actionbioscience.org lesson

To accompany the interview with Stephen S. Morse, Ph.D.:
"Emerging and Reemerging Infectious Diseases: A Global Problem" (May 2004)
www.actionbioscience.org/newfrontiers/morse.html

The Cantankerous Pathogen (January 2005)

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Grades & Levels:

- **Handout 1:** high school (general–advanced)
- **Handout 2:** high school (advanced/AP)–undergraduate (year 1)

Time Recommendations:

- 1–2 class periods for article review and discussion questions
- 2 class periods for hand-washing lab
- 1 class period for epidemiology modeling activity
- up to 1 week for the advanced extension projects

NSES (USA) Content Standards, 9–12:

- NSES 1.2. Unifying Concepts and Processes: Evidence, models, and explanation
- NSES 2.1. Science as Inquiry: Abilities necessary to do scientific inquiry
- NSES 4.4. Life Science: Interdependence of organisms
- NSES 7.1. Science in Personal and Social Perspectives: Personal and community health
- NSES 7.4. Science in Personal and Social Perspectives: Environmental quality
- NSES 7.5. Science in Personal and Social Perspectives: Natural and human-induced hazards
- NSES 7.6. Science in Personal and Social Perspectives: Sci/tech in local, nat'l, and global challenges

Note: View the NSES content standards on this site to choose other curricular applications for additional activities at www.actionbioscience.org/educators/correlationcharts.html

Lesson Objectives: Students will…

- explore what factors influence the spread of infectious diseases
- explain how human manipulation of the environment affects the transmission of diseases
- describe what kinds of problems and decisions concerning infectious diseases are confronting both individual citizens and public officials in modern society

Key Words Include:
infectious disease, microbe, pathogen, virus, natural selection, drug resistance, biowarfare, epidemic, epidemiology, pandemic, antibiotic, vaccine, attenuation, HIV, SARS, influenza, malaria, AIDS, public health, population density

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Preparation

Article Discussion (for handouts 1 and 2): Several approaches are possible for using the Article Discussion questions on page 2:

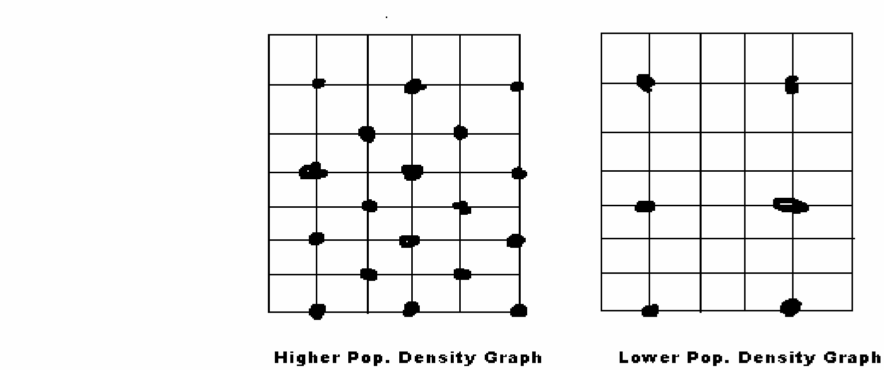
1. Have students read the article on their own, www.actionbioscience.org/newfrontiers/morse.html, after which the instructor can pose the questions in class for group discussion.

2. Have students read the article on their own, then divide into small groups for discussion; give a copy of the questions to each group.
3. Give students copies of the questions and have them do the reading and complete the content questions on their own, perhaps as a short-answer writing assignment. Have them discuss their answers and the more complex questions either as a large group or in small groups.

Student Handouts 1 and 2: Refer students to "useful links for student research" in the "Educator Resources" section at the end of the Morse article. These links help students with their activities and provide a source for research information.

Part A of Student Handout 1 involves growing bacteria on nutrient agar plates, so it is important for students to observe standard sterile protocol when working with these organisms. Doing so is particularly important with this activity because the overuse of antimicrobial substances in our society has already created resistant strains, some of which may appear on students' plates. For anyone unfamiliar with these methods, see Micklos and Freyer's *DNA Science: A First Course,* 2nd ed. (Cold Spring Harbor Laboratory Press, 2003). In addition to nutrient agar plates, you will need a supply of sterile cotton swabs and a collection of antimicrobial substances—or have your students bring in ones they are interested in testing. The activity is intended for groups of two to three students sharing a common set of supplies. Make sure students wash their hands thoroughly whenever they are done working with the nutrient agar plates.

