How Do mRNA Vaccines Work?

Teacher Guide

Lesson Summary:

This lesson engages students in interpreting text and illustrations to make models that show how mRNA vaccines work to prevent COVID-19 infections.

It is recommended that students work in pairs and that ample time be allowed for developing their models, taking photos, and preparing slides for their presentation. Students who struggle with model making will need encouragement and support.

Consider creating a "Question Board" where students can write questions that they have about the COVID-19 vaccine. Take time to answer these questions at the end of the lesson. The teacher can answer the questions or assign the questions to students for their research.

Estimated Time Needed: 40-60 minutes

Key Concepts:

The Pfizer and Moderna COVID-19 vaccines are mRNA vaccines. They use mRNA created in a laboratory to provide cells with the information for how to make a protein that triggers an immune response. This immune response teaches the immune system to produce antibodies that protect people from getting sick from the virus that causes COVID-19.

Supplies Needed for Each Pair of Students:

- 1 clear plastic sheet protector *(to "laminate" the **Cell in Muscle** diagram)*
- 1 smooth 1" diameter polystyrene foam ball *("virus")*
  https://www.amazon.com/Crafjie-Styrofoam-Polystyrene-Supplies-Decorations/dp/B08ZKCB77S
- 12 red map tack push pins *("spike proteins")*
  https://www.amazon.com/Tacks-Push-Pins-Small-Packs/dp/B07SD14FWJ?th=1
- 4 green tri-beads *("antibodies")*
  https://www.amazon.com/Darice-06102-7-T12-Christmas-1000PK-Green/dp/B006CAK0DO
- 1 small piece of green clay – precut into approximately ½ X ½ X ½ inch pieces
  https://shop.crayola.com/modeling-compounds/model-magic-4-oz-pack-assorted-colors-5744.html

 This lesson was developed with support from the National Institutes of Health under Award Number R25GM132758-03S1. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

- 1 blue plastic 12mm x 12mm bead *("ribosome")*
  https://www.amazon.com/Tara-Assorted-Design-Pieces-Plastic/dp/B07MS8B4X9?th=1
- 1 blue sparky chenille stem - cut in half *("mRNA")*
  https://www.amazon.com/AKOAK-Chenille-Metallic-Cleaners-Tinsel/dp/B07HVS9P6P
- 1 1 ounce sized portion cup *(carries "mRNA" into "cell")*
  https://www.amazon.com/Disposable-Portion-Cups-200-Count/dp/B07GXCMSQC

Lesson Preparation:

