COVID-19 Version 1.2 Experiments

**Experiment 1,** **Flattening the Curve:**

This experiment looks at the general effect of physical distancing practices on the spread of COVID-19. Physical distancing works by decreasing the numbers of individuals each person contacts in one day. Mask use works by decreasing the probability that a contact will result in a transmission. Both factors are built into the model as a contact-rate parameter *δ*: a value of 1 represents normal social contacts without protection and a value of 0 represents total isolation.

Copy the scenario data for this experiment from the table below or from the workbook Experiment Data sheet.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Scenario 1 | Scenario 2 | Scenario 3 |
| Contact factor | 1 | 0.5 | 0.33 |
| Fraction isolated (sympt) | 0.1 | 0.1 | 0.1 |
| Fraction isolated (asympt) | 0 | 0 | 0 |
| Doubling time | 3.5 | 3.5 | 3.5 |
| Initially immune | 0% | 0% | 0% |

1. For each of the scenarios in the experiment, identify model estimates of
   1. the maximum number of patients requiring hospitalization per hundred thousand people;
   2. the day on which the hospitalization requirement reaches its maximum;
   3. the day when the number of hospitalizations is less than 10, which can serve as a marker for the end of the outbreak;
   4. the percentage of the population that gets the disease during the simulation;
   5. the total population that dies during the simulation.
2. Use the answers to question 1 to contrast the outcomes when there is no physical distancing, when physical distancing cuts the infectivity in half, and when physical distancing cuts the infectivity to one third. Discuss the offsetting disadvantages of different amounts of physical distancing. Focus on the issues of hospital capacity, duration of the crisis, number of deaths, and vulnerability to another outbreak after the end of the scenario. Don’t focus on the specific numerical values, which depend too much on the estimates used for the parameter values. Instead, focus on the trends and the human impact.
3. The number of initial symptomatic patients in our standard scenario is large—one out of every thousand people. This might actually be correct for localities where there was a lot of community spread before the implementation of any public health measures. For those communities that had more warning and responded more quickly, change the value of I0 from 100 to 10. Describe the difference that this change makes. Focus on the general trend, not the specific results. This is easier to do if you keep your attention on the graphs rather than the numbers. Then change the value of I0 back to 100 for the other experiments!
4. In an interview on The Today Show on March 18, US Surgeon General Jerome Adams said, ``If we can get all America to pitch in for the next 15 days, we can flatten the curve.'' This suggests that a 15-day lockdown would have had a permanent benefit. To address this question, set the contact factor to 0 in Scenario 1. Go to the Scenario 1 sheet to see the value of I on day 15. Refer to question 3 to describe what the long-term impact of a 15-day lockdown would have been if not followed up by additional restrictions.

**Experiment 2, Blunting the Surge:**

This experiment looks at the issues being addressed by the health care systems of countries that were taken by surprise, like the United States, but instead took strong physical distancing action at roughly the point where 0.1% of the population was symptomatic. This is probably the scenario that was faced by cities such as Detroit, Denver, and Miami at the beginning of April. Of course the number of reported cases was far lower, but this was with very limited testing.

Copy the scenario data for this experiment from the table below or from the workbook Experiment Data sheet. Make sure that you have reset the value of I0 to 1000.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Scenario 1 | Scenario 2 | Scenario 3 |
| Contact factor | 0.3 | 0.25 | 0.20 |
| Fraction isolated (sympt) | 0.1 | 0.1 | 0.1 |
| Fraction isolated (asympt) | 0 | 0 | 0 |
| Doubling time | 3.5 | 3.5 | 3.5 |
| Initially immune | 0% | 0% | 0% |

1. Report the same data as in question 1.
2. Use the answers to question 5 to describe the effect of achieving lower contact factors in the three scenarios. Focus on the questions of whether the physical distancing was enough to protect the health care system and how long it takes to blunt the outbreak. Don’t focus on the specific numerical values, which depend too much on the estimates used for the parameter values. Instead, focus on the trends.
3. On April 1st, the head of the National Institute for Allergy and Infectious Diseases, Dr. Anthony Fauci, warned that even with aggressive measures, the total number of deaths from COVID-19 in the United States during the time required to control the initial outbreak could be 100,000 to 200,000. (In the event, the figure of 200,000 was reached in late September.) He also suggested that the most aggressive measures could reduce these numbers noticeably. Assess Dr. Fauci’s claims by modifying the scenarios to see what values of the contact factor give deaths in this range*.* Given that masks reduce transmission by about a factor of 4 and physical distancing by about a factor of 2, does the model support the claim that more aggressive measures would have significantly impacted the death rate?

