Science Learning Packet

BIO B:
Bacteria and Viruses Packet

science learning activities for SPS students during the COVID-19 school closure.

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Due to the COVID-19 closure, teachers were asked to provide packets of home activities. This is not intended to take the place of regular classroom instruction but will help supplement student learning and provide opportunities for student learning while they are absent from school. Assignments are not required or graded. Because of the unprecedented nature of this health crisis and the District’s swift closure, some home activities may not be accessible.

If you have difficulty accessing the material or have any questions, please contact your student’s teacher.
Suggested Lesson Resources Take Home Packet

High School Biology B – Bacteria and Viruses

With the school closure due to the novel coronavirus (COVID-19), you might be wondering: What are viruses? How do viruses and other “germs” make us sick? What can we do to prevent and treat infections?

This unit is designed to supplement your learning from Biology. In the unit you will explore the world of bacteria and viruses and the human immune system that works to fight them off. You will also research past outbreaks of disease to see how scientists learn from and address health issues.

Why should you do this?
These are optional, ungraded materials to help you continue your learning during the school closure. However, the Biology standards are not covered in any other science course in high school. This is an opportunity to learn about infectious diseases and the immune system, topics which are very relevant today! The lessons also include numerous connections to the Genetics and Evolution units in Biology B. Goals are listed for each activity in the materials.

What resources do I need?
This packet and a pencil or pen. You may find it useful to have scrap paper, a highlighter, and markers or colored pencils, but this isn’t required. We recommend that you call a friend to talk through the lessons and/or share your learning with someone in your household.

What about online resources?
This packet references several videos and websites that you can access with a phone. If you don’t have internet access on your phone, you may find it helpful to call or text a friend to ask questions. If this is not possible, just skip those suggestions and use the materials in the packet.

What resources do I have to be successful?
If you can access Schoology, your teacher may be providing resources on their class webpage. If not, everything you need is in this packet. You can also ask questions of your teacher by sending them an email or contacting them using their usual procedure.

Timeline:
This packet will take about 2 weeks to complete. Below we have provided a suggestion on how you might work through the materials. Please adjust for you / your family.

Unit Driving Question: How can we use science to understand and prevent infectious diseases such as COVID-19?

<table>
<thead>
<tr>
<th>Day</th>
<th>Activity</th>
<th>Extensions (if interested and time allows)</th>
</tr>
</thead>
</table>
| 1   | 1.1 Introduction to Bacteria PowerPoint lesson  
1.1 Bacteria Reading  
00 Learning Tracking Tool | 1.2 OPTIONAL Introduction to Viruses Reading  
1.2 OPTIONAL Are Viruses Dead or Alive Reading |
| 2   | 1.2 Bacteria vs. Viruses PowerPoint lesson  
00 Learning Tracking Tool | |


<table>
<thead>
<tr>
<th>Week</th>
<th>Lesson 1.3 Fighting Pathogens PowerPoint lesson</th>
<th>Lesson 1.3 How Does the Immune System Work Reading</th>
<th>Learning Tracking Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1.3 OPTIONAL Cells of the Immune System Reading</td>
<td>1.3 OPTIONAL Antigens and Antibodies Reading</td>
<td>1.3 OPTIONAL Allergies Reading (you might spend an extra day on these extensions)</td>
</tr>
<tr>
<td>4</td>
<td>2.1 Understanding Pandemics PowerPoint lesson</td>
<td>2.1 Coronavirus Reading</td>
<td>Learning Tracking Tool</td>
</tr>
<tr>
<td>5</td>
<td>2.2 Research a Pathogen PowerPoint lesson</td>
<td>2.2 Research a Disease Pathogen student worksheet</td>
<td>Learning Tracking Tool</td>
</tr>
<tr>
<td></td>
<td>You might want to spend an extra day or two to research multiple pathogens</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2.3 How Viruses Change Over Time PowerPoint lesson</td>
<td>2.3 Introduction to Ebola Reading</td>
<td>Learning Tracking Tool</td>
</tr>
<tr>
<td>7</td>
<td>2.3 Ebola Student Worksheet</td>
<td>2.3 Sequence Sheet</td>
<td>Learning Tracking Tool</td>
</tr>
<tr>
<td>8</td>
<td>Finish Ebola Student Worksheet and check work using the provided key</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>3.1 and 3.2 Support Your Community! instructions</td>
<td>These activities may be ongoing and will vary in time.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>3.1 and 3.2 Support Your Community! instructions</td>
<td>These activities may be ongoing and will vary in time.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Learning Tracking Tool</td>
<td>Learning Tracking Tool</td>
<td>Learning Tracking Tool</td>
</tr>
</tbody>
</table>
Directions for Parents and Guardians
Biology B - Bacteria and Viruses: Understanding the Microbes that Make Us Sick

Answer key provided at back of packet

How to use these materials:
Seattle Public Schools Science is offering these materials as possible resources during the school closure. You may choose to adapt these resources to the needs of your student. These resources are being provided electronically on teachers’ Schoology pages and the Seattle Public Schools website and in print at school distribution sites.

If you have any questions, please reach out to your student’s Biology teacher.

A note on standards:
These lessons are supplemental, and in some cases, go beyond the Biology B instructional materials and the Next Generation Science Standards. However, we have typically had little opportunity to engage students in understanding microbiology, infectious diseases, and the immune system. During this unique moment, we believe that lessons like these can be responsive to the needs and interests of our students. The lessons also include numerous connections to the Genetics and Evolution units in Biology B. Goals are listed for each activity in the student-facing materials.

Lessons

Unit Driving Question (the question that students are trying to answer throughout the unit):
How can we use science to understand and prevent infectious diseases such as COVID-19?

Learning Tracking Tool (students summarize what they learn in each activity of the unit and identify how the activity helps them to figure out the unit driving question - this is a worksheet that your student is likely familiar with from their Biology class):
File: 00 Learning Tracking Tool Bacteria and Viruses

Lesson 1. Bacteria and Viruses: Understanding the Microbes that Make Us Sick
We’re hearing a lot about viruses in the news right now. What are the germs (bacteria and viruses) that make us sick? In this lesson students will explore background information on bacteria, viruses, and how we fight off pathogens. Work through the PowerPoints one at a time. We recommend doing one per day and supplementing with the readings as time allows.

Files:
1.1 Introduction to Bacteria PowerPoint lesson
1.1 Bacteria Reading
1.2 Bacteria vs. Viruses PowerPoint lesson
1.2 OPTIONAL Introduction to Viruses Reading
1.2 OPTIONAL Are Viruses Dead or Alive Reading
1.3 Fighting Pathogens PowerPoint lesson
1.3 How Does the Immune System Work Reading
1.3 OPTIONAL Cells of the Immune System Reading
1.3 OPTIONAL Antigens and Antibodies Reading
1.3 OPTIONAL Allergies Reading
Lesson 2. Think Like a Scientist: Case Studies on Past Pandemics

How can we use science to understand and respond to the current COVID-19 crisis? In this lesson students will use their understanding of bacteria and viruses to explore past pandemics. In activity 2.1 students will learn more about coronaviruses and how governments and scientists respond to health emergencies. In 2.2 students will research a pathogen that resulted in a past epidemic or pandemic and the scientific advances that occurred in the wake of these events. In activity 2.3 students use resources from HHMI BioInteractive – Ebola: Disease Detectives to explore the Ebola epidemic and how scientists study mutations in Ebola viruses. This lesson should be split over several days: one day for 2.1, one or more for 2.2 and two days of 2.3.

 glimpses of the past can provide perspective on current events. Understanding how and why pandemics have occurred in the past can help us to better understand the COVID-19 situation. This lesson will incorporate case studies of past pandemics to explore how science and public health have responded to these events.

Files:
- 2.1 Understanding Pandemics PowerPoint lesson
- 2.1 Coronavirus Reading
- 2.2 Research a Pathogen PowerPoint lesson
- 2.2 Research a Disease Pathogen student worksheet
- 2.3 How Viruses Change Over Time PowerPoint lesson
- 2.3 Introduction to Ebola Reading
- 2.3 Ebola Student Worksheet
- 2.3 Sequence Sheet

Lesson 3. Support Your Community!

How can we use our knowledge to support each other? In this lesson students do something to care for themselves and others in response to the COVID-19 situation. The time to complete these activities will vary and may be ongoing.

Files:
- 3.1 and 3.2 Support Your Community! instructions
## Learning Tracking Tool for Bacteria and Viruses:
How can we use science to understand and prevent infectious diseases such as COVID-19?

<table>
<thead>
<tr>
<th>Lesson</th>
<th>What did we do?</th>
<th>How can our learning be used to explain the phenomenon?</th>
<th>Self-Assess: Where am I with my understanding of the phenomenon?</th>
<th>What questions do I have?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Introduction to Bacteria</td>
<td></td>
<td></td>
<td>(Example: Ready to explain, starting to get it, need more information)</td>
<td></td>
</tr>
<tr>
<td>1.2 Bacteria vs. Viruses</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3 Fighting Pathogens</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Understanding Pandemics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lesson</td>
<td>What did we do? What did we figure out? Summarize key information and activities with a description and/or picture.</td>
<td>How can our learning be used to explain the phenomenon? Describe what you will add to your explanation of the phenomenon.</td>
<td>Self-Assess: Where am I with my understanding of the phenomenon? (Example: Ready to explain, starting to get it, need more information)</td>
<td>What questions do I have? What additional information do you need to understand the phenomenon?</td>
</tr>
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<td>-----------------</td>
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</tr>
<tr>
<td>2.2 Research a Pathogen</td>
<td></td>
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<td></td>
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<tr>
<td>2.3 How Viruses Change Over Time</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3.1 Care for Yourself and Your Household</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2 Care for Your Community</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
How to use this PowerPoint

• Work at your own pace. Your health and your family come first.
• If possible, you might find it helpful to go through activities at the same time as a peer. Then you can communicate through text, email, or a call if you have questions or to share ideas.
• You might find it helpful to have a piece of scrap paper and a pencil or pen to record questions or ideas.
• Read through the slides one at a time. Take your time to explore the images and any links.
• If you come across something you don’t understand, make a note of which slide you are on and come back to it after you go through the whole PowerPoint. If you are still confused, feel free to email your teacher with a question. You could also ask someone in your household or reach out to a peer through text, email, or a call.
• When you finish, consider sharing what you learned with someone in your household or a friend through text, email, or a call. Explaining your thinking will help you to retain and make sense of the information.

Goals

After reviewing this PowerPoint, you should be able to:
1) Identify several similarities and differences between prokaryotic cells (example: bacteria) and eukaryotic cells (example: human).
2) Describe the diversity of bacteria on Earth.
3) Identify several helpful things that bacteria do in the environment and for humans.

Initial Ideas

1) What do you think of when you hear the word “bacteria”?
2) How do you think bacteria compare to human cells in terms of their size and structure?
3) Can you think of anything good or helpful that bacteria do?
Fast Facts: Importance of bacteria and micro-organisms

- Micro-organisms such as bacteria and archaea (prokaryotes) colonize every environment on earth
- More than 80% of life's history is bacterial
- You have more bacterial cells than human cells in and on your body (and that's a good thing!)
- Microbes play a key role in the biosphere
- Pathogenic microbes globally are the most important cause of human disease and death

What are bacteria?

Bacteria are prokaryotes

Prokaryotic Cells Are Small and Lack Organelles

Prokaryotic cells are much smaller than eukaryotic cells and do not have the same internal organization. Prokaryotic cells lack organelles, instead carrying out all cellular functions in one central space. The single, circular DNA is also free-floating in the cytoplasm.

Prokaryotic Organisms:
- Typically single-cell
- No organelle
- Single, circular DNA not contained in a nucleus

...and one-tenth the size of a human hair

Prokaryotic and Eukaryotic Cells Have Different Structures

While all cells have a cell membrane, cytoplasm, ribosomes and DNA, there are specific structural differences between prokaryotic and eukaryotic cells. Eukaryotic cells contain a variety of membrane-enclosed organelles while prokaryotic cells do not.

Basic Prokaryotic Cell

- Prokaryotic and eukaryotic cells share these common structures:
  - Cell membrane
  - Cytoplasm
  - Ribosomes
  - Genetic material (DNA)

Basic Eukaryotic Cell

- Prokaryotic cells have a cell wall.
- Eukaryotic cells have specialized compartments (organelles) for specific cell functions.
Comparing prokaryotes (bacteria) with eukaryotes (humans)

Use your learning from the previous slides to fill in the blanks in the table below.

