Yale SCHOOL OF MEDICINE

As of September 16, 2020

Teacher Guide 9: Vaccine Development

In this module, students will learn about the immune system and how it eliminates disease-causing pathogens from our bodies. Using their knowledge of the immune system, students will design and test vaccines that protect against infection by COVD-19.

NGSS in this Module

Science and Engineering Practices:

Developing and Using Models

- Develop a model to describe unobservable mechanisms. (MS)

Constructing Explanations and Designing Solutions

- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources.

Obtaining, Evaluating, and Communicating Information

Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Disciplinary Core Ideas:

From Molecules to Organisms: Structures and Processes --
LS1.A Structure and Function

- Systems of specialized cells within organisms help them perform the essential functions of life.

- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.

Engineering Design

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a design meets them.

Crosscutting Concepts:

Cause and Effect: Mechanism and Prediction

- Cause-and-effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system.

- Systems can be designed to cause a desired effect.

Scale, Proportion, and Quantity

- Some systems can only be studied indirectly because they are too small, too large, too fast or too slow to observe directly.

Systems and System Models

- Systems can be designed to do specific tasks

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

- Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Structure and Function

- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal their function and/or solve a problem.

- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of their various materials.

Key Terms:
Pathogen
Antibodies
B-cell
T-cell
Immune memory
Parameters
Distribution
Vaccine
Symptoms

Yale SCHOOL OF MEDICINE

As of September 16, 2020

Module 9: Vaccine Development

The Story:

While looking up information about treatments for COVID-19 on behalf of their sick friend Tash, Ray and June find out that many different countries and companies are attempting to produce a vaccine for the disease. Though they understand what vaccines are, Ray and June don't understand how they work. Together they investigate how vaccines work within the human body. How do vaccines produce a resistance to biological pathogens, and how are vaccines discovered and produced?

Performance Expectations:

1. List the types of organisms and molecules that can make us sick.
2. Diagram an immune response to the presence of foreign organisms and label the components.
3. List symptoms of illness during an COVID-19 infection and the possible causes of those symptoms.
4. Describe the concept of immune memory and its role in making us less susceptible to infection.
5. Explain how a vaccine generates immunity without making us sick.
6. Describe how the safety and effectiveness of a vaccine is determined.
7. Suggest an equitable plan for distributing the vaccine.

Challenges:

1. What are "pathogens" and how does our immune system deal with them?
2. Designing a Vaccine
3. Testing and Distributing a Vaccine

Challenge 1: What are “pathogens” and how does our immune system deal with them?

Learning Targets:

- I can define “pathogen”.
- I can compare and contrast 4 main pathogens based on their structure and how they cause infection.
- I can develop a model (diagram) to explain how the immune system works.
- I can describe how B-cells and T-cells function

Estimated Time: 60 minutes

1.1 Activity - Understanding Pathogens

a. **Read:** “What You Need to Know About Pathogens and the Spread of Disease” https://www.healthline.com/health/what-is-a-pathogen

b. Write and Discuss:

- What is a pathogen?
- What are some of the features of pathogens?
- How do pathogens infect us?
- How are viruses different from other pathogens?

1.2 Activity: How the Immune System works.

a.

b. **Watch:** “Immune System” [8:55] https://www.youtube.com/watch?v=fSEFXl2XQpc

c. **Read**: “How is a chaperone like our immune system”?

Imagine you are hosting a large party and have invited all of your friends and many of you classmates. Unfortunately, you hear a rumor that a few uninvited kids plan to crash the party and cause a disruption. You don’t know the identity of the uninvited kids but to protect the party from them you hire a few chaperones.

Because the chaperones don’t know the identities of the potential party crashers, they circulate through the party and look for anyone who is misbehaving. At one point, they see a couple of kids pouring fish oil into the punch. The chaperones confront the beverage polluters and escort them from the party. Before letting them go, the chaperones take a picture of the party crashers so they can easily recognize them amongst the other guests if they return to the party.

