Modeling the Virus That Causes COVID-19

Construct a Million-to-One Scale Model Using Paper or Cardstock

OVERVIEW
Virus particles are extremely small. They are completely invisible in ordinary white light. A particle (virion) of SARS-CoV-2, the virus that causes Covid-19, is approximately 100 nanometers across. How big is that?

In this activity, students learn about the shape and relative size of the virus by constructing a paper model of a single virus particle.

LEARNING OBJECTIVES
Students construct a virus model and compare it to ordinary things using the same scale.

SCIENCE, HEALTH AND MATH SKILLS
• Comparing and contrasting
• Measuring
• Interpreting information

NGSS SCIENCE AND ENGINEERING PRACTICES
• Asking questions and defining problems
• Developing and using models
• Planning and carrying our investigations
• Using mathematics and computational thinking

TIME
One or two 45-minute class periods
(you may have students construct the virion model in class or as an assignment)

MATERIALS FOR SCIENCE INVESTIGATION
Students
• Cutouts printed on white cardstock paper or plain white paper
• Crayons or colored pencils (a pre-colored version is available for color printers)
• Rectangle of aluminum foil (approximately 4 x 14 cm)
• Clear plastic tape
• Straight edge ruler
• Ballpoint pen
• Scissors
• Student handouts below (paper or electronic copies)
  a. Student Sheet A: Visualizing the Size of the SARS-CoV-2 Virion
  b. Student Sheet B: Visualizing the Size of the SARS-CoV-2 Virion Quiz
  c. Student Sheet C: Coronaviruses Are Tiny!
  d. Student Sheet D: 3-2-1 Questions
SET UP AND TEACHING TIPS
This activity enables students to work individually to construct a virus model. The model is easier to construct and sturdier if made from cardstock. However, it can be made and assembled using plain white paper. In either case, the cutouts must be printed onto the paper or cardstock ahead of time. Students will need to cut the templates carefully, so have extra copies on hand in case they have to start over.

PROCEDURE

ENGAGE
1. Ask students, *Have you ever seen a virus?* [It is not possible to see viruses directly, because they are very small.] Encourage student to share what they know, or want to know, about viruses. List their ideas. Make certain to include the following information as part of the discussion.
   • Viruses are small infectious agents that require living cells to make copies of themselves.
   • Viruses replicate (make copies of themselves) by invading living cells.
   • Most viruses are too small to see with a usual light microscope (such as the kind students have in their biology classes).
   • Viruses are responsible for many different diseases in humans, including the common cold, flu, smallpox, HIV/AIDS and COVID-19 or coronavirus disease. Viruses also infect other animals and even plants.
   • All viruses consist of genetic material surrounded by a protective coat. Some viruses, such as coronavirus, also are surrounded by a viral envelope.

EXPLORE
2. Discuss the purpose of the activity with students. They will learn more about a virus, called SARS-CoV-2 by constructing a paper model that enables them to visualize a single SARS-CoV-2 virus particle. SARS-CoV-2 stands for Severe Acute Respiratory Syndrome CoronaVirus 2.
3. Demonstrate how to cut and fold the model from the cardstock or paper templates.
4. Also demonstrate how to measure and fold the rectangle of aluminum file to create a long narrow strip about 1 cm by 14 cm. Once folded, twist the strip three or four times to create a helix. When students create the strips, have them set the strips aside until they have almost completed construction of the paper sphere. This strip represents the capsid with genetic material.
5. Tell students that detailed instructions are included on the Student Page A for making the model. Reiterate the following important steps in constructing the model.
   • Make sure students use care in cutting of the templates to yield the best models.
   • Make sure students score the dashed lines with the ruler and ballpoint pen. This is particularly important if they are constructing the models from cardstock.
   • Have students tape together the matching edges of each of the five model parts before joining them together. Students may want to cut several small pieces of tape in advance to facilitate folding and taping the edges of the sections.
   • Taping from the inside makes the neatest looking model. However, the last few hexagons and pentagons will have to be taped on the outside.
   • All viruses consist of genetic material surrounded by a protective coat. Some viruses, such as coronavirus, also are surrounded by a viral envelope.
   • Students should insert the aluminum strip representing the capsid inside the model before taping it closed.
EXPLAIN

6. Have each student measure or estimate the diameter of their virus models. Ask, *Since the model is not a perfect sphere, what is best way to measure it?* Discuss different ways to estimate the diameter of the model.