<table>
<thead>
<tr>
<th></th>
<th>Prokaryotic Cells (Bacteria and Archaea)</th>
<th>Eukaryotic Cells (Plants, Animals, Fungi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single or multi-cellular?</td>
<td>Typically single-cell organisms</td>
<td>Many single-cell and all multicellular organisms</td>
</tr>
<tr>
<td>Size (which is larger?)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nucleus (Y/N)</td>
<td>No nucleus</td>
<td>Yes, nucleus present</td>
</tr>
<tr>
<td>Organelles (Y/N)</td>
<td>No membrane-bound organelles</td>
<td>Yes, membrane-bound organelles present</td>
</tr>
<tr>
<td>DNA structure</td>
<td>Circular DNA</td>
<td>Chromosomes in nucleus</td>
</tr>
</tbody>
</table>

Why are bacteria important?

Prokaryotes make up 2 of the 3 “domains of life” on Earth.

Bacteria and Archaea, Life’s Prokaryotic Domains

Prokaryotes like bacteria and archaea are found everywhere.
**Bacteria are diverse**

We classify bacteria by:

1. **Shape/structure**
   - Cocci
   - Bacilli
   - Spirochaetes

2. **Response to oxygen**
   - Aerobic
   - Anaerobic

3. **How they obtain energy**
   - Autotrophs that make their own food (like plants)
   - Heterotrophs that take in food (like us)

4. **Gram Staining**
   - (cell wall type)

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**Bacteria help plants to access nitrogen**

**Nitrogen-fixing bacteria** – Bacteria that take nitrogen gas ($N_2$) and convert it into ammonia which can be used by plants for growth.

Rhizobium Bacteria – Symbiotic bacteria that live in root nodules of plants and fix nitrogen.

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**Nitrogen Cycle**
Bacteria are decomposers

Bacteria help recycle carbon by digesting organic wastes. They break down dead plants and animals, returning CO$_2$ to the atmosphere.

Carbon Cycle

Check Your Understanding

1) Where are bacteria found on Earth?
2) How common are prokaryotes like bacteria and archaea?
3) What role do bacteria play in the environment?
4) Identify at least two helpful things that bacteria do in the human body.

What’s Next?

1) Read the Bacteria Reading.
2) Make an entry in your Learning Tracking Tool titled “Introduction to Bacteria.”
Activity 4.1: Bacteria Handout

Where bacteria live and their role in ecosystems

Bacteria are tiny single-celled organisms. Most species are only about 1/10th the size of plant and animal cells, and many are even smaller. Bacterial cells may be many different shapes including spheres, rods, and spirals. Although bacteria are unicellular, some species clump together to form chains and others form films that stick to surfaces (such as plaque on your teeth). Bacteria live in many different environments, including in conditions that no plant or animal cells can survive. For example, some species live without oxygen or light at temperatures of -10°C. Although bacteria are too small to see without a microscope, they are much more abundant than any other type of cell on earth. In fact, if you could take the mass of all the bacteria on earth it would be greater than the mass of all of the plants and animals! More than 1,000 species of bacteria live in or on our bodies. You have about 100 trillion bacterial cells in and on your body right now. That means that bacterial cells outnumber your body cells 10 to 1.

Bacteria directly influence plant, animal and human health. Because some species of bacteria make plants and animals sick, like the MRSA bacteria in Figure 2, many people think of bacteria as generally harmful. In fact, most species of bacteria are not harmful to other organisms, and many are very helpful. For example, bacteria in our intestines play essential roles in supporting digestion of food and producing vitamin B and vitamin K. Many helpful species of bacteria also live in or on plants. For example, some bacteria live inside plant roots and convert nitrogen from the air into a form that the plant can use to make proteins and other organic molecules.

Bacteria are very abundant in soil. A spoonful of soil contains 50 million bacterial cells representing up to 10,000 different species. Many of these species are decomposers that play an important role in nutrient cycling in ecosystems. Many types of organic material (such as cellulose that makes up wood) can only be broken down by certain species of bacteria that are able to digest them.

Figure 0 - This picture of rod-shaped bacteria cells was taken with an electron microscope. If this bacterium cell were an inch long, a cell of an onion would be about 40 inches long. Credit: FEI

Figure 0 - Scanning electron microscope image of MRSA bacteria, or Staphylococcus aureus. Although these bacteria cause humans to be sick, most bacteria are helpful. Credit: CDC/Janice Haney Carr
How bacteria get their food

Some bacteria are producers like plants; they make their own food from inorganic materials through the process of photosynthesis. Other species of bacteria are consumers like animals; they must eat organic matter produced by other organisms. It is important to remember that most decomposers are consumers – we distinguish them as decomposers because of their important role in returning matter from the bodies of dead organisms back into the environment through the process of digestion and cellular respiration. Many complex organic molecules that make up hair, bone, and wood can only be digested by bacteria, which makes them essential for returning nutrients back to the environment.

Bacteria absorb their food through their cell membranes. Food particles have to be very tiny to move through the cell membrane, so digestion takes place outside their cells. Many bacteria feed on the waste products from other organisms because they contain the organic molecules that were indigestible to the original consumer. In soil, these waste products are called detritus. Detritus is a major food source for bacteria. Like fungi, some bacteria secrete enzymes that can break down polymers into monomers that can then be absorbed.

How bacteria use matter and energy from their food to grow

Like all organisms, bacteria use food in two main ways: for gaining matter for growth (through the process of biosynthesis) and for gaining energy for movement and functioning (through the process of cellular respiration). Although bacterial cells are simpler than the cells that make up plants, animals or fungi, they are still made up of many different complex organic molecules including proteins, carbohydrates, and fats. Therefore, they must perform biosynthesis in order to rearrange atoms that they take in as food molecules into new organic molecules that make up their cellular structures.

Bacteria also release energy from their food through the process of cellular respiration. Many species of bacteria perform the exact same type of cellular respiration that plants, animals and fungi do. By rearranging food molecules containing high-energy C-C and C-H bonds into the inorganic products of carbon dioxide and water, energy is released that the cells can use to move and grow.

Although all bacteria get energy by rearranging organic molecules, many species perform different variations of the cellular respiration process. For example, some species can extract energy from organic molecules without oxygen. Fermentation is one such process that releases energy from organic molecules without the presence of oxygen. Fermentation is less efficient than cellular respiration though, which means that it releases less energy per gram of glucose. This is because fermentation creates high-energy byproducts such as ethanol (alcohol) or lactic...
acid. Bacteria that produce lactic acid through fermentation are called lactobacillus and are used to make foods such as yogurt, pickles, and sauerkraut.
How to use this PowerPoint

• **Work at your own pace.** Your health and your family come first.
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Bacteria vs. Viruses
What are viruses?
How do bacteria and viruses compare?

Goals

After reviewing this PowerPoint, you should be able to:
1) Describe how viruses compare to bacteria and to eukaryotic cells (example: human).
2) Describe how viruses replicate in host cells.

Initial Ideas

1) What do you think of when you hear the word “virus”?
2) Can you name any viruses? How many?
3) How do you think bacteria and viruses compare in terms of size and structure?
4) How do you think bacteria and viruses make us sick?
What are viruses?

Virus structure

Made up of:
1. Core of nucleic acid (DNA or RNA)
   Note: RNA is a molecule very similar to DNA
2. Capsid = protein coating

How do bacteria and viruses compare?

Comparing Bacteria and Viruses

Use your learning from the previous slides to fill in the blanks in the table below

<table>
<thead>
<tr>
<th></th>
<th>Viruses</th>
<th>Prokaryotes (Bacteria and Archaea)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>Non-cellular particles</td>
<td>Cells</td>
</tr>
<tr>
<td>Size (which is larger?)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DNA and/or RNA?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of genes</td>
<td>10s to 100s of genes</td>
<td>100s to 1000s of genes</td>
</tr>
</tbody>
</table>
Comparing Bacteria and Viruses

**Answers:**

<table>
<thead>
<tr>
<th></th>
<th>Viruses</th>
<th>Prokaryotes (Bacteria and Archaea)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure</strong></td>
<td>Non-cellular particles</td>
<td>Cells</td>
</tr>
<tr>
<td><strong>Size (which is larger?)</strong></td>
<td>Smaller</td>
<td>Larger</td>
</tr>
<tr>
<td><strong>DNA and/or RNA?</strong></td>
<td>Either DNA or RNA (not both)</td>
<td>Contain DNA and RNA inside the cells</td>
</tr>
<tr>
<td><strong>Number of genes</strong></td>
<td>10s to 100s of genes</td>
<td>100s to 1000s of genes</td>
</tr>
</tbody>
</table>

Viruses can only replicate in host cells

1. **Attack site:** A virus particle binds to receptor molecules on the cell surface.
2. **Penetration:** The virus enters the host cell and releases its nucleic acid.
3. **Synthesis:** The virus hijacks host cell machinery and resources to mass-produce more viral nucleic acid and proteins.
4. **Assembly:** New virus particles are produced.
5. **Release:** New virus particles exit the host cell.

Viruses can invade both prokaryotic and eukaryotic cells.

Yes, viruses can attack bacteria!

How do viruses evolve (change over time)?

- Mutations in the DNA or RNA
- Viruses can exchange genes with other viruses

**Antigenic Drift and Shift Create New Influenza Strains**

- **Antigenic Drift:** Gradual change caused by point mutations that occur during the virus replication.
- **Antigenic Shift:** Induced by genetic exchange between two different viruses that simultaneously infect the same cell.
Review Your Initial Ideas
1) What do you think of when you hear the word “virus”?  
2) Can you name any viruses? How many?  
3) How do you think bacteria and viruses compare in terms of size and structure?  
4) How do you think bacteria and viruses make us sick?

What’s Next?
1) Read the Bacteria vs. Viruses Reading. For more on viruses, read one or both of the optional readings.
2) Make an entry in your Learning Tracking Tool titled “Bacteria vs. Viruses.”
Bacteria vs. Viruses

**Bacteria** are single-cell, living organisms that can survive without a host. They can live on surfaces, in soil, in water, and in the air.

Your body has a rich diversity of bacteria. The normal adult has 1.2 kg (2.6 lb) of bacteria on and in their body. This normal flora is not harmful in normal circumstances. Some of the important functions of normal flora are a) act as a barrier to infection and colonization by pathogenic bacteria, b) intestinal flora synthesizes some vitamins we need, and c) to stimulate the immune system.

Many species of bacteria are also essential for environmental health. Nitrogen-fixing bacteria take nitrogen gas from the atmosphere and converts it to ammonia, which plants can use to grow. Other bacteria can act as decomposers, recycling carbon by digesting organic waste.

However, some bacteria are harmful. They can cause diseases such as pneumonia and food poisoning. You can kill these bacteria by messing with their ability to do cellular respiration (produce energy) or their ability to grow. Antibiotics are used to treat bacterial infections because antibiotics kill bacteria.

**Viruses** are not cells; they have no metabolism and they cannot survive alone. A virus is a chain of DNA or RNA (genetic material) and needs a host cell in order to stay alive. Once a virus gets into a cell it tricks the cells into replicating it! Antibiotics are completely useless against viruses. If you have a virus, like a cold or the flu, a doctor would be silly to prescribe an antibiotic because antibiotics will not kill the virus. There are some antiviral drugs that help protect you from a viral infection. Antivirals either make it harder for the virus to get into the cell or they prevent the virus from reproducing once they are inside of your cells.

<table>
<thead>
<tr>
<th>BACTERIA</th>
<th>VIRUSES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LIVING?</strong></td>
<td>Living organism</td>
</tr>
<tr>
<td><strong>NUMBER OF CELLS</strong></td>
<td>Unicellular, one cell</td>
</tr>
<tr>
<td><strong>TREATMENT</strong></td>
<td>Antibiotics</td>
</tr>
<tr>
<td><strong>INFECTION</strong></td>
<td>Localized area of body</td>
</tr>
<tr>
<td><strong>BENEFITS</strong></td>
<td>Some bacteria are beneficial (e.g. certain bacteria are required in the gut)</td>
</tr>
<tr>
<td><strong>REPRODUCTION</strong></td>
<td>Splits into 2</td>
</tr>
<tr>
<td><strong>SIZE</strong></td>
<td>Larger</td>
</tr>
</tbody>
</table>
Bacteria vs Viruses

Instructions: Read the information about bacteria and viruses. Then consider the table below describing how bacteria and viruses enter the body.

