Epidemiology (updated 4/6/2020)

**Epidemiology** is the study of the source, spread, and control of disease in a population. **Etiology** is the source of a disease outbreak within a population. A variety of microorganisms can cause human disease. **Pathogenic organisms** are of five main types: viruses, bacteria, fungi, protozoa, and even worms. An **epidemic** is defined as an increase in the occurrence of a disease over a given time, within a specific area or affecting a particular population. A **pandemic** is a global outbreak of disease, such as is seen with COVID-19 (Coronavirus). Pandemics occur when a novel virus develops (see antigenic shift below), can infect people, and can spread between people easily. A highly infectious novel virus poses a significant risk because people won’t have a **pre-existing immunity** against it (their immune system has never been exposed to it, so they won’t have antibodies against it), so it can spread rapidly between people worldwide.

**What an epidemiologist does:**

The role of an **epidemiologist** is to collect pertinent information about an epidemic, such as the causative agent, number of cases, the location and history of the disease, and contributing factors. These details become valuable in controlling the progression of the epidemic – whether it involves development of a vaccine or other therapeutic agent, or the quarantine of infected individuals. Depending upon the **morbidity rate** or **mortality rate** of the disease, strict measures may have to be implemented to control it. US public health departments, such as the CDC and the **National Institutes of Health (NIH)**, are required to track and report many communicable diseases (e.g. avian flu, swine flu, cholera, hepatitis, measles, syphilis, SARS, Ebola, etc...). **Morbidity rate** is the percentage of people that become sick from a disease within a given population. Not everyone exposed to pathogens necessarily become ill. **Mortality rate** is the percentage of people that die from a disease within a given population. In general, morbidity rate is always much higher than mortality rate. For example the yearly morbidity rate for the common flu (influenza) in the United States ranges between 5 – 20%; whereas the mortality rate for the flu is much lower at 0.02%. Collectively, of all this epidemiological information is critical in guiding the decisions of health care officials, like the (CDC) in response to disease outbreak.

**Ways to study epidemiology:**

There are two ways to study epidemiology: **descriptive epidemiology** and **analytical epidemiology**. “**Descriptive epidemiology** can identify patterns among cases and in populations by time, place and person. From these observations, epidemiologists develop hypotheses about the causes of these patterns and about the factors that increase risk of disease. In other words, epidemiologists can use descriptive epidemiology to generate hypotheses, but only rarely to test those hypotheses.”¹ According to the Centers for Disease Control (CDC), there are the 5 “W’s” of descriptive epidemiology¹:

- What = health issue of concern
- Who = person
- Where = place
- When = time
- Why/how = causes, risk factors, modes of transmission

When investigators find that people having a certain characteristic are more likely than those without the characteristic to contract a disease, the characteristic is said to be associated with the disease. This characteristic might be a

1) **Demographic factor** (age, race, sex)
2) **Constitutional factor** (blood type, immune status, diabetic, or other underlying health issue)
3) **Behavioral factor** (smokes, or has a behavior that puts them at higher risk of contracting the disease
4) **Circumstantial factor** (having visited a place where a disease outbreak has occurred, having been in close proximity with an infected person, living near a toxic waste site, living next to a nuclear reactor, etc...)
The role of descriptive epidemiology is to identify factors associated with disease in order to help health officials appropriately target public health prevention and control activities that predispose people to becoming infected. It also guides additional research into the causes of disease. In this experiment, we will simulate an infectious epidemic in the class. Your objectives will be to (1) analyze the source and transmission of the epidemic and (2) predict its impact on the class based on trends in its progression.

**Analytical epidemiology** is how epidemiologists experimentally test hypotheses generated by descriptive epidemiology. Consider the following example of analytical epidemiology: “The key feature of analytic epidemiology is a comparison group. Consider a large outbreak of hepatitis A that occurred in Pennsylvania in 2003. Investigators found almost all of the case-patients had eaten at a particular restaurant during the 2–6 weeks (i.e., the typical incubation period for hepatitis A) before onset of illness. While the investigators were able to narrow down their hypotheses to the restaurant and were able to exclude the food preparers and servers as the source, they did not know which particular food may have been contaminated. The investigators asked the case-patients which restaurant foods they had eaten, but that only indicated which foods were popular. The investigators, therefore, also enrolled and interviewed a comparison or control group — a group of persons who had eaten at the restaurant during the same period but who did not get sick. Of 133 items on the restaurant’s menu, the most striking difference between the case and control groups was in the proportion that ate salsa (94% of case-patients ate, compared with 39% of controls). Further investigation of the ingredients in the salsa implicated green onions as the source of infection. Shortly thereafter, the Food and Drug Administration issued an advisory to the public about green onions and risk of hepatitis A. This action was in direct response to the convincing results of the analytic epidemiology, which compared the exposure history of case-patients with that of an appropriate comparison group.”

Another way to conduct analytical epidemiology is to perform observational and experimental studies of how a disease spreads and what types of exposure put people at risk of contracting the disease. The laboratory experiment outlined below is an example of an analytical epidemiological study, albeit with a very small sample size.

