Lesson 1 – Structure and Size: Comparing Viruses, Bacteria, and Eukaryotic Cells

LESSON QUESTIONS

- What are the similarities and differences in structure between viruses, bacteria and eukaryotic cells?
- How does the size and structure of viruses, bacteria and eukaryotic cells relate to their functions?

LESSON OBJECTIVES

- Compare the structure of viruses, bacteria and eukaryotic cells.
- Relate the size and structure of viruses, bacteria and eukaryotic cells to their functions.

DOK 2 – 4

OVERVIEW

In this lesson, students investigate the relative sizes of viruses, bacteria and cells of eukaryotes. Students work in groups to choose one of each type of biological entity. For example, the group might choose influenza virus, E. coli and a human T-cell. Groups research online to collect information about each. (DOK2) Information will include the relative sizes, structures, and functions. Students create a graphic organizer to classify and organize the information. They create a graphic to show the relative scale of each structure. They calculate ratios of surface areas to volumes to observe the square-cube law. Groups share their graphic organizers to compare information. Comparison of information allows students to identify patterns. (DOK2) One such pattern is the size trend: most viruses are smaller than most bacteria, which are smaller than most eukaryotic cells. As a class, information is compiled to identify and explain phenomena in terms of concepts. (DOK3) For example, students could choose to explain that smaller size is a structural characteristic that enables viruses to infect bacteria or eukaryotic cells. In a hands-on activity, student groups design a simple model of a virus particle, bacterium or eukaryotic cell. Student groups will build a 3-D model of their structure. Depending on time and resources, the models are built either from everyday materials (DOK3), or by using CAD software to program a 3-D printer. (DOK4)

LENGTH

Up to three 45-minute sessions

GLOSSARY TERMS

virus, bacteria, eukaryote, prokaryote, parasite, square-cube law

STANDARDS

- **Next Generation Science Standards**
  - MS-LS1-1. Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.
  - MS-LS1-2. Develop and use a model to describe the function of a cell as a whole and ways the parts of cells contribute to the function.
- **Common Core State Standards**
  - RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
  - RST.6-8.4 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 relevant to grades 6-8 texts and topics.
  - RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
  - RST.6-8.8 Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.
  - RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.
  - 6.RP.A.3.D Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities.

MATERIALS

- Computer with internet access
- Graph paper
- Meter ruler
- Modeling materials or 3-D printer

BACKGROUND FOR TEACHER

The goal of this lesson is for students to compare the structure and function of viruses, bacteria and eukaryotic cells. Students may have misconceptions about the relative sizes of microscopic organisms. For example, they may think that bacteria are about the same size as eukaryotic cells. Students might think that all eukaryotic cells are too small to see, or that all eukaryotic cells are the same size. Students might have misconceptions about the relative sizes of bacteria and viruses. Such misconceptions arise from the difficulty of visualizing cells, bacteria and viruses. When a student looks at a micrograph of a virus, they may have difficulty understanding how small it actually is. This lesson addresses such misconceptions by using scale models. Scale diagrams show the relative sizes of cells. Students also calculate the ratio of linear sizes and volumes to see a biological application of the square-cube law. This activity enables students to identify patterns related to size, leading to an understanding that an increase in size can lead to an increase in complexity. Students will also be able to explain that smaller organisms can parasitize or infect larger organisms, but rarely the other way around. Modeling cells, bacteria and viruses in 3-D serves to emphasize the relationship between size and complexity. Depending on prior knowledge, consider reviewing the definitions of viruses, bacteria and eukaryotes, particularly the cells of eukaryotes (see Glossary). You may also wish to discuss why scientists generally agree that viruses are non-living.