7. As students will observe, when constructed, the virion model is approximately 10 cm across. This is one tenth of a meter or 100 million nanometers. The actual virion itself is about 100 nanometers across. That makes the paper model one million times larger than the virus. One million anything is hard to imagine!

8. Discuss the size of the virus particle.
   - An idea of the size differences can be gained by looking at a common object or person of a known size, then multiplying that size by 1 million. A person 1.524 meters tall (5 feet) would become 152,400 meters or 1,524 kilometers tall (947 miles). Ok, that is not easy to imagine either!
   - Try this on for size. A grain of sand 1 mm in diameter multiplied by 1 million would become a boulder 1 kilometer in size compared to the paper model. That’s asteroid size.

9. The last word about the model is its shape. The virion is actually spherical. This model is a paper version of a small soccer ball. It has 20 hexagons and 12 pentagons and rolls easily. Making a perfectly spherical paper model with this technique would be very difficult!

EXTEND

10. Optional Project: Challenge students to create a virus calculator using a data-organizing spreadsheet program. Using 100 nm for the size of the SARS-CoV-2 virion as the denominator, the calculator should quickly determine the size comparison of common object selected by the students.

11. Have students read the accompanying essay, *Coronaviruses are Tiny!* After reading the essay, students should create a 3–2–1 chart about SARS-CoV-2 using the template provided or in their science notebook.
   - 3 Things You Found Out or Learned About Coronaviruses
   - 2 Things Surprising Things That You’d Like to Learn More About
   - 1 Question That You Still Have

Viruses replicate (make copies of themselves) by invading living cells. Viruses are responsible for many different diseases in humans, including the common cold, flu, smallpox, HIV/AIDS and COVID-19 or coronavirus disease. Viruses also infect other animals and even plants. Coronaviruses are surrounded by a viral envelope.
THE SCIENCE

Viruses and other microbes are so small they are measured in micrometers (or microns). Even smaller particles are measured in nanometers. One micron is 1000 times smaller than a millimeter. An individual SARS-CoV-2 virion is about 100 nanometers across. One nanometer is 1000 times smaller than a micron!

RESOURCES

COVID HEALTHY ACTIONS, COMMUNITY KNOWLEDGE AND SCIENCE

A SCIENCE-BASED CURRICULUM FOR THE COVID-19 PANDEMIC

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Visualizing the Size of the SARS-CoV-2 Virion

OVERVIEW

• Refer to Modeling the Virus That Causes COVID-19 for information on the model
• Follow the step-by-step instructions on page 2 for making the model
• Find the pre-colored cutouts on pages 5–6 for the model

MATERIALS

• Cutouts printed on white cardstock paper or plain white paper
• Crayons or colored pencils (a pre-colored version is available for color printers)
• Rectangle of aluminum foil (approximately 4 x 14 cm)
• Clear plastic tape
• Straight edge ruler
• Ballpoint pen
• Scissors
**PAPER SARS-CoV-2 PARTICLE MODEL**

**INSTRUCTIONS**

1. Use crayons or colored pencils to fill in cutouts *Viral Envelope, B, C, D, E*. Skip this step if you are using the pre-colored version cutouts.

2. Cut out the *Viral Envelope* along the outer, solid lines.

3. Optional: use a straight edge and ballpoint pen to score the dashed lines. The groove created makes accurate neat folds between edges.

4. Fold all the hexagon and pentagon edges inward along the scored dashed lines.

5. Join the corresponding edges together with small pieces of clear tape. The edges can be taped from the outside.

6. Repeat steps 2–5 onto cutouts *B, C, D, E* and tape them to the *Viral Envelope* by aligning the corresponding edges.

7. Transfer the *Capsid Pattern* onto aluminum foil by cutting out the pattern; tracing the pattern onto the foil; scoring, cutting and folding the foil.

