Using Vaccines to Fight Outbreaks

Name: ______________________________

Date: ______________________________

Student worksheet — *Answer Key*

Part 1: What are vaccines and what do they do?

Watch these videos and answer questions 1-4.

- *Immune System, Part 2: Crash Course* video (https://youtu.be/2DFN4IBZ3rI)
- *How to Make a COVID-19 Vaccine* video (https://youtu.be/DcdZQHD4MJE)

1. List at least three ways the acquired immune system is different from the innate immune system.

   Specific *– The acquired immune system adapts to recognize and fight off specific pathogens. The innate immune system reacts generally to anything that seems foreign.*

   Memory *– The acquired immune system remembers a pathogen, while the innate immune system does not.*

   Systemic *– The acquired immune system fights throughout your whole body at once. The innate immune system has a localized reaction to anything that seems foreign.*

   Time *– The innate immune system acts quickly, while the adaptive immune system takes time to build its response.*

2. Explain how vaccines interact with the acquired immune system and how that benefits individuals.

   Vaccines trigger the acquired immune system and train it to recognize an antigen present on a specific pathogen. If that pathogen later infects the individual, their acquired immune system quickly recognizes the pathogen, using antibodies to the antigen, and attacks it. This leads to an elimination of the pathogen before a full infection can occur. In other words, the vaccine protects an individual from getting the disease caused by the pathogen.

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3. List one key similarity and one key difference between a vaccine and the pathogen it protects against.

   Similarity — *A vaccine physically resembles the pathogen it protects against. Some or all of the physical pathogen is present in the vaccine. The pathogen itself, either dead or attenuated, can be given as a vaccine. Alternatively, subunit vaccines take part of the pathogen and display an antigen that is on the pathogen. In all cases, a successful vaccine shares antigens with the pathogen and creates an adaptive immune response, which can recognize both the vaccine and the original pathogen.*

   Difference *— The pathogen can give you the disease, but the vaccine cannot. Sometimes there are mild side effects for a vaccine, like a fever or sore muscles, but people who get the vaccine do not get the disease caused by the pathogen.*

4. Describe what each phase of a vaccine trial accomplishes.

Phase 1 Tens of individuals	*Establishes whether the vaccine produces a strong immune response and whether there are serious side effects.*
Phase 2 Hundreds of individuals	*Starts establishing dose(s) and timing needed to produce a strong immune response. Determines if there are serious less-common side effects and/ or common mild side effects.*
Phase 3 Thousands of individuals	*Determines whether the vaccine is effective in lowering the infection rate and, if so, by how much. Establishes whether there are any rare, serious side effects and generates comprehensive data on common and rare, mild side effects. Finalizes most effective dose(s) and timing.*

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Part 2: How do vaccines affect outbreaks?

SimPandemic is an online simulator that lets you explore how various factors change a pandemic's evolution.

- Navigate to ***Using Vaccines to Fight Outbreaks* notebook** (https://sbgo.org/vaccinesimpact) at SimPandemic.
- Read through the material and study the graphs for scenarios 1-3. Use what you learn to answer questions 5-9.

5. Fill out *Table 1: Outcomes for Scenarios 1-3* based on the graphs and tables in scenarios 1-3. You will use this information to support your claims in other questions. (Note: SimPandemic reports economic outcomes of the pandemic, too. While this feature is not used in this lesson, you might find it interesting to take look at.)

Outcomes	Scenarios		
	1. COVID-19 Outbreak with No Interventions	**2. COVID-19 Introduced After a Strong Vaccination Campaign**	**3. Strong COVID-19 Vaccination Campaign During an Outbreak**
Total Infections per 100,000	*95,687*	*15*	*36,402*
Hospitalized (% of capacity)	*150-200%*	*<100%*	*100-150%*
Total Deaths Caused by Pandemic per 100,000	*277*	*0*	*114*
Total Number Immune per 100,000 at Day 365	*95,410*	*81,017*	*94,039*

Table 1: Outcomes for Scenarios 1-3

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6. In which scenario (1, 2, or 3) is someone most likely to get sick? In which scenario are they least likely to get sick? Support your claims using evidence from Table 1.

   Most likely to get sick – scenario 1. Highest total infections per 100,000.

   Least likely to get sick – scenario 2. Lowest total infections per 100,000.

7. In scenarios 2 and 3, the simulation settings are such that it takes 30 days to run the vaccination campaign and 14 days to develop immunity. Explain the logic behind these setting choices. *Hint*: there are two reasons, one is biological and one is logistical.