TEACHER NOTES

The over-arching question of this lesson is: How does size relate to function? After completing the lesson, students should be able to identify and illustrate relative sizes, structures, and functions of eukaryotic cells, bacteria and viruses. Students should also be able to calculate ratios of surface areas to volumes and plot them to observe the square-cube law (as size increases, volume grows faster than surface area). Once students have completed the math component, pool the class data so that they can see the size trend from viruses to bacteria to eukaryotic cells. If needed, guide them to infer that smaller size is a key factor enabling organisms to parasitize or infect others. If needed, review metric units of size (e.g., millimeters, microns and nanometers). In this context, it may help students to provide a linear scale of units and to review powers of ten. In Elaborate, when students build their scale models, time and resources may not allow for detailed models. In this case, groups should focus on differences in size and shape. If a 3-D printer is unavailable, modeling clay will work as an alternative for this activity.

Whittle-Down Strategy
Use this strategy in Explain: (1) Students work individually to generate a list of five words. Encourage students to use any words that are relevant to the concept of sizes of viruses, bacteria and eukaryotic cells. (2) Students work in pairs or small groups. (3) In their groups, students share and discuss their words. Encourage students to use evidence-based reasoning in their justifications for words they chose. One student records all of the words contributed by each member. Through discussion each group narrows (whittles) down the list of words to the three that they consider to be the most relevant. (4) The aim is for students to focus on the terms that are the most relevant to understanding the topic. (5) Each group shares its three words with the class, again using evidence-based reasoning to justify why they included those words. (6) Display the words to the class, using your preferred method (whiteboard, flipchart, etc.). Students work individually to write a summary of why those words help to explain the key concepts (viruses, bacteria and eukaryotic cells, scaling, comparative sizes, square-cube law, etc.).

LESSON RESOURCES

- Lesson animation:
    - *A Virus Attacks a Cell* https://vimeo.com/227174435

- Lesson glossary

- 3-D model printing files:
    - Influenza virus 3D model, NIH 3D print exchange, https://3dprint.nih.gov/discover/3dpx-000030
    - Streptococcus 3D model, provided by NIH 3D print exchange, https://3dprint.nih.gov/discover/3DPX-004652
    - Dendritic cell 3D model, provided by Donny Bliss and Sriram Subramaniam, NIH, (file available in lesson 1 resources section)

ENGAGE

1. Show students a meter ruler.
2. Point out the one millimeter gradations, and compare this to the full length of the ruler.
3. Explain that the meter is 1000 times the length of the millimeter.

4. Ask students to write pairs of things that they think are 1000 times the size of something else (e.g., length of blue whale and rat, Grand Canyon depth and elephant height). Guessing is fine. Allow students to use their imaginations! Explain that they will explore sizes of things that cause disease.

EXPLORE 1

1. Ask students to list different types of diseases they have heard of.
2. As a class, review definitions of the glossary terms: virus, bacteria, eukaryote, prokaryote and parasite.
3. Working in small groups, students classify the diseases they listed according to whether they are caused by viruses, bacteria or eukaryotes.
4. Tell students that they will investigate the structure and function of viruses, bacteria and eukaryotic cells with the goal of comparing their sizes.

EXPLORE 2

1. Students watch the animation *A Virus Attacks a Cell*. Ask students to journal their impression of the virus's size compared to the size of the cell it infected.
2. Ask students to choose one of each of the viruses, bacteria and eukaryotic cells in their student worksheets.
3. Students research online to find parameters related to the size of their chosen virus, bacterium and eukaryotic cell.
4. Ask students to use their graph paper to create a linear scale from 0 to 0.1mm in increments of 0.01mm.
5. Students indicate the absolute sizes of their virus, bacterium and eukaryotic cell on the linear scale. (Students will find that their scales are too big to accurately show the sizes of bacteria and viruses relative to eukaryotic cells.)
6. Ask students to calculate the ratios of sizes of their virus, bacterium and eukaryotic cell (e.g., virus = 0.005 microns, prokaryote = 5 microns, eukaryote = 50 microns is a ratio of 1:1000:10000).
7. Check student understanding using a formative assessment strategy (e.g., thumbs up/down or stop/go cards).
8. Review relevant concepts including scale, ratios, metric units of length, and powers of ten.
9. Tell students they will use the "whittle-down" strategy to explain their learning.