8. Draw vertical parallel lines on the front and back of the folded foil capsid with a marker, and form the foil capsid with fingers to make a helical coil.

9. Insert the foil capsid inside the SARS-CoV-2 model and tape closed the remaining edges.
Visualizing the Size of the SARS-CoV-2 Virion Quiz

**QUIZ**
The model you constructed of the virion that causes COVID-19 is approximately 10 centimeters in diameter. The actual virion is considerably smaller. It is approximately 100 nanometers across.

- 1 Centimeter = 0.01 meter
- 1 Nanometer = 0.000000001 meter

### QUESTIONS

1. How many times larger is the model of the SARS-CoV-2 virion than the actual virion?
   - Use this number to answer the following questions.

2. If the actual SARS-CoV-2 virion were 10 cm in diameter, how tall would you be compared to it?
   - Use your height in meters.

3. Pick three common objects around you and calculate how big they would be compared to the 10 cm virion.
   - List the objects and sizes below.

   **Object + Size 1**

   **Object + Size 2**

   **Object + Size 3**
Coronaviruses Are Tiny

Student Reading

Virus particles cannot be seen with the most powerful optical (visible light) microscopes. Their diameters are considerably less than the wavelengths of visible light. The SARS-CoV-2 virion is 100 nanometers (100 billionths of a meter) or $1 \times 10^{-7}$ m in scientific notation.

The extremely small size of the SARS-CoV-2 virion causes one to wonder—how could a face mask possibly block the entry or exit of these particles? The pores in fabric are much larger than the particles. They should slip right through. The answer lies in the transport mechanism of the particles. A person infected with the coronavirus expels virus particles by coughing, sneezing, talking, shouting, and just plain breathing. In doing so, droplets of moisture, containing the particles, are expelled. These droplets are much larger than the particles and can be blocked by cloth face coverings. Wearing a face mask is a frontline defense against Covid-19. Another defense is physical distancing, which means staying about six feet apart from people who do not live in your household.
What does the SARS-CoV-2 virion look like? The image below was created with a Transmission Electron Microscope. It is an electron micrograph of SARS-CoV-2 virus particles, isolated from a patient. The image captured and color-enhanced at the NIAID Integrated Research Facility (IRF) in Fort Detrick, Maryland.

*Figure 1.* Transmission electron micrograph of SARS-CoV-2 virus particles isolated from a patient. Image captured and color-enhanced at the NIAID Integrated Research Facility (IRF) in Fort Detrick, Maryland.
Based on images such as the one above, The Centers for Disease Control and Prevention (CDC) created the following illustration. It shows the protein spikes on the outer surface or envelope of the virus. The spikes give the impression of a corona or crown surrounding the virion. For this reason, this and similar viruses are called coronaviruses. The virus’s full name is Severe Acute Respiratory Syndrome coronavirus 2/SARS-CoV-2.

Figure 2. Illustration of Severe Acute Respiratory Syndrome coronavirus 2/SARS-CoV-2 ultrastructural morphology.
The genetic material of SARS-CoV-2 is a single strand of RNA, which is contained inside a protein shell called a capsid. Together, the genetic material and the capsid make up the nucleocapsid. The nucleocapsid is spiral shaped in SARS-CoV-2 (see diagram below).

**Figure 3.** Diagram of coronavirus structure (based on Rohan Bir Singh, M.D., SARS-CoV-2 Structure from Features, Evaluation, and Treatment of Coronavirus, © 2020, StatPearls Publishing LLC.)
Coronaviruses Are Tiny!

Student Reading

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Figure 1: NIAD, Figure 2: Centers for Disease Control and Prevention
Figure 3: Baylor College of Medicine

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3–2–1 Questions

3
THINGS YOU FOUND OUT OR LEARNED ABOUT CORONAVIRUSES
1.

2.

3.

2
SURPRISING THINGS THAT YOU’D LIKE TO LEARN MORE ABOUT
1.

2.

1
QUESTION YOU STILL HAVE
1.