity uses zoonotic diseases as the basis of inquiry and investigation. After completing the activity, students will (1) understand symbiotic interactions, (2) understand pathogens and zoonotic diseases, (3) appreciate how globalization and habitat encroachment increase the risk for spillover events, (4) appreciate the value of collaboration and a multidisciplinary approach in investigating outbreaks, and (5) develop oral communication skills that are relevant to scientific collaboration. This low-cost activity requires minimal preparation and can be completed in one hour or extended over several. It can be done with several different zoonotic disease outbreak scenarios and is scalable so that these concepts can be taught not only to students, but to doctors, veterinarians, and policymakers.

**Materials**

- Introductory handouts to be completed prior to activity (Table 1)
- Any pre-reading material (see below for example)
- Cards for doctors, veterinarians, and wildlife biologists (Figure 1)
- A disease outbreak scenario (see below and Table 2)
- Follow-up discussion questions (Table 4)

**Before You Begin**

We suggest giving an introductory lecture or required reading on parasites, pathogens, zoonotic diseases, or emerging infectious diseases. Students can also define terms before the activity. A few example terms are listed in Table 1. Understanding these terms will help them better follow the activity and solve the mystery. An example of a pre-reading exercise is Wolfe et al. (2005), which gives details of emerging zoonotic diseases, including some of the causes. This may be more suited for college-level classes, but sections could be tailored to high school.

Another thing that will need to be prepared ahead of time is “profession cards” with instructions for the different groups. Example cards for the scenario described below are shown in Figure 1. These cards are to be handed out to the student groups. There are three different types of cards, one for each profession: doctors, veterinarians, and wildlife biologists. Cards for each profession will be used to guide the students through the activity. Each profession is

| Term              | Definition                                                                 |
|-------------------|-----------------------------------------------------------------------------|
| Zoonosis          | A disease that is transmitted between animals and humans                      |
| Spillover event   | The process of a disease being transmitted to a novel species                 |
| One Health        | The integrated approach to understanding infectious diseases by focusing on the health of humans, animals, and the environment |
| Virus             | An infective agent consisting of genetic material in a protein coat; can multiply only within the cells of a host |
| Bacteria          | unicellular prokaryotes that have the potential to cause disease and have no organelles or nucleus |
| Symbiosis         | An interaction between two different species living in close physical association |
| Parasitism        | A symbiotic association in which one organism benefits and the other is harmed |
| Host              | An animal or plant on or in which a pathogen or parasite lives                |
| Pathogen          | An infectious agent that causes disease                                       |
| Disease           | An abnormal condition that can be caused by a pathogen                       |
| Reservoir host    | The host that is essential for maintaining the pathogen in nature and that usually does not show signs or symptoms of disease |
| Amplification host| A host in which infectious agents rapidly multiply to high levels and an important source of infection |
| Environmental change | Alterations in environmental conditions that can be caused by natural or human processes; for example, climate change |

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**Table 1. List of terms and definitions for students to define before the activity.**
Table 2. Examples of other zoonotic disease scenarios involving humans and other animals. Listed are the pathogens/parasites and the diseases that they cause, along with the specific outbreak that can be adapted into a scenario.

| Disease     | Type of Pathogen/Parasite | Scenario                                                                 |
|-------------|---------------------------|--------------------------------------------------------------------------|
| Lyme disease| Bacterium                 | Decrease in rodent diversity in the eastern U.S. causes an increase in Lyme disease in humans. This scenario can involve a discussion of environmental issues, since urbanization decreases rodent diversity (Ostfeld & Keesing, 2000). |
| Brucellosis | Bacterium                 | Outbreak in Texas in 2017. Several people became ill after drinking raw milk. Also shows the importance of pasteurization. |
| Swine flu   | Virus                     | Outbreak in 2009. Started in California. Found to be contracted from pigs. |
| SARS        | Virus                     | Outbreak in 2003 in Guangdong, China. Bats found to be reservoir hosts. It is transmitted to humans through civets in markets. |
| Trichinosis | Parasite (nematode)       | Outbreak in 1995 in Lebanon. People became infected after eating uncooked pork in a local dish (Haim et al., 1997). |
required to solve the mystery. Cards with different questions for Parts B and C will have to be created for other potential scenarios listed in Table 2.

**Example Scenario**

This scenario takes place in a small town named Hendra outside Brisbane, Australia. There are several horse farms in the area. One night, a female racehorse suddenly became ill at a stable. The stable hand and trainer attended to her, and at first the cause was not clear. The horse died a few days later, and a total of 18 horses at the farm also became ill. Twelve of these horses died soon after showing signs of disease. The other six horses were euthanized to prevent the spread of the disease. Everyone thought the outbreak was over. However, a week later, the trainer and the stable hand became sick. The trainer died of respiratory and renal failure. Health officials were notified: this is not just a pathogen that infects horses. Your job is to help prevent the spread of this disease by determining where the pathogen originated and how people and horses become infected.