Part A of Student Handout 2 requires that you prepare a set of "maps" of varying population densities for each group of students; you will need at least five different density "maps." The easiest way to do this is to use graph paper and make grids on the paper with different proportionate distances between marks on the grid (i.e., different densities; see below for an example). Then simply have the students assign the "person" at the center as the infected individual.



If you only have access to six-sided dice, you can use two pennies to simulate a four-sided die: toss the pennies one at a time and let two heads = north, two tails = south, 1st penny head/2nd penny tail = east, and 1st penny tail/2nd penny head = west. In addition to using dice, it is possible to use random number generators (one for 1–4, the other for 1–6) to generate the direction and distance moves.

One way to make this simulation even more accurate is to have students roll and move ALL the people on the graph during each turn, since in reality people would be moving around. It is usually far too time-consuming to have the students do this, but real epidemiological models take such movement into account, and including this feature in the simulation process makes a nice extra-credit question.

The Cantankerous Pathogen

For Educators: Article Discussion

About the interview with Stephen S. Morse, Ph.D.: “Emerging and Reemerging Infectious Diseases: A Global Problem” www.actionbioscience.org/newfrontiers/morse.html

Article Content Questions

1. What evidence is there that infectious diseases are on the rise?
2. What are “zoonoses” and what are some examples of them?
3. What kinds of ecological changes have introduced infectious diseases into the human population?
4. What is a pandemic and what causes one to happen?
5. What tropical disease might global warming reintroduce to the United States?
6. How much can infectious diseases potentially cost society?
7. What kinds of concerns are there about the introduction of bioengineered viruses?
8. What has been a long-standing problem about infectious diseases (particularly in industrialized nations)?

Article Extension Questions

1. How might people reduce the transmission of infectious diseases found in animals into the human population?
2. Besides viruses and bacteria, what other microbes and parasites have evolved resistance to treatment with antimicrobial medications?
3. What are some ways that medical and public health professionals might prevent the development and spread of resistant pathogens?
4. What measures could scientists and political leaders take to reduce the risk of biowarfare?
5. What steps could both individuals and public health officials take to curb the emergence of infectious diseases?

The Cantankerous Pathogen
Student Handout 1

A. Why Do We Need to Wash?

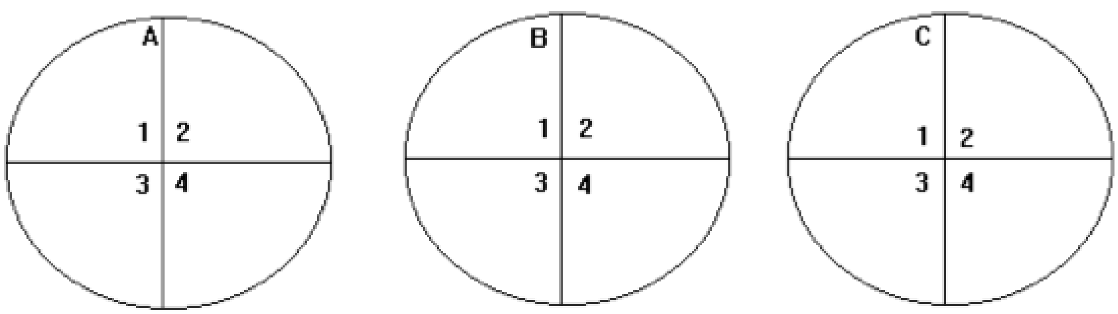
Bacteria are the single most common organisms on the face of the Earth. From the inside of our intestines to the boiling mud baths of Yellowstone National Park, they are everywhere around us and affect almost every aspect of our lives. Some consume the oil on our faces (and occasionally create pimples as a result), while others produce the yogurt and cheese we eat. In everything we do, bacteria are there, playing some kind of role.

One role they have in our lives, though, is a negative one. Many bacteria can and do cause infections and diseases. So a very important question we all need to know the answer to is how to kill those bacteria that can harm us. Even more importantly, do the methods we have already devised to do so really work? Does washing our hands really work? Do all those cleansers and sprays that are supposed to protect us from bacteria actually kill them?

