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Welcome

Washington State is an international hub for global health. The global health ecosystem employs more than 14,000 people at more than 260 Washington-based organizations who envision a world with health equity for all, and they are working in all 195 countries around the world to make that vision a reality.

The global health community is using science, innovation, and humanity to tackle some of the world’s most complex problems. And we at the Washington Global Health Alliance (WGHA) are fierce believers in the power of partnerships to drive that progress and equity for all.

Founded in 2007, WGHA was the first organization of its kind and has over 60 members working to achieve health equity. WGHA’s programs are centered on four key pillars: equity, innovation, funding, and advocacy. The Alliance brings members together through events and conversations designed to advance progress on the four pillars, share best practices, and create a culture of collaboration among its members so they can have a greater impact in the world.

WGHA exists to connect and inform the global health community, and we are already thinking of the next generation of global health dreamers and doers.

The STEM Global curriculum was designed with the next generation in mind. We hope it equips educators with the information and resources you need to bring global health into your classrooms. And we hope it inspires students to consider how you could use STEM skills to solve the world’s most complex problems and what your own pathway to a global health career might be. WGHA is grateful to the many STEM Global partners who made this program possible.

Learn more at wghalliance.org
About the STEM Global Program

Inspiring the next generation of global health dreamers and doers

Through STEM Global, the Washington Global Health Alliance and its members are inspiring and preparing the next generation of global health researchers, practitioners, and champions.

- **Students** can experience global health in action and learn how STEM skills solve the world’s most complex problems and increase health equity.

- **Teachers** can explore new ways to integrate global health into their classrooms and champion global health opportunities for their students.

The instructional materials featured in this collection provide strategies for integrating global health concepts into secondary STEM classrooms and highlight career pathways in the interdisciplinary field of global health. Learn more at: [https://www.wghalliance.org/initiative/stem-global](https://www.wghalliance.org/initiative/stem-global)
About the STEM Global Partners

Bill & Melinda Gates Foundation
Discovery Center
www.discovergates.org

The Bill & Melinda Gates Foundation Discovery Center—located near Seattle Center—provides free field trip (in-person and virtual) opportunities for students to engage with contemporary global health challenges and innovative solutions in a museum-like setting. At the Discovery Center, students will encounter powerful stories about the impact of the Bill & Melinda Gates Foundation and its partners toward improving the quality of life for billions of people. The interactive exhibits let students explore first-hand bold, innovative solutions to the most pressing challenges facing communities around the globe. Bring your curiosity and leave inspired to take action for a cause you care about! Permanent exhibits include five galleries and a theater. Admission to the Discovery Center is free. The Discovery Center hosts events, lectures, and classes, as well as a variety of programs for educators, including free (in-person and virtual) field trip experiences.

Fred Hutchinson Cancer Research Center Science Education Partnership

The Science Education Partnership (SEP) at Fred Hutchinson Cancer Research Center in Seattle exemplifies a true partnership between scientists and educators. Since 1991, SEP has paired research scientists with over 580 secondary school science teachers in Washington State. We believe that teachers and scientists both play a crucial role in promoting a greater understanding of biomedical research in our community and have much to offer one another. Through workshops and a summer professional development program, teachers learn molecular biology techniques and participate in laboratory research. SEP also helps mentor scientists refine their teaching skills and enhance their ability to communicate science to the broader community. Research experiences for high school students are also available. In addition, SEP provides a variety of high quality instructional resources developed by teachers and scientists, as well as the material resources needed to explore life science concepts in a classroom laboratory setting.
Institute for Health Metrics and Evaluation
www.healthdata.org

An independent population health research organization based at the University of Washington School of Medicine, the Institute for Health Metrics and Evaluation (IHME) works with collaborators around the world to develop timely, relevant, and scientifically valid evidence that illuminates the state of health everywhere. In making our research available and approachable, we aim to inform health policy and practice in pursuit of our vision: all people living long lives in full health.

Northwest Association for Biomedical Research
www.nwabr.org

NWABR is the Northwest’s leading voice for understanding biomedical research and its ethical conduct. NWABR envisions a future time where the public recognizes and values the contribution of ethically conducted biomedical research and where this research leads to significant improvement in community health. NWABR works to achieve this vision through the promotion of the public’s trust in biomedical research, and its ethical conduct. NWABR’s diverse membership spans academic, industry, non-profit research institutes, health care, and voluntary health organizations. NWABR offers a summer science camp, a youth ethics summit, curriculum materials for secondary teachers, and a research ambassadors program that provides speakers on a wide range of topics.

Pacific Science Center
www.pacificsciencecenter.org

Pacific Science Center (PacSci) is an interactive science institution in Seattle that ignites curiosity in every child and fuels a passion for discovery, experimentation, and critical thinking in all of us. PacSci offers virtual and in-person programming and experiences for curious minds of all ages. You can experience PacSci from anywhere through Virtual Field Trips, Curiosity at Home, and a variety of content available online. Check out pacsci.org for more information.

PATH
www.path.org

PATH is a global team dedicated to achieving health equity so all people and communities can thrive. We advise and partner with governments, multilateral organizations, businesses, and social investors to solve the world’s most pressing health challenges. Their team includes scientists, clinicians, business leaders, engineers, advocates, and experts from dozens of other specialties. Together, they work with global and local stakeholders in more than 70 countries to develop and scale up responsive, sustainable, human-centered health solutions to barriers to health and wellbeing.
Funding, Credits, & Copyright

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Credits

STEM GLOBAL TEAM
Maurizio Vecchione, President and CEO; Nancy Kevorkian, Director of Operations; Kayla Jan, Manager of Programs and Events.

CURRICULUM DESIGN, EDITING, AND PRODUCTION
Kristen Clapper Bergsman, PhD, Principal/Owner, Laughing Crow Curriculum LLC

GRAPHIC DESIGN TEAM
The Medium. Learn more at www.the-medium.net

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CURRICULUM DEVELOPMENT TEAM

• Bill & Melinda Gates Discovery Center: Patrick McMahon, BMGF Senior Communications Officer, Manager, Discovery Center Visitor Engagement & Experience; David McIntosh, BMGF Communications Officer, Schools, Education & Youth Engagement; Ashley Hill, Education and Outreach Specialist, Triangle Associates.