**Experiment 3, Testing Rate:**

Like many countries, the United States initially had a shortage of testing supplies and adopted policies that reserved testing for the sickest of individuals. This experiment considers the impact of widespread availability of testing, as was the case in Taiwan and South Korea from the beginning, in comparison with limited testing as initially happened in Italy and the United States, and probably also in many countries less in the international news, such as Russia and India. Even in September, data from the Centers for Disease Control indicate that only about 15% of symptomatic cases in the United States have been confirmed by testing.

Copy the scenario data for this experiment from the table below or from the workbook Experiment Data sheet. Note that scenario 1 for this experiment is the base scenario of Experiment 2. It would be helpful to revisit the graphs for the Experiment 2 data right before entering the Experiment 3 data.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Scenario 1 | Scenario 2 | Scenario 3 |
| Contact factor | 0.3 | 0.3 | 0.3 |
| Fraction isolated (sympt) | 0.1 | 0.4 | 0.7 |
| Fraction isolated (asympt) | 0 | 0 | 0 |
| Doubling time | 3.5 | 3.5 | 3.5 |
| Initially immune | 0% | 0% | 0% |

1. Compare the output data and the graphs for the three scenarios, which span a wide range of values for the fraction of symptomatic people who are tested. What impact does our estimate of this parameter have on the outcomes? What do the results of this experiment suggest for public health policy?

**Experiment 4, Doubling Time:**

Of all the characteristics of an infectious disease, by far the most important for population dynamics is how rapidly the infection spreads in a population consisting of mostly susceptible people along with a few infectives. Experts think of growth rate in terms of the *basic reproductive number*, which represents the average number of disease transmissions from one infective patient to a population composed largely of susceptibles. Spread of a novel disease fits an exponential function in the early stages, so an equally useful way to think of the growth rate is in terms of the doubling time. The latter is easier to measure. If you aren’t doing much testing, then you can’t estimate the number of transmissions. You can’t measure the doubling time for infections either. But you *can* measure the doubling time for hospitalizations. In this experiment, we will see how much of a difference is made by changing the doubling time estimate. For reference, 3.5 days is a best estimate for doubling time, with 5 days as a best case scenario. As of September, the *worst case scenario* used in the prediction model of the Centers for Disease Control corresponds to a doubling time of about 5 days; in other words, the data used by the CDC is far too optimistic.

Copy the scenario data for this experiment from the table below or from the workbook Experiment Data sheet.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Scenario 1 | Scenario 2 | Scenario 3 |
| Contact factor | 0.3 | 0.3 | 0.3 |
| Fraction isolated (sympt) | 0.3 | 0.3 | 0.3 |
| Fraction isolated (asympt) | 0 | 0 | 0 |
| Doubling time | 3.5 | 4.25 | 5 |
| Initially immune | 0% | 0% | 0% |

1. Compare the output data and the graphs for the three scenarios, which span a wide range of values for doubling time. What impact does our estimate of this parameter have on the outcomes? What do the results of this experiment suggest for public health policy?

**Experiment 5, Herd Immunity:**

*Herd immunity* is a term used to indicate the protection given to susceptibles by having a large number of removed (recovered or vaccinated) individuals in the population. If most of the population is removed, then infectives encounter fewer susceptibles, so the disease spreads more slowly. In this scenario, we assume that there are no public policy or social restrictions that would slow the spread so that we can see how much better the public health situation would be if we could start with a known percentage of individuals in the removed class. This is not merely idle speculation, as the scenarios given here could well occur if the epidemic is brought under control by physical distancing and then all restrictions are removed, or if a vaccine is developed and used to remove large numbers of people from the at-risk category. A scenario such as this will not occur before testing is more widespread, so we use 0.7 for the fraction of symptomatics being tested.

