TEACHER LESSON PLAN

Unit 2: Lesson 3 – Discovery and Development of Vaccines

LESSON QUESTIONS

- What is the purpose of a vaccine?
- What are the different ways in which vaccines are made?
- How do vaccines protect populations of people?

LESSON OBJECTIVES

- State the purpose of a vaccine.
- Give examples of different ways in which vaccines are made.
- Analyze how vaccines protect populations of people.

OVERVIEW

In this lesson, students investigate the production and effectiveness of vaccines. In the first activity, students watch video clips and explore online resources to identify various diseases for which vaccines are available and to distinguish the different ways in which vaccines are made. In the second activity, students use a computer model to simulate herd immunity. Students use statistics and graphs to analyze data and compare how different immunization rates confer varying degrees of protection on vaccinated and unvaccinated populations.

LENGTH

Two to three 45-minute sessions

GLOSSARY TERMS

cell culture adaptation, herd immunity, conjugate vaccine, immunity, passive immunity, inactivated vaccine, live weakened viral vaccine, plasmid, recombinant vaccine, toxin, toxoid vaccine, vaccine

STANDARDS

- **Next Generation Science Standards**
    - HS-LS1-2.4.1 Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions— including energy, matter, and information flows—within and between systems at different scales.

- HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

- HS-LS2-8 Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.

- HS-LS3-1 Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

- HS-LS4-3 Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.

- **Common Core State Standards**

  - RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

  - RST.11-12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context.

  - RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

  - WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
  - WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research.

  - WHST.11-12.6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

  - WHST.11-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

- HSS.IC.B Make inferences and justify conclusions from sample surveys, experiments, and observational studies.

- HSS.IC.A Understand and evaluate random processes underlying statistical experiments.

- HSS.ID.A Summarize, represent, and interpret data on a single count or measurement variable.

MATERIALS

- Student worksheet
- Computer with internet access
- For Activity 1, each group will need:
  - Types of Vaccines activity packet (includes Type of Vaccines Presentation Tables and related student sheets for inactivated, weakened virus, recombinant, conjugate or toxoid vaccines)
  - Mobile phone or tablet to download *Vaccines On the Go; What You Should Know* app (optional)
- For Activity 2, each group will need:
  - Understanding Herd (Community) Immunity sheet

BACKGROUND FOR TEACHER

What is a vaccine? Vaccines protect people from disease by preparing our immune systems to fight potential pathogens before we encounter them in the environment. Vaccines provide specific (adaptive) immunity without having to experience the harmful, and sometimes deadly, symptoms of disease. Scientists have successfully employed several approaches to making vaccines. Students investigate each approach and consider its advantages and disadvantages.

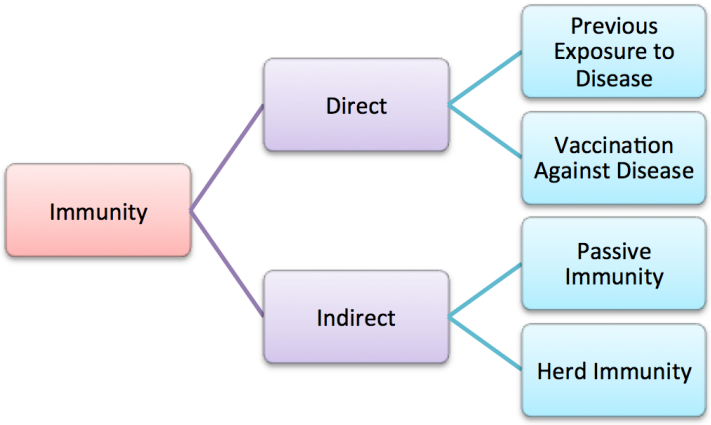
Vaccine Type	Method	Advantages	Disadvantages	Examples
Inactivated virus	Use killed viruses	Vaccine virus cannot cause disease	Immune response not as strong, so several doses usually needed	Polio shot, hepatitis A
Live, weakened virus	Use viruses grown repeatedly in the laboratory in a different cell type than they typically infect so they change and become weaker when given as a vaccine	Strong immune response Typically only one or two doses needed for immunity	May cause side effects due to low level viral replication	Measles, mumps, rubella, rotavirus, chickenpox