• Fred Hutch SEP: Jeanne Ting Chowning, PhD, Senior Director, Science Education; Regina Wu, Program Manager, Frontiers in Cancer Research; Hanako Osuga, Program Coordinator/Data Systems Lead; partnering teachers and staff.

• IHME: Austin Carter, Doctoral Candidate and IHME Researcher; Josef Frostad, Doctoral Candidate and IHME Researcher; Sean Lassiter, IHME Senior Education Program Manager; Sarah Wozniak, IHME; Justin Lo, IHME.

• NWABR: Wendi Russac, NWABR Education Manager.

• Pacific Science Center: Brittany Strachota, Tinker Tank Program Lead, Pacific Science Center.

• PATH: Mike Eisenstein, PATH Product Development Shop Manager; Daniel Myers, PATH Product Development Coordinator; and Geneva Goldwood, PATH Product Development Engineer.

• Laughing Crow Curriculum: Kristen Clapper Bergsman, PhD, Principal/Owner; Janneke Petersen.
Photography Credits

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- **Pg 11**: stemteachingtools.org
- **Pg 13**: Front view of smiley teenage girl with headphones during online school, freepik.com
- **Pg 14, 21**: Microscopic view of Coronavirus disease, Pugun_Sj, freepik.com
- **Pg 14, 223**: Rock Formations, adnorf, pexels.com
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- **Pg 33, 56, 77, 104, 118, 187, 283, 298, 314**: Cheerful child excited using computer for online learning, Ijeab, freepik.com
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- **Pg 304, 305**: Group of diverse occupation people, Rawpixel, freepik.com
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Copyright Statement

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Why Global Health Education is Important

Inspiring and preparing the next generation of global health thinkers, doers, and dreamers.

When the STEM Global project was launched, the novel coronavirus SARS-CoV-2 did not exist. While the epidemics of interest to the global health field certainly existed across the world, and our shared history is rich with the stories of previous pandemics that shook generations before us, the emergence of a new virus brought the concerns of global health right into our homes, schools, businesses, and places of work in the United States.

In the midst of the COVID-19 pandemic, it is not difficult to understand why global health education is important. The pandemic has impacted many aspects of our lives: it has caused death, illness, isolation, and with it, a collective trauma and impact to mental health. It has influenced global markets, regional economies, and household incomes; it has laid bare once again the health inequities caused by structural racism, ableism, sexism and nationalism. It has changed the way we approach work, school, shopping, and socializing; it has taken away the rituals that mark important events—graduations, proms, birthdays, weddings, funerals. We grieve for those lives lost and families forever changed. We honor those on the front lines of the pandemic—the health care workers, biomedical researchers, emergency responders, and essential workers who provide critical services and maintain important infrastructures—as well as the people who stayed home, masked up, and sought out vaccinations to protect themselves and their communities.

Currently, people across the world are collectively experiencing what has been the focus of the field of global health all along. However, not all communities—and not all families—are experiencing this pandemic the same. This highly interdisciplinary and diverse field is not just focused on understanding the emergence of diseases and methods of prevention and treatment. It also investigates all related aspects, such as the logistics of manufacturing and transporting critical health supplies, the mental toll of illness, the economic costs and impacts of disease, and the disparities felt unevenly across different communities. It explores the biomedical, social, economic, legal, and ethical aspects of health and illness in communities across the globe. It is not difficult to understand now, given our lived experience with a pandemic, why the field of global health is important.

In K-12 schooling, it is important to bring global health education into the curriculum to help students make sense of their world and the experiences of others across the globe, and to prepare the next generation of global health experts ready to solve complex problems in the future. The topics of global health can be integrated across subjects, including the STEM subjects of science, engineering, technology, math, as well as the social studies disciplines of economics, geography, government, and history. As educators struggled to help students make sense of a quickly changing world during the early days of the COVID-19 pandemic, curriculum materials were designed in particular for life sciences teachers to unpack the biological concepts of viruses, viral transmission, immunology, and vaccines. However, global health topics have long been woven into science and history.
classrooms, often through the use of case studies of past epidemics and pandemics. History is rich with the stories of cholera, tuberculosis, influenza, malaria, the bubonic plague, and many other sources of disease and illness. Each year, the news media reports on the emergence of new diseases, like those caused by the Zika virus or Ebola virus, MERS and SARS, or contemporary outbreaks of older ones, such as HIV/AIDS, zoonotic forms of influenza, or localized epidemics of tuberculosis. There are also the non-infectious, chronic diseases and conditions that affect people around the world, such as cancer, diabetes, malnutrition, and diarrhea. Each of these stories represent real people, families, and children.

The study of these topics not only are important for students to develop an understanding of concepts from STEM and social studies disciplines, but also as a way to foster a sense of empathy, care, and concern for others.

The topic of global health offers science teachers a way to bring contemporary science and engineering topics into their classrooms—topics which are authentic, real-world, and relevant to students and their communities, past, present, and future. As Van Horne and Bell explain in Practice Brief #2 of the STEM Teaching Tools series, K-12 students are often asked to engage in investigations of science topics that are static and “settled,” in that the answers are already known, the results are to be confirmed rather than investigated, and the underlying scientific concepts have already been discovered. However, here lies an opportunity for the three-dimensional instruction set forth in the Next Generation Science Standards, in which “the integration of contemporary scientific problems in K-12 instruction can give learners exciting ways to learn and apply disciplinary core ideas of science, engage purposefully in the science and engineering practices, and even make meaningful contributions to science, engineering, and/or their communities through their investigations.”

Featuring contemporary science topics in the classroom illuminates for students the cutting edge of scientific research, shows the highly interdisciplinary nature of today’s STEM fields, and demonstrates not only the utility of scientific, engineering, mathematical, and computational practices to the real world, but their relevance to students’ own lives and communities. This engagement with practice-focused instruction and contemporary science topics can show students that science is a “cumulative, social, and creative enterprise.”
How to Use this Collection

The instructional materials featured in this collection provide strategies for integrating global health concepts into secondary STEM classrooms. These resources include both units of instruction and stand-alone lesson plans intended for middle and high school educators who teach in formal and informal learning settings. Instructional materials are provided for teachers of the following disciplines: life sciences/biology; earth and space sciences/data literacy; and physical sciences/engineering design. In addition, curriculum resources are provided that specifically highlight career pathways in the interdisciplinary field of global health. These materials were authored by staff of STEM Global partner organizations with support from curriculum design experts at Laughing Crow Curriculum. The authors of these materials were able to leverage their particular areas of expertise within the field of global health and STEM education. Therefore, the topics of study are diverse, including scientific phenomena and engineering design challenges centered on HIV, COVID-19, cancer, air pollution, and vaccine delivery.

