

M104B Performance Task

Preventing Pandemics

The Modeling Cycle

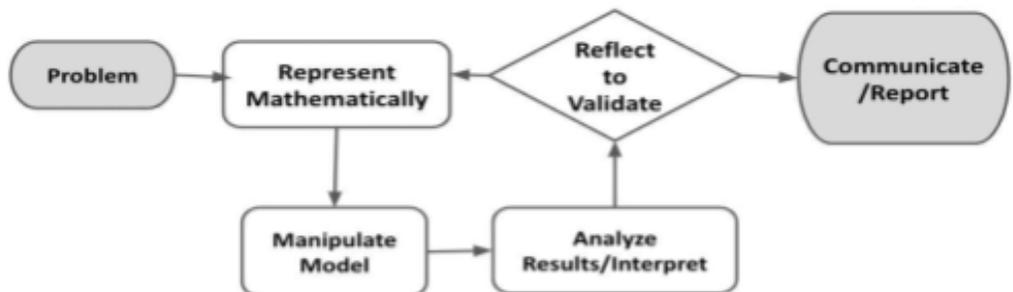
Our world has experienced many pandemics. We are currently trying to eradicate COVID-19. The first reported cases of COVID-19 happened on December 31, 2019, in Wuhan, China. Over the next few months, we would see COVID-19 grow to be a global pandemic. By March 2020, cases in the United States were on the rise. The rate of infection was fast and can be explained with mathematical models.

To follow the course of a disease, we need to know how many people, on average, are infected by an infected person if no precautions are taken. This basic **reproduction number**, or **basic reproduction rate**, is called R_0 .¹ R_0 is about 4 for COVID-19. If mutations occur that make the virus more contagious, the R_0 value increases accordingly. In past infectious outbreaks, the R_0 value for polio was between 10-12; for measles, it was between 12–18. In addition to R_0 , the time, D , during which the infected person is infectious also plays a role. For COVID-19, D is about 5 days. For COVID-19, on average, one infected person infects four other people within five days. Watch [Video 1](#) and [Video 2](#) to understand more about what exponential growth means in terms of COVID-19.

The fast rate of infection of COVID-19 prompted the federal and state governments to institute a shutdown of all non-essential activities. Government agencies suggested other preventative measures such as vaccinations, social distancing, masking, increased sanitation and hygiene and other strategies. These preventative measures were intended to “flatten the curve” of new COVID-19 cases.

In this task, you will consider the question, “**How does exponential growth and exponential decay explain the spread and slowdown of COVID-19?**” You will use the models and your takeaways from this task to act as an immunologist and craft a persuasive message the President will use in a press conference. The message should help educate the public about stopping the spread of infection and mitigating future infectious disease and virus outbreaks.

As mentioned already, these rates can be explained with mathematical models. Mathematical models are used to make sense of ideas and phenomena in our world. As illustrated in the image below, the modeling cycle is a process of collecting data about an idea or problem, creating models of that data, analyzing the story told by those models, and reporting the results to the appropriate audience. In this task, you will engage with this mathematical modeling cycle to analyze data, evaluate findings, and identify growth and decay of a global pandemic.



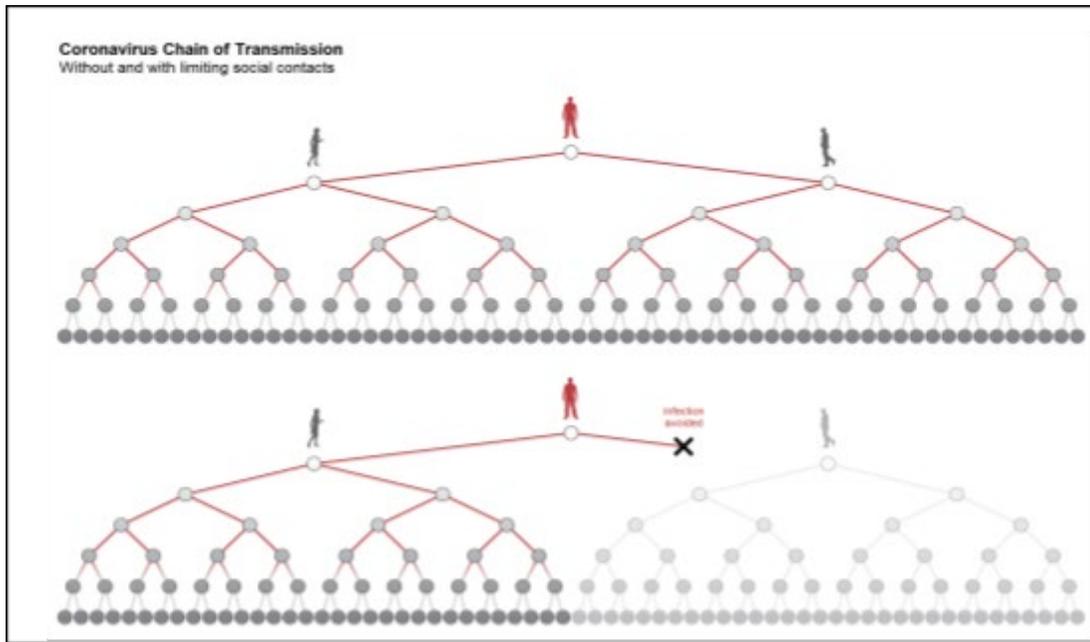
Source: Diagram of Modeling Process. From “Progressions for the Common Core State Standards for Mathematics.”