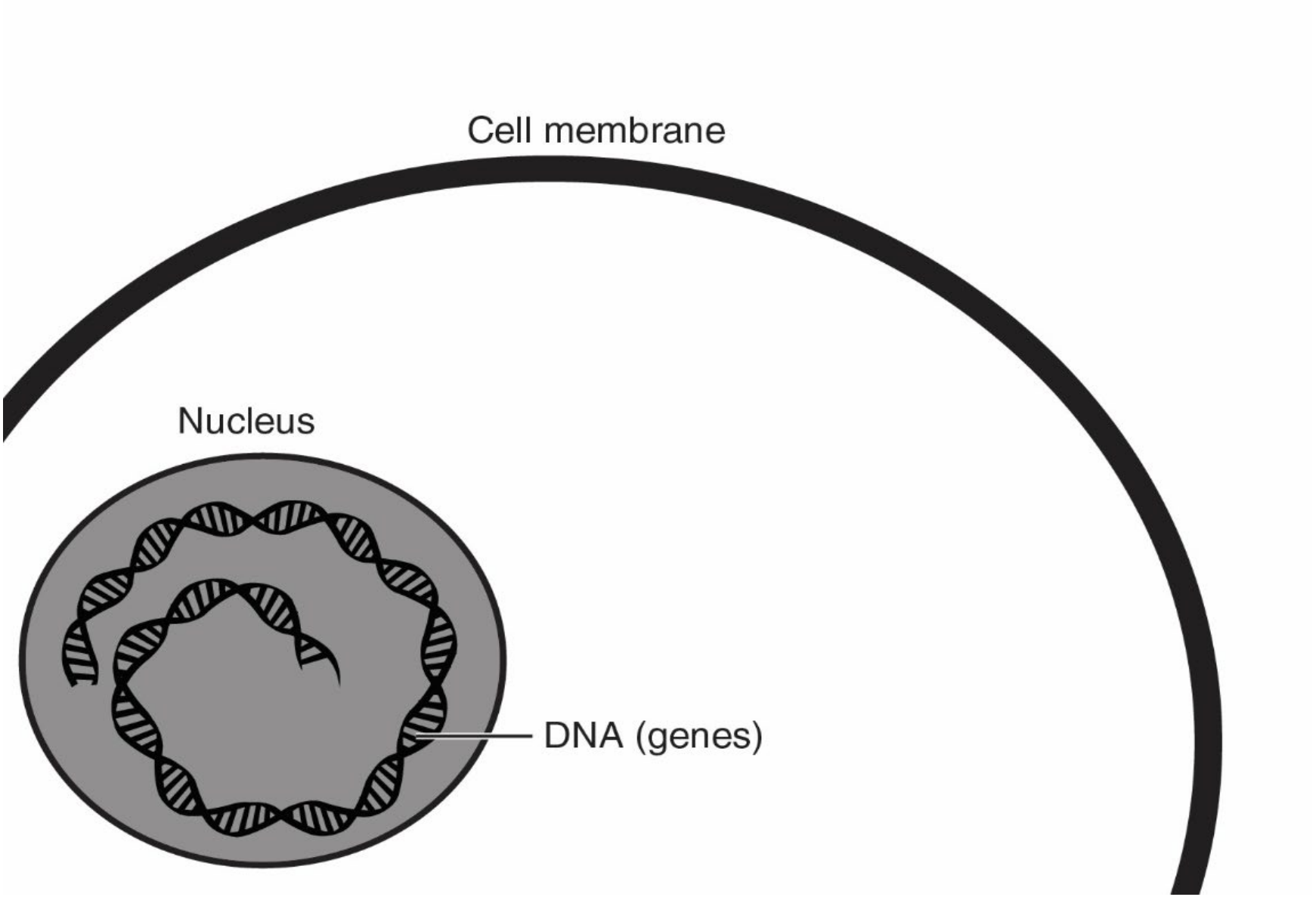
- Anticipate a lot of student discussion about how to model different things. Encourage students to be creative and use their own interpretations and ingenuity when making their models.
- Sharing everyone's slide show in Part G could be redundant and time consuming. Consider explaining that several students will be selected to present their slide show to the entire class.
- Each student will need 1 copy of the **How do mRNA Vaccines Work?** student handout and 1 copy of the **Cell in Muscle** diagram *(see page iii)*
- If you cannot make color copies of student handouts, make a class set of color copies of **Color Versions of Diagrams** *(see page v*).
- Each pair of students will need:
    - Cell phone (or tablet) with capacity to save photos
    - A materials bag containing:
        - 1 polystyrene foam ball
        - 12 red map tacks
        - 4 green tribeads
        - 1 small piece of green polymer clay *(put clay into a small plastic bag)*
        - 1 blue bead
        - 1 blue sparkly chenille stem cut in half
        - 1 1-ounce portion cup

Note: Obtain enough materials for all of your classes or have students disassemble their models at the end of each class to prepare the materials for reuse by the next class. Discard the clay and chenille stems after each use and replace with new clay and chenille stems. The other materials can be reused.