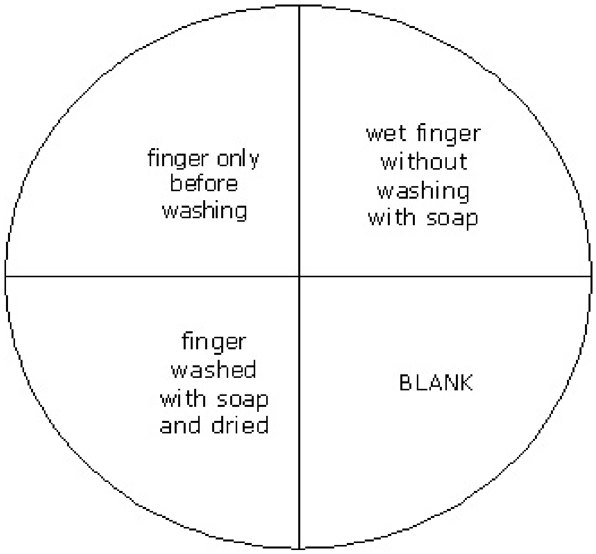
Brainstorm with your lab partners what kinds of substances you think will kill bacteria, and then follow the steps in this lab to help you determine if your hypotheses about combating bacteria are right or wrong.

Directions

1. Collect three petri dishes with nutrient agar from your teacher. Label them A, B, and C on the outside bottom of the plates, and draw quadrants on the bottoms, as shown below.



2. In plate A, you are going to examine the bacteria that live on your skin and the effects of washing. Using a clean, sterile swab, wipe your dry finger several times and gently rub the swab in quadrant 1, as shown below. Then wet your finger, swab it several times with a new swab, and rub that sample in quadrant 2. Finally, wash your finger with a non-antimicrobial soap (e.g., Ivory) and then swab it again several times and place the sample in quadrant 3. (See illustration on next page.)



3. In the remaining two plates, use cotton swabs to apply various substances you would like to test to see how effective they are at killing bacteria (e.g., rubbing alcohol, soap, antibiotic, disinfectant spray, etc.). Simply dip a swab in the test substance and gently wipe it in one of the quadrants. You have eight quadrants, so you can test eight substances, but be sure to label the plates and record what you tested for bacterial inhibition in each one. When you are finished applying the substances, allow your plates to sit for 7 minutes to absorb the substances.

4. Using clean swabs, dip them first in a beaker of distilled water and then gently rub the surface of one of your finger tips. Next, gently wipe the swab on one of the quadrants in plate B. Place the swab in the sterilizing solution provided by your teacher.

5. Repeat step 4 using different fingers and a different swab each time until all eight quadrants have samples on them.

6. Place all three of your petri plates in the incubator over night. The next day, count how many bacterial colonies are in each quadrant and record the results. DO NOT UNDER ANY CIRCUMSTANCES OPEN ANY OF YOUR PLATES!!!

7. Place ALL petri dishes in the biohazard disposal provided by your teacher.

Analysis and Conclusions

1. Look at petri dish A and answer the following questions:
   a. Was there any growth in section 1?
   b. Was there any growth in section 2?
   c. Was there any growth in section 3?
   d. Was there any growth in section 4?
   e. How were you able to tell which sections had growth and which sections did not?
   f. Which quadrant on plate A had more growth on it? Why do you think this was the case?
   g. What does the information of plate A tell you about normal human hygiene?
2. Now look at plates B and C. Which quadrants of your dishes grew bacteria and which ones didn't?

3. What does this tell you about the effectiveness of each of the antimicrobial substances?
4. What does this lab tell you about advertisements for soaps and cleaners?
5. With all these bacteria growing, why do you think people are not more sick or sick more often?
6. What does this lab tell you about the value of washing your hands regularly and using antimicrobial substances?
7. Based on what you found, who do you think should be required to wash their hands or use antimicrobial substances? Why?
8. Given the rise in bacteria that are resistant to drugs and other chemicals because of the misuse and overuse of antimicrobial substances, are there situations in which we should NOT use antimicrobial substances?
9. How could we decrease the exposure of bacteria and other microbes to antimicrobial soaps while stopping or slowing the spread of disease at the same time?