<table>
<thead>
<tr>
<th>HOW BACTERIA &amp; VIRUSES ENTER THE BODY</th>
<th>BACTERIA</th>
<th>VIRUSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>To cause disease, pathogenic bacteria must gain access into the body. The range of access routes for bacteria includes:</td>
<td>Cuts</td>
<td>Coughs</td>
</tr>
<tr>
<td>✷ Contaminated food or water</td>
<td>Sneeze</td>
<td>Sneezes</td>
</tr>
<tr>
<td>✷ Close contact with an infected person</td>
<td>Vomits</td>
<td></td>
</tr>
<tr>
<td>✷ Contact with the feces of an infected person</td>
<td>Bites from infected animals or insects</td>
<td></td>
</tr>
<tr>
<td>✷ Breathing in the exhaled droplets when an infected person coughs or sneezes</td>
<td>Exposure to infected bodily fluids through activities such as sexual intercourse or sharing hypodermic needles</td>
<td></td>
</tr>
<tr>
<td>✷ Indirectly, by touching contaminated surfaces, such as taps, toilet handles, toys and nappies.</td>
<td>Forgetting to wash your hands after handling pets and animals is another way for germs to be taken in by mouth.</td>
<td></td>
</tr>
</tbody>
</table>
Introduction to Viruses

Introduction

Scientists estimate that there are roughly $10^{31}$ viruses at any given moment. That’s a one with 31 zeroes after it! If you were somehow able to wrangle up all $10^{31}$ of these viruses and line them end-to-end, your virus column would extend nearly 200 light years into space. To put it another way, there are over ten million times more viruses on Earth than there are stars in the entire universe.

Does that mean there are $10^{31}$ viruses just waiting to infect us? Actually, most of these viruses are found in oceans, where they attack bacteria and other microbes. It may seem odd that bacteria can get a virus, but scientists think that every kind of living organism is probably host to at least one virus!

What is a virus?

A virus is a tiny, infectious particle that can reproduce only by infecting a host cell. Viruses "commandeer" (take over) the host cell and use its resources to make more viruses, basically reprogramming it to become a virus factory. Because they can't reproduce by themselves (without a host), viruses are not considered living. Nor do viruses have cells: they're very small, much smaller than the cells of living things, and are basically just packages of genetic material and protein.

Still, viruses have some important features in common with cell-based life. For instance, they have genetic material. Also, like cell-based life, viruses have genetic variation and can evolve. So, even though they don't meet the definition of life, viruses seem to be in a "questionable" zone.

How are viruses different from bacteria?

Even though they can both make us sick, bacteria and viruses are very different at the biological level. Bacteria are small and single-celled, but they are living organisms that do not depend on a host cell to reproduce. Because of these differences, bacterial and viral infections are treated very differently. For instance, antibiotics are only helpful against bacteria, not viruses.

Bacteria are also much bigger than viruses. The diameter of a typical virus is about 20 - 300 nanometers (nm) (1 nm=10^{-9} meters!). This is considerably smaller than a typical E. coli bacterium, which has a diameter of roughly 1000 nm. Tens of millions of viruses could fit on the head of a pin.

The structure of a virus

There are a lot of different viruses in the world. So, viruses vary a ton in their sizes, shapes, and life cycles. Viruses do, however, have a few key features in common. These include:

- A protective protein shell, or capsid
- A nucleic acid genome made of DNA or RNA, tucked inside of the capsid
- A layer of membrane called the envelope (some but not all viruses)
Virus capsids

The capsid, or protein shell, of a virus is made up of many protein molecules (not just one big, hollow one). The proteins join to make units called capsomers, which together make up the capsid. How does a virus make a capsid? The virus (not the host cell) has genetic material that provides the instructions for making the capsid proteins. Capsids come in many forms, but they often take one of the following shapes (or a variation of these shapes):

1. Icosahedral – Icosahedral capsids have twenty faces, and are named after the twenty-sided shape called an icosahedron.

2. Filamentous – Filamentous capsids are named after their linear, thin, thread-like appearance. They may also be called rod-shaped or helical.

3. Head-tail – These capsids are kind of a hybrid between the filamentous and icosahedral shapes. They basically consist of an icosahedral head attached to a filamentous tail.

Virus envelopes

In addition to the capsid, some viruses also have an external membrane known as an envelope, which surrounds the entire capsid. Envelopes contain proteins that are specified by the virus, which often help viral particles bind to host cells.

Although envelopes are common, especially among animal viruses, they are not found in every virus (i.e., are not a universal virus feature).

Virus genomes

All viruses have genetic material (a genome). You, like all other cell-based life, use DNA as your genetic material. Viral genetic material (genomes) come in various shapes, sizes, and varieties, though they are generally much smaller than the genomes of cellular organisms.

What is a viral infection?

In everyday life, we tend to think of a viral infection as the nasty collection of symptoms we get when catch a virus, such as the flu or the chicken pox. But what’s actually happening in your body when you have a virus?

At the microscopic scale, a viral infection means that many viruses are using your cells to make more copies of themselves. The viral lifecycle is the set of steps in which a virus recognizes and enters a host cell, "reprograms" the host by providing instructions in the form of genetic material, and uses the host’s resources to make more virus particles (the output of the viral "program").
For a typical virus, the lifecycle can be divided into five broad steps (though the details of these steps will be different for each virus):

1. **Attachment.** Virus binds to receptor on cell surface.
2. **Entry.** Virus enters cell by endocytosis.
3. **Replication and gene expression.** The genetic material is copied and translated into viral proteins using. The viral proteins produced include capsid proteins.
4. **Assembly.** Capsid proteins and genetic material come together to make new viral particles.
5. **Release.** The host cell **lyses** (bursts), releasing the viral particles, which can then infect other host cells.

![General diagram of a virus lifecycle](figure_5_general_steps_of_a_viral_infection.png)

*Figure 5 General steps of a viral infection*

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**Read This!**

**Key Concepts from this Article:**

- A **virus** is an infectious particle that reproduces by "commandeering" (taking over) a host cell and using its machinery to make more viruses.
- A virus is made up of genetic material inside a protein shell called a **capsid.** Some viruses have an external membrane **envelope.**
- Viruses are very diverse. They come in different shapes and structures, have different kinds of genomes, and infect different hosts.
- Viruses reproduce by **infecting** their host cells and reprogramming them to become virus-making "factories."

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Are viruses dead or alive?

If life were a monster movie, would viruses be vampires or zombies? Werewolves or Frankenstein’s monster? Would they be something else entirely? The first step in answering these questions comes down to – are viruses alive or dead? How do we determine whether something is alive? Let’s compare viruses to the 7 criteria researchers have set to determine if something is alive.

1. Living things must maintain homeostasis

Homeostasis is all about balance – can something control its internal temperature, or its internal contents? In earlier drafts of criteria for life, the requirement was that living things must be made of cells. Viruses are not made out of cells. A single virus particle is known as a **virion**, and is made up of a set of genes bundled within a protective protein shell called a **capsid**. Certain virus strains will have an extra membrane (lipid bilayer) surrounding it called an envelope. Viruses do not have nuclei, organelles, or cytoplasm like cells do, and so they have no way to monitor or create change in their internal environment. This criterion asks whether an individual virion is capable maintaining a steady-state internal environment on its own. Though some have argued that the capsid and envelope help virions resist change in their environment, the general consensus is that viruses do not pass this first requirement for life. Still, very few things in biology are black and white, so let’s check out how viruses do with the rest of the list before we make our final decision.

*Do virus pass this criteria for life? Verdict: Fail*

2. Living things have different levels of organization.

Life is a complicated idea, and live organisms reflect that complexity in their structure. Smaller building blocks come together to make a larger product. Viruses certainly do this. They have genes made from nucleic acids and a capsid made of smaller subunits called capsomeres.

*Do virus pass this criteria for life? Verdict: Pass*

3. Living things reproduce.

One of the basic urges in nature is for a species to pass on its genetic information. Viruses definitely multiply. While our immune system could certainly handle a single virion, it’s the hundreds of thousands of virions created in a short period of time that harm our cells. Viruses must use host cells to create more virions. Since viruses don’t have organelles, nuclei, or even ribosomes, they don’t have the tools they need to copy their genes, much less create whole new virions. Instead, viruses enter living cells and then hijack the host’s cellular equipment to copy viral genetic information, build new capsids, and assemble everything together. We use the term replicate, instead of reproduce, to indicate viruses need a host cell to multiply.

*Do virus pass this criteria for life? Verdict: Maybe*
4. Living things grow.

Living things grow. They use energy and nutrients to become larger in size or more complex. Viruses manipulate host cells into building new viruses which means each virion is created in its fully-formed state, and will neither increase in size nor in complexity throughout its existence. Viruses do not grow.

*Do virus pass this criteria for life? Verdict: Fail*

5. Living things use energy.

This criterion is somewhat tricky. Creating new virion units is a major undertaking, from building nucleic acids to putting capsids together – that costs a lot of energy. However, all the energy that goes into this construction comes from, you guessed it, the host. While viruses will definitely benefit from the use of energy, they are latching onto the host's metabolism to get to it (maybe they're vampires?).

*Do virus pass this criteria for life? Verdict: Maybe*

6. Living things respond to stimuli.

Whether viruses respond to their environment is one of the trickiest questions to answer. A response to a stimulus is defined by an almost immediate reaction to some change in the environment. While they don't change behaviors in response to touch or sound or light the way that humans, bacteria, or sea sponges might, there has not been enough research done to definitively say that viruses do not respond to anything.

*Do virus pass this criteria for life? Verdict: Unknown*

7. Living things adapt to their environment.

Adaptation and evolution happen through unintentional changes (mutations) that are advantageous to an entire species. Viruses definitely adapt to their surroundings. Unlike the previous requirement, which required an immediate response, adaptation is a process that takes place over time. A virus can live in two different phases – the lytic phase (where the virus actively replicates in a host cell) and the lysogenic phase (where the viral DNA incorporate itself into the cell's DNA and multiples whenever the cell multiplies). Sometimes a host does not have enough energy or supplies to support the virus to actively replicate, so it will switch to the lysogenic phase. The virus can eventually reenter the lytic phase when conditions are right. This ability to adapt is what makes Human Immunodeficiency Virus (HIV) as hard to treat as it is. HIV mutates quickly because it makes frequent mistakes while replicating its genome. Because the virus is constantly changing, it makes it very hard to design drugs and vaccines against it. One drug might prevent a large number of virions from replicating, but just a few will be unaffected. Those surviving virions will continue to infect more cells, making copies of the resistant strains.

*Do virus pass this criteria for life? Verdict: Pass*
Where does this leave us? Are viruses alive or dead? Well, we know they’re not dead. Death is what happens when a living organism stops performing biological functions, and for the moment we’re only interested in the active particles. So were they ever alive? Most biologists say no. Viruses are not made out of cells, they can’t keep themselves in a stable state, they don’t grow, and they can’t make their own energy. Even though they definitely replicate and adapt to their environment, viruses are more like androids than real living organisms. (Think Data from Star Trek, Arnold Schwarzenegger in Terminator, the Cylons in Battlestar Galactica or the robots in I, Robot). Just like crazy killer robots, viruses are created fully formed, and rely on host materials to build and power themselves.

Consider the following:

- If a virus isn’t alive, does that affect how we deal with viral infections? Absolutely. Antibiotics, for example, are used to treat bacterial infections, and are useless at dealing with a viral infection like the flu or chickenpox. Antibiotics target certain parts of bacteria in the hopes of killing them; with viruses it’s hard to kill something that isn’t quite alive to begin with. Instead of destroying the virus, antiviral medicines try to shut off the replication cycle, like shutting down the android production line.

- What happens if a virus infects another virus? Scientists found a bacteria-sized giant virus which they named mamavirus. Upon further study, it turned out that this giant virus actually had a smaller virus associated with it. When mamavirus infected amoebae, it created a giant virus factory, whose machinery was then hijacked by the smaller virus (Sputnik). Some scientists have pointed out the fact that if a virus can get sick, then it is should be considered a living thing. (Pearson).

Sources:


1. What is something NEW you learned from the article?
2. Do you think viruses a living entity? Why or why not?
3. If viruses are getting the energy to replicate from the host, how might that affect the host’s energy? How do you see this happen when someone gets sick from a virus such as Coronavirus or the Flu?
How to use this PowerPoint

• Work at your own pace. Your health and your family come first.
• If possible, you might find it helpful to go through activities at the same time as a peer. Then you can communicate through text, email, or a call if you have questions or to share ideas.
• You might find it helpful to have a piece of scrap paper and a pencil or pen to record questions or ideas.
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• When you finish, consider sharing what you learned with someone in your household or a friend through text, email, or a call. Explaining your thinking will help you to retain and make sense of the information.