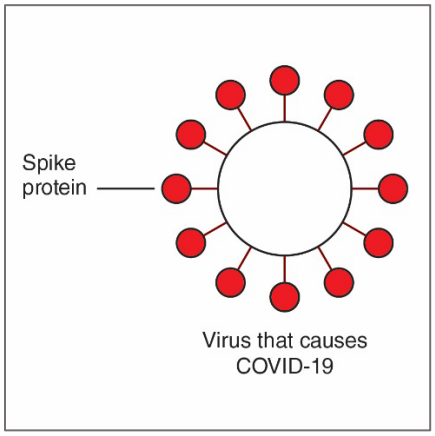
Suggested information related to mRNA vaccines:

- **CDC: Vaccines for COVID-19**
  https://www.cdc.gov/coronavirus/2019-ncov/vaccines/index.html
- **FDA: COVID-19 Vaccines**
  https://www.fda.gov/emergency-preparedness-and-response/coronavirus-disease-2019-covid-19/covid-19-vaccines
- **Science, Simplified: Videos that answer big questions about the coronavirus**
  https://www.scripps.edu/covid-19/science-simplified/
- **CDC: Myths and Facts about COVID-19 Vaccines**
  https://www.cdc.gov/coronavirus/2019-ncov/vaccines/facts.html