**The Activity**

The goal of the activity is to determine the type of pathogen and the chain of transmission. The activity is conducted in a “jigsaw” format: first the students are split into groups in which they become “experts” on a given subject, and then they form new groups in which they use their newly acquired knowledge to help solve a problem: determining the chain of transmission.

The first groups should consist of three to five students or more, depending on the size of the class. Each group is randomly given a card with a profession on it: doctor, veterinarian, or wildlife biologist. In the first part of the activity, the students become “experts” on their profession and gather information they can contribute to their new groups in the second part. After listening to the instructor read the scenario, the students work together to answer the first set of questions (Parts A and B) on their cards. These questions are specific to each profession. The purpose of Part A is to get students thinking about their profession and how it can contribute to solving the mystery. Actively searching for this information on the Internet is not required. Students should be able to come up with a few ideas about how their given profession is important and the kind of information they would need to contribute to determine the chain of transmission. For Part B, students should pick three things that are related to their occupation and how the specific information would help solve the mystery. After Parts A and B are completed, students answer the questions in Part C. The answers in Part C provide clues to the first two parts, so we recommend putting the Part C questions on the back of the cards.

The answers to Part B for each profession are as follows. Students in the doctor group should pick (1) “A virus was found in sick people,” (2) “It affects people’s lungs and kidneys,” and (3) “People can be vaccinated against this virus.” The veterinarians should pick (1) “A vaccine can be made for horses,” (2) “It’s found in saliva and urine of horses,” and (3) “Hay is contaminated with the same virus.”

### Table 3. Answers to questions in Part C of the activity.

| Profession       | Question                                      | Answer                                                                 |
|------------------|-----------------------------------------------|------------------------------------------------------------------------|
| Doctors          | (1) Would antibiotics be an appropriate treatment? | No, because antibiotics are used to treat bacteria and this is caused by a virus. |
|                  | (2) How might you test for the virus in the tissues of humans? | Take samples of suspected tissues and look for virus DNA/RNA. |
|                  | (3) What kinds of symptoms might people show for a pathogen that affects the lungs and kidneys? | Different color of urine, coughing, mucus, etc. |
| Veterinarians    | (1) Would antibiotics be an appropriate treatment? | No, because antibiotics are used to treat bacteria and this is caused by a virus. |
|                  | (2) In terms of transmission, what is the significance of finding the virus in hay and finding the virus in horse saliva? | Consuming hay is most likely how horses become infected. The saliva is important because that is how it can get transmitted to humans. |
| Wildlife biologists | (1) What is a reservoir host? | The host that is essential for maintaining the pathogen in nature and that usually does not show signs or symptoms of disease. |
|                  | (2) What is significant about a bat species testing positive for the pathogen and no other animal species? | This bat species is most likely the reservoir host for this virus. Other species in the area are probably not reservoir hosts. |
|                  | (3) In terms of transmission, why is finding the pathogen in bat urine important to this case? | Because this is how hay could become contaminated. Bats urinate on hay and then horses consume it. |
The wildlife biologists should pick (1) "Urine from several bats tested positive," (2) "46 species of wild animals tested negative," and (3) "One bat species tested positive." The answers to part C for each profession are listed in Table 3.

After the students answer the questions in their first groups, they form new groups. Each of the new groups should consist of at least one doctor, one veterinarian, and one wildlife biologist. These students will be the experts and contribute knowledge they acquired from their previous profession groups. (There can be more than one student per profession in the new groups if space is limited or for large class sizes.) The students will now determine the chain of transmission by using the clues and information they gathered throughout the activity. Once they have an answer, they can come up to the board and share it. Writing on the board can help determine if most groups got the correct answer. The chain of transmission and options for supplemental questions and discussion are presented below.

**Alternative Approach**

Another approach to the activity is to have three different outbreak scenarios prepared (scenario 1, scenario 2, and scenario 3). Each student is given a profession card (doctor, veterinarian, or wildlife biologist) for one of the scenarios. Students with the same profession and the same scenario (e.g., doctors, scenario 1) get into a group and answer Parts A and B on the cards. Then those groups split up and create new groups. The new groups are still part of the same scenario and have at least one student from each profession. These new groups figure out the chain of transmission and present their scenario and chain of transmission to the class. Students can draw their chain of transmission on the board or on a poster-sized piece of paper. Students will practice their public-speaking and presentation skills, while the class learns about various zoonotic disease outbreaks and how these diseases are transmitted.

**Discussion of Findings**

After the students share their results with the class, discussion of the activity begins. The chain of transmission is shown in Figure 2. During the 1994 outbreak, this pathogen was found to be a virus and was named Hendra virus after the Australian town. Bats of the genus Pteropus, commonly called flying foxes, are the reservoir hosts for the virus (Halpin et al., 2000) and pass the virus to horses when they urinate on hay or grass in a pasture. It should be noted that investigations into outbreaks and chains of transmission can take several years. The first Hendra virus outbreak occurred in 1994, but the paper incriminating bats as the reservoir host was not published until 2000.

