SIR Questions

**Development Questions:**

1. Why did we not include the new infections data set in the area plot?

**Analysis Questions:**

1. Compare the days when the maximum number of new infections occurred and when the maximum infected population size occurred. Explain the time lag between these events.
2. Make a record of the maximum number of infectives and the day on which this occurs. Then change the initial fraction of infectives to 0.01 and record the changes in these two quantities. Go back to an initial fraction of 0.001 and observe how long it takes for the population of infectives to increase by a factor of 10, so as to reach 0.01. Use the results to draw conclusions about how a different initial number of infectives changes the course of an epidemic.
3. COVID-19 has a basic reproductive number of approximately 5. Set R0 to 5 (with initial infective fraction at 0.001) and describe the changes in the epidemic progress. Pay attention to the key output quantities and also the speed with which the epidemic develops and resolves. (Note: Even with the same basic reproductive number the SIR model with a 5-day disease duration is not a good match for COVID-19.)
4. The duration of COVID-19 infectivity is approximately 10 days rather than 5. Change this parameter and describe the effect this has on the progress of the epidemic. It is helpful to think of the end of the epidemic as roughly the point when the number of infectives is down to what it was initially. (Note: We still are not modeling COVID-19, because the SIR model fails to account for a long incubation period and asymptomatic transmission.)
5. The Incan Empire had a population of over one million when it was conquered by 168 Spanish Conquistadores in 1525. The Spanish had gunpowder weapons and horses, but these advantages would not have been sufficient to defeat the huge Incan army. (It took about 2 minutes to reload a single-shot arquebus.) They also benefitted by joining forces with peoples subjugated by the Incas, but that would not have happened on its own. In *Guns, Germs, and Steel*, author Jared Diamond argues that the key factor in the Incan defeat was the European diseases the Spanish brought with them. To test this theory, set the basic reproductive number at 5 and the duration at 20, values that roughly match smallpox. Describe the effect introduction of smallpox into Incan civilization would have had, even without considering the death toll of the disease.
6. The most contagious human disease is thought to be measles, with a basic reproductive number of approximately 15. It has an infective period of about 8 days. Describe the progress of a measles outbreak caused by 1 initial infective in a population of 10000 that had not previously been exposed. This event would have happened numerous times in human history.
7. Do a more thorough study of the effect of the basic reproductive number on the total number of people who get a disease having an infectious period averaging 5 days.
   1. Set the duration to 5 days. Label two columns “R0” and “total I”. Enter the numbers 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 3.0, 3.5, 4.0, 4.5, and 5.0 in the R0 column. Fill in the total I column one value at a time using the corresponding value of R0. Use the percentage of people who are no longer susceptible at the end of the simulation as a measure of the total number infected.
   2. Get a graph of the results. The easiest way to do this is to select the two-column table of numbers, click Insert, and choose a scatter plot with a smooth curve. This combination of key strokes will be correctly interpreted by Excel, so you won’t have to change the data series.
   3. Describe and explain the results.
8. Isolation[[1]](#footnote-1) of the sick to combat infection dates back centuries, at least to the establishment of a leper colony in England in 1084. Set the initial fraction of infectives to 0.001 and the duration and basic reproductive number to 5.
   1. Compare the effects of isolation levels of 20%, 50%, and 80% with the base level of 0%.
   2. Make a table to record the total percentage of people who get infected for the isolation levels 0%, 10%, 20%, and up to 90%. Make a graph of the results. Explain what the graph tells us about the effectiveness of isolation (note that the results you see are specifically for a disease with a five-day duration and two days of infectivity before symptoms appear).
9. Vaccination grew out of a practice called “variolation,” the deliberate use of cowpox infection to confer immunity against smallpox, which was discovered independently in China in the 17th Century and by the English doctor Edward Jenner in 1796. Vaccination with killed pathogen began in 1798 and quickly replaced variolation. Set the initial fraction of infectives to 0.001 and make sure q is 0.
   1. Set the infectious duration and basic reproductive number to 5. Enter “% infected” in cell I1 and extend the light blue highlight to cells I1 and I2. Use references to cells B8 and B128 to enter a formula in cell I2 to calculate the percentage of the original susceptibles who are no longer susceptible at the end of the simulation. [Check using v=0.5. The percent infected should be 90.6.]
   2. Make a table to record the total percentage of eligible people who eventually get infected for the vaccination levels 0%, 10%, 20%, and up to 60% and 65%, 70%, and up to 90%. Make a graph of the results (see directions in question 7b).
   3. Do an internet search of the term “herd immunity.” Add what you learn through reading with what you learned by experiment to draw some conclusions about the effectiveness of vaccination at different levels.
   4. Compare the effectiveness of vaccination with that of isolation.
10. There is some confusion in public discourse about the concept of herd immunity. This question will clarify the concept.
    1. Set the initial infectives to 0.001, the initial immunity to 0.8, the duration to 5, and the basic reproductive number to 4.53. Record the initial and final percentage of susceptibles and the initial percentage of infectives.
    2. Change the initial immunity to 0 and record the initial and final percentages of susceptibles and the percentages of susceptibles and infectives on day 14.
    3. Explain herd immunity, focusing on what conditions need to be present to protect the susceptible population.

1. The word ``quarantine’’ is often used incorrectly for the practice of isolation. Quarantine is the practice of isolating individuals who are thought to have been exposed to a disease, not individuals who are showing symptoms. [↑](#footnote-ref-1)