   Biological *– It takes time for a vaccine to engage the acquired immune system and form antibodies. Until antibodies are made, an individual is not immune and can still catch the disease.*

   Logistical *– Manufacturing, distributing, and administering a vaccine takes time and cannot be accomplished in a single day.*

8. In scenario 2, if you were to draw a line on the graph representing vaccinated individuals, describe where you would place it on the graph relative to the line representing immune individuals (orange line). Explain your logic.

   No vaccine is 100% effective. In this scenario, the vaccine was set to 90% effectiveness. This means that the line representing vaccinated individuals should have the same shape as the line representing immune individuals, but be slightly higher and peak around 90,000 individuals. Particularly astute students might also note that the line representing vaccinated individuals should be shifted over 14 days because it takes time for immunity to build after vaccination and in this scenario, that window of time was set to 14 days.

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9. How might an effective vaccine administered to a large percentage of the population during a pandemic change the pandemic's outcome? Support your claim(s) using evidence from Table 1.

   Students should recognize that this is a direct comparison between the outcomes of scenario 1 and scenario 3. The vaccination campaign during the outbreak diminishes the severity of the pandemic. Students should quote outcomes from Table 1 that show that despite hospitals being overwhelmed in both scenarios, the total number of infections and deaths is significantly lower in scenario 3. Particularly astute students might notice that the total number immune at the end of the simulation are similar, but that immunity in scenario 1 comes solely from COVID-19 recovery, while immunity in scenario 3 comes both from those who have recovered from COVID-19 and those who were successfully vaccinated.

Part 3: How do the parameters of a vaccination campaign change outcomes for individuals and populations?

In this part, you will use the Sandbox to run your own simulations with settings you put in. If you have questions about how to use the Sandbox, read the FAQ (**https://www.sciencebuddies.org/simpandemic/faq**). Make sure to save your work as you go (see FAQ).

- When you have completed all your simulations, paste the URL for them here for your teacher to see:

  ____

- Use what you learn from your own simulations to answer questions 10-12.

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10. Run your own scenarios to investigate the effects of two different vaccine variables on the outcomes of an outbreak that is underway: how effective the vaccine is and what percentage of the population gets vaccinated.

    To get started, press the Customize Settings button.

    - In Population Statistics, increase the "Number already infected (Adult)" from 1 to 10.
    - In Vaccine, set "Implement vaccine" to "Yes."
    - In Vaccine, set "Start day" to 45, "How long does it take to vaccinate everyone?" to 30, and "How long does it take for the vaccine to become effective?" to 14 days.
    - Experiment with different "Percentage vaccinated" and "Effectiveness" settings. A good starting range for percentage vaccinated is low ≤40% and high ≥75%. A good starting range for effectiveness is low ≤30% and high ≥80%.

Record your data in Table 2.

Settings	**Scenarios**			
	High Effectiveness, High % Vaccinated	High Effectiveness, Low % Vaccinated	Low Effectiveness, High % Vaccinated	Low Effectiveness, Low % Vaccinated
Effectiveness (%)	≥80%	≥80%	≤30%	≤30%
Percentage vaccinated (%)	≥75%	≥40%	≤75%	≤40%
Outcomes				
Total Infections per 100,000	Lowest			Highest
Hospitalized (% of capacity)				
Total Deaths Caused by Pandemic per 100,000	Lowest			Highest
Total Number Immune per 100,000 at Day 365				

Table 2: Outcomes for Custom Scenarios

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11. Based on your data, does it matter how effective a vaccine is? Support your claim using evidence.

    Yes, students should see that if you hold the percentage vaccinated steady, there are a lot more people who are infected and a lot more deaths if the vaccine has a low effectiveness setting. Students should reference specific numbers from their version of Table 2 in their answer.

12. Individuals who are too young or whose immune systems are too weak cannot be vaccinated. How important do you think it is on a population level to vaccinate everyone who can be vaccinated? Support your claim using evidence from the scenarios you ran and/or scenarios 1-3.

    Students should point out, using numerical examples from their simulations, that there is a trend in their data: when more people get vaccinated, fewer people become infected and the less overwhelmed the hospital system is. They should note that while we see immunity increase regardless, the cause of the immunity is different. Those who become immune from a vaccine are never infected and thus, never infect others (including those who cannot be vaccinated). In contrast, those who become immune from surviving COVID-19 may infect others (including those who cannot be vaccinated). In conclusion, the more people who are vaccinated, the fewer people who are left to infect those who cannot be vaccinated. Actions of individuals can affect the population as a whole.