Goals
After reviewing this PowerPoint, you should be able to:
1) Identify several pathogens.
2) Describe how bacteria and viruses make us sick.
3) Describe the immune system.
4) Identify several ways that you can help prevent infections.
5) Explain the difference between antibiotics, antivirals, and vaccinations.

What are pathogens?
A pathogen is anything that can produce disease. Pathogens are often called “germs.”

Parasites (e.g. helminths) → Tapeworm
Protozoa (e.g. plasmodia) → Malaria
Fungi (e.g. tinea) → Athlete’s foot
Prokaryote (i.e. bacteria) → Leprosy
Cellular (living)

Virus (e.g. HIV) → AIDS
Acellular (non-living)

Prion → CJD
How do bacteria and viruses make us sick?

Viruses make us sick by killing cells or disrupting cell functions.

Bacteria make us sick by killing or damaging cells, giving off toxins (chemicals) that damage cells, or by disrupting our immune system.

Infection occurs when bacteria and viruses enter our bodies and start to reproduce. Disease or illness occurs when bacteria and viruses damage our cells.

Disease or illness occurs when bacteria and viruses damage our cells.

How does your body protect itself?

Step 1: Keep pathogens out!

Your skin, mucous, and stomach acid are all examples of your first line of defense against pathogens. They help to prevent pathogens from entering the body.

What can you do to prevent pathogens from entering your body?

From the Centers for Disease Control (CDC):

- Cough or sneeze into a tissue or your elbow. If you sneeze or cough into a tissue, throw it in the trash right away.
- Keep your hands out of your mouth, nose, and eyes. This will help keep germs out of your body.
- Wash your hands with soap and water for at least 20 seconds. Follow these five steps—wet, lather (make bubbles), scrub (rub together), rinse and dry. You can sing the “Happy Birthday” song twice.
- If you don’t have soap and water, use hand sanitizer.
- Keep things clean. Clean the things you touch the most, like desks, doorknobs, light switches, and remote controls.
- If you feel sick, stay home. Just like you don’t want to get other people’s germs in your body, other people don’t want to get your germs either!
Step 2: Identify and remove pathogens

- Your white blood cells locate and destroy cells that aren’t yours and identify cells that have been invaded by pathogens

Want more detail? Check out these videos: TedEd video on the Immune System or Amoeba Sisters video on the Immune System

There are several readings with more details, too!

Vaccinations

- Vaccinations stimulate your immune system to make antibodies to the pathogen (example: the flu shot)
- Check out this reading showing the role of vaccinations in protecting a population.
- Thought Question: Why would you need “booster” shots for some vaccinations?

Antibiotics

- Antibiotics are used against bacteria
- Antibiotics are NOT effective against viruses
- Some are specific while others are broad-spectrum (kills a lot of different types of bacteria)

The discovery of antibiotics

How Penicillin Was Discovered

Antivirals

- Antivirals are drugs that can treat people who have already been infected by a virus.
- They also can be used to prevent or limit infection when given before or shortly after exposure, before illness occurs.
- Antiviral drugs are only effective only when administered within a certain time frame before or after exposure.
How do scientists fight pathogens on a larger scale?

ep·i·de·mi·ol·o·gy
ˌepəˈdēmēˈäləjē/
noun
noun: epidemiology
• the branch of medicine that deals with the incidence, distribution, and possible control of diseases and other factors relating to health

Check Your Understanding

1. What are pathogens?
2. How does your body prevent pathogens from getting in?
3. How does your body fight off pathogens if they do make it inside?
4. Identify several things that you can do to help your body fight off pathogens.
5. Share your ideas from #4 with someone in your household or a friend!

What’s Next?

1) Read the How Does the Immune System Work Reading. You may also want to read the optional readings for more information.
2) Make an entry in your Learning Tracking Tool titled “Fighting Pathogens.”
How does the immune system work?

The immune system (from the Latin word *immunis*, meaning: “free” or “untouched”) protects the body like a guardian from harmful influences from the environment and is essential for survival. It is made up of different organs, cells and proteins and aside from the nervous system, it is the most complex system that the human body has.

As long as our body’s system of defense is running smoothly, we do not notice the immune system. And yet, different groups of cells work together and form alliances against just about any pathogen (germ). But illness can occur if the performance of the immune system is compromised, if the pathogen is especially aggressive, or sometimes also if the body is confronted with a pathogen it has not come into contact before.

The tasks of the immune system

Without an immune system, a human being would be just as exposed to the harmful influences of pathogens or other substances from the outside environment as to changes harmful to health happening inside of the body. The main tasks of the body’s immune system are:

- Neutralizing pathogens like bacteria, viruses, parasites or fungi that have entered the body, and removing them from the body
- Recognizing and neutralizing harmful substances from the environment
- Fighting against the body’s own cells that have changed due to an illness, for example cancerous cells

Differentiation between self and non-self substances

For protection to be effective it is important, however, that the immune system can differentiate between “self” and “non-self” cells, organisms and substances. Usually, the body should not work against its own healthy cells.

The immune system can be activated by many “non-self” substances. These are called antigens. The proteins on the surfaces of bacteria, fungi and viruses, for example, are all antigens. When the antigens bind to, for example, special receptors on the defense cells, a series of cell processes is started. Then the immune system can recall stored “memories” in order to more quickly be ready to defend against known pathogens.

The body’s own cells have surface proteins, too. But the immune system does not work against them, because it has already learned at an earlier stage to identify specifically these cell proteins as “self.” If the immune system identifies the cells of its own body as “non-self,” it is also called an autoimmune reaction.

Innate immune system

There are two main parts of the immune system: the innate and the adaptive immune system.

The evolutionary older innate immune system provides a general defense against pathogens, so it is also called the nonspecific immune system. It works mostly at the level of immune cells like “scavenger cells” or “killer cells.” These cells mostly fight against bacterial infections.

Adaptive immune system

In the adaptive immune system, particular agents like the so-called antibodies target very specific pathogens that the body has already had contact with. That is why this is also called a learned defense or a specific immune response. By constantly adapting and learning the body can also fight against bacteria or viruses that change over time.

Yet these two immune systems do not work independently of each other. They complement each other in any reaction to a pathogen or harmful substance, and are closely connected with each other.

How does the immune system work?

Instructions: Read the article at the station and answer the following questions:

1. What are some of the tasks of the immune system?

2. How does the body/the immune system know what “stuff” to attack and what to leave alone? (Determining self from non-self)

3. What is the innate immune system? Briefly describe what it does.

4. What is the adapted immune system? Briefly describe what it does.

5. What are some questions you have?
**Cells of the Immune System**

Your immune cells are called leukocytes, or white blood cells.

**Macrophages** - These large cells "eat" invaders (antigens). Once “eaten” the invader (antigen) is broken down by enzymes inside the macrophage. Macrophages can signal the body to flood an infected area with water which makes it easier for them to “eat” invaders (antigens).

**Neutrophils** - These cells release chemicals that kill bacteria. The chemicals are also dangerous to the neutrophils (themselves) and therefore they are only able to live for a few days after releasing chemicals in the infected area.

**B cells** - These cells are made in your bone marrow. B cells float around your entire body in the blood looking for invaders (antigens). Each B cell can only recognize one type of antigen. When a B cell encounters an antigen that it recognizes it matures into a plasma cell and divides rapidly. Plasma cells (mature B cells) are factories for antibodies. They produces antibodies that are specific to the antigen the B cell originally recognized. Antibodies attach to antigens and signal the antigen for destruction. Antibodies can also surround an intruder, preventing it from attacking your other cells. B cells and antibodies only protect you from invaders (antigens) floating throughout your blood.

**T cells** - These cells are made in the bone marrow as well. They travel to the lymph nodes throughout your body where they are taught to recognize invaders (antigens). T cells are specific to a specific antigen. Your body makes tens of millions of different T cells in the hope of recognizing all the different types of invaders they might encounter throughout your lifetime. When a body cell is infected by an invader it presents parts of the invader on its cell membrane (like a little flag). They can then kill those cells. T cells only protect your cells once they’re infected.

**Natural Killer Cells** - These cells kill foreign cells and infected self cells. Natural killer cells make a hole in the plasma membrane of the cell causing water to rush into the pore and the cell bursts and dies. Natural killer cells kill anything that doesn't present "self proteins" (for example, an infected cell waving a flag with invader parts).

# Cells of the Immune System

Instructions: Read through the descriptions of the cells of the immune system at your station and fill out the table below.

<table>
<thead>
<tr>
<th>Name</th>
<th>Sketch</th>
<th>Where does it work</th>
<th>What does it do</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macrophage</td>
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<tr>
<td>Neutrophil</td>
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<td>B cells</td>
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<td>T cells</td>
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<tr>
<td>Natural Killer T cells</td>
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</tbody>
</table>

What are some questions you have?
Antigens and Antibodies

Antibodies are proteins. They are made of chains of amino acids that are folded into a specific shape based on the sequence and properties of the amino acids. Antibodies all have the same basic structure. Each antibody is made of four chains (shown in the image as blue/dark blue and green/dark green sections). There are two long heavy chains (colored blue/dark blue) and two shorter light chains (green/dark green). The place where they bind antigens is found at the tips of the two arms, in a pocket formed between the light and heavy chain (shown in the image as the pink box, called the antigen-binding site).

Antigens are molecules, such as proteins and carbohydrates (usually on the surface or inside bacteria, viruses, parasites and fungi), that can fit into the antigen-binding site; very similar to how enzymes have a specific binding sites that match with specific substrates.

Antibodies are specific to antigens. This means having antibodies for measles does NOT protect you from the mumps. And having antibodies for one type of influenza (seasonal flu) does not necessarily protect you from another type of influenza. Your B cells make antibodies both randomly (sort of like a “just in case” scenario) and when presented with a new antigen. Each B cell only makes one type of antibody, though it can divide and make other B cells that make that same antibody. These antibodies make it easier for the rest of your immune system to destroy antigens (see image).
Antigens and Antibodies

Instructions: Read the information about Antibodies and Antigens and answer the questions below.

1. Briefly describe how antibodies work.

Using the image below, create an antibody to match three of the antigens below.

2. Why do you think it is important that antibodies match antigens exactly?

3. What could happen if antibodies were not specific?
# Allergies

Bacterial and viral infections rarely cause you to feel sick. The symptoms you feel, such as a fever, aches, and a cough, are really caused by your body’s immune response to the infection. When your body realizes it is infected it reacts by increasing the local blood flow. This causes inflammation, which can make you feel hot, stiff, and stuffy. Your temperature may increase as your body tries to make its internal environment too hot for the pathogen to survive. You get puss and mucus as white blood cells kill and clean out dead cells. Bacteria and viruses do very little damage to your body when compared to the damage your actual immune system causes. However, without your immune system the bacteria and viruses would build up to the point where your body could no longer function.

Unfortunately your body can create an immune response to things that are not pathogenic (infectious). This could include certain foods, animals, and environmental factors like pollen and grass.

When people come into contact with something they are allergic to, there can be many different reactions. Eyes may become very itchy, and noses may become drippy or stuffy. They may cough and sneeze. They may develop a rash called hives. Their faces may swell up. If it is a food allergy, the person may get an upset stomach.

Sometimes a person’s throat may swell up so much that the person can no longer breathe. This is called anaphylaxis. When this happens, a doctor must give the person a medicine called epinephrine to make the swelling go down. Some people with allergies to very common things, like bee stings or fish, carry this medicine with them so it can be used quickly in an emergency. The device they use to inject the medicine is called an epinephrine autoinjector, or an EpiPen.
Common Allergies Word Search

ANIMALS
CINNAMON
DUST
MITES
EGG
FISH

GARLIC
GRASS
INSECTS
LATEX
MILK

MOLD
NICKEL
PEANUT
PENICILLIN
POLLEN

SHELLFISH
SOY
SULFATES
TREENUTS
WHEAT
How to use this PowerPoint

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Goals

After reviewing this PowerPoint, you should be able to:

1) Define “pandemic.”
2) Identify several past pandemics.
3) Identify ways that governments respond to health emergencies.

Epidemic vs. Pandemic

**An epidemic** is a rise in the number of cases of a disease beyond what is normally expected in a geographical area.

Example: During flu season there may be a flu epidemic in certain areas.