EXPLAIN

1. Using their work from Explore 2, students work independently.
2. From the video they watched in Explore 2 and their online research, students generate a list of five words in the student worksheet key concepts summary table ("my words") box. These can be any words that are relevant to the concept of sizes

of viruses, bacteria and eukaryotic cells, as well as other concepts they encountered in Explore 2 (scaling, comparative sizes, square-cube law).
3. Students move into small groups.
4. In their groups, students share their words along with their reasoning for the words they chose.
5. One student in each group records the complete list of words.
6. Each group narrows (whittles) down its list to the three most important words. All students record the group choices in the "my group" box on their worksheets.
7. Groups then share their words with the class.
8. Display the words to the class using your preferred method (whiteboard, flipchart, etc.).
9. Students work individually to write a summary of why those words help to explain the key concepts (viruses, bacteria and eukaryotic cells, scaling, comparative sizes, square-cube law, etc.).

ELABORATE

1. Students work in small groups to build scale models of a virus, a bacterium and a eukaryotic cell.
2. Encourage groups to research online to find details about specific viruses, bacteria and eukaryotic cells.
3. Students use the 3-D printer or modeling materials to build their models.
4. As students are building their models, encourage them to think about how structure and size are related to function. In particular, reinforce the concept that small size allows viruses to produce many infective particles with the resources of a single bacterium or eukaryotic cell.

EVALUATE

1. Students work individually or in pairs (e.g., struggling or ESL students) to complete the "Structure and Size Comparison" questions on the worksheet.
2. Review answers as a class.
3. Use an exit slip strategy to assess student understanding. Sample questions might include:
    a. What is the significance of the tiny size of viruses compared to living cells?
    b. How did the modeling activity help you to think about the differences between viruses, bacteria, and eukaryotic cells?
    c. What do the differences between the structures of viruses and bacteria tell you about how they function?

RUBRIC: STUDENT WORKSHEET

Key Concepts Summary Table

- Students should be able to articulate and justify how the words they chose help to explain the key concepts of the lesson.

Questions: Structure and Size Comparison

1. The influenza virus measures 120 nanometers (nm) across. The bacterium that causes diphtheria 0.5 microns (µm) in diameter. What is the approximate ratio of the sizes of these two disease-causing agents? Show your method.

- Sample answer:
  1. Convert both numbers to the same units. (Since 0.5 microns is a decimal it is easier to start by converting microns to nanometers, but either approach is fine.)
     0.5 microns = 500 nanometers
  2. Divide the larger number by the smaller to get the ratio.
     500:120 = 50:12
  3. Simplify by dividing by the highest common factor.
     50/2 = 25
     12/2 = 6
  4. Therefore, the ratio is 25:6 (about 5:1).

2. Use the square-cube law to explain the relationship between the surface areas and volumes of the virus and bacterium. (Hint: You do not have to calculate the surface areas and volumes.)

- Answers will vary. Sample answer: Since the virus is much smaller than the bacterium, the cube square law dictates that it will have a much larger volume relative to its surface area than the bacterium.

3. Josh couldn't make it to class and missed this lesson. Describe a model using everyday objects that you would use to describe to Josh the difference in scale between a human cell and a virus.

- Answers will vary. Sample answer: Assume that a virus measures 0.005 microns across, and a eukaryote measures 50 microns across. Those measures are in a ratio of 1:10,000. Therefore, I would show Josh two objects that differ by a factor of 1 to 10,000. For example, say a coffee bean represents a virus. It is 1 cm long. Therefore, an object 10,000 cm long would be the relative size of the human cell. A football field is 100 yards long. Since 100 yards = 91.44 meters (or 9144 cm) that would be about the same difference in scale.