**Diseases can spread from non-human animals to humans:**

In some cases humans can contract a disease from an animal. There are two ways a disease-causing agent in an animal can be transmitted to humans: **direct transmission** or an **antigenic shift** in the disease organism. A **zoonotic disease** is an infectious disease caused by bacteria, viruses, or parasites that directly transmits from non-human animals to humans. Rabies, salmonella, Ebola, toxoplasmosis, ringworm, Creutzfeldt-Jakob disease, Bovine spongiform encephalopathy (or prion disease), and many others, are zoonotic diseases that can be transmitted to people directly from animals through close proximity or transmission of bodily fluids (such as a bite). Another way that people can contract a disease from an animal is when a disease-causing agent, usually a virus, in an animal host mutates by changing the antigens on its surface so that it can infect a new host, a human. This method of transmission of disease is called an **antigenic shift**. Antigenic shifts pose a high risk to people because they lack pre-existing immunity to it. This is how COVID-19 became a pandemic. In Wuhan, China, a person became infected with a coronavirus from an animal at a wet market. A **wet market** is where live (or dead) animals such as cats, dogs, fish, rabbits, pigs, snakes, chickens, primates, and other wildlife are sold for human consumption. Wet markets are named because of the constant washing of the market floors when they are covered in blood from the animals. Wet markets put people, and live and dead animals, in constant close contact, which makes it easy for viruses to undergo an antigenic shift from infecting animals to infecting humans. The virus can undergo an additional mutation to becoming infectious from person to person, and a pandemic can begin. It is also possible for people to transmit diseases to animals, called **anthropozoonosis**, but this type of transmission occurs very rarely.

**Laboratory Procedure**

1. Each student is given a plastic Falcon tube (labeled with a number) that is filled with 14 ml of a clear solution that represents his/her “bodily fluid”. Using a clean transfer pipette take half a dropper-full of your fluid and add it to a clean glass test tube (labeled 0) **BEFORE** you exchange fluids with another person. This will be your initial bodily fluid sample.

2. **When given the signal by the instructor**, each student will use a clean transfer pipette to exchange ‘fluids’ with someone at their table by putting a dropper-full of his/her own solution from their Falcon tube into the other person’s Falcon tube. Cap and mix your solution after the exchange. **Each person should only make one contact during this round and should record the name of the contact.** [CAUTION: Avoid contact of the solution with skin. If you do, rinse with water and wipe up any spills on table or floor.]

3. After this first exchange, add a half dropper-full of your fluid to a clean glass test tube (labeled #1).

4. **At the instructor’s signal**, each student should find a second contact, exchange one dropper-full of their Falcon tube solution to another student’s Falcon tube, and record the name of the contact. Cap and mix your solution, and then add half a dropper-full of that solution to a clean glass test tube labeled #2.

5. **At the instructor’s signal**, each student should find a third contact, exchange one dropper-full of their Falcon tube solution to another student’s Falcon tube, and record the name of the contact. Cap and mix your solution, and then add half a dropper-full of that solution to a clean glass test tube labeled #3.

6. **At the instructor’s signal**, perform a fourth exchange. Your falcon tube will now serve as tube #4.

7. After 4 rounds are completed, you will add a **diagnostic indicator** to all test tubes (glass tubes 0, 1, 2, &3 and the Falcon tube) to test for infection. The solutions of infected individuals will turn bright pink compared to the rest which remain yellowish/orange.

   **[The diagnostic indicator is phenol red, which will turn an alkaline solution (pH > 8.2) bright pink.]**

8. Pour out solutions in test tubes down sink, rinse well, and invert tubes upside down in rack to dry.

9. Working together **as a class**, try to analyze the spread of infection, identify the etiology, and answer the questions below.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Had Contact With:</th>
<th>Infected? Check the box:</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 = original body fluid</td>
<td></td>
<td>YES</td>
</tr>
<tr>
<td>1 = first exchange</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 = second exchange</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 = third exchange</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 = fourth exchange</td>
<td></td>
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</tbody>
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**Questions**

1. How many people were infected after
   a. round 1?
   b. round 2?
   c. round 3?
   d. round 4?
2. Can you predict the identity of the original infected individual?

Graph below the number of infected individuals per round, for all four rounds of contact.

3. Now use the data to predict the number of infected individuals after 5 rounds of contact. ________________

4. What is the morbidity rate for the class? ________________

**Theoretical Versus Actual Spread of Infectious Disease:**

The graph below describes the difference between theoretical spread of infectious disease and actual spread of infectious disease. In a population with very few infected individuals, the disease spreads rapidly to newly infected individuals. When the number of individuals is plotted against the number of interactions per individual, the result is an exponential growth curve. Essentially, the exponential growth curve predicts an infinite and “theoretical” increase in the rate of disease transmission due to an unlimited potential number of new people in a population that potentially can become infected. In reality however, the actual rate of disease transmission is limited by the number of newly infected individuals. To put it another way, disease transmission becomes limited because infected people cannot spread the disease to other people who are already infected. So in real world situations, the exponential curve gives way to a logistic growth curve, which becomes less steep as the number of infected increases. Examples of the two curves are shown below. Notice that both are very similar when the number of interactions per person is low, but as that number climbs, the logistic curve flattens away from the exponential.

Why would it be considered normal for the number of infected individuals to not reach its maximum (total number of individuals in population)? ________________________________