**A pandemic** is used to describe a disease that has spread across many countries and affects a large number of people.

Example: COVID-19 is now considered a pandemic because of the number of cases across the world.
CNBC Video:
Lessons from the 1918 Influenza Pandemic

Make a T-chart for notes:

<table>
<thead>
<tr>
<th>What I notice:</th>
<th>What I wonder:</th>
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Check Your Understanding

1) What is the difference between an epidemic and a pandemic? Explain using an example.
2) Identify several past pandemics.
3) Identify ways that governments respond to health emergencies.

What's Next?
1) Read the Coronavirus Reading.
2) Make an entry in your Learning Tracking Tool titled “Understanding Pandemics.”

CORONAVIRUS

What the 1918 influenza pandemic can teach governments about coronavirus

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Text for video from lesson 2.1 Understanding Pandemics

VIDEO 11:05
How the US government responds to a pandemic

KEY POINTS

Past outbreaks provide a blueprint for governments navigating the challenges of COVID-19, which has spread to [more than 200,000 people worldwide](https://www.cnbc.com/2020/03/18/coronavirus-response-lessons-from-the-1918-influenza-pandemic.html), according to Johns Hopkins University on Wednesday.

Pandemics such as the 1918 influenza offer one key takeaway: Clear communication from the federal government is key.

“The main lesson from 1918 is very clear: that you tell the truth in a public health setting,” John Barry, author of the “The Great Influenza: The Story of the Deadliest Pandemic in History,” told CNBC.

The 1918 influenza pandemic, also known as the Spanish flu, killed an estimated 50 million worldwide, including 675,000 in the U.S., [according to the CDC](https://www.cnbc.com/2020/03/18/coronavirus-response-lessons-from-the-1918-influenza-pandemic.html). The pandemic occurred in three waves: the spring of 1918, fall of 1918, and winter and spring of 1919. In the midst of World War I, the federal government had limited resources to fight it.

An estimated 30% of U.S. physicians were engaged in military service, so Congress passed funding in October 1918 to recruit doctors and nurses. At the time, there were no vaccines or lab tests to detect the virus, which meant government officials relied on “non-pharmaceutical interventions” such as quarantine, isolation and limits on public gatherings.
In Chicago, for example, the mortality rate at one hospital reached nearly 40%, yet the city’s public health commissioner proclaimed, “Worry kills more people than the epidemic,” according to research published in 2005 by the Institute of Medicine.

Public health experts agree transparency from the government is key in containing this pandemic a century later.

“We need to have a unified message that is based on evidence and we need to explain what is known and what is not known, and there’s a fair bit that’s not known about this coronavirus, which makes it a little bit more difficult than some of those that we’ve seen in the past,” said Wendy Mariner, professor of public health law at Boston University.

WATCH: How the U.S. government responds to a pandemic

TRENDING NOW

CDC says coronavirus RNA found in Princess Cruise ship cabins for up to 17 days after passengers left

‘Troubling and astronomical’ coronavirus cases increase urgency for hospital beds in New York
Coronaviruses (CoV) are a large family of viruses that cause illness ranging from the common cold to more severe diseases such as Middle East Respiratory Syndrome (MERS-CoV) and Severe Acute Respiratory Syndrome (SARS-CoV).

Coronaviruses are zoonotic, which means they are transmitted between animals and humans. Detailed investigations found that SARS-CoV was transmitted from civet cats to humans and MERS-CoV from camels to humans. Currently, several known coronaviruses are circulating in animals that have not yet infected humans.

What is novel coronavirus? - Novel coronavirus (COVID-19) is a new virus strain spreading from person-to-person in many countries, including the United States. Health experts are concerned because little is known about this new virus and it has the potential to cause severe illness and pneumonia in some people.

How does novel coronavirus spread? - Health experts are still learning the details. Currently, it is thought to spread:
- via respiratory droplets produced when an infected person coughs or sneezes.
- between people who are in close contact with one another (within about 6 feet).

How severe is novel coronavirus? - Experts are still learning about the range of illness from novel coronavirus. Reported cases have ranged from mild illness (like a common cold) to severe pneumonia that requires hospitalization. So far, deaths have been reported mainly in older adults who had other health conditions.

What are the symptoms? - People who have been diagnosed with novel coronavirus have reported symptoms that may appear in as few as 2 days or as long as 14 days after exposure to the virus:

Stigma Reduction - Misinformation about coronavirus and COVID-19 can create fear and hostility that hurts people and makes it harder to keep everyone healthy. We’re stronger as a community when we stand together against discrimination.

Prevention – Experts recommend the following to help prevent the spread of novel coronavirus:
- Wash your hands for at least 20 seconds often
- Avoid touching your face, eyes, mouth, or nose
- Stay home if you are sick and avoid people who are sick
- Cough/sneeze into your elbow/sleeve

Sources: Washington State Department of Health and the World Health Organizations
Coronavirus

1) How is this Novel Coronavirus related to the common cold?

2) How does Covid-19 spread?

3) What can you do to reduce your chances of being infected? (use the above article and what you’ve been told by teachers/parents/experts)

4) If you become infected, what can you do to reduce your chances of spreading novel coronavirus (or anything else!) to others?

5) What is a zoonotic virus? Do you know of any other zoonotic viruses? What are they?

Sources: Washington State Department of Health and the World Health Organizations
Trigger Warning

These resources are intended to help us understand past pandemics and how we have overcome them. They provide information on pathogens and how science is used to respond to the spread of infections. However, these resources might be upsetting to some. If you are struggling with the current COVID-19 situation, please feel free to skip these resources or to pick and choose.

How to use this PowerPoint

• Work at your own pace. Your health and your family come first.
• If possible, you might find it helpful to go through activities at the same time as a peer. Then you can communicate through text, email, or a call if you have questions or to share ideas.
• You might find it helpful to have a piece of scrap paper and a pencil or pen to record questions or ideas.
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• When you finish, consider sharing what you learned with someone in your household or a friend through text, email, or a call. Explaining your thinking will help you to retain and make sense of the information.

Goals

After reviewing this PowerPoint, you should be able to:
1) Describe one or more past pandemics.
2) Identify if the pathogen is a bacterium or virus.
3) Identify symptoms and treatments.
Student Choice

**Directions:** Choose one or more of the pathogens listed below to learn more about. Record your learning on 2.2 Research a Disease Pathogen student worksheet.

A. [PBS American Experience Video on 1918 Influenza](#) (51:31) – *Trigger warning*: This video references the deaths from the 1918 flu pandemic in a number of ways, including descriptions of individuals who passed away and images of bodies covered in sheets and coffins. The video may be upsetting to some individuals. Skip the video if they are feeling overwhelmed by COVID-19 events.

B. [TEDEd Video on Beating Smallpox](#) (4:33)

C. [Medical News Today Website on Cholera](#) and [WHO Video on Cholera](#) (6:58)

D. [National Geographic Video: Plague 101](#) (4:16)

E. [Johns Hopkins Website on Zika Virus](#)

F. [Viral Explorer Interactive](#) (multiple pathogen types included)

Check Your Understanding

1) **Describe one or more past pandemics.**

2) **Identify if the pathogen is a bacterium or virus.**

3) **Identify symptoms and treatments.**

Make an entry in your Learning Tracking Tool titled “Research a Pathogen.”

You can Google search for the videos and resources listed here. As an alternative, text information is provided in this packet.
Research a Disease Pathogen

Choose a pathogen other than COVID-19, Ebola, and the flu to research.

Name of pathogen / disease: ______________________________________________________

Cause (circle): Bacterial / Viral / Other: __________________________

What are the symptoms of the disease?

How is the pathogen spread from person to person? (airborne, contact, blood, etc.)

What treatment(s) are available?

Name one additional interesting thing that you learned about the pathogen:
What is the Zika Virus?

Zika virus is similar to dengue fever - (http://www.hopkinsmedicine.org/healthlibrary/conditions/adult/travel_medicine/dengue_fever_85,p01425/), yellow fever - (http://www.hopkinsmedicine.org/healthlibrary/conditions/adult/travel_medicine/yellow_fever_85,P01465/) and West Nile virus - (http://www.hopkinsmedicine.org/healthlibrary/conditions/adult/infectious_diseases/west_nile_virus_85,p08120/). Carried by infected Aedes aegypti mosquitoes, Zika is largely transmitted through bites, but can also occur through intrauterine infection.

If a woman is bitten by an infected mosquito and becomes infected, Zika can cross into the placenta and affect the fetus. While anyone can contract Zika, pregnant women are the most at risk due to the potential for fetal microcephaly (https://www.hopkinsmedicine.org/zika-virus/microcephaly.html) and other neurologic abnormalities. Sexual transmission of this virus can occur. Transmission has been reported from infected men and women to their sexual partners. The virus can be transmitted through anal, oral or vaginal sex.

Symptoms of this virus are generally mild, with fever, rash and joint pain present. Most people who develop the virus do not have symptoms.

For more detailed information about the Zika virus, including symptoms, diagnosis and prevention, visit the Johns Hopkins Health Library - (http://www.hopkinsmedicine.org/healthlibrary/conditions/adult/infectious_diseases/infectious_diseases_22,ZikaVirus/).

What is the Zika Virus?

Experts at The Johns Hopkins Hospital are closely monitoring the spread of Zika virus and offering useful information to help prevent transmission of the mosquito-borne illness. Infectious disease expert Dr. Lisa Maragakis discusses the virus, concerns around pregnancy and the current state of vaccines.

How to Protect Yourself from Zika Virus

Zika virus has become a public health concern, so how can you protect yourself from the mosquito-borne illness? Dr. Crystal Ugochi Aguhi offers tips to prevent mosquito bites when in warmer climates.

Key Facts About Zika Virus

- Zika virus was first reported in Uganda in 1947, but a Zika virus outbreak was not reported in the Americas until 2015.

- Symptoms of Zika are mostly mild, with only one in five infected individuals exhibiting any signs of illness. Hospitalization is rare with this infection.
• Zika can be diagnosed through a blood test.
• The Centers for Disease Control and Prevention keeps an updated list [link](http://wwwnc.cdc.gov/travel/notices/) of countries where Zika outbreaks have occurred. Pregnant women should speak to their obstetrician-gynecologist if they must travel to an affected area, as well as take precautions to prevent mosquito bites.
• There is currently no vaccine or antiviral treatment for Zika.

**Additional Resources**

The [Centers for Disease Control and Prevention](http://wwwnc.cdc.gov/travel/notices/) regularly updates travel advisories for Zika virus, as well as preventive guidelines.
For anyone who plans to travel to Zika-affected areas, avoiding mosquito bites is the best way to avoid exposure to the virus.

Zika virus is primarily spread through the **bite of infected mosquitoes.**

**Mother-to-baby & sexual activity**
- If a pregnant woman is bitten by an infected mosquito, the infection can cross the placenta, infecting the fetus.
- The virus can also be transmitted sexually.

**Transfusion**
- The virus can also be transmitted through blood transfusion or laboratory exposure.

1 in 5 affected people will exhibit symptoms.

Symptoms of Zika virus are generally mild. People infected with Zika virus rarely need hospitalization.

**Rash**
**Headache**
**Fever**
**Itchy eyes**

**The best way to protect yourself**
- Women who are pregnant or trying to become pregnant should consider limiting travel to countries affected by Zika virus outbreaks.
- People traveling to these areas should follow these prevention methods:

  - Use **environmental protection agency-approved bug spray**
  - Wear **long-sleeve shirts and long pants**
  - **Stay indoors**

For more information, please visit [http://www.hopkinsmedicine.org/zika-virus/](http://www.hopkinsmedicine.org/zika-virus/)
Cholera is an acute epidemic infectious disease. It is characterized by watery diarrhea, extreme loss of fluid and electrolytes, and severe dehydration. It can be fatal.

It is caused by the bacterium *Vibrio cholera* (*V. cholera*).

Despite being easy to treat, cholera is estimated to affect between 3 and 5 million people each year, and it causes over 100,000 deaths worldwide.

Due to severe dehydration, fatality rates are high when untreated, especially among children and infants. Death can occur in otherwise healthy adults within hours. Those who recover usually have long-term immunity against re-infection.

Cholera was prevalent in the United States in the 1800s, but now it is rare because there are well-developed sanitary systems and living conditions.

When traveling to Asia, Africa and some parts of Latin America, however, people need to protect themselves against cholera by having the appropriate vaccinations beforehand, drinking only water that is boiled or from a sealed bottle and following good handwashing practices.

Diarrhea is the key symptom of cholera.

The cause of cholera is infection by the *V. cholera* bacteria. These bacteria were discovered in 1883.

The German bacteriologist, Robert Koch (1843-1910), studied the disease during an epidemic in Egypt. He found a bacterium in the intestines of those who had died of cholera but could neither isolate the organism nor infect animals with it.