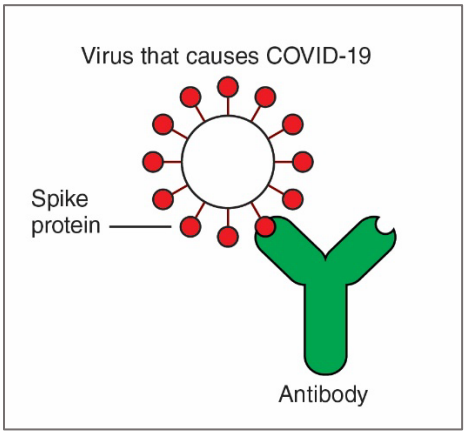
Cell in Muscle



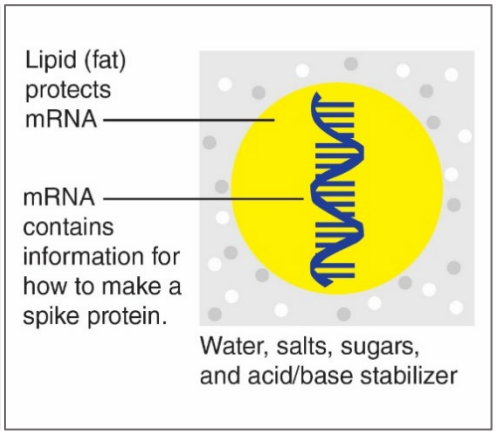
Color Versions of Diagrams



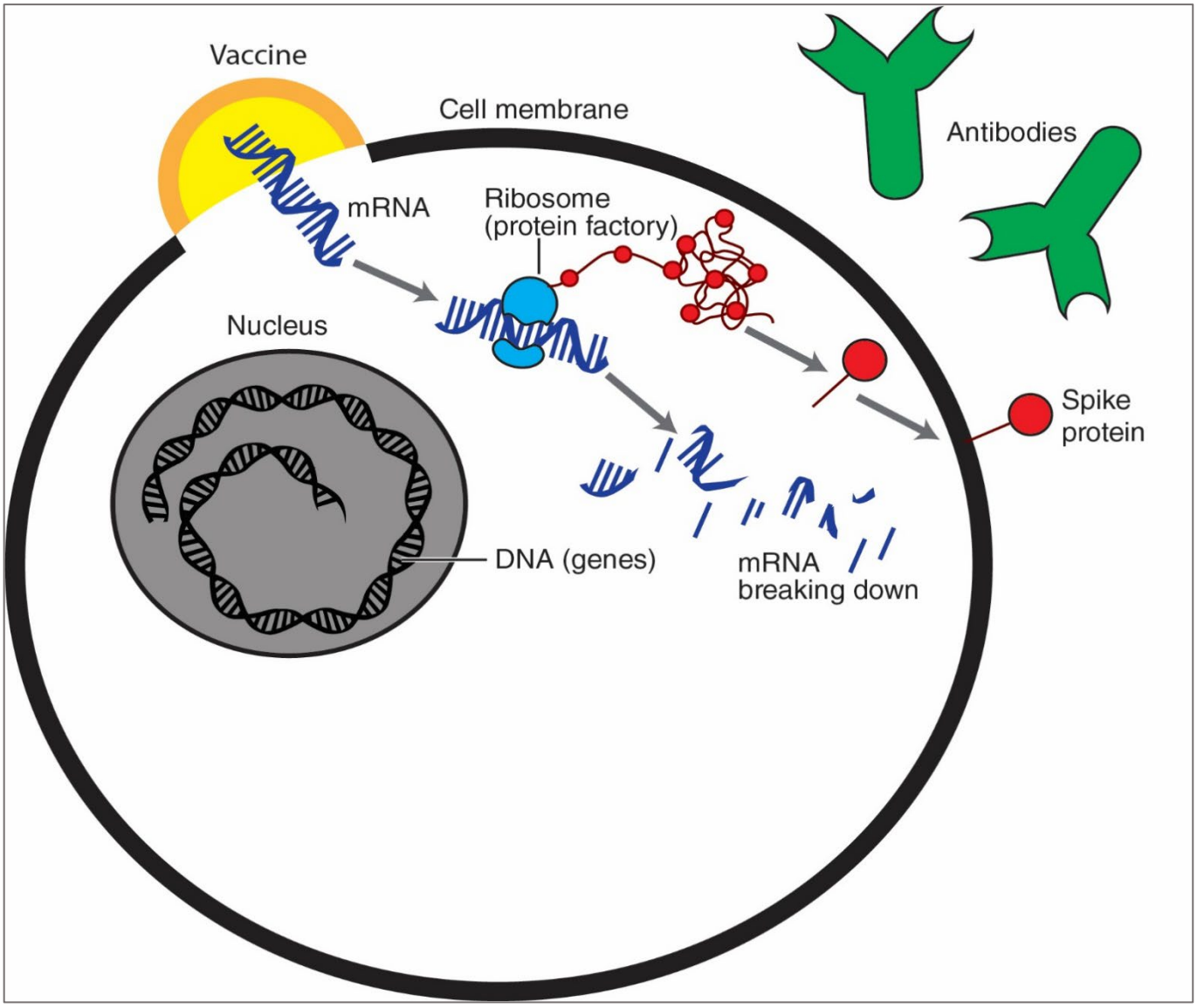
A. Model of the Virus that Causes COVID-19



B. Models of Antibodies that Fight the COVID-19 Virus



C. Model of an mRNA Vaccine



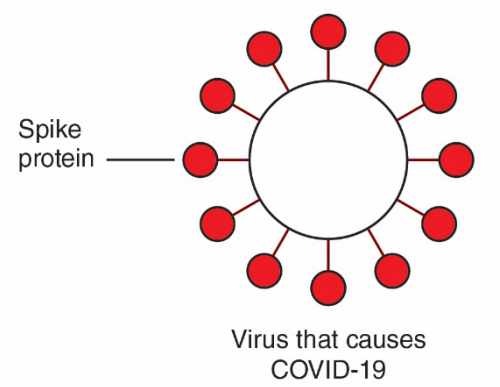
D. Model of Vaccination

How Do mRNA Vaccines Work?

Some people are hesitant to get a COVID-19 vaccine because they do not understand how the new mRNA vaccines work. You will make models and take photos that could be used to help people understand how mRNA vaccines work. You will take pictures of the models and then create a slide show that could be used to educate the community about mRNA vaccines.