B. Tuberculosis Essay: A Case Study in Emerging Drug Resistance

Reread Morse's article and then do additional research on the rise of antibiotic-resistant bacteria, making sure to learn the answers to the following questions:

- What are antibiotics and how do they work?
- How have bacteria changed in response to our use of antibiotics to treat diseases?
- What kinds of misuses of antibiotics have led to the increase in the number of drug-resistant bacteria?
- Why can't drug companies develop new antibiotics as fast as bacteria can develop resistance to them?
- What is tuberculosis, and what is the history of its treatment?
- What types of antibiotics has tuberculosis become resistant to?
- What are the dangers facing hospitals and medical clinics because of the rise of drug-resistant strains of tuberculosis?

When you have found the answers to these questions, write a brief essay on what problems the medical community and public health officials face because of the resurgence of tuberculosis, and what steps you think they will have to take to address this growing health care crisis.

C. Public Health Awareness

As an extension of the lab about the effects of washing and the essay on drug-resistant bacteria, design an advertising campaign to increase public awareness of the value of simple hygiene and the dangers of misusing antimicrobial substances. Use the examples of existing resistance that you observed in the lab to help you create and draw story boards for the kinds of television ads you would like to run, and develop a brochure and poster public health officials could place in clinics and other community spaces to generate awareness.

The Cantankerous Pathogen
Student Handout 2

1. Modeling the Spread of Disease

Everyone gets sick. Whether it is the common cold or dramatically more serious illnesses like AIDS, some pathogenic organism has infected each of us at one point or another in our lives. But in most cases, the number of people who get sick from the same pathogen remains relatively low, and the worst that happens is that a few people (usually the very young and the very old) die because their immune systems are not able to fight off the disease and recover.

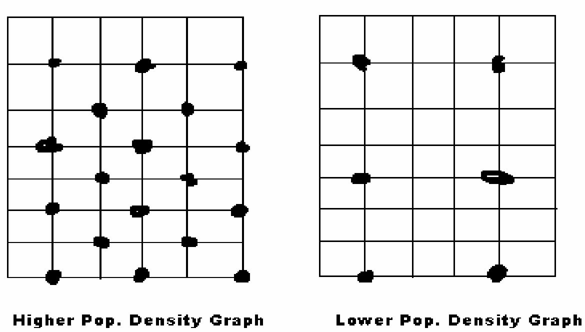
Occasionally, however, a pathogen arises that causes a huge number of people to become ill, and when that happens, scientists call this outbreak an **epidemic**. History is full of famous examples of great epidemics that killed literally millions of people, including the bubonic plague of medieval Europe and the influenza crisis of 1918. But even ordinary, seldom fatal diseases like the common cold can become epidemics; it is just a matter of having a large enough number of people become infected by the same thing at the same time.

The study of epidemics and how diseases spread is known as **epidemiology**, and in this assignment, you are going to do one of the most common activities of an epidemiologist: model the spread of a disease and determine how to advise the community affected by it. Specifically, you need to find out how the density of a population impacts the rate at which a disease can spread and then hypothesize how various medical tools, such as vaccination and antibiotic treatment, will affect this rate so that you can figure out what kinds of public healthy policies our society needs.

A. Creating a Model

Three factors influence the spread of any infectious disease: population density, percentage of population vaccinated, and **virulence**—that is, how successfully the pathogen can infect. Start by generating a graph of the effects of population density on disease in general, and then use it to make predictions about the influence of various factors on the spread of disease.

To create the graph, you will model the spread of a disease for a specific population density and then share your data with the other members of your class.



1. Each dot on your graph represents a human being; in this simulation, you will move the infected person according to the following rules:
   a. Roll the four-sided die and determine the direction a person moves according to the following number assignments:

      1 = north
      2 = east
      3 = south
      4 = west

   b. Next, role the six-sided die to determine how many squares the infected person moves in that direction, and trace that path with a drawn line.

2. Repeat steps a and b, keeping a tally of each time you roll the two dice. Continue rolling the two dice and moving the original infected person until she lands on the same intersection point containing an uninfected person. That second person now has the disease, as we are assuming 100% transmission.