Later that year, Koch went to India, where he succeeded in isolating the bacteria. He discovered that they thrived in damp, dirty linen and moist
V. cholerae bacteria live in shallow, salty water on microscopic crustaceans. They can also exist as colonies of biofilms that coat the surface of the water, plants, stones, shells, and similar items, and they can live among the eggs of midges, which serve as a reservoir for cholera bacteria.

Toxic strains of cholera bacteria produce a poison that triggers violent diarrhea in humans.

When the bacteria enter areas where humans live, they can quickly cause severe epidemics. Weather changes, population loss, and improved sanitation can all end an outbreak.

**Symptoms**

Only around 1 in 20 cholera infections are severe, and a high percentage of infected people show no symptoms.

If symptoms appear, they will do so between 12 hours and 5 days after exposure. They range from mild or asymptomatic to severe.

They typically include:

- large volumes of explosive watery diarrhea, sometimes called “rice water stools” because it can look like water that has been used to wash rice
- vomiting
- leg cramps

A person with cholera can quickly lose fluids, up to 20 liters a day, so severe dehydration and shock can occur.

Signs of dehydration include:

- loose skin
- sunken eyes
- decreased secretion, for example, less sweating
- fast heart beat
- low blood pressure
- dizziness or lightheadedness
- rapid weight loss

Shock can lead to collapse of the circulatory system. It is a life-threatening condition and a medical emergency.

**Causes**

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Cholera is more common where there is overcrowding and poor sanitation.

Cholera bacteria enter the body through the mouth, often in food or water that has been contaminated with human waste, due to poor sanitation and hygiene.

They can also enter by eating seafood that is raw or not completely cooked, in particular shellfish native to estuary environments, such as oysters or crabs.

Poorly cleaned vegetables irrigated by contaminated water sources are another common source of infection.

In situations where sanitation is severely challenged, such as in refugee camps or communities with highly limited water resources, a single affected victim can contaminate all the water for an entire population.

Diagnosis

A doctor may suspect cholera if a patient has severe watery diarrhea, vomiting, and rapid dehydration, especially if they have recently traveled to a place that has a recent history of cholera, or poor sanitation, or if they have recently consumed shellfish.

Treatment

It is normally dehydration that leads to death from cholera, so the most important treatment is to give oral hydration solution (ORS), also known as oral rehydration therapy (ORT).

The treatment consists of large volumes of water mixed with a blend of sugar and salts.

Prepackaged mixtures are commercially available, but widespread distribution in developing countries is limited by cost, so homemade ORS recipes are often used, with common household ingredients.

Severe cases of cholera require intravenous fluid replacement. An adult weighing 70 kilograms will need at least 7 liters of intravenous fluids.

Antibiotics can shorten the duration of the illness, but the WHO does not recommend the mass use of antibiotics for cholera, because of the growing risk of bacterial resistance.

Anti-diarrheal medicines are not used because they prevent the bacteria from being flushed out of the body.

With proper care and treatment, the fatality rate should be around 1 percent.
Prevention

Cholera is often spread through food and because of poor hygiene. Some simple measures can reduce the risk of contracting cholera.

Handwashing is important to prevent the spread of disease.

When traveling in areas where the disease is endemic, it is important to:

- Eat only fruit you have peeled.
- Avoid salads, raw fish, and uncooked vegetables.
- Ensure that food is thoroughly cooked.
- Make sure water is bottled or boiled and safe to consume.
- Avoid street food, as this can carry cholera and other diseases.

Travelers should learn about cholera before visiting a country where it is prevalent.

Individuals should seek medical attention immediately if they experience symptoms such as leg cramps, vomiting, and diarrhea while in a community where the disease exists.

There are currently three cholera vaccines recommended by the World Health Organization (WHO). These are Dukoral, Shanchol, and Euvichol. All three require two doses to give full protection.

Dukoral needs to be taken with clean water, and it provides roughly 65 percent protection for 2 years. Shanchol and Euvichol do not need to be taken with water, and they provide 65 percent protection for 5 years. All the vaccines offer higher protection nearer to the time they are given.

Risk factors

People most at risk of consuming food or water infected with the V. cholera include:

- people who work in healthcare and treat individuals with cholera
- relief workers who respond to cholera outbreaks
- people who are traveling in areas where cholera can still be transmitted that do not follow hygiene and food safety precautions

Wide-spreading epidemics of cholera often occur due to water supplies that are contaminated with human waste and street food vendors.

The following people are also at risk of a more severe reaction to V. cholera than others:
people with achlorhydia, a condition that removes hydrochloric acid from the stomach
- individuals with blood type O
- people who have chronic medical conditions
- those without access to ORT and other medical services

Effective hygiene measures can help reduce the risk presented by cholera.

RELATED COVERAGE

What you need to know about typhoid
Medically reviewed by University of Illinois
Typhoid is a bacterial infection that can be fatal if not treated quickly with antibiotics. The bacterium that causes it lives in the bloodstream and...
# How to use this PowerPoint

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- When you finish, consider sharing what you learned with someone in your household or a friend through text, email, or a call. Explaining your thinking will help you to retain and make sense of the information.

## Goals

**After reviewing this PowerPoint, you should be able to:**

1. Describe Ebola as a pathogen and the Ebola epidemic.
2. Analyze and interpret DNA sequence data to explain how viruses change (evolve) over time during an outbreak.
3. Describe the work scientists do to understanding viruses.

## Procedure – Split this over 2 days

1. Read 2.3 Introduction to Ebola Reading.
2. Watch [Think Like a Scientist Video on Ebola](https://www.biointeractive.org/classroom-resources/think-scientist-natural-selection-outbreak-or-transcript-included-in-this-packet) – **Trigger warning:** The video shows grave sites during the Ebola outbreak which may be upsetting to some individuals. Skip the video if you are feeling overwhelmed by COVID-19 events.
3. Open 2.3 Ebola Student Worksheet and 2.3 Sequence Sheet. It is ideal if you can print the 2.3 Sequence Sheet and cut out the strips, but if you can’t, just look at it and do your best to visually compare and group the strips. Follow the directions on the worksheet.
Check Your Understanding

1. Check your work using the provided Answer Key.
2. This is a challenging assignment! Review and make corrections to deepen your understanding.
3. Review your learning with a friend or family member.

Make an entry in your Learning Tracking Tool titled “How Viruses Change Over Time.”
We first started hearing these rumors about a mysterious hemorrhagic disease in Guinea. And, honestly, I wasn't thinking Ebola at all. The biggest concern was that there was some evolutionary selection going on there. The virus could be changing into something really scary.

The Ebola outbreak in West Africa is believed to have started sometime in late 2013 with sort of cases coming up in a village in Guinea. The epidemic started when a bat came in contact with a human and the virus passed from that animal to the person. Ebola spreads through direct contact with body fluids of someone that's infected with Ebola. They start to get a high fever, develop vomiting and diarrhea, bleeding, blood pressure goes down. You go into a shock and systematic organ failure, and that's how people die.

The virus in that time began to spread. It moved over into neighboring Liberia and Sierra Leone, then before you knew it there were 28,000 cases, at least, with 11,000 reported deaths.

When outbreaks happen we have to stop them right away because there is this possibility that the virus will accidentally have a change that could make that outbreak escalate. I'm a computational geneticist, which is someone who uses computers to look at data from biology, from our genomes. The genome of a virus is so incredibly important to all aspects of its intervention, prevention, understanding. It's basically a blueprint that every organism on Earth has, that defines it. Every time a virus replicates, it just reproduces its genome. And when that happens, sometimes an accidental change can happen. A new mutation changes that genome sequence just a little bit. Most of those mutations either have no effect or a detrimental effect and get cleared out. Very rarely, it's possible they can pick up a change that somehow is beneficial to them. One of the major drivers of evolution is natural selection. And in the context of viruses, you see that. That if a virus basically has some mutation that makes it spread more quickly or infect more people, it will become more common in the population. And that's why, you know, it's a real issue when you're talking about an outbreak of something like Ebola that's not believed to happen in humans that often as you're giving it more and more opportunities in this new environment in human infection to mutate and change and to have a widespread impact.

I'm a disease ecologist and epidemiologist and my nightmare outbreak scenario actually happened. I got to live it last year. Sierra Leone and Liberia are just recovering from some very brutal, brutal civil wars. 85% of the health clinics in Sierra Leone were destroyed during the civil war. And west
Africa has a very high population density. They have some very good roads. So if you take a health system that's in shambles and you, you add an Ebola outbreak and a rapidly moving population then you have a... the perfect storm.

[music plays]

[SABETI:] When the outbreak hit Sierra Leone, Kenema Government Hospital was really the only hospital that was prepared to deal with patients with hemorrhagic fever. And Kenema was extraordinary and prepared for 1 or 2 or 3 cases, but before you knew it, there were hundreds. And at a certain point everyone has their threshold and they were overwhelmed. And what happened was that one of the nurses became infected, and then that spread through the clinical staff.

[MOSES:] One of the tragedies of Ebola is that it spreads through love and through people taking care of people that they care about.

[SABETI:] In this outbreak we have 11,000 deaths. But what's really shocking is that 800 of those deaths are health care worker. It's estimated there was a 20-fold increased risk of a health care worker. My team also lost a number of our clinical care workers. All clinicians, all healthcare workers, all loved ones of individuals who are sick are putting themselves at risk every time they go to care for somebody who is ill like this.

[SABETI:] The Ebola outbreak we saw in West Africa was by far the largest outbreak we've ever seen of Ebola. And so this is, as opposed to small numbers of cases, you're giving the virus many opportunities to replicate and to pass from human to human. And each of those is an opportunity for an accidental mutation to allow it to adapt. And there is new evidence that there was a mutation that occurred early in the outbreak, a few months into the outbreak, that changed one of the important genes of the Ebola genome. And that that mutation likely not only increased infectivity, but did so in a way that was more specific to humans and primates. But the story to be told is not one that is answered by genomics, it's just answered by a faster response. The more time you give it to change, the more chance it will.

[MOSES:] I do think that the world is not prepared for a long and sustained disease pandemic. The main reason why is because you see such disparities in health, quality of health. It's no accident that that the epidemic happened the way it did in Sierra Leone. If Sierra Leone had the health system and the health infrastructure that we had in the US, you would have seen 2 cases like we saw in the US, instead of thousands and thousands of cases that we saw here. As long as there are countries that do not have proper health systems, everyone in the world is vulnerable.

[music plays]

[SABETI:] This outbreak did provide an opportunity to learn a lot more, but while there's tremendous new information that came to light, it didn't have to happen that way and it shouldn't have happened that way. We can get much, much better at picking up cases as they emerge and stopping these outbreaks from happening. And so to me, actually, to think like a scientist is to be creative, to be open minded, to be curious, to get ideas from all over, and then to identify ways of systematically proving
out what you've done. You know, I love that, that balance between the creativity and the rigor. And I think as long as we're on this Earth, viruses will be too. And so, I think that's really why it's important to understand the biology, to appreciate it, to not assume that we need to completely eradicate them, but just to understand how to control them and how to respond when something gets out of control.

[music plays]
BACKGROUND READING

The Ebola virus is a zoonotic virus, which means that it can spread from animals to humans. Once a person is infected, the virus affects multiple organ systems in the body. Infected cells can attach themselves to blood vessels, causing uncontrollable internal bleeding in some patients, accompanied by high fever—a condition known as hemorrhagic fever. Other common symptoms include liver and kidney failure, vomiting, and diarrhea. On average, 50% of people that contract Ebola die from the disease, though fatality rates of past outbreaks have varied from 25% to 90%.

The first documented outbreak occurred in 1976 in the Democratic Republic of the Congo, in Central Africa, and infected about 300 people. Since then there have been several other outbreaks in Central Africa, but the largest on record began in Guinea, a country in West Africa, in December 2013. The virus spread to the neighboring countries of Sierra Leone and Liberia. By April 2016, over 28,000 cases, and more than 11,000 deaths, were reported in West Africa.

The 2013–2016 outbreak was unprecedented in size and duration. This drastic increase in cases could be attributed to several possible factors. As this was the first known Ebola outbreak in West Africa, regional differences could be one factor. Central Africa is predominantly forested with limited access to roads, while West Africa has several large cities and better transportation infrastructure, making it easier for infected patients to travel between communities and across borders, spreading the disease.

During the 2013–2016 outbreak, the Kenema Government Hospital in Sierra Leone collaborated with scientists in Pardis Sabeti’s lab at the Broad Institute to use genetic analysis to screen suspected patients and accurately diagnose infection. They also wanted to determine how the virus was changing over time.