A. Model of the Virus that Causes COVID-19

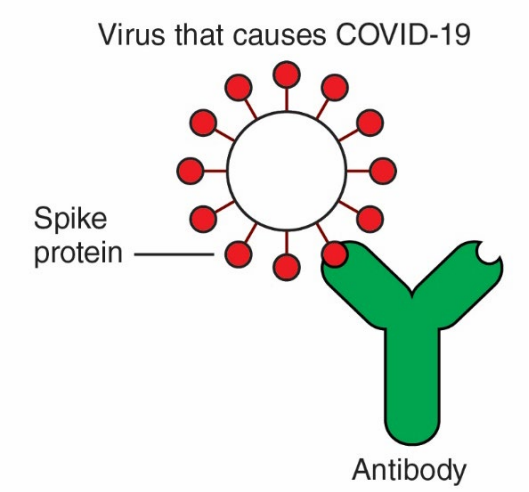
The surface of the virus that causes COVID-19 is covered with spike proteins. The spike proteins attach to receptors on the surface of cells in the lungs. This allows the virus to attach to and invade lung cells.



1. Use a foam ball and 6 red pins to create a model of a virus that can infect cells and cause COVID-19. ***Use your cell phone to take a picture of this model.***

B. Model of Antibodies that Fight the COVID-19 Virus

If your cells are infected by the virus that causes COVID-19, the cells will make many new viruses and you will get sick. You can get better because your immune system learns how to produce antibodies to fight the viruses. These antibodies are Y-shaped molecules with a specific shape that allows them to attach to spike proteins on the COVID-19 virus. When antibodies attach to the COVID-19 virus, they keep the spike proteins on the virus from attaching to receptors and infecting cells.



Once you have had COVID-19, you are less likely to get the illness again because your immune system has already learned how to make antibodies to fight the COVID-19 virus.

2. Use a small piece of green clay and 1 green bead to make 1 antibody molecule that can attach to spike proteins. *Hint: attach two tiny balls of green clay to the "arms of the Y" as shown in the picture below.* ***Use your cell phone to take a picture of your model.***

3. When COVID-19 viruses invade your body, your body produces antibodies to prevent COVID-19 viruses from infecting cells. How could these antibodies prevent the COVID-19 viruses from infecting your cells?

They could attach to the spike proteins on viruses and block the spike proteins from attaching to and infecting a cell.

The first time you are infected with the COVID-19 virus you will get sick. This is because it takes a while for your body to recognize the COVID-19 virus as an invader and produce enough antibodies to fight the COVID-19 viruses. The antibodies that you produce will help you get better. These antibodies will remain in your body to protect you if you are exposed to the COVID-19 virus again.

4. How could the antibodies prevent the COVID-19 virus from attaching to and infecting cells in your body?

   They could attach to the spike proteins on viruses and block the spike proteins from attaching to and infecting a cell.

5. Why do people get sick the first time they are infected with COVID-19 viruses?

   It takes a while for them to begin producing enough antibodies to fight the virus.

6. People who have been sick with COVID-19 are immune to the disease. Explain how they are protected if they are exposed to the COVID-19 virus.

   They make antibodies that can prevent the virus from attaching to their cells.

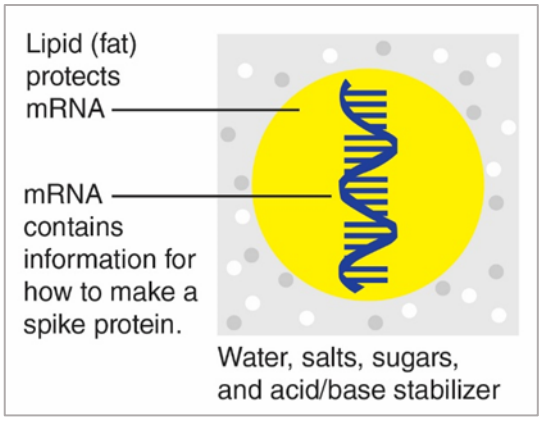
C. Model of an mRNA Vaccine

Getting sick with COVID-19 can be unpleasant and even dangerous. There is a safer way to become immune to COVID-19. Vaccines are a much safer and more effective way prevent COVID-19 illness. A vaccine protects you by teaching your immune system to make antibodies to fight the COVID-19 viruses.

7. An effective COVID-19 vaccine causes your __***Immune***____ system to produce ____***Antibodies***_____ to protect against the COVID-19 virus.