The instructional materials included in this collection are designed for the Next Generation Science Standards (NGSS). This approach includes anchoring instruction with a scientific phenomenon or engineering design challenge and identifying questions that guide student sensemaking and instruction. With NGSS, students engage fully in three dimensions of science and engineering learning: Disciplinary Core Concepts, Science and Engineering Practices, and Crosscutting Concepts. Moreover, many of the included lesson plans engage students in developing understandings of the social and ethical implications of global health problems and their potential solutions. Within each lesson material, NGSS alignments are identified. In addition, a summary table of NGSS alignments is provided below after the Lesson Summaries.

To use this collection of instructional materials, look over the Table of Contents. Materials are organized first by discipline (e.g., life sciences/biology, earth and space sciences/data literacy, and physical sciences/engineering design) and then by grade level (e.g., middle school or high school). Each lesson or unit begins with an overview, which provides brief information that summarizes the lesson topic, timing, anchoring phenomenon/design challenge, and NGSS alignments. This at-a-glance information can help educators decide if a resource is a potential match for their instructional setting and audience before diving deeper into the lesson plans. For each instructional resource contained in this collection, lesson plans are followed by the resources necessary for instruction, including student handouts, teacher answer keys, and slide decks. As a companion to this document, the STEM Global Curriculum Collection Google drive folder contains digital versions of the instructional resources so that teachers can save a copy, make adaptations, and use them with their own learning management systems. Google Docs, Slides and Sheets can be downloaded as Microsoft Word, PowerPoint, or Excel files or saved in PDF format.
Remote Instruction Adaptations

In response to the COVID-19 pandemic that closed schools and drove instruction online, many of the instructional materials featured in this collection have been adapted for remote learning settings. Look for the remote instruction icon which denotes which materials have these suggested adaptations incorporated into the lesson plans.

These adaptations assume that instruction is being delivered fully remotely in an online environment, however educators can adapt for hybrid learning settings by pulling from both the regular lesson plan and the remote instruction adaptations.
Summaries of Featured Instructional Resources

Brief summaries are provided below of each of the instructional resources featured in this collection. The summaries are organized by science discipline. Suggested courses and grade levels are provided.

- **LIFE SCIENCES/BIOLOGY**
- **EARTH SCIENCES/ DATA LITERACY**
- **PHYSICAL SCIENCES/ ENGINEERING DESIGN**
- **GLOBAL HEALTH CAREERS**
LIFE SCIENCES/BIOLOGY

COVID Testing & Inequities

Brief Overview: In this seven-lesson unit, students develop an understanding of molecular biology through an exploration of viral and antibody testing used for detecting SARS-CoV-2 infections, which causes the disease known as COVID-19. This unit engages students in learning about molecular biology through an authentic, contemporary, and highly relevant topic. Students explore patient case studies to make a diagnosis and further recommendations for their care. Two wet labs are included which use gel electrophoresis and an indirect ELISA. Students also learn about and discuss health inequities and bioethical issues related to the COVID-19 pandemic. The unit incorporates opportunities for engaging with productive uncertainty, developing scientific argumentation practices, and considering bioethical implications of scientific discoveries and policy decisions. These lesson plans include suggested adaptations for remote instruction settings.

Diagnostic Detective

Brief Overview: In this short unit, students investigate the importance of HIV testing and how scientists have designed tests that utilize natural immune proteins called antibodies. The students develop questions around why it is that 25% of people infected with HIV do not know they are infected. Students investigate the societal pressures that inform these decisions. Students can also challenge their own assumptions about HIV. Through learning about HIV and HIV testing, students develop an understanding of the immune system and protein structure and function, as well as developing the scientific practice of planning out an investigation. This lesson includes suggested adaptations for remote instruction settings.

Code Cracking: Decoding Cancer Causing Mutations

Brief Overview: This lesson is intended to be integrated into a High School Biology genetics unit and allows students to investigate and understand that cancer is a result of an accumulation of mutations in the genes that control cell proliferation. Cancer has a global impact, impacting lives around the world. However, cancer (both rates of incidences and cancer related deaths) disproportionately affects people in different countries of the globe. Students will learn about risk factors and prevention strategies to help them unpack some of the reasons for these disparities. In the culminating mini-project, students will conduct online research on the global disparities of cancer by investigating either a type of cancer across multiple countries/regions or the rates of different types of cancer in a single country/region. Optional extension activities are included. This lesson includes suggested adaptations for remote instruction settings.
EARTH SCIENCES/DATA LITERACY

Data Driven: Investigating the Human Health Effects of Air Pollution in Washington State, High School Version

Brief Overview: This lesson explores past, current, and future trends of air pollution in Washington State and provides opportunities for students to better understand the phenomena through intensive interaction and manipulation of data using spreadsheet software. Through this lesson, students will develop an understanding of foundational data science principles and recognize techniques for manipulating and analyzing data. In particular, students will develop skills in vetting data quality and generating basic descriptive statistics, including calculating mean, median, min, and max. Students will also gain skills in interpreting trends and patterns in data and making informed and evidence-based conclusions. In addition, students will gain an understanding of how air pollution effects human health and the global epidemiology of outcomes attributed to air pollution. This lesson includes suggested adaptations for remote instruction settings.

Data Driven: Investigating the Human Health Effects of Air Pollution in Washington State, Middle School Version

Brief Overview: In this data science lesson, students practice analyzing and interpreting data in order to answer an investigative question about air pollution in Washington State. Student groups first collaborate to graph air pollution data from a city in Washington State. They then compile data as a class in order to observe trends and patterns across cities to make a claim about whether the time of year affects the amount of air pollution in Washington. Through this lesson, students will develop an understanding of foundational data science principles and recognize techniques for manipulating and analyzing data. Students will also gain skills in interpreting trends and patterns in data and writing evidence-based claims. In addition, students will gain an understanding of how air pollution affects human health and the global epidemiology of outcomes attributed to air pollution. This lesson includes suggested adaptations for remote instruction settings.
PHYSICAL SCIENCES/ENGINEERING DESIGN

Drone Drop Challenge

**Brief Overview:** An authentic global health challenge is the delivery of critical medical supplies to remote communities accessible only by foot, bicycle, or motorbike. In this engineering design challenge—a variation on the classic egg drop challenge—students work in teams to design, prototype, and test a vaccine container that will be delivered via drone technology. Students apply an understanding of motion and forces to inform their design and testing of the vaccine container. This activity represents a partial design cycle, but could be extended to include re-design, re-test, and optimize phases.