Our immune system works similar to the chaperones and shares three important features. First, the chaperones have to circulate through the party and be alert to signs of trouble or disruption. Our immune system contains several different types of cells whose job is to monitor conditions throughout the body and respond to signs of damage. Second, the chaperones have to eliminate the cause of the disruption (the party crashers). Our immune system has cells that eliminate pathogens or produce proteins that eliminate pathogens. Third, the chaperones can remember the identities of the party crashers which allows them to more easily find the party crashers if they return. After removing a pathogen, our immune system can remember the identity of the pathogen so that if it returns, our immune system can remove the pathogen before it makes us sick.

- Antibodies from B-cells
- Cytotoxic T-lymphocytes (CD8+)
- Helper T-cells (CD4+) to stimulate and regulate B-cells and CTL

d. Answer and Discuss:

- How does the immune system eliminate pathogens from our bodies?
- How does the immune system recognize pathogens and other foreign organisms?

e. Review the following:

- Receptors on B-cells and T-cells bind to specific peptides and other small macromolecules.
- Each B-cell and T-cell expresses a receptor on its surface that binds to a unique biological molecule which is usually a peptide from a protein but can be nucleic acid or carbohydrate.
- Specific cells in our bodies engulf pathogens, digest those pathogens and present small pieces of those pathogens on their cell membrane.
- Specific receptors on T-cells and B-cells can bind to those small pieces.

f. Answer and Discuss:

- How does the immune system remember pathogens that have infected us?
- How does the immune system's memory protect us from future infection?

Challenge 2: Designing Vaccines

Learning Targets:

- I can explain how vaccines work.
- I can compare and contrast different approaches to vaccine development.

2.1 Activity: Find out about vaccines.

a. **Watch:**
   - "How do vaccines work?" [2:28] https://www.youtube.com/watch?v=-muloWofsCE
   - "Coronavirus Vaccine Strategy" | WSJ [4:18] https://www.youtube.com/watch?v=7SuKywEZ5AM

b. **Read:** "The race for coronavirus vaccines: a graphical guide" (April 2020) **https://www.nature.com/articles/d41586-020-01221-y**

c. **Construct a Table, Present, and Discuss:** Compare and contrast the eight types of approaches to creating a vaccine for SARS-CoV2.

d. **Further research:** Since April 2020, what progress has been made in development, production, and distribution of a vaccine for SARS-CoV2?

e. **Reflect and Answer/Discuss:**

   - How do vaccines generate memory in the immune system?
   - How do vaccines usually avoid making us sick?
   - What components of COVID-19 would make a good vaccine?
   - What are the different types of vaccines? Which one would work best for COVID-19?

Challenge 3: Testing and Distributing a Vaccine

Learning Targets

- I can identify testing parameters for a vaccine.
- I can prioritize factors to consider for vaccine distribution.

Estimated time: 60 minutes

Activity 1 - Implementing a vaccination program

Brainstorm and Discuss:

- What parameters of a coronavirus vaccine should be tested?
- How could these parameters be tested?

Read: "COVID-19 vaccine makers seek diversity in clinical trials in Connecticut and elsewhere"
https://ctmirror.org/2020/09/14/covid-vaccine-makers-seek-diversity-in-clinical-trials-in-ct-and-elsewhere/

- Based on your review of the FDA guidelines and understanding of diversity in clinical trials, modify your brainstormed list of parameters.

Activity 2 - Distribution Decisions

Answer and Discuss:

- What factors need to be considered when planning for the distribution of a vaccine? Prioritize the factors you identified.
- Should people who are the most vulnerable to contracting COVID-19 be given priority for vaccination? Consider the elderly in nursing homes, the incarcerated, and the undocumented. Cite 3 sources that support your claim.

Professional Opportunities

Virologist https://www.betterteam.com/virologist-job-description

Microbiologist
https://www.bls.gov/ooh/life-physical-and-social-science/microbiologists.htmhttps://www.bls.gov/ooh/life-physical-and-social-science/microbiologists.htm

Immunologist https://www.careerexplorer.com/careers/immunologist/
Research Scientist https://www.careersinpublichealth.net/careers/research-scientist/
Pharmaceutical Scientist
https://www.zippia.com/pharmaceutical-scientist-jobs/https://www.zippia.com/pharmaceutical-scientist-jobs/