To fight COVID-19, scientists developed new kinds of vaccines called mRNA vaccines. The *Pfizer* and *Moderna* vaccines that are commonly used are both mRNA vaccines.

What are the ingredients in an mRNA vaccine? mRNA vaccines do <u>not</u> contain any living or killed viruses. The main ingredient of mRNA vaccines is mRNA molecules that carry information to tell a cell how to make spike proteins. The mRNA is inside a lipid (fat) coating that protects the mRNA and carries it into the cell. The vaccine also contains small amounts of other ingredients such as water, salts, sugar, and acid/base stabilizers that protect the delicate mRNA molecules.



Ingredients in an mRNA Vaccine

8. Use the small plastic cup and the blue sparkly wire to model the lipid and mRNA parts of an mRNA vaccine. ***Use your cell phone to take a picture of this model.***

9. What does the sparkly wire represent? _____***mRNA***_____

10. What does the small cup represent? _____***Lipid that protects mRNA***_____

11. Some people claim that mRNA vaccines can cause infection with the virus that causes COVID-19. Explain why this is <u>not</u> possible.

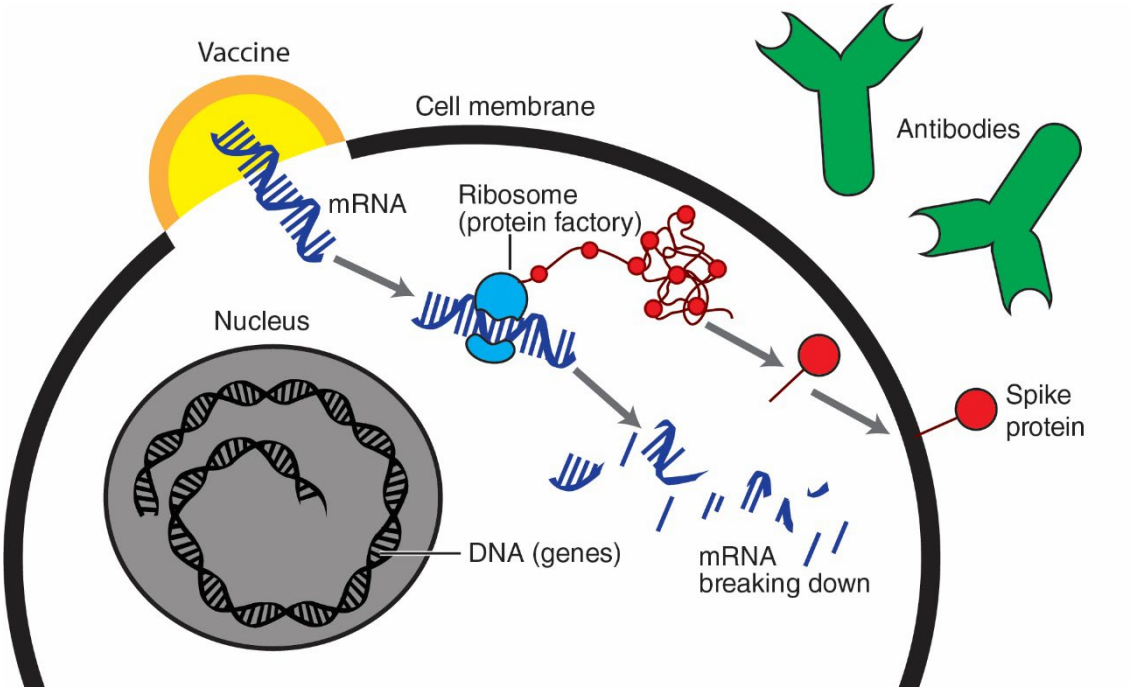
    The vaccine does not contain any living or killed viruses.

12. Some people claim that mRNA vaccines contain harmful substances such as preservatives, antibiotics, medicines, food proteins (eggs, gluten, nuts), metals, and latex. Is this claim supported by the information in the text and the diagram above? Explain why or why not.

