Unit 2: Lesson 3 – 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, 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:**
  - Activity worksheets
  - Computer with Internet access

BACKGROUND FOR TEACHER

What is a vaccine?

Vaccines protect people from disease. Vaccines prepare our immune systems to fight potential pathogens before we encounter them in the environment, giving us specific (adaptive) immunity without having to experience the harmful, and sometimes deadly, symptoms of disease.

Ways that vaccines are made

Scientists have successfully employed several approaches to making vaccines. Students investigate each approach and consider its advantages and disadvantages.

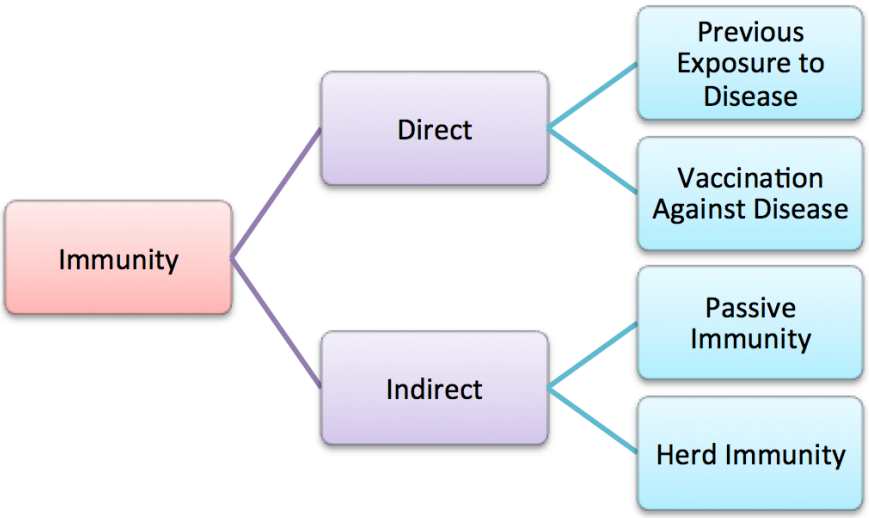
Vaccine Type	Method	Advantages	Disadvantages	Examples
Inactivated virus	Use killed viruses	Virus cannot cause any disease	Immune response not as strong, so several doses usually needed	Polio shot, hepatitis A
Live, weakened virus	Use viruses grown repeatedly in the laboratory in a different cell type 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, shingles
Recombinant	Gene that codes for surface antigen 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

Vaccines: 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 goes higher, everyone has a lower 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 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. Again, 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 its immune system has time to build protective responses before the 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.

GLOSSARY

The following glossary terms are required vocabulary for this lesson. It is not necessary for students to recall all the details, but students should be able to articulate how these relate to vaccines and vaccination.

- **Cell culture adaptation** — The process by which viruses are weakened in a laboratory, so that they can be used in a vaccine. In this process, viruses are grown in cell types that are not those in which the virus is used to growing, so that as it gets better at growing in the new cell type, it gets worse at growing in the type of cell it typically infects.
- **Herd immunity** — When most members of a community are immune to a particular pathogen even those who are not immune are less likely to be infected. The pathogen has less opportunity to find susceptible hosts, even those who may not be immune because they are too young to be immunized or their immune systems are weakened by illness or treatments to illness. Studies have shown that it is better to be a susceptible person in a highly immune population than to be an immune person in a highly susceptible population.
- **Conjugate vaccine** — A vaccine made by attaching a helper protein to a disease causing protein so that an immune response will be made against the disease causing protein.
- **Immunity** — ability to resist infection
- **Inactivated vaccine** — A vaccine made using a killed virus.
- Live, weakened viral vaccine — A vaccine made using a live virus that has been weakened, so that it does not cause disease.

- Immunity generated by one person's immune system but used to protect another person. An example is the antibodies found in a baby from the mom's blood or breast milk.
- **Plasmid** — A small, circular piece of DNA into which a gene for a protein of interest can be inserted. When the plasmid is translated to produce proteins, the protein of interest is also produced.
- **Recombinant vaccine** — A vaccine made using genetic engineering technology
- **Toxin** — A harmful chemical; some bacteria produce disease causing toxins
- **Toxoid vaccine** — A vaccine made using an inactivated toxin produced by bacteria. A toxoid is an inactivated toxin.
- **Vaccine** — A tool that introduces the immune system to potential pathogens in a controlled manner, so that it does not cause disease but it does allow for the development of protective immunity.