¹ <https://www.news-medical.net/health/What-is-R0.aspx>

Preventing Pandemics

Launch

As the pandemic grew, the numbers associated with the virus grew. Researchers had more data to work with to help identify things like chains of transmission, or how people were spreading the virus to others, and lenses through which to examine the data, like considering whether social contact was being limited or not and how that influenced the spread of the virus. The graphs below are the visual results of some of that data. Inspect the graphs and answer the questions that follow to demonstrate your mathematical, research-scientist thinking.



Source: Growth of COVID-19 Cases & Decay of COVID-19 Cases.

QUESTION 1

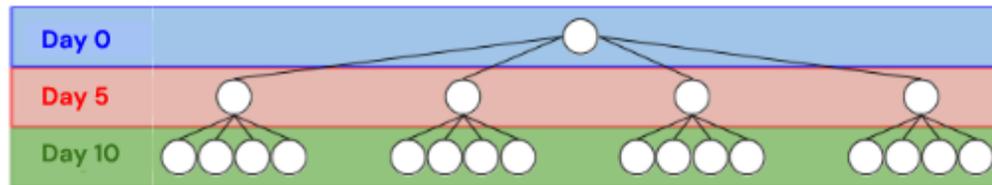


What's going on in the graphs above? Write a headline (think catchy Instagram post) that captures, in your own words, each graph's main idea.

QUESTION 2



Analyze this diagram. In your own words, what is it communicating?



Source: Day-by-Day Growth of COVID-19 Cases.

Problem, Formulate, and Represent Mathematically

In the **Problem, Formulate, and Represent Mathematically** sections, you will examine the growth rate of COVID-19, model its spread using a table, graph, and a formula, and apply that model to calculate and make predictions about new infections and the growth rate. The **Problem, Formulate, and Represent Mathematically Checklist** will be used to ensure you have the necessary components before moving on to the remaining parts of the task.

Problem

In dealing with a major worldwide pandemic, it is important to understand not only the number of people who are affected, but also the number of people who might become affected and by when. Understanding these things depends on determining **how** the numbers are changing mathematically, **when** they are changing, and **why** they are changing the way that they are, among other factors. The following steps will help you begin to identify this rate of growth and be on your way to understanding and helping solve problems like this in the future!

Formulate and Represent Mathematically

ACTION 1



Recall or review the information in the launch and in the graphs presented in the launch

Considerations:

→ **How**—*mathematically*—did the cases of COVID-19 grow before the preventative measures were put in place?

QUESTION 3



Complete the table below.

Time in Days:	0	5	10	20	30	x
Number of newly infected people	1					
Total number of people infected						

QUESTION 4



Create a **formula** to calculate the number of newly infected people for any number of days, x .

QUESTION 5



Create a graph to visually represent the growth of new COVID-19 cases over a 3-week period.

Use current population data to determine the number of days it would take for the number of newly infected people to equal the population of our —

- Class
- School
- State

Problem, Formulate, and Represent Mathematically Checklist

Requirement	Fulfilled?
I modeled the spread of COVID-19 for 0, 5, 10, 20, 30, and x days using a table.	<input type="checkbox"/>
I modeled the spread of COVID-19 over a 3-week period using a graph.	<input type="checkbox"/>
I calculated and explained when the mathematical model would reach the population of the state.	<input type="checkbox"/>
Teacher Consultation:	_____

Manipulate Model and Compute, Interpret, and Validate

In the **Manipulate Model and Compute, Interpret, and Validate** sections, you will consider how measures to limit the spread of the virus influence mathematical models of its growth. You will also use formulas and a digital modeling applet to visualize, interpret, and then validate these changes using mathematical terminology and referencing specific variables. The **Manipulate, Compute, Interpret, and Validate Checklist** will be used to ensure you have the necessary components before moving on to the final part of the task.