Recombinant	Gene that codes for surface protein is put into a plasmid in yeast or bacterial cells. Purified protein is used for the vaccine.	Since no genetic material is used in the vaccine it cannot cause disease	Technically complicated and expensive to produce	Hepatitis B, HPV
Conjugate	Isolate a protein from the pathogen and attach a "helper" protein to cause immune response	Cannot cause disease	Typically require multiple doses	pneumococcal, *Haemophilus influenzae* type b
Toxoid	Use inactive disease-causing toxins produced by the bacteria (called toxoids)	Cannot cause disease	Typically require multiple doses	Diphtheria, tetanus, pertussis

Herd (Community) Immunity

A key goal of immunization programs is to protect as many people as possible. Practitioners have long recognized that achieving total vaccination among the entire population is difficult, if not impossible. Some people may be unable to be vaccinated due to illness or a compromised immune system, while still others may choose not to vaccinate due to religious beliefs or skepticism of science. However, the principle of herd (or community) immunity relies on the fact that populations with higher rates of protected individuals are more protected. In such a population, a pathogen has less opportunity to move from person to person throughout the community. As students will see in the lesson, herd immunity is a function of probability. As the level of immunity in the population increases, everyone has a decreased chance of being infected. If a high enough proportion of the population is immunized, even unvaccinated people will be protected from the disease, simply because there are so few opportunities for the spread of infection. Herd immunity is, therefore, a type of indirect immunity.

People can be protected from diseases directly or indirectly:



Previous exposure to disease – A person's own immune system responds to an infection and acquires "memory" that affords protection if he or she is exposed to the same disease in the future. However, the person may have symptoms of the disease while acquiring this immunity.

Vaccination against disease – The vaccine stimulates the person's immune system. The immune system acquires memory that provides protection if exposed to the disease in the future. The benefit, compared with having the disease, is that the person will not experience the symptoms of the illness.

Passive immunity – When babies are born, they have some antibodies from their mothers, called maternal antibodies. These antibodies will protect the baby for a few weeks or months after birth. However once these antibodies are no longer present, the baby will become susceptible to infection. The infant vaccine schedule is set up so that a baby's immune system has time to build protective responses before a lack of maternal antibodies leaves them vulnerable.

Herd immunity – Herd (or community) immunity occurs when a certain percentage of people in a population are immune. The pathogen has less opportunity to infect the low numbers of susceptible people in the community. Vaccinated people protect the few who are not immunized by insulating them from disease. As the numbers of unvaccinated people rise, the effects of herd immunity weaken, setting the stage for outbreaks.

TEACHER NOTES

Even if students just completed studies of the immune system, they may not be aware of direct and indirect immunity, described in "background for teacher" section. In order to provide context for the materials covered in the next few lessons, you may want to introduce the diagram and discuss the ways immunity can be achieved prior to starting the lesson.

LESSON RESOURCES

- Lesson glossary
- Lesson diagram supplement (Diagrams Related to Herd Immunity)
- *Vaccines and Your Baby* (video series), Vaccine Education Center at Children's Hospital of Philadelphia, http://www.chop.edu/centers-programs/vaccine-education-center/video/vaccines-and-your-baby
- Making Vaccines: How are vaccines made?, Vaccine Education Center at Children's Hospital of Philadelphia, http://www.chop.edu/centers-programs/vaccine-education-center/making-vaccines/how-are-vaccines-made

- *Vaccines on the Go: What You Should Know* mobile app (available for free on iTunes and at the Google Play Store) http://www.chop.edu/centers-programs/parents-pack/vaccines-go-what-you-should-know

- Herd Immunity Simulation website:
  - http://www.software3d.com/Home/Vax/Immunity.php

  Additional Resources that may be helpful:
  - Vaccine Science: Vaccines and the Immune System – How do vaccines work?, Vaccine Education Center at Children's Hospital of Philadelphia, http://www.chop.edu/centers-programs/vaccine-education-center/vaccine-science/vaccines-and-immune-system
  - Vaccinated or Unvaccinated: What You Should Know, Vaccine Education Center at Children's Hospital of Philadelphia, https://media.chop.edu/data/files/pdfs/vaccine-education-center-vaccinated-unvaccinated.pdf
  - Herd Immunity and Vaccine Duration, Vaccine Update, November 2014, Vaccine Education Center at Children's Hospital of Philadelphia, http://www.chop.edu/news/herd-immunity-and-vaccine-duration
  - Vaccines, Herd Immunity, and Gummy Bears, Oh My! (video), ExSciEd, https://www.youtube.com/watch?v=CPcC4oGB_o8
  - Vaccines and Herd Immunity (video), Bozman Science, https://www.youtube.com/watch?v=kLUzwT9tWxY
  - What is Herd Immunity?, NOVA, http://www.pbs.org/wgbh/nova/body/herd-immunity.html

ENGAGE

1. Ask students to write anonymously on a slip of paper yes or no to the question: "Have you ever been vaccinated?" Students fold the paper and place it in a bowl or plastic bag.
2. Count up the number of slips that indicate yes and those that indicate no. Share this count with the class.
3. Initiate a brief class discussion about why people are or are not vaccinated.
4. Explain to students that they will learn how vaccines are made and how vaccines provide immunity.