Special Delivery: Design a Vaccine Delivery Solution

**Brief Overview:** A contemporary global health challenge is the delivery of vaccines to people living in remote villages around the world. Many remote areas struggle to receive necessary vaccines for various reasons, including rough terrain between medical facilities and villages and towns that is impassable to most vehicles. This activity engages students in the engineering design process as they design, build, and test a model of a vehicle capable of traveling rough terrain without damaging the vaccines it is transporting. In this simulated design task, students use K’nex and LEGO building materials to construct a vehicle that can travel along a rough track. This activity could be used to introduce students to the engineering design process. Suggestions are provided for increasing the complexity of the design challenge (e.g., carry more than one container, design a vehicle without wheels, etc.) as well as for incorporating an additional design challenge focused on the cold chain process of vaccine delivery.
GLOBAL HEALTH CAREERS

Exploring Pathways to Global Health Careers

Brief Overview: This lesson engages students in exploring careers in the global health sector. The goal is to broaden students’ awareness of the types of careers available within the field and to develop an understanding of the educational pathways required for these types of careers. Students begin by reading about careers in global health. They then work in groups to explore the website of a global health organization and share their findings with the class. Next, students explore a careers pathway poster and choose a career to research, using a set of provided fact sheets and additional online resources. They share their findings in small groups and then summarize what they learned about these careers in an Exit Ticket. *This lesson can easily be adapted for both synchronous and asynchronous remote instruction settings.*

Pathways to Global Health Careers Poster & Fact Sheets

Brief Overview: Global health organizations currently employ more than 14,000 people just in Washington State. The global health workforce—in the U.S. and worldwide—attracts people with diverse backgrounds, as it takes an interdisciplinary approach to solve some of the world’s most complex problems. This Pathways to Global Health Careers poster features a beautiful infographic that maps the broad variety of careers that make up the global health sector and the education required to land them. A set of Global Health Careers Fact Sheets accompany the poster, providing information on featured jobs across eight different career and technical education career clusters. Featured information on each job includes median salary, job description, minimum education requirements, certification/licensure, and internships/apprenticeships/volunteer opportunities. *These digital resources can be used in remote instruction settings.*
# NGSS Alignment Summary

The table below summarizes how the lesson plans and activities contained within each instructional resource are aligned to Performance Expectations (PEs) in the Next Generation Science Standards. Both middle school (MS) and high school (HS) grade band alignments are reported.

![NGSS Logo](image)

### NGSS* Performance Expectations (PEs) by Scientific Discipline

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<td><strong>HS-LS1-1:</strong> Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.</td>
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<td><strong>HS-LS1-2:</strong> Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.</td>
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<td><strong>HS-LS1-4:</strong> Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.</td>
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<td><strong>HS-LS3-2:</strong> Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations from meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.</td>
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<td><strong>HS-LS4-2:</strong> Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.</td>
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<td><strong>HS-LS4-3:</strong> Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.</td>
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<td><strong>HS-LS4-4:</strong> Construct an explanation based on evidence for how natural selection leads to adaptation of populations.</td>
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*Next Generation Science Standards is a registered trademark of WestEd. Neither WestEd nor the lead states and partners that developed the Next Generation Science Standards were involved in the production of this product, and do not endorse it.*
## EARTH & SPACE SCIENCES

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<td>Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.</td>
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<td>Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.</td>
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<td>Use a computational representation to illustrate the relationship among Earth systems and how those relationships are being modified due to human activity.</td>
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## PHYSICAL SCIENCES

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<th>Global Health Careers</th>
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</thead>
<tbody>
<tr>
<td><strong>NGSS Performance Expectations (PEs)</strong></td>
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<td><strong>MS-PS3-5</strong></td>
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<tr>
<td>Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.</td>
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<td><strong>HS-PS2-3</strong></td>
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<td>Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.</td>
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</tbody>
</table>

## ENGINEERING DESIGN

<table>
<thead>
<tr>
<th>Performance Expectation</th>
<th>COVID Testing</th>
<th>Diagnostic Detective</th>
<th>Code Cracking</th>
<th>Data Driven (HS)</th>
<th>Data Driven (MS)</th>
<th>Drone Drop Challenge</th>
<th>Special Delivery</th>
<th>Global Health Careers</th>
</tr>
</thead>
<tbody>
<tr>
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<td><strong>MS-ETS1-1</strong></td>
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<tr>
<td>Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.</td>
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<tr>
<td>Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.</td>
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<td><strong>MS-ETS1-4</strong></td>
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<tr>
<td>Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. (With lesson extensions focused on re-design and optimization).</td>
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<tr>
<td>Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.</td>
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<tr>
<td>Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.</td>
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<tr>
<td>Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.</td>
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</table>

## NATURE OF SCIENCE (APPENDIX H)

<table>
<thead>
<tr>
<th>Performance Expectation</th>
<th>COVID Testing</th>
<th>Diagnostic Detective</th>
<th>Code Cracking</th>
<th>Data Driven (HS)</th>
<th>Data Driven (MS)</th>
<th>Drone Drop Challenge</th>
<th>Special Delivery</th>
<th>Global Health Careers</th>
</tr>
</thead>
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<tr>
<td><strong>Nature of Science</strong></td>
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<tr>
<td>Science is a Human Endeavor</td>
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<td><strong>Nature of Science</strong></td>
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<tr>
<td>Science Addresses Questions About the Natural and Material World</td>
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</tbody>
</table>


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Life Sciences/Biology

COVID-19 Testing & Inequities
10–12 50-minute class periods | Grades 9-12

Diagnostic Detective
6 50-minute class periods | Grades 9-10

Code Cracking: Decoding Cancer Causing Mutations
3 or more 50-minute class periods | Grades 9-10
COVID-19 Testing and Inequities