3. Now, with two people having the disease, continue moving according to the rules, keeping a tally of the total number of combined rolls, until a total of four people have become infected (including the original person).

4. Next, calculate population density by counting the number of people per square decimeter on your graph. Share your data with the rest of the class: the original population density of your graph and the total tally of die tosses to infect three people.

5. With all the data from the class, generate a graph using population density as your independent variable and the number of combined rolls as your dependent variable.

If you now look at the graph you have made, you can see how it can be used to model the spread of disease. If the number of die tosses is equivalent to the passage of time (the more you did them, the longer it took for the disease to spread around), then your graph gives you information about the relationship between the amount of time a disease has been around versus how many people are in a population. In other words, you can see how rapidly a disease spreads in different concentrations of people and vice versa.

B. Using the Model

Using your graph, answer the following questions; be sure to use a fresh copy of your graph when answering requires adding lines to the original.

1. What is the effect of population density on the spread of infection, and what are the implications for outbreaks of disease in urban vs. rural areas?
2. How would the use of antibiotics in a population change the shape of your graph (draw a new, labeled line to answer)?
3. How would vaccinating the population change the shape of your graph for each of the following conditions (again, draw a new, labeled line on your graph to answer):
   a. 0% of the population successfully vaccinated?
   b. 25% of the population successfully vaccinated?
   c. 50% successfully vaccinated?
   d. 75% successfully vaccinated?
4. How would the virulence of a disease change the shape of your graph for each of the following levels (again, draw new lines on the graph):

   a. 25% of the time the virus infects successfully?
   b. 50% of the time?
   c. 75% of the time?
5. Use your answers to questions 3 and 4:
   a. What is the implication, for new epidemics, of microbes developing antibiotic resistance?
   b. What is the effect of vaccination on the spread of a disease, and does the entire population of an area need to be vaccinated to prevent the spread of a disease?
   c. What is the effect of the virulence of a pathogen on the likelihood of an epidemic?
6. The mode of pathogen transmission can also influence its rate of spread. How might the shape of your curve change for pathogens that are (draw new lines when appropriate):
   a. Airborne ?
   b. Transmitted by direct physical touch?
   c. Transmitted by shared contact (e.g., drinking from same glass, wearing same clothes, sitting in same seat, etc.)?
   d. Waterborne?
   e. Transmitted by contamination (e.g., food poisoning)?
7. From a public health standpoint, in what locations and in which disease situations should government officials focus their energies?
8. Are there certain situations for which it could be argued that vaccination should be mandatory?
9. How lethal and fast acting a given pathogen is also, obviously, influences heavily the rate at which a given disease spreads. AIDS and Ebola virus infections are both usually fatal, but the first can take decades to kill, whereas the other kills within hours. So how would population density affect the respective rates at which these two diseases would spread?
10. Bubonic plague, when left untreated, is one of the deadliest diseases ever to evolve. It devastated the populations of Europe and Asia in the 14th century, when it was very much an urban disease. But today the most common place for its recurrence in the United States is rural New Mexico and Arizona, one of the most sparsely populated parts of the world. What does this tell you about the influence of population density on the spread of certain diseases?

<u>Extra Credit:</u> If this simulation were rewritten to reflect more accurately the way the real world works, what single key instruction would you need to add to the steps of the simulation?

2. Mutations, Zoonoses, and Epidemics

Research how the genetic material of the influenza virus works and why it mutates more often than certain other viruses. Then research how various types of influenza found in ducks, pigs, and humans can interact with each other at the molecular level, and find out which of these organisms can spread influenza to humans, creating a "zoonosis." Finally, use this information to write a short essay explaining why almost all of the major influenza epidemics originate in Southeast Asian countries like China (hint: you may have to do further research about the living conditions in this part of the world).

3. Epidemic's Problem: A Case Study

A. Introduction

Everyone gets sick. Whether it is the common cold or dramatically more serious illnesses like AIDS, some pathogenic organism has infected each of us at one point or another in our lives. But in most cases, the number of people who get sick from the same pathogen remains relatively low, and the worst that happens is that a few people (usually the very young and the very old) die because their immune systems are not able to fight off the disease and recover.