EXPLORE

1. Students explore online sources and the lesson glossary to complete the vocabulary table in their worksheets.
2. Explain to students that their task is to research how a particular type of vaccine is made.

3. Propose a guiding question to students: *Why are different approaches needed to make vaccines for different illnesses?*
4. Working in small groups, students complete the activity Types of Vaccines (Activity 1). Each group is assigned or chooses one of the five different types of vaccines. If students are choosing the type of vaccine to research, ensure that each type of vaccine is chosen by at least one group.
5. Each group researches their chosen vaccine and completes the corresponding sheet (inactivated, weakened virus, recombinant, conjugate or toxoid).

EXPLAIN

1. Groups create a presentation to share their findings with the class. Guide students as needed to choose an appropriate presentation format. (To save time, a simple oral presentation would be appropriate.)
2. Each group presents its findings to the class.
3. During the presentations, students complete the Activity 1 Types of Vaccines Presentation Tables.
4. Lead a class discussion on the various approaches, reviewing vaccine types, method of production, advantages, disadvantages and examples.

ELABORATE

1. Explain to students that their task is to explore a computer simulation of herd immunity.
2. Propose a guiding question to students: *How does immunization rate affect the proportion of people who are protected?*
3. Working in small groups, students complete the Understanding Herd Immunity activity (Activity 2). Ensure students read the background passage that briefly explains the principles of herd immunity. If needed, allow students to explore additional resources to understand herd immunity.
4. Students work in pairs to conduct the simulation. Assign each pair an immunization rate from 0.1 to 0.9 to use in their simulation. Ensure each rate is assigned to at least one pair of students. If you have fewer than nine pairs of students, you can assign more than one rate to a pair.
5. Students conduct 15 trials for their assigned immunization rate, and then calculate the mean and standard deviation for four percentages displayed in the simulation: percent of the *total* population infected, percent of the *vaccinated* population infected, percent of the *unvaccinated* population infected and percent of those infected that had been vaccinated.
6. To demonstrate the effect of herd immunity, students will need to pool their data to create a class data set.
7. Create a collaborative spreadsheet (such as a Google Sheet) where students can add the data from their simulations. Student activity sheet refers to “pooling” data in a collaborative document in step 12.

8. Students add the means of the four percentages to the collaborative document. If more than one group is working on the same immunization rate, they should pool their data before calculating the mean.
9. Students work in their pairs or individually to graph the pooled data from the collaborative document.
10. Use your projector or smart board to how students the Figures 1 and 2 from the Diagrams Related to Herd Immunity supplemental document. The figures show sample data from the simulations.

EVALUATE

1. Students self-evaluate their responses to the Activity 1 questions.
2. Evaluate students based on their "Types of Vaccines" presentations in Activity 1. Use the Activity 1 rubric as a guide to the correct responses.
3. Assess students for Activity 2 based on their completion of the activity questions. Use the Activity 2 rubric as a guide to the correct responses.

RUBRIC - ACTIVITY 1: Types of Vaccines

Inactivated Virus Vaccines

2. a. US President Franklin D. Roosevelt was directly affected by the poliovirus.

2. b. Dr. Jonas Salk made the polio vaccine by first purifying the virus, and then using a chemical to completely kill the virus.

2. c. The last case of natural polio in the United States occurred in 1979.

4. a. List two benefits of using an inactivated virus to make a vaccine.

- 1. The vaccine cannot cause the disease it is preventing.
  2. The vaccine can be given to people with weakened immunity.

4. b. Name one disadvantage of using an inactivated virus to make a vaccine.

- Several doses of an inactivated virus vaccine are usually needed to achieve immunity.

4. c. Describe how inactivated virus vaccines are made.

- The chemical formaldehyde is used to kill the disease-causing virus.

4. d. List four vaccines made using inactivated viruses.