FRED HUTCHINSON CANCER RESEARCH CENTER’S SCIENCE EDUCATION PARTNERSHIP

Brief Overview: In this seven-lesson unit, students develop an understanding of molecular biology through an exploration of viral and antibody testing used for detecting SARS-CoV-2 infections, which causes the disease known as COVID-19. This unit engages students in learning about molecular biology through an authentic, contemporary, and highly relevant topic. In this unit, students answer the questions: How do you know if you have COVID-19?; How do you know if you have already had a COVID-19 infection in the past?; and Who gets tested for COVID-19? Students explore patient case studies to make a diagnosis and further recommendations for their care. Two wet labs are included which use gel electrophoresis and an indirect ELISA. Students also learn about and discuss health inequities and bioethical issues related to the COVID-19 pandemic. The unit incorporates opportunities for engaging with productive uncertainty, developing scientific argumentation practices, and considering bioethical implications of scientific discoveries and policy decisions. The last lesson in this unit, Lesson 7: Policies and the Nature of Science, is currently in development. All lesson plans include suggested adaptations for remote instruction settings.

www.fredhutch.org

Time:

10 to 12 50-minute class periods for the full unit

Subject & Grade Level(s):

High School Biology, AP Biology, Biotechnology, Grades 9-12

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Lesson Sequence

Lesson 1: COVID-19 Diagnostic Testing

Introduction
In this lesson, students will explore the importance of COVID-19 testing and the biology behind diagnostic tests developed for detecting viral antigens and viral genomic sequences.

Lesson 2: Molecular Testing

Using knowledge and the Patient Information sheet from the previous lesson, students will perform gel electrophoresis on patient samples processed using the RT-PCR method for detecting the SARS-CoV-2 virus. After analyzing results, students will determine if their patient currently has an infection.

Lesson 3: Antibody Testing

Students will learn about antibodies and the body’s response to viral infection. During the wet lab activity, students will perform an ELISA to figure out if their patient has been infected by SAR-CoV-2 and make a recommendation about what their patient should do based on their molecular and antibody test results.

Lesson 4: Bioethics and COVID-19

Students will begin to recognize that science happens in a social context. They will consider some of the ethical issues related to the COVID-19 pandemic.

Lesson 5: Health Inequities and COVID-19

Students will recognize that there are differences in how the COVID-19 pandemic impacts particular communities, with Black, Latinx, and Indigenous communities being particularly hard hit. Students will look at data related to COVID-19 health inequities and reflect on what drives those disparities. They will engage with a seminar reading to deepen their understanding of the role of structural racism in exacerbating the effects of the pandemic in communities of color.

Lesson 6: Nextstrain Overview

Students will look at real COVID-19 genomic tracking data to see the viral evolution as well as how the movement of the virus has changed over the course of the pandemic.

Lesson 7: Policies and the Nature of Science

(Coming Soon!) Students will analyze the evolving recommendations around COVID-19 guidelines, think critically about how the types of news reporting can influence an individual’s level of precaution taken during the pandemic, and realize how different pieces of information can vary from source to source, impacting the public’s understanding of COVID-19 guidelines.
Next Generation Science Standards

The lessons in this unit build toward the following Performance Expectation(s) from the NRC Framework and Next Generation Science Standards.

PERFORMANCE EXPECTATIONS

**HS-LS1-1**: From Molecules to Organisms: Structures and Processes. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.

**HS-LS4-2**: Biological Evolution: Unity and Diversity. Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

**HS-LS4-3**: Biological Evolution: Unity and Diversity. Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.

**HS-LS4-4**: Biological Evolution: Unity and Diversity. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

**HS-ETS1-3**: Engineering Design. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Appendix H: Nature of Science

- Science is a Human Endeavor
- Science Addresses Questions About the Natural and Material World

Building Toward the Social Justice Education Standards

The lessons in this unit build toward the following standards from Social Justice Standards: The Teaching Tolerance Anti-bias Framework from Learning for Justice:

GRADE LEVEL OUTCOMES AND SCENARIOS

- **Justice 12 JU.9-12.12**: Recognize, describe and distinguish unfairness and injustice at different levels of society.
- **Justice 13 JU.9-12.13**: Explain the short and long-term impact of biased words and behaviors and unjust practices, laws and institutions that limit the rights and freedoms of people based on their identity groups.
- **Justice 15 JU.9-12.15**: Identify figures, groups, events and a variety of strategies and philosophies relevant to the history of social justice around the world.
ADDITIONAL INFORMATION:
For more information on Fred Hutch’s Science Education Partnership (SEP), our approach to science teaching and learning, and additional background information and resources, please see the Unit Preface and Unit Overview documents.

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AUTHORSHIP CREDIT:
Core Development Team
- Jeanne Ting Chowning, PhD, Sr. Director, Science Education, Fred Hutchinson Cancer Research Center
- Hanako Osuga, Science Resource Coordinator, Science Education Partnership, Fred Hutchinson Cancer Research Center
- Regina Wu, Frontiers in Cancer Research Program Manager, Fred Hutchinson Cancer Research Center
- Kristen Bergsman, PhD, Curriculum Writer, Laughing Crow Curriculum LLC
- Kim Kotovic, PhD, Curriculum Advisor, Kotovic Consulting LLC

Science Education Partnership Staff, Fred Hutchinson Cancer Research Center
- Kristen Bergsman, PhD, Curriculum Design Project Lead/Program Manager
- Kay Lalish, PhD, Pathways Explorer Program Manager
- Caren Brinkema, Lab Manager/Special Projects

Lesson 4 Credits
These materials are based on ones originally developed by the Northwest Association for Biomedical Research (NWABR), particularly the curriculum unit Bioethics 101: Reasoning and Justification.

Lesson 5 Credits
Activity 5.1 builds off of a lesson generously shared by educator Renee Agatsuma.
Lesson 1

COVID-19 Diagnostic Testing Introduction

Overview: How do you know if you have COVID-19? How do you know if you have already had a COVID-19 infection? From the early days of the SARS-CoV-2 pandemic, COVID-19 testing has been mired in confusion. Questions about accuracy, access, and cost have important implications for public health and health outcomes. In this lesson, students will explore how scientists test for viral infection and what the future of testing might look like as the world starts to reopen.