Tracking Virus Spread

Ebola spreads by close contact with an infected patient’s bodily fluids, such as blood, saliva, urine, or sweat. In addition to contact tracing, in which outbreak responders try to identify those exposed to infected people, scientists can also track how Ebola spreads from person to person by using DNA sequencing. Each Ebola patient has the virus in his or her blood. The Ebola virus has a genome made of RNA, made up of a sequence of letters (G, C, A, and U). Over time, as the virus replicates, random changes to the sequence of letters occur, referred to as mutations. During infection, the virus replicates many times, creating many possible mutations. Many of these mutations will be detrimental to the virus and even result in defective viruses, others will be neutral, and a small number of mutations may confer some type of advantage. If the infected patient passes the virus on to a
second person, the second person may inherit the mutated virus, which will, over the duration of the infection, accumulate additional mutations. In this way, viruses transmitted from one person to another are related to one another and may accumulate differences over time.

Scientists isolate virus RNA from blood samples and then convert the RNA to DNA. Using DNA sequencing, they then compare virus sequences isolated from individuals in different locations and at different times in an outbreak. By identifying differences in the viral genomes, scientists can reconstruct the history of how the virus spreads and mutates. Tracking mutations over time can also reveal whether the virus is becoming potentially more dangerous.

Within the first few weeks of the outbreak in Sierra Leone, scientists from Sabeti’s lab sequenced Ebola samples from 78 patients. They compared the data to a reference sequence from a patient in Guinea, where the Ebola outbreak began. In the activity, you will analyze a subset of the actual virus sequences collected by the Sabeti lab and compare your results to theirs.

**Figure 2. A mutation is a change in the nucleotide sequence.** These mutations show changes in a DNA sequence. The Ebola virus has a genome made of RNA, but it was converted to DNA for sequencing.
INTRODUCTION

In this activity, you will analyze sequences of Ebola viruses isolated from patients in Sierra Leone during the Ebola outbreak of 2013–2016 to track the virus spread. Do you have what it takes to be a disease detective?

BACKGROUND INFORMATION

To prepare for this activity, you will first watch the 8-minute video Think Like a Scientist: Natural Selection in an Outbreak ([https://www.youtube.com/watch?v=Tq2GhPZvdkJ](https://www.youtube.com/watch?v=Tq2GhPZvdkJ)), featuring computational geneticist Pardis Sabeti and epidemiologist Lina Moses. Then, answer the following question:

1. Thinking about what you saw in the video and what Drs. Sabeti and Moses discussed, identify three factors that contributed to the number of individuals infected in the Ebola outbreak.

Read the background reading provided and answer the questions below.

2. Define the term “mutation.”

3. In your own words, why is it important to examine the sequence of the Ebola virus genome during an outbreak?

PROCEDURE

• Obtain a set of DNA sequences that includes the reference sample from Guinea and 15 Ebola DNA sequences from samples of patients in Sierra Leone.

• The shaded nucleotides in sequences 1–15 represent mutations that occurred in these different viruses compared to the reference sequence. (Remember that the reference sequence is from a virus that was present at the start of the outbreak.) Move the Ebola sequences 1–15 around to identify patterns in the mutations.

• Group sequences according to any patterns you see.

• Every sequence should be in a group, even if they are not identical. Use your groupings to answer the analysis questions.
ANALYSIS QUESTIONS

Part 1

1. Describe the criteria you used to assign the sequences to different groups.

2. Describe alternate criteria you could have used, and explain why you opted for the criteria you described in your answer to Question 1.

3. If a sequence has a larger number of mutations when compared to the reference sequence, does that mean it is from earlier or later in the outbreak? Explain your answer.

4. Create a visual that highlights the relationship between your groups. Examples of effective visuals include flowcharts and trees. Be sure that your visual includes an arrow indicating passage of time during the outbreak.
Part 2

Broad scientists created the visual below. They grouped the sequences based on sets of shared identical mutations, or core mutations. Take your virus sequences and group them as illustrated in Figure 1.

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Figure 1. Groups of Ebola virus sequences. The sequences in each group have a set of shared core mutations. Within each group, some viruses may have additional mutations that are not shared by other viruses in the group.

1. Compare the groupings in Figure 1 to your groupings. What are the similarities and differences?

2. Using the grouping in Figure 1, list the core mutations that occurred between one group and the other. Core mutations are mutations shared by every virus in the group. Describe the mutation by indicating the nucleotide number in the sequence.

   a. Differences between the reference sample and the Group 1 sequences:

   b. Differences between groups 1 and 2:

   c. Differences between groups 2 and 3:
3. What can you infer from this diagram about when each group of patients contracted Ebola relative to one another?

4. Explain how the sequences and groupings support the hypothesis that mutations accumulate over time.

5. How can you explain the fact that some sequences have additional (noncore) mutations that did not spread into other groups?

6. If a particular mutation was advantageous to the virus, in that it allows the virus to spread faster, what would you notice happening over time to the sequences of the virus you collected in a population?

REFERENCES


2. Tam, Ruth. 2014. “This is how you get Ebola, as explained by science.” PBS Newshour.

EXTENSION ACTIVITY
For more information on the Ebola virus, visit the Click and Learn interactive “Virus Explorer” (https://www.hhmi.org/biointeractive/virus-explorer), click on Ebola, and complete the chart below. The host category has been completed for you as an example.

<table>
<thead>
<tr>
<th>Categories of Exploration</th>
<th>Circle the correct choice(s) below</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host</td>
<td>Humans, Mammals, Birds, Reptiles, Plants, and Bacteria</td>
<td>Ebola can infect humans, other primates, and bats</td>
</tr>
<tr>
<td>Envelope</td>
<td>Enveloped or Naked</td>
<td></td>
</tr>
<tr>
<td>Structure</td>
<td>Spherical, Helical, Isohedral, or Conical</td>
<td></td>
</tr>
<tr>
<td>Genome Type</td>
<td>ds DNA, ss + RNA, ss – RNA, Segmented, Linear, or Circular</td>
<td></td>
</tr>
<tr>
<td>Transmission</td>
<td>Human-to-human, Zoonotic, Arthropod, Vector, Plant-to-plant, Bacterium-to-bacterium</td>
<td></td>
</tr>
<tr>
<td>Vaccine</td>
<td>Vaccine Available or No Vaccine Available</td>
<td></td>
</tr>
</tbody>
</table>

In the interactive, click on the cross section and write down the labels for Figure 2 below.

A. 
B. 
C. 
D. 
E. 
F.

Figure 2. Cross section of Ebola virus.
<table>
<thead>
<tr>
<th>Reference</th>
<th>C T A T G C A A G C A G T T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence 1</td>
<td>C C A T G T A A G T G G T T</td>
</tr>
<tr>
<td>Sequence 2</td>
<td>T C A T G T C A G C A A A C T</td>
</tr>
<tr>
<td>Sequence 3</td>
<td>C C G T G T A A G C A G T T</td>
</tr>
<tr>
<td>Sequence 4</td>
<td>C C A T G T A A G C A G T T</td>
</tr>
<tr>
<td>Sequence 5</td>
<td>T C A T G T C A G C A A A C T</td>
</tr>
<tr>
<td>Sequence 6</td>
<td>C C A T G T A A G C A G T T</td>
</tr>
<tr>
<td>Sequence 7</td>
<td>T C A T G T C A G C A A A C T</td>
</tr>
<tr>
<td>Sequence 8</td>
<td>T C A T G T C A G C A A A C C</td>
</tr>
<tr>
<td>Sequence 9</td>
<td>C C A T G T A G G G C A G T T</td>
</tr>
<tr>
<td>Sequence 10</td>
<td>T C A G G G T C A A A C A A C T</td>
</tr>
<tr>
<td>Sequence 11</td>
<td>C C A T G T A A G C A G T T</td>
</tr>
<tr>
<td>Sequence 12</td>
<td>T C A T G T C A G C A A A C C</td>
</tr>
<tr>
<td>Sequence 13</td>
<td>C C A T G T A A G C A G T T</td>
</tr>
<tr>
<td>Sequence 14</td>
<td>C C A T A A T A T A A G C A G T T</td>
</tr>
<tr>
<td>Sequence 15</td>
<td>T C A T G T C A G C A A A C C</td>
</tr>
</tbody>
</table>
OVERVIEW

In this lesson, students will analyze Ebola sequences that were obtained from patients in Sierra Leone during the 2014 outbreak in West Africa. Students are challenged to place sequences into groups based on similarities to determine the transmission history of the virus. Students then compare their results to those of scientists at the Broad Institute of MIT and Harvard, who followed a similar procedure at the beginning of the outbreak.

KEY CONCEPTS AND LEARNING OBJECTIVES

- As viruses reproduce, they accumulate mutations in their genomes.
- Since mutations accumulate over time, analyzing virus sequences from infected individuals can help researchers track, understand, and treat diseases.

Students will be able to

- analyze and interpret sequence data.
- develop visuals to summarize and convey their findings.

CURRICULUM CONNECTIONS

<table>
<thead>
<tr>
<th>Curriculum</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGSS (April 2013)</td>
<td>HS-LS-3, HS-LS-4, S.P.4, Cross-cutting Concept: Patterns</td>
</tr>
<tr>
<td>IB Biology (2016)</td>
<td>5.2, B.4</td>
</tr>
</tbody>
</table>

KEY TERMS

Ebola, mutation, outbreak, virus, sequencing

TIME REQUIREMENTS

This activity was designed to be completed in a 45-minute class period with additional time required for watching a video and reading background information. An optional extension activity will require additional time and may be assigned as homework.

SUGGESTED AUDIENCE

This lesson is appropriate for high school biology (all levels including AP and IB) and introductory college biology.

PRIOR KNOWLEDGE

- Students should understand the basic mechanism of viral replication: that a virus invades a host cell in order to hijack its cellular machinery and reproduce.
- Although this activity does not mention cladistics, students would benefit from previous experience grouping organisms according to shared-derived characteristics, as this procedure is similar to what they will do with the virus sequences.
TEACHING TIPS

• Before conducting this activity, have students watch the 8-minute video Think Like a Scientist: Natural Selection in an Outbreak (https://www.youtube.com/watch?v=Tq2GhPZvdkJf) featuring computational geneticist Pardis Sabeti and epidemiologist Lina Moses and complete the background reading: Introduction to Ebola.

• In the video Think Like a Scientist: Natural Selection in an Outbreak, changes in the virus sequences are portrayed as changes in how the virus looks using drawings of the virus on squares of paper. This video provides an opportunity for discussing how creating effective artistic representations of scientific processes can be challenging. You may want to discuss with students whether this is an effective visual for illustrating how mutations occur and how some mutations spread by natural selection. Make sure that students understand that the mutations they are looking at in this activity are single-nucleotide changes in the virus genome. Some changes will have no effect on the virus, while others could affect the structure or function of particular proteins in the virus, but these are subtle changes, unlikely to affect the overall structure of the virus.

• Printing tip: Print the sequence sheet in color on card stock so, you can reuse them (recommend one set of sequences per 2-4 students). Provide the background reading electronically or print off a class set and reuse. This activity has two parts. In the first part, students group virus sequences. In the second, they compare their groupings to ones selected by scientists at the Broad Institute. Do not provide students Part 2 of this activity (pages 3-4) until they have completed Part 1 (pages 1-2).

• Make sure students understand that Ebola is an RNA virus. Scientists studying Ebola and other RNA viruses use reverse transcription to copy the RNA to DNA prior to sequencing, so the data that students analyze is DNA, but the actual genetic material inside the virus particles is RNA.

• If you have already covered evolution in your class, you may point out to your students the parallels between the sequence analysis they did in this activity to grouping organisms by shared-derived characteristics. In both cases, there is an underlying assumption of parsimony (all other things being equal, the best hypothesis is the one that requires the fewest evolutionary changes) and trait accumulation.

ANSWERS

Background Questions:

1. Thinking about what you saw in the video and what Drs. Sabeti and Moses discussed, identify three factors that contributed to the number of individuals infected in the Ebola outbreak.

Students’ answers will vary, but they may mention that the virus has a selective advantage that makes it spread more rapidly, that the infection occurred in the healthcare staff, or that there was a high density of bats in the area, a poor healthcare infrastructure, high human population density, or good roads to allow for rapid movement between populations.

2. Define the term “mutation.”

Answers will vary, but the reading states that “random changes to the sequence of letters occur.” Students should indicate that these letters are nucleotides within a sequence of DNA or in the case of Ebola, RNA.