- Hepatitis A, influenza injection, polio injection, rabies

Weakened Virus Vaccines

2. a. Over time, the chickenpox virus grown in the laboratory became worse and worse at growing in children.

2. b. The chickenpox vaccine doesn't cause disease because the virus does not grow well in children, but it does provide long-lasting immunity.

4. a. List two benefits of using a weakened virus to make a vaccine.

- One or two doses can provide life-long immunity.

4. b. Name one disadvantage of using a weakened virus to make a vaccine.

- This type of vaccine cannot usually be given to people with weakened immunity.

4. c. Describe how weakened virus vaccines are made.

- The virus is grown repeatedly in cells in the laboratory, and becomes less able to grow in the type of cells it usually infects. (Called cell culture adaptation.)

4. d. List four vaccines made using weakened viruses.

- Chickenpox, influenza (nasal spray), measles, mumps, rubella, polio (oral), rotavirus, shingles

Recombinant Vaccines

2. a. The number of people in the United States infected with Hepatitis B is about one million.

2. b. People infected with Hepatitis B virus may die from liver cancer.

2. c. The Hepatitis B vaccine is made using only the surface protein of the virus.

4. a. List two benefits of using recombinant technology to make a vaccine.

- 1. These vaccines can be given to people with weakened immunity.
  2. These vaccines may give life-long immunity.

4. b. Describe one disadvantage of using recombinant technology to make a vaccine.

- Multiple doses of the vaccine are needed to provide life-long immunity.

4. c. Describe how recombinant vaccines are made.

- The gene for a viral surface protein is inserted into a circular piece of DNA, known as a plasmid, which enables the cell to produce copies of the desired protein.

4. d. List two vaccines made using recombinant technology.

- Hepatitis B, HPV

Toxoid Vaccines

2. a. DTaP is an acronym for which diseases?

i. diptheria
ii. tetanus
iii. pertussis

2. b. To make the DTaP vaccine, the bacterial toxins are purified, then treated with a chemical to make them harmless.

2. c. A toxin that has been made harmless is called a toxoid.

4. a. Name a benefit of using just part of a bacteria to make a vaccine.

- A toxoid vaccine can be given to people with weakened immune systems

4. b. Name one disadvantage of using just part of a bacteria to make a vaccine.

- Several doses of a toxoid vaccine are usually needed to achieve immunity.

4. c. Describe how toxoid vaccines are made.

- The toxins produced by the bacteria are chemically inactivated to create a toxoid to which the body will develop an immune response.

4. d. What is the maximum age at which DTaP should be given?

- Age 7.

4. e. What is the name of the immunization against diphtheria, tetanus and pertussis that can offer protection to older individuals?

- Tdap is a booster immunization for individuals at age 11 and older.

Conjugate Vaccines

2. a. A possible effect of meningitis is profound deafness.

2. b.The pneumococcal vaccine is made by stripping away a sugar coating covering the bacteria and attaching it to a harmless protein.

4. a. Name a benefit of using the outer coating of bacteria to make a vaccine.

- It can be given to people with weakened immunity.

4. b. Name one disadvantage of using the outer coating of bacteria to make a vaccine.

- Several doses are needed to provide immunity.

4. c. Describe how conjugate vaccines are made.

- Taking the sugar coating of the bacteria and attaching it to a harmless protein that allows the body to produce a stronger immune response.

RUBRIC – ACTIVITY 2: Understanding Herd (Community) Immunity

Activity 2 Questions

1. Explain the relationship between immunization rate and percent of population infected.

    - A higher immunization rate results in lower infection rate.

2. How does the percent of the unvaccinated population who are infected change as the immunization rate increases?

    - As the immunization rate increases, the percent of unvaccinated that become infected decreases (demonstration of herd immunity).

3. Is there a point in your data where the unvaccinated population seems to be protected from infection? Explain your answer.

    - Unvaccinated population may become protected from infection around 50% immunization rate, based on graph of percentage of unvaccinated population infected and immunization rate.

4. Predict what happens when the immunization rate is 0 and then 1.0. Explain your answer.
    - When the immunization rate is 0 all people will be infected because without vaccination the only direct protection is disease. When the immunization rate is 1.0, no one will be infected because everyone is protected.

5. Check your answer to #4 by running the simulation with the immunization rate at 0 and then 1.0. Did you predict the simulation result correctly? Explain the simulation result.
    - Answers will vary depending on answer to #4. Students should demonstrate that they understand how immunization rate determines the proportion of population protected and at risk of infection.