Manipulate Model and Compute

ACTION 2



Once researchers knew more about COVID-19, responsive measures were put into place to try to stop the spread of the virus as effectively and efficiently as possible. Ideally, effective measures would help slow or even stop the growth rate. Think about the information about growth rates you have learned so far and applied to your mathematical modeling. Now consider how your model might be manipulated to consider the mathematical effects of these measures on growth rate.

Measures like physical distancing and the use of face masks cause the infection to spread more slowly.

- This is expressed by the *effective reproduction number*, R_{eff} .
- Containment measures (*i.e.*, social distancing, masking) will reduce the R value.
- If the spread of infection is reduced by $x\%$, then the effective reproduction number

would be defined as $R_{eff} = \left(1 - \frac{x}{100}\right) \cdot R_0$.

- This means that if the spread of infection is reduced to 20%, then the effective reproduction number $R_{eff} = 3.2$.

Explore the GeoGebra applet to find out more about how to contain the spread of COVID-19. With the help of sliders, you can modify the effects of physical distancing and face masks. You can also change the time at which each or both measures are implemented. As you explore, think about how the usefulness of each of these preventive measures is represented numerically. You will find the applet here: <https://www.geogebra.org/m/qavutkx5>.

Interpret

QUESTION 6



What does "flattening the curve" mean in mathematical terms?

QUESTION 7



On the graph in the GeoGebra applet, what does "measures start at" mean?

QUESTION 8



What do the decimals of "physical distancing effectivity" and "face mask effectivity" mean?

Validate

QUESTION 9



What combination of masking and social distancing causes the curve to flatten after 5 days, 10 days, and 30 days? How many cases of infection are you preventing?

Manipulate Model and Compute, Interpret, and Validate Checklist

Requirement	Fulfilled?
Explain the concept of flattening the curve in accurate mathematical terms.	<input type="checkbox"/>
Accurately explain the three different variables from the GeoGebra graph.	<input type="checkbox"/>
Mathematically justify my combination of preventative measures after 5, 10, and 30 days.	
Accurately calculate the number of cases that have been prevented.	<input type="checkbox"/>
Teacher Consultation:	_____

Reflect and Report

In the **Reflect and Report** section, you will use the models you created and manipulated to reflect upon what you learned. You will use what you learned to craft messaging about how best to mitigate the spread of viruses and disease in the future with others. The **Reflect and Report Checklist** can be used to ensure you have the necessary components before finalizing your work on this task.

Reflect

QUESTION 10



What have you learned as a result of this task?

Considerations:

- How can studying a pandemic that is almost over lead to modeling and data that will serve in limiting the spread of future diseases?
- What is one efficient, concise message that can come from this study to help those in power better respond to a pandemic next time?

Report

ACTION 3



You are a world-renowned immunologist and have been given the role of Chief Medical Officer to the President of the United States.

Given your new role, how would you use your knowledge about the spread of infection, the data you have collected, and the impact of COVID-19 to provide guidance to the president on mitigating future infectious disease and virus outbreaks?

Write a concise, clear message that the President can use in a press conference. Make sure your message is:

- At least 1-2 paragraphs;
- Technically sound mathematically and conceptually yet understandable by the average household television audience; and
- Persuasive enough to convince the President and the audience that these measures are statistically sound and absolutely necessary.



Have a classmate try reading your message aloud; help each other with a peer review to refine your messages, making them as concise and clear as possible.

Reflect and Report Checklist

Requirement	Fulfilled?
I have reflected upon what I have learned in this task and how it can be used to help limit the spread of future infectious diseases.	<input type="checkbox"/>
I created a clear, concise message that is appropriate for the identified audience and platform and will be influential in effecting change.	<input type="checkbox"/>
Teacher Consultation:	_____

Extension

Students can further engage with the concepts from this task with the extension featured below.

1. Consider the following as it relates to what you have already learned about the mathematics behind the spread of infectious diseases and viruses:
 - a. The percentage of people who are immune (through vaccination or recovery from the virus), P_I in the total population also affects the R_{eff} value.
 - b. Taking this effect into account is more complicated because this group becomes larger over time.
 - c. At the beginning of the pandemic, P_I is zero, whereas at the end, when everybody is immune, the value is 100. The way in which P_I is used to calculate R_{eff} is the same as that for physical distancing or face masks: $R_{eff} = \left(1 - \frac{x}{100}\right) \cdot R_0$
2. Find the minimum value of P_I required to contain the spread of the virus (*i.e.*, to reduce the R value to 1.)
3. What would happen if, at the start, more than 1 person was infected?
4. Compare the percentage of the population that needs to be immunized to achieve herd immunity for the following illnesses:
 - a. COVID-19 ($R_0 = 4$)
 - b. Measles ($R_0 = 15$)
 - c. Polio ($R_0 = 10$)