Occasionally, however, a pathogen arises that causes a huge number of people to become ill, and when that happens, scientists call this outbreak an **epidemic**. History is full of such incidents, and one of the most famous occurred in 1918. World War I was finally drawing to a close, and although the United States had only been an active participant for a little over one year, the rest of the world had been involved in a very intensive and bloody struggle since 1914. Over the course of those four years there were nearly 9.2 million combat deaths, and 15 million more war-related deaths occurred when a strain of influenza appeared that had never been seen before. At least 25% of the American population got it in 1918 and about 500,000 people died. The estimates of the number of people worldwide who died that year are anywhere from 20 million to 100 million. Then, just as suddenly as it appeared, the flu was gone, and the organism that caused it seemed to disappear completely.

What made this particular flu so strange was that, besides its particularly high fatality rate and rapid spread, there was the fact that it infected and was particularly fatal for young adults 20–40 years old; many were orphaned as one or both parents died. Children under age 5 and the elderly aged 70–74 years were also most susceptible, but that is generally expected. In addition, there was a "coincidental" outbreak of a disease around the world at the same time in millions of pigs, thousands of which died of a new disease that appeared to be very similar to flu—it was called swine influenza or swine flu. Curiously, doctors later discovered that almost everyone who was alive in 1918 had antibodies in their blood to this swine flu but that anyone born after 1918 did not.

The 1918 influenza outbreak is considered the most significant epidemic since the Black Death, or bubonic plague. Were proportional numbers of people to contract and die from the disease today, the Centers for Disease Control and Prevention (CDC) estimates that an outbreak in the modern world would kill half a billion people.

B. The Case

In January of 1976, a flulike disease was infecting many of the soldiers at Fort Dix, New Jersey. Enough soldiers became sick that the base's doctor in charge of preventive medicine sent out throat washings from some of the sick soldiers for testing on January 29th. The results came back that most of those tested had an adenovirus; however, about seven of those tested did not have an adenovirus but showed evidence of having some unknown virus. Samples from these seven were sent to the CDC in Atlanta for further testing, and the results showed that antibodies to the swine flu virus also reacted with the unknown virus.

On Wednesday, February 4th, 18-year-old Private David Lewis went to sick call at Fort Dix with what appeared to be a bad case of the flu. Within a few hours, he was dead from the disease. Up to this time, he had been very healthy and in excellent physical condition. Samples from his throat were immediately sent for testing and showed that antibodies to the swine flu also reacted with the virus in Private Lewis' specimen. Interestingly enough, further investigation showed that none of the soldiers, including Private Lewis, whose samples had shown a reaction with antibodies to swine flu had been anywhere near any pigs.

At this point, only about 10 soldiers showed any clinical evidence of this unknown flu strain, and on February 12th, which was a Friday, all of the above information was given to Dr. David Sender, head of the CDC. He immediately called an emergency meeting of some of the top influenza experts in the United States for the next day to decide what to do.

At this meeting, the participants would confront three thorny problems:

- Was there any possibility of Private Lewis' death becoming the start of another flu pandemic (a worldwide epidemic) like the one in 1918?
- In 1976 (unlike in 1918), it was possible to make a vaccine for a particular strain of virus, but the process takes months and is very expensive, involving growing the virus in millions of chicken eggs. To produce vaccine in time for the flu season, which generally starts in late October, any immunization program would need to be very far along by then. And since there were other strains of the flu also known to be deadly, which flu strain should be chosen to make that year's vaccine "crop"?
- In addition, 1976 was a presidential election year, which also meant the entire House of Representatives and a third of the Senate were up for election as well. The election would take place right when this potential epidemic might be starting. Under these circumstances, what should the U.S. government's response be, given the hundreds of millions of tax dollars at stake?

C. The Challenge

You are a member of that emergency meeting in February 1976. The President of the United States will be reading your proposal. You have all the evidence they had at the time and a matter of hours to make quarantine and vaccination decisions.

1. Working with two other people, propose and write up a course of action for the U.S. government, being sure to support and explain your reasoning in detail.

2. Next, interview people who were 18 years old or older in 1976 and find out what they remember specifically about the swine flu epidemic that year and what they did about it. Critique your report in light of this new evidence, and write alterations (if any) to your proposed course of action accordingly. Be prepared to make your presentation to the entire class for discussion.