Once a horse becomes infected, the virus rapidly proliferates within it, and the horse can then pass the virus to humans. When veterinarians, horse trainers, or stable hands work with sick horses, they are infected when coming into contact with their bodily fluids. Because this is a virus, a vaccine was able to be developed for horses. However, there is a lot of controversy surrounding the vaccine. This information can be obtained from a quick Internet search, and a discussion about this debate can be tailored for class discussion.

This Hendra virus scenario is an example of how the One Health approach can be used to understand the source of an outbreak and the chain of transmission. This virus likely spilled over to horses and humans because of bats coming into developed areas. This happens during periods of environmental change and periods of low food shortage. For example, deforestation can cause wildlife and domesticated animals to come into contact. This is the perfect opportunity for pathogen spillover. Thus, other stakeholders who

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**Hendra virus**

Family: Paramyxoviridae  
Genus: Henipavirus

![Diagram](image-url)

Figure 2. Answer to the mystery: chain of transmission. This disease was caused by Hendra virus. It is transmitted from bats (reservoir host) to horses (amplification host). Horses transmit the virus to humans. There are no records of human-to-human transmission.
Table 4. Supplemental questions for students after they determine the chain of transmission.

| Questions for high school students                                      |
|------------------------------------------------------------------------|
| (1) How would you treat a viral infection?                             |
| (2) How would you prevent this disease in the future?                  |

| Questions for college students                                         |
|-----------------------------------------------------------------------|
| (1) Using your cell phones or computers, figure out what this virus is called. |
| (2) Using your cell phones or computers, is there currently a vaccine for this virus? |
| (3) Is the vaccine being used in horses?                               |
| (4) How did habitat encroachment play a role in this outbreak?         |

| Open-ended discussion questions                                        |
|-----------------------------------------------------------------------|
| (1) What are ways to increase the effectiveness of identifying the pathogen and putting effective control measures in place in the future? |
| (2) Why do you think this virus spilled over into humans? (hint: think One Health) |
| (3) What other professionals would have helped with this outbreak?    |
| (4) Why is the One Health approach necessary for understanding and preventing zoonotic diseases? |
| (5) How do you think globalization influences the spread of zoonotic diseases? |

Students can help solve and prevent future outbreaks include ecologists, landowners and developers, and policymakers.

We list several questions and answers that may be applicable to high school and college students in Table 4. Some questions deal with specifics of this virus and the disease. Other questions are more open-ended and involve brainstorming and critical thinking. We also list other scenarios that can be adapted to this activity format in Table 2. These different scenarios can be chosen according to where the school is located. For example, Lyme disease can be used if students live in New England, and the swine flu scenario can be used in California, where the first case was reported. In addition, some of the scenarios involve other aspects of the disease. For instance, the brucellosis outbreak involved people drinking raw milk, and trichinosis was contracted by people eating uncooked pork in a local dish during Christmas and New Year’s celebrations.

Conclusions

This activity can be done in high school and college classrooms over one class period or several. It is inexpensive, requires minimal preparation time, and can be tailored to fit different diseases of interest. Collaboration is the future of science, and emerging infectious diseases represent a challenge too big for one person or profession. The One Health Initiative uses a collaborative approach to bring together health and environmental professionals to prevent, identify, and solve complex health issues. In addition to collaboration, students learn important concepts that are required in high school education.

This activity aligns with several Next Generation Science Standards for high school (e.g., HS-LS2-2,4,5,6; HS-ESS3-3,4,5,6). For example, it is a good fit with HS-LS2-6, which aims “to evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.” Students will learn that when environments are altered, interactions between humans, domestic animals, and wildlife can be directly affected, creating new ecosystems with new sets of “consequences.” In the Hendra outbreak, bats likely came into contact with horses because of habitat encroachment and disturbance (Jones et al., 2013), and it has been suggested that habitat loss and increased stress may increase transmission from bats to horses (Plowright et al., 2008). These kinds of unforeseen impacts of environmental change are rarely taught in classrooms. However, the economic costs of zoonotic diseases are in the billions. Global estimated direct costs of zoonotic outbreaks during 2000–2010 totaled $20 billion, with another $200 billion in indirect costs (World Bank, 2010).

Many college students taking biology classes are interested in human medicine, veterinary sciences, and wildlife biology. Learning how their future profession could contribute to the One Health Initiative is an important introduction to this collaborative movement and an ever-expanding network of professionals. Even students taking biology classes for non-science majors should be exposed to these concepts. They too will be affected by issues regarding human, animal, and environmental health in the context of emerging diseases. Future landowners, land developers, and policymakers who can make informed decisions with One Health in mind will be needed in an era of global change.

In addition to high school and college students, this activity can be used to teach and inform health officials around the world about the importance of One Health. This activity can be integrated into trainings on developing regional and global research networks and how scientific collaboration can be used in biosurveillance, pathogen detection, and pathogen characterization (Fair et al., 2016). Zoonotic diseases have increased in frequency and will continue to increase because of global change. Teaching students about One Health can provide these future professionals the knowledge that healthy people, healthy animals, and a healthy environment can reduce the threat of infectious diseases.
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