Copy the scenario data for this experiment from the table below or from the workbook Experiment Data sheet.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Scenario 1 | Scenario 2 | Scenario 3 |
| Contact factor | 1 | 1 | 1 |
| Fraction isolated (sympt) | 0.3 | 0.3 | 0.3 |
| Fraction isolated (asympt) | 0 | 0 | 0 |
| Doubling time | 3.5 | 3.5 | 3.5 |
| Initially immune | 60% | 70% | 80% |

1. Record the total number of deaths for these scenarios. Discuss the results, focusing on the effect of different levels of herd immunity when there are no efforts to slow the spread. Keep in mind that this scenario occurs only after 50 to 70% of people have been infected, so the total numbers of deaths are in addition to those from an earlier scenario with a large number of deaths.
2. Discuss the claim made by Senator Rand Paul at a Senate hearing on September 22, 2020 that current case loads were low in New York because the state had suffered a sufficient number of cases to achieve herd immunity. At the time, experts estimated that 22% of New Yorkers were immune because of past infection. Assume testing is at 70%, which is a very optimistic estimate.
3. In early May, network news reported on a study showing that it would take 50-60% of people having acquired immunity to provide an adequate level of herd immunity to the rest of the population. (The source of this claim was unclear.) Explore this claim by setting the initial immunity to 60% and varying the amount of testing for symptomatic patients. Try setting the testing parameter to values from 0.1 to 0.8.
4. Herd immunity is a very subtle concept. Scenario 3 of the herd immunity experiment begins with 70% immune and ends with 27% still at risk, indicating that very few people got the disease. Change the initial immunity to 0 and leave everything else the same. What is the final percentage still at risk? The number of removed individuals reaches 70,000 on approximately day 72, corresponding to 70% immune. Explain why herd immunity did not protect the population.

**Experiment 6, Contact Tracing:**

A large number of public health authorities and epidemiologists in the United States and around the world have talked about the need to supplement testing with contact tracing. Some countries, such as Taiwan and South Korea, instituted an aggressive program of contact tracing early in the course of the pandemic. Some U.S. states began a contact tracing program in early May, but generally there has been minimal contact tracing in the United States. While a model that has no human social network or geographic variation cannot examine contact tracing directly, we can still examine it indirectly. The point of contact tracing is that we cannot test everyone who is symptom-free every few days, but we could specifically test symptom-free people we know have been exposed. If we identify 40% of asymptomatic infectives in this way, the result would be equivalent to testing 40% of *all* symptom-free people, but with far less actual testing. Thus, we can model contact tracing as an increase in the fraction of asymptomatic infectives who are tested—this is the parameter pCA.

Copy the scenario data for this experiment from the table below or from the workbook Experiment Data sheet. Note that Scenario 1 is the same as in Experiment 5.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Scenario 1 | Scenario 2 | Scenario 3 |
| Contact factor | 1 | 1 | 1 |
| Fraction isolated (sympt) | 0.7 | 0.7 | 0.7 |
| Fraction isolated (asympt) | 0 | 0.3 | 0.6 |
| Doubling time | 3.5 | 3.5 | 3.5 |
| Initially immune | 50% | 50% | 50% |

1. Describe the effect of increased contact tracing and testing of asymptomatics on the extent of herd immunity conferred by having 50% of the population initially immune, given that there is no physical distancing. Keep in mind that any deaths the model predicts are in addition to all of the deaths that occurred during the period prior to the given level of initial immunity.
2. Suppose we consider a death toll of 50,000 (after the initial wave of deaths) to be a minimally acceptable level of herd immunity. Determine how much initial immunity is necessary to achieve this result given asymptomatic testing rates of 0, 30%, and 60%. Report your results to the nearest 1%. Discuss the practicability of this target in terms of how we can get to the starting point.
3. Predict what would happen if we had extensive contact tracing, but without testing of asymptomatic people.

**Concluding Questions:**

1. Based on your findings, particularly with Experiment 6, where should we look for possible solutions to the Covid-19 crisis?
2. All of the results in these experiments are based on the assumptions in the model and the estimates of the parameters. If we want better predictions of what will happen, what do we need to do to make the model better?