Unit Progression

<table>
<thead>
<tr>
<th>#</th>
<th>Lesson Title</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>COVID-19 Diagnostic Testing Introduction</td>
</tr>
<tr>
<td>2</td>
<td>Molecular Testing</td>
</tr>
<tr>
<td>3</td>
<td>Antibody Testing</td>
</tr>
<tr>
<td>4</td>
<td>Bioethics and COVID-19</td>
</tr>
<tr>
<td>5</td>
<td>Health Inequities and COVID-19</td>
</tr>
<tr>
<td>6</td>
<td>Nextstrain Overview</td>
</tr>
<tr>
<td>7</td>
<td>Policies and the Nature of Science (Coming Soon!)</td>
</tr>
</tbody>
</table>

Remote Learning Adaptations

Suggestions for adapting the activities for remote teaching and learning settings are included at the end of the lesson here.
Student Understandings

**WHAT STUDENTS FIGURE OUT**
- Viral tests tell you if you have a current viral infection by testing for the presence of the virus.
- Antibody tests tell you if you had a previous viral infection by testing for the antibodies produced by your immune system in response to the virus.
- No test is ever perfect. All tests occasionally result in false positive or false negative results.
- The viral load, the amount of virus present in an infected person, changes throughout the course of infection.
- The immune system begins antibody production a few days after infection.

**WHAT STUDENTS WILL DO**
- Discuss why SARS-CoV-2 testing is important.
- Use argumentation to prioritize factors that go into test development to come to a consensus.
- Practice making claims using evidence and reasoning to understand diagnostic test results.

**PREVIOUS KNOWLEDGE**
- This lesson should be part of a larger unit on COVID-19 and SARS-CoV-2, or can fit within a unit focused on infectious diseases.
- Students should have some previous knowledge of viral replication, viral infection, and gel electrophoresis.

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**Next Generation Science Standards**

This lesson builds toward the following Performance Expectation(s) from the NRC Framework and Next Generation Science Standards.

**PERFORMANCE EXPECTATIONS**

**HS-ETS1-3**: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

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**STUDENT ASSESSMENT OPPORTUNITIES**

- Class discussions and turn and talk moments during Activity 1.1.
- Organization of activity cards during Activity 1.2, including students’ top three choices and their reasoning for choosing them.
- Students’ responses on Student Handout 1.2: Diagnostic Testing Worksheet during Activity 1.3 and Activity 1.4.
Teacher Preparation

Print copies of the materials listed below or upload them to your classroom learning management system.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Description</th>
<th>Quantity</th>
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</thead>
<tbody>
<tr>
<td>Lesson 1 COVID-19 Testing Slide Deck (Teacher)</td>
<td>Slide deck for teacher to use when enacting the lesson in-person or for student use for self-directed remote learning</td>
<td>N/A</td>
</tr>
<tr>
<td>Optional Extension: Specificity &amp; Sensitivity Slide Deck</td>
<td>Slide deck for optional extension activity that explains how math and statistics are important in test development</td>
<td>N/A</td>
</tr>
<tr>
<td>Student Handout 1.1: Viral Test - Factors in Development Activity Cards</td>
<td>Activity cards for Activity 1.2: Factors When Developing Test</td>
<td>1 per group</td>
</tr>
<tr>
<td>Scissors</td>
<td>Scissors are needed if students will be cutting out the activity cards themselves</td>
<td>1 per group</td>
</tr>
<tr>
<td>Student Handout 1.2: Diagnostic Testing Worksheet</td>
<td>Worksheet that goes along with the slide deck</td>
<td>1 per student</td>
</tr>
<tr>
<td>Student Handout 1.3: SARS-CoV-2 RNA and Antigen Graph</td>
<td>A copy of the graph for students to discuss in their groups</td>
<td>1 per group</td>
</tr>
<tr>
<td>Student Handout 1.4: Patient Information</td>
<td>Includes descriptions of the patients that student will test and a place to record their results</td>
<td>1 patient sheet per group</td>
</tr>
</tbody>
</table>
Instructional Procedure

OVERVIEW

<table>
<thead>
<tr>
<th>Activity</th>
<th>Details</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity 1.1</td>
<td>Introduction</td>
<td>10 min</td>
</tr>
<tr>
<td>Activity 1.2</td>
<td>Factors When Developing Tests</td>
<td>15 min</td>
</tr>
<tr>
<td>Activity 1.3</td>
<td>Understanding Diagnostic Tests</td>
<td>15 min</td>
</tr>
<tr>
<td>Activity 1.4</td>
<td>Graph Interpretation</td>
<td>5 min</td>
</tr>
<tr>
<td>Activity 1.5</td>
<td>Introduce Patient Information</td>
<td>5 min</td>
</tr>
</tbody>
</table>

ACTIVITY 1.1: INTRODUCTION (10 MINUTES)

1. **(Slide #2)** Explain that the class will be exploring SARS-CoV-2, the virus that causes COVID-19 illness.

2. **Present the class with the first discussion question** and collect answers from the class.

   **Discussion Question:** How do we know if a person has or has had COVID-19?

3. **(Slide #3)** Expected answers include symptom checking and testing. Review the information on Slide #3.

4. **(Slide #4)** Present the class with the next discussion questions.

   **Discussion Question:** During the pandemic and as states start to reopen, why is it important to know if you have COVID-19?

5. **(Slide #5)** Present the different headlines about COVID testing. There is a lot of confusion among the general population about testing that occurred early in the pandemic and is still occurring even now. A scientific understanding of SARS-CoV-2 and the tests for COVID-19 is helpful to create a scientifically literate population and reduce confusion and misinformation.
ACTIVITY 1.2: FACTORS WHEN DEVELOPING TESTS (15 MINUTES)

6. Explain that when developing standards and guidelines for testing, the Centers for Disease Control and Prevention (CDC) have to consider many different factors.
   a. (Slide #6) Turn & Talk: Have students discuss “What are important factors and issues to think about when developing viral tests?” Have them record their answers in a notebook.
   b. Pass out the Student Handout 1.1: Viral Test - Factors in Development Cards, one per group.
   c. Group Task: In their groups, students will add, cut out, and prioritize the different factors by most important to least important. Discuss until your group comes to a consensus.
   d. Record: Students will record their group’s reasoning for their top three choices.
   e. Share Out: If time is permitting, ask each group to select one student to present their top three choices and their reasoning.