NOTES

- The following websites may help students who need to review the basics of immune system function**.**
    - How Your Immune System Works, from How Stuff Works.com http://science.howstuffworks.com/life/human-biology/immune-system2.htm
    - Immune system learning module, from the Vaccine Education Center at The Children's Hospital of Philadelphia http://vec.chop.edu/service/vaccine-education-center/related-information/vaccine-information-for-educators/immune-system-module.html
- For the herd immunity simulation, students will need to access the Herd Immunity Simulation website: http://www.software3d.com/Home/Vax/Immunity.php

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 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 interactive 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 Activity 1 in their worksheets. Each group chooses one of the five different types of vaccines. Note that there are five separate worksheets for each type of vaccine (inactivated, weakened virus, recombinant, conjugate or toxoid). Ensure that each type of vaccine is chosen by at least one group.
5. Each group researches their chosen vaccine and completes the specific worksheet.

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 will be appropriate.)
2. Each group presents its findings to the class.
3. During the presentations, students complete the Types of Vaccines Presentation Worksheet.
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 Activity 2 in their worksheets. Ensure students read the background passage that briefly explains the principle 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 on 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.
8. Students add the means of the four percentages to the collaborative document.
9. Calculate the mean percentages for each of the immunization rates in the class data, and provide those means for students to enter this summary data to the Class Data Analysis table in their worksheets.
10. Students work in their pairs or individually to graph the pooled data from the collaborative document.
11. Use your projector or smart board to show students the Herd Immunity Models. Figures 1 and 2 show sample data from the simulations.

EVALUATE

1. Students self-evaluate their responses to questions in the Activity 1 worksheets.
2. Evaluate students based on their presentations on the types of vaccines they researched in Activity 1. Use the Activity 1 Types of Vaccines rubric as a guide to the correct responses on the Types of Vaccines Presentation Worksheet.
3. Assess students for Activity 2 based on their completion of the questions in the simulation evaluation worksheet.

Activity 1: Types of Vaccines RUBRIC for self-evaluation

Inactivated Vaccine

Question	Correct Response(s)
2a	Franklin D. Roosevelt
2b	purifying, completely kill
2c	last, 1979
4a	1. Vaccine cannot cause the disease it is preventing, 2. Vaccine can be given to people with weakened immunity
4b	Several doses are usually needed to achieve immunity
4c	Using the chemical formaldehyde to kill the disease-causing virus
4d	Hepatitis A, influenza injection, polio injection, rabies

Weakened Virus Vaccine

Question	Correct Response(s)
2a	worse and worse
2b	grow well in children, long-lasting immunity
4a	One or two doses provide life-long immunity
4b	Cannot usually be given to people with weakened immunity
4c	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.)
4d	Chickenpox, influenza (nasal spray), measles, mumps, rubella, polio (oral), rotavirus, shingles

Recombinant Vaccine

Question	Correct Response(s)
2a	1 million
2b	liver cancer
2c	Surface protein
4a	1. Can be given to people with weakened immunity 2. May give life-long immunity
4b	Multiple doses are needed
4c	Inserting the gene for a viral surface protein into a circular piece of DNA, known as a plasmid, which enables the cell to produce copies of the desired protein.
4d	Hepatitis B, HPV

Toxoid Vaccine

Question	Correct Response(s)
2a	a. diphtheria, b. tetanus, c. pertussis
2b	toxins
2c	toxin, toxoid
4a	Can be given to people with weakened immune systems
4b	Several doses are needed
4c	Chemically inactivating the toxins produced by the bacteria to create a toxoid to which the body will develop an immune response.
4d	Age 7. Tdap is a booster immunization for individuals at age 11 and older.