    No, the vaccines only contain mRNA, lipid, and small amounts of sugar, salts, and acid/base stabilizers.

D. Model of Vaccination

COVID-19 vaccines are given in the muscle of the upper arm or upper thigh, depending on the age of the person who is being vaccinated. After vaccination, the mRNA enters cells in the muscle. The diagram below shows what happens to cells in your muscle when you get a COVID-19 vaccine.



13. Use the **Cell in Muscle** diagram and your model of an mRNA vaccine to show mRNA being delivered to a cell in a muscle. ***Use your cell phone to take a picture of this model.***

E. Model of mRNA Producing Spike Proteins

Once inside the cell, the mRNA remains in the cytoplasm. It does not enter the nucleus. The mRNA enters the cell's ribosomes (protein factories) and begins producing spike proteins. After the spike proteins are made, the cell breaks down the mRNA and it leaves the body as waste.

14. Insert the mRNA into a blue bead. What does the blue bead represent?

    Ribosome (protein factory)

15. Add some spike proteins to the cell. What did you use to represent the spike proteins that are produced when the ribosome uses the mRNA information?

    The red pins

16. ***Use your cell phone to take a picture of this model*** that shows the mRNA attached to a ribosome and producing spike proteins.

17. Some people are concerned that mRNA is going to change their DNA (genes). Based on your model and the information the text above, is it possible for mRNA to change people's genes? Explain why or why not.

    The mRNA does not enter the nucleus where the DNA (genes) are located. The mRNA breaks down and leaves as a waste.

F. Model of the Immune System Making Antibodies

The spike proteins that are made inside the cell will then move though the cell membrane and attach to the outer surface of the cell. Your immune system will recognize that the spike proteins do not belong there, because the surface of human cells does not have spike proteins. This will teach your immune system to produce antibodies to fight off what it thinks is an infection.

18. Make a model to show the spike proteins on the cell surface and three antibodies that are produced by the immune system after a vaccination. ***Use your cell phone to take a picture of this model.***

19. What did you use to represent antibodies?

    The green beads with clay

20. What triggered the production of these antibodies—spike proteins on viruses or spike proteins produced by cells?

    Spike proteins produced by cells attached to the outer surface of the cell.

21. Explain how these antibodies protect against invading COVID-19 viruses.

    The antibodies attach to spike proteins on the virus. This keeps the virus from attaching to and infecting cells.

22. Traditional vaccines contained weakened or killed viruses or parts of viruses. How is an mRNA vaccine different from a traditional vaccine?

    An mRNA vaccine does not contain viruses or parts of viruses. Instead, mRNA vaccines teach your cells how to make spike proteins that trigger the production of antibodies.

G. Model of Antibodies Protecting from COVID-19 Illness

With the COVID-19 vaccine, your body learns how to protect itself against future infection from the virus that causes COVID-19. Any side effects from getting the COVID-19 vaccine are normal signs that your body is building protection against the virus.

The benefit of the COVID-19 vaccine is that people get this protection from a vaccine, without ever having to risk the potentially serious consequences of getting sick with COVID-19.

23. Make a model to show how the antibodies protect a person if a COVID-19 virus enters their body. ***Use your cell phone to take a picture of this model.***

24. What are some side effects of COVID-19 vaccinations?

    Student answers will vary but may include: sore arm, mild fever, fatigue, muscle pains. The antibodies attach to spike proteins on the virus. This keeps the virus from attaching to and infecting cells.

25. Which is more dangerous, getting sick with COVID-19 or having side effects of a COVID-19 vaccination? Explain your answer.

    The side effects of the vaccine are mild. Particularly compared to the symptoms of COVID-19 that may be dangerous and may cause long lasting health problems or death.

26. Use the seven pictures that you took to create a slide show presentation to help people understand how mRNA vaccines work.

    Each slide in the slide show should include:

    - One of the pictures that you took
    - Labels for the picture
    - A caption (description) that explains the picture