7. Optional extension for biotech classes: (Slide #7) Present the Specificity & Sensitivity sliddeck. This adds a math component to the lesson.

ACTIVITY 1.3: UNDERSTANDING DIAGNOSTIC TESTING (15 MINUTES)

8. (Slide #8) Present the EdPuzzle video by Jackson Laboratory (1:57 min). There are 10 embedded multiple choice questions in the video to help guide student learning.

9. Tell students that you will first be exploring Diagnostic Testing (Slides #9-14). Present the slides, including watching several videos.
   a. (Slide #10) Pass out the Student Handout 1.2: Diagnostic Testing Worksheet. Tell the students to make notes about the similarities and differences between the two diagnostic tests using the Venn diagram as they watch the next video “An Introduction to COVID-19 Tests” (0:51 min).
   b. Highlight the proteins as antigens and RNA on the SARS-CoV-2 diagram.
   c. (Slide #11) Explain that molecular tests are the most common testing method. These are the tests that are used at most of the drive-through and walk-up testing sites, and they are the tests that are registered with the CDC to track infection rates.
   d. (Slide #13) Watch the EdPuzzle video (3:36 min) to introduce students to RT-PCR. This technology is used in molecular tests.
10. (Slides #15-18) Explain the reagents that are provided in the CDC testing panel. Explain the three primer probe mixes provided.

11. Have students filled in the table in Question 5 on the Student Handout 1.2: Diagnostic Testing Worksheet. Sample student answers are provided below for teacher use:

<table>
<thead>
<tr>
<th>CoV_N1</th>
<th>Detects a part of the COVID-19 virus’ mRNA.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoV_N2</td>
<td>Detects a part of the COVID-19 virus’ mRNA.</td>
</tr>
<tr>
<td>RP</td>
<td>Targets human RNase P for detection of human nucleic acids.</td>
</tr>
</tbody>
</table>

The virus is present in the sample and the person may be positive for COVID-19.

One control sample:

1. **mCoV_P**: Noninfectious positive control material; yields a positive result in each assay included in the panel.

ACTIVITY 1.4: GRAPH INTERPRETATION (5 MINUTES)

12. (Slide #19) Pass out a copy of Student Handout 1.3: SARS-CoV-2 RNA and Antigen Graph to each group. Show students the figure on Slide #19.

13. Turn & Talk: Using the graph, have students discuss and answer Questions 6-8 on the Student Handout 1.2: Diagnostic Testing Worksheet. Alternatively, this can be assigned as individual homework if a copy of Student Handout 1.3 is given to each student.

ACTIVITY 1.5: INTRODUCE PATIENT INFORMATION (5 MINUTES)

14. (Slide #20) Pass out Student Handout 1.4: Patient Information. Each group will get one patient. Tell the students that we will be testing these patients for past and present COVID-19 infections and give recommendations on what they should do. Each patient has a short description on why they have come for testing.

15. Ask students to read the description with their group members. Based on the information given, can you make a prediction?

16. In Lesson 2, students will be using gel electrophoresis to analyze patient samples that have been processed using the RT-PCR primers provided by the CDC. At that point, they will be able to complete the rest of the handout for their patient.
ADAPTATIONS FOR REMOTE INSTRUCTION

As an alternative to the in-person instructional procedure on the previous pages, the table below provides suggested instructional procedures adapted for remote learning settings. This lesson assumes students have computer and internet access at home.

<table>
<thead>
<tr>
<th>Learning Activity</th>
<th>Remote Instruction Procedure</th>
</tr>
</thead>
</table>
| **Activity 1.1: Introduction**  
(10 min)  
0. Before the class: Upload all handouts and the slide deck(s) to your classroom learning management system. Create a digital bulletin board with the following two questions:  
a. “How do we know if a person has or has had COVID-19?”  
b. “During the pandemic and as states start to reopen, why is it important to know if you have COVID-19?”  
1. If you are able, present the Lesson 1 slide deck during a synchronous class meeting. If not, students can be instructed to work through Slides #1-5 of the slide deck on their own, responding to the two questions in a digital bulletin board. |
| **Activity 1.2: Factors When Developing Tests**  
(15 min)  
2. Ask students to respond to the following question in a digital bulletin board: “What are important factors and issues to think about when developing viral tests?”  
3. Ask students to work individually to organize/prioritize the activity cards on Student Handout 1.1: Viral Test - Factors in Development Cards. Students have the option of cutting out the cards, organizing them, and submitting a photo along with a description of their reasoning, or typing up a document that includes the order of their cards and a description of their reasoning. |
| **Activity 1.3: Understanding Diagnostic Testing**  
(15 min)  
4. If you are able, present the Lesson 1 slide deck during a synchronous class meeting. If not, students can be instructed to work through Slides #8-18 of the slide deck on their own while completing the relevant sections of Student Handout 1.2: Diagnostic Testing Worksheet. |
| **Activity 1.4: Graph Interpretation**  
(5 min)  
5. Students can use Slide #19 or Student Handout 1.3: SARS-CoV-2 RNA and Antigen Graph to view the graph.  
6. Have students use the graph to answer Questions 6-8 on the Student Handout 1.2: Diagnostic Testing Worksheet. |
| **Activity 1.5: Introduce Patient Information**  
(5 min)  
7. Assign one patient from Student Handout 1.4: Patient Information to small groups of students (there are 9 patients total).  
8. If possible, have students meet in breakout rooms during a synchronous class meeting to read their patient’s description and make a prediction if they will test positive or negative. They should record their prediction for their patient on the handout, but leave the rest of the handout to be completed in Lesson 2. If students are unable to meet in groups in breakout rooms, this activity can be completed independently. |
Suggested Lesson Extensions

EXTENSIONS
► Slides #22-26 of the Lesson 1 slide deck can be shown to provide more information on antigen diagnostic tests.
► More information on Specificity & Sensitivity is provided in this slidedeck and explains how math and statistics are important in test development.

OPPORTUNITIES FOR PRODUCTIVE UNCERTAINTY
► During Activity 1.4, students interpret SARS-CoV-2 RNA and Antigen Graph and respond to prompts on Student Handout 1.3. These prompts challenge students to use the graph to build claim-evidence-reason statements about the data.