Conjugate Vaccine

Question	Correct Response(s)
2a	meningitis
2b	sugar coating, harmless protein
4a	Can be given to people with weakened immunity
4b	several doses are needed
4c	Taking the sugar coating of the bacteria and attaching it to a harmless protein that allows the body to produce a stronger immune response.
4d	*Haemophilus influenzae* type b (Hib), meningococcal, pneumococcal

Activity 2: Herd Immunity Models

To reinforce learning, show these figures to students.

Figure 1. The percentage of the infected population and percentage of the vaccinated population who are infected declines with the immunization rate. The rapid drop in infection above immunization rate of 0.7 indicates herd immunity.

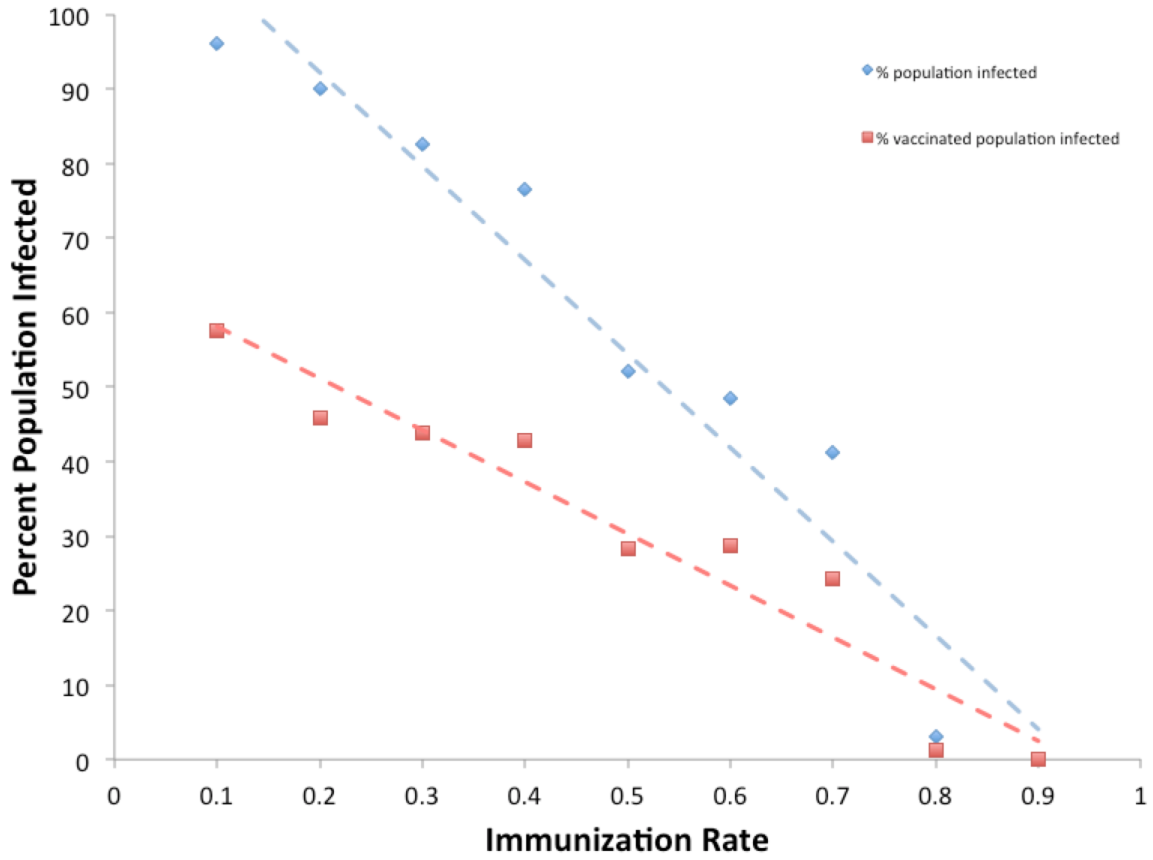
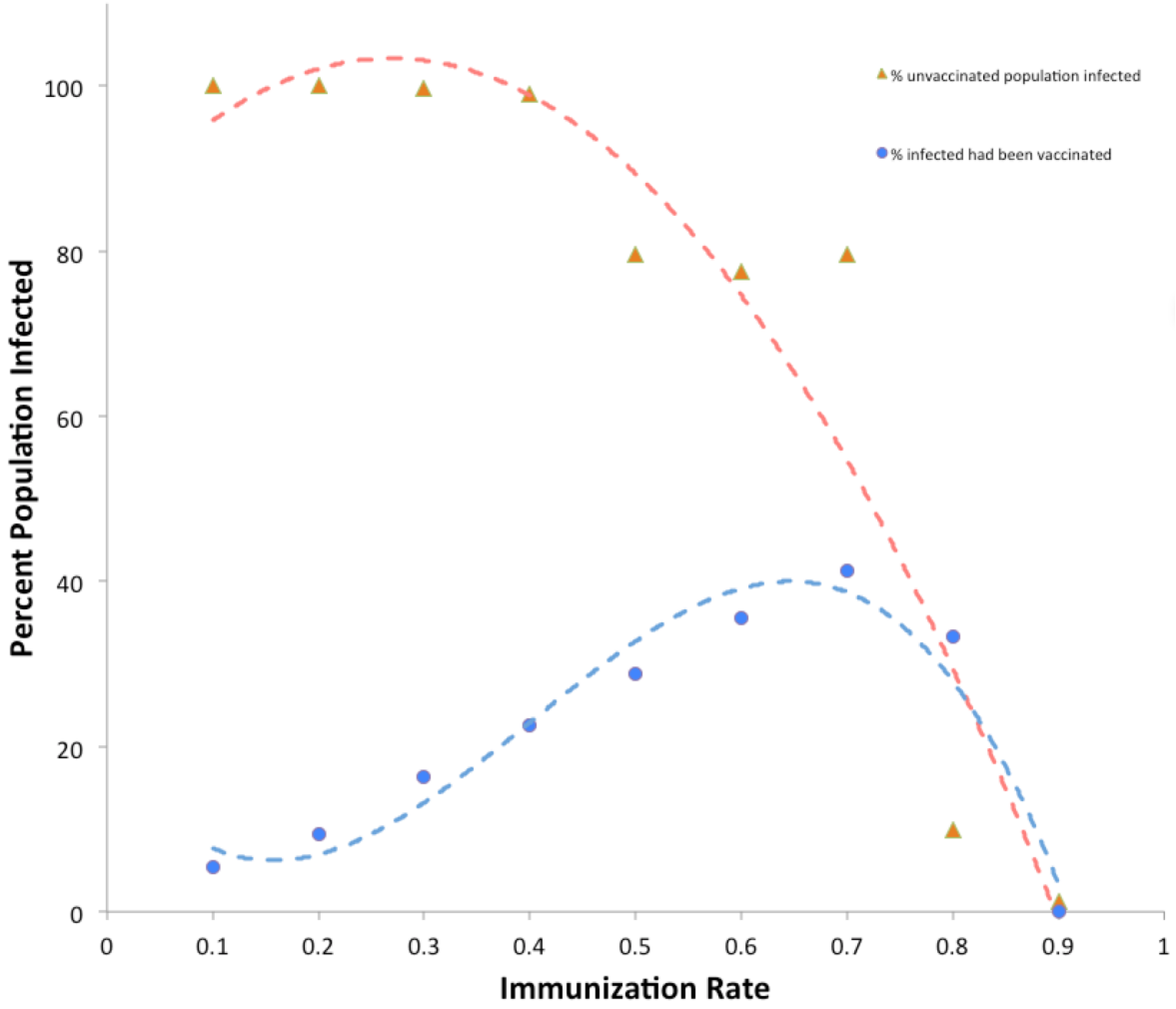


Figure 2. The percent of the unvaccinated population who become infected (triangles) drops after immunization rates above 50%, indicating herd immunity. The percent of those infected who were vaccinated drops above immunization rates of 80%, again showing a herd immunity effect. (Lines are for illustrative purposes only and do not represent functional relationships.)



Simulation Evaluation Worksheet Rubric

1. Relationship between immunization rate and % of population infected: Higher immunization rate results in lower infection rate.
2. As the immunization rate increases, the percent of unvaccinated that become infected decreases (demonstration of herd immunity).

3. Unvaccinated population may become protected from infection around 50% immunization rate, based on graph of percentage of unvaccinated population infected and immunization rate.
4. 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. 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.