3. In your own words, why is it important to examine the sequence of the Ebola virus genome during an outbreak?

Students’ answers will vary but should include some of the following points: knowing how the virus is mutating over time is important for understanding how it is spreading; it can diagnose individuals who are infected; and it can help determine whether the virus is becoming more infectious.
Analysis Questions, Part 1:

1. Describe the criteria you used to assign the sequences to different groups.
Students could have used one or more of the following attributes: identical sequences; sequences that only differ by one mutation; mutation location; number of mutations; or viruses that share sets of mutations.

2. Describe alternate criteria you could have used, and explain why you opted for the criteria you described in your answer to Question 1.
See answer to Question 1 for additional criteria. Explanations should clearly indicate why the student selected the criteria that they did.

3. If a sequence has a larger number of mutations when compared to the reference sequence, does that mean it is from earlier or later in the outbreak? Explain your answer.
It’s from later in the outbreak. Mutations accumulate over time. The more mutations there are between a sample and the reference sample, the later in the outbreak it was collected.

4. Create a visual that highlights the relationship between your groups. Examples of effective visuals include flowcharts and trees. Be sure that your visual includes an arrow indicating passage of time during the outbreak.
An effective visual should include the reference sample and show how the different groups are related to each other over time.

Analysis Questions, Part 2:

1. Compare the groupings in Figure 1 to your groupings. What are the similarities and differences?
Answers will vary. Students should mention the number of groups, the criteria used to group sequences, or the positioning of different sequences.

2. Using the grouping in Figure 1, list the core mutations that occurred between one group and the other. Core mutations are mutations shared by every virus in the group. Describe the mutation by indicating the nucleotide number in the sequence.
   a. Differences between the reference sample and the Group 1 sequences: C in position 2 and T in position 5
   b. Differences between groups 1 and 2: T in position 1, C in position 7, A in position 12, and C in position 13
   c. Difference between groups 2 and 3: C in position 14

3. What can you infer from this diagram about when each group of patients contracted Ebola relative to one another?
Patients infected with Group 1 viruses became infected after the reference patient; patients with Group 2 viruses became infected after Group 1; patients with Group 3 viruses became infected after Group 2.

4. Explain how the sequences and groupings support the hypothesis that mutations accumulate over time.
Group 2 and 3 sequences have the same core mutations present in the Group 1 sequences. Group 3 sequences had the core mutations present in Group 2 sequences. This observation is consistent with the hypothesis that mutations accumulate over time. Mutations that arise in one virus will be passed on as the virus replicates and infects other people, and additional mutations then occur in these viruses as they replicate, and so on.

5. How can you explain the fact that some sequences have additional (noncore) mutations that did not spread into other groups?
Mutations that interfere with the essential functions of the virus are rapidly lost from the population and do not spread to other groups.
6. If a particular mutation was advantageous to the virus, in that it allows the virus to spread faster, what would you notice happening over time to the sequences of the virus you collected in a population?

Students should explain that over time almost all the virus sequences collected in samples from that population will have that mutation.

EXTENSION ACTIVITY

Depending on your students’ knowledge about viruses, it may also be useful for them to visit the Click and Learn interactive “Virus Explorer” (https://www.hhmi.org/biointeractive/virus-explorer). The Click and Learn explores different viruses, but you could have them focus on Ebola by completing the quick exploration activity below.

<table>
<thead>
<tr>
<th>Categories of Exploration</th>
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<td>Humans, Mammals, Birds, Reptiles, Plants, and Bacteria</td>
<td>Ebola can infect humans, other primates, and bats</td>
</tr>
<tr>
<td>Envelope</td>
<td>Enveloped or Naked</td>
<td>Some viruses exit their host cell by budding. In the process, part of the host cell membrane envelops the virus particle, forming an envelope.</td>
</tr>
<tr>
<td>Structure</td>
<td>Spherical, Helical, Icosahedral, or Conical</td>
<td>Typically described based on the overall shape of the protein layer that surrounds the virus genetic material.</td>
</tr>
<tr>
<td>Genome Type</td>
<td>ds DNA, ss + RNA, ss – RNA, Segmented, Linear, or Circular</td>
<td>Genomes vary by the type of nucleic acid, number of strands of nucleic acid, the sense or polarity of the strands, and the structure.</td>
</tr>
<tr>
<td>Transmission</td>
<td>Human-to-human, Zoonotic, Arthropod, Vector, Plant-to-plant, Bacterium-to-bacterium</td>
<td>The mechanism in which a virus passes from one host to another depends on several factors, including which organisms the virus is able to infect, which type of cells the virus infects, and how the virus is released from an organism. An organism that serves to transmit the virus from one host to another is termed a vector.</td>
</tr>
<tr>
<td>Vaccine</td>
<td>Vaccine Available or No Vaccine Available</td>
<td>A vaccine is a substance that, when taken into the body, should induce a protective immune response to a virus.</td>
</tr>
</tbody>
</table>
In the interactive, click on the cross section and write down the labels for Figure 2 below.

A. Glycoprotein  
B. Lipid Envelope  
C. Matrix Protein  
D. RNA Genome  
E. Nucleocapsid Proteins  
F. Polymerase

Figure 2. Cross section of Ebola virus.

REFERENCES

2. Tam, Ruth. 2014. “This is how you get Ebola, as explained by science.” PBS Newshour.

AUTHORS

This lesson was adapted from a teacher guide created by a collaborative group at the Broad Institute. The original activity is available at http://scienceintheclassroom.org/sites/default/files/disease_detectives_-_introduction_to_sequence_analysis.pdf

Edited by Melissa Csikari and Laura Bonetta, PhD, HHMI, and Stephanie Keep, consultant.

Reviewed by Nathan Yozwiak, PhD, Broad Institute.
Bacteria and Viruses: Understanding the Microbes that Make Us Sick

Lesson 3: Support Your Community!

How can we use our knowledge to support each other? For this lesson you are invited to do something to care for yourself and others in response to the COVID-19 situation. The time to complete these activities will vary and may be ongoing.

3.1 Care for Yourself and Your Household
This will look different depending on your household’s unique needs. Some ideas you might consider (adapted from the CDC):

- Take breaks from watching, reading, or listening to news stories, including social media. Hearing about the pandemic repeatedly can be upsetting.
- Take care of your body. Take deep breaths, stretch, or meditate. Try to eat healthy, well-balanced meals, exercise regularly, get plenty of sleep, and avoid alcohol and drugs.
- Make time to unwind. Try to do some other activities you enjoy.
- Connect with others. Talk with people you trust about your concerns and how you are feeling.
- Help your family to prepare a meal.
- Ask your parents/guardians/household if there are things that you can do to help. This might be taking on some extra chores or caring for younger siblings so that others can work.

3.2 Care for Your Community

- Practice social distancing. While your personal risk may be low, you are protecting others who may be vulnerable to infections.
- Reach out to family and friends (text, call, video chat, email, etc.). Staying connected while social distancing helps to prevent isolation and keep up morale.
- With your family’s permission and support, collaborate with neighbors to check on those who are vulnerable.
- If your family is able, consider supporting essential services like the food bank and blood donation.

Make entries in your Learning Tracking Tool for each part of the lesson.
## TEACHER KEY Learning Tracking Tool for Bacteria and Viruses:
How can we use science to understand and prevent infectious diseases such as COVID-19?

<table>
<thead>
<tr>
<th>Lesson</th>
<th>What did we do?</th>
<th>How can our learning be used to explain the phenomenon?</th>
<th>Self-Assess: Where am I with my understanding of the phenomenon?</th>
<th>What questions do I have?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Introduction to Bacteria</td>
<td>Bacteria are found in every environment on Earth. Bacteria are abundant and diverse. They have circular DNA and no organelles. Bacteria do lots of useful things, like decomposing materials and helping in the nitrogen cycle. There are more bacteria in and on our bodies than human cells, and our normal flora of bacteria help prevent infections by harmful bacteria and even make vitamins.</td>
<td>Students MIGHT say: Bacteria cells are different from our cells, which is important for designing treatments. Not all bacteria cause illnesses, many do useful things. Keeping our normal bacteria around helps prevent infection.</td>
<td>Many options! Example: How do viruses compare to bacteria?</td>
<td></td>
</tr>
<tr>
<td>1.2 Bacteria vs. Viruses</td>
<td>Viruses are much smaller than bacteria. They are not cells. Viruses are strands of DNA or RNA in a capsid (protein coating). They cannot reproduce on their own, and instead trick a host cell into replicating the virus.</td>
<td>Students MIGHT say: Viruses have completely different structures from bacteria, so treatments for bacterial and viral infections will need to be different. Viruses change over time because of mutations in the DNA or RNA.</td>
<td>Many options! Example: How does the body fight off bacteria and viruses?</td>
<td></td>
</tr>
<tr>
<td>1.3 Fighting Pathogens</td>
<td>Pathogens are things that make us sick, including bacteria, viruses, parasites, and fungi. The body’s immune systems work to prevent pathogens from getting in and to stop infections when they do get in. Personal actions like handwashing help prevent infections. We also use medicines including vaccines, antibiotics, and antivirals to fight infections.</td>
<td>Students MIGHT say: Our body’s immune system is a natural defense against pathogens. We can support the immune system with personal and group actions (ex. staying home when sick) and with new medicines to fight pathogens.</td>
<td>Many options! Example: How can we treat the COVID-19 virus?</td>
<td></td>
</tr>
<tr>
<td>2.1 Understanding Pandemics</td>
<td>An epidemic is a rise in the number of cases of a disease in a particular area while a pandemic is when a disease is seen in many people across several countries. COVID-19 is a pandemic. Past pandemics include the 1918 Spanish Flu. Governments respond to pandemics by limiting activities and closing gathering places.</td>
<td>Students MIGHT say: To fight COVID-19 we will need to employ pandemic strategies such as social distancing to limit the spread of the infection. Researchers are looking for vaccines and other treatment options.</td>
<td>Many options! Example: What can we learn from past pandemics?</td>
<td></td>
</tr>
<tr>
<td>Lesson</td>
<td>What did we do? What did we figure out?</td>
<td>How can our learning be used to explain the phenomenon?</td>
<td><strong>Self-Assess:</strong> Where am I with my understanding of the phenomenon? (Example: Ready to explain, starting to get it, need more information)</td>
<td>What questions do I have? What additional information do you need to understand the phenomenon?</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------</td>
<td>--------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>2.2 Research a Pathogen</td>
<td>Answers will vary depending on which pathogen(s) students choose to study. Epidemics and pandemics can be caused by bacterial or viral infections.</td>
<td><strong>Students MIGHT say:</strong> We have overcome past pandemics. Strategies include social distancing, quarantine, and mass vaccinations. All of these have been or may be applied to the COVID-19 situation.</td>
<td>Many options! Example: How do new viruses arise?</td>
<td></td>
</tr>
<tr>
<td>2.3 How Viruses Change Over Time</td>
<td>Like COVID-19, Ebola is a zoonotic virus that can spread from animals to humans. In 2013-2016 there was an Ebola outbreak in West Africa. As viruses reproduce, the accumulate mutations (changes) in their genetic material, DNA or RNA. Studying these mutations over time helps scientists to track the spread of a virus.</td>
<td><strong>Students MIGHT say:</strong> Scientists can study mutations in COVID-19 to understand how the virus is spreading. Scientists will also study the genetic material to design a vaccine.</td>
<td>Many options! Example: How much has COVID-19 mutated so far? When will we have a vaccine?</td>
<td></td>
</tr>
<tr>
<td>3.1 Care for Yourself and Your Household</td>
<td>Many options! Example: I helped my family by babysitting my younger siblings so that my parents could work. Together we prepared a meal so that we could eat together when my parents were done working.</td>
<td><strong>Students MIGHT say:</strong> In order to fight COVID-19, we need to practice social distancing. This means that many people need to stay home from school and their workplaces.</td>
<td>Many options! Example: How long will we have to practice social distancing?</td>
<td></td>
</tr>
<tr>
<td>3.2 Care for Your Community</td>
<td>Many options! Example: I am using video calling to talk to my grandparents twice a week. This allows us to check on them while still practicing social distancing.</td>
<td><strong>Students MIGHT say:</strong> Some individuals are more vulnerable to infections. By practicing social distancing we are protecting those individuals. We can support our family, friends, and neighbors by finding ways to connect through phone calls, texts, etc.</td>
<td>Many options! Example: What else can I do to help my community right now? Do some research to find ideas!</td>
<td></td>
</tr>
</tbody>
</table>