OPPORTUNITIES FOR PERSONAL CONNECTIONS TO STUDENTS
► The COVID-19 pandemic has affected everyone’s lives. This lesson allows students to better understand how the virus is detected and how to make informed decisions based on test results.
► Teachers can emphasize how the topic of this unit authentically relates to students’ own lives. Testing has become useful not only for diagnosing COVID, but as a way to gain entry and access to many things. Negative tests are required in some areas in order to attend sporting events, concerts, and performing arts events, to dine-in at restaurants, to travel on an airplane or gain entry to a foreign country, and to return to school or work after being required to quarantine due to a potential exposure. Some school districts and colleges require weekly COVID testing as a way to identify active cases and prevent larger outbreaks.

Notes on Adaptations and Inclusivity

INCLUSIVITY FOR ALL LEARNERS
Consider how the lesson activities may need to be adapted to be accessible for all learners. For example, what accommodations may a student with a visual or mobility impairment need to engage in these activities? How might you elicit, build connections with, and leverage students’ everyday expertise with COVID-19 and global health? How might you group students with diverse expertise and learning needs into teams so that they can support each other?

VIDEO CAPTIONING
EdPuzzle videos allow for English closed captions. Students can review sections of the video to answer the multiple choice questions.
SCIENTIFIC VOCABULARY

Students may need some support in understanding the terminology embedded within this lesson. This may be particularly true for emerging bilingual students and students with lower reading levels. Terms should be defined contextually as the lesson unfolds. The following list captures some of the terms used in the lesson materials.

- **Antigen**: A molecule that normally triggers an immune response, including pieces of a virus.
- **Antigen Test**: A test that detects viral proteins.
- **Coronavirus (CoV)**: A large family of viruses that cause illness ranging from the common cold to more severe diseases such as Severe Acute Respiratory Syndrome (SARS-CoV).
- **COVID-19**: The respiratory disease caused by the SARS-CoV-2 virus.
- **Diagnostic Test**: A test used to confirm or rule out conditions and diseases.
- **False Negative**: A test result which indicates that a person does not have a specific disease or condition when the person actually does have the disease or condition.
- **False Positive**: A test result which indicates that a person has a specific disease or condition when the person actually does not have the disease or condition.
- **Molecular Test**: A test that detects the genomic material of a virus.
- **Pandemic**: An outbreak of a disease that is prevalent over multiple countries or continents across the world.
- **RT-PCR**: Reverse transcription polymerase chain reaction, a technology used to make billions of copies of a target sequence of RNA for detection.
  - **Primers**: Short fragments of DNA that recognize specific nucleic acid sequences.
  - **Probes**: Fluorescent tags used in PCR to show real-time amplification of the DNA.
  - **Reverse transcriptase**: The enzyme that builds a complementary DNA strand from RNA.
- **SARS-CoV-2**: The virus that causes COVID-19.
- **Sensitivity**: The percentage of sick people who are correctly identified as having the condition.
- **Specificity**: The extent to which a diagnostic test is specific for a particular condition determined by the percentage of healthy people who are correctly identified as not having the condition.
- **Taq polymerase**: The enzyme that builds a complementary DNA strand from another DNA strand.
- **Virus**: An infectious agent that infects cells, replicates, and may cause disease.

CAREER CONNECTIONS

Career connections are not explicitly called out in the activities in this unit, however there are many careers related to COVID testing that teachers may wish to highlight. The career connection for Lesson 1 includes:

**Virologist**: A medical doctor who specializes in the diagnosis, management, and treatment of infectious diseases caused by viruses or a scientist/researcher who studies viruses to understand how they replicate, infect, and transmit. They may work at the public health level to track outbreaks of diseases caused by viral infections or may work to develop and research potential vaccines or antiviral drugs. Virologists work in hospitals, universities, health departments, private industries (e.g., biotech and pharmaceutical companies) and with agencies such as the CDC or the World Health Organization (WHO). Medical doctors must have a MD degree while researchers must have a PhD or a PhD/MD.

Additional careers are featured on the STEM Global - Pathways to Global Health Careers **poster** and accompanying **fact sheets**. Read more about each job by exploring these resources.
Viral Test - Factors in Development

What are important factors and issues to think about when developing viral tests?

Name: ___________________________ Date: ___________ Period: _____

When developing standards and guidelines for testing, the Centers for Disease Control and Prevention (CDC) have to consider many different factors.

► In your group, write any additional factors you came up with on the blank cards.
► Cut out the cards and organize them by prioritizing the different factors by most important to least important.
► Discuss until your group comes to consensus on the organization of the cards. During your group discussion, keep in mind your classroom norms.
► Record your reasoning for your top three choices.

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>(percent of false negatives)</td>
<td>(percent of false positives)</td>
</tr>
<tr>
<td>Cost</td>
<td>Resources Needed</td>
</tr>
<tr>
<td></td>
<td>(nasal swabs or other materials)</td>
</tr>
<tr>
<td>Processing Time</td>
<td>Access to Tests</td>
</tr>
<tr>
<td>Who Can Process Samples</td>
<td>Who Can Get a Test</td>
</tr>
<tr>
<td>Manufacturing Capability</td>
<td>Safety</td>
</tr>
</tbody>
</table>
Diagnostic Testing Worksheet

Name: ___________________________ Date: ___________ Period: ______

**Directions:** Answer the following questions using information from the slide deck presentation.

1. What do molecular tests detect?

2. What can they tell us about the patient?

3. What is the other type of diagnostic test?

4. How does RT-PCR detect the virus?

5. Use the background information to fill in the table:

<table>
<thead>
<tr>
<th>PCR TEST</th>
<th>WHAT DOES IT DETECT?</th>
<th>WHAT DOES IT TELL US?</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoV_N1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CoV_N2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Directions:** Answer the following questions using the “SARS-CoV-2 RNA and Antigen” graph.

6. What does this graph tell us? List your observations.

7. Use evidence and reasoning to support the provided claim.

<table>
<thead>
<tr>
<th>CLAIM: A patient that tests negative for SARS-CoV-2 (using a molecular test) could have been infected in the past.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVIDENCE: The graph shows...</td>
</tr>
<tr>
<td>REASONING: If...</td>
</tr>
</tbody>
</table>

8. Develop a claim from the provided evidence and reasoning.

<table>
<thead>
<tr>
<th>CLAIM:</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVIDENCE: The graph shows that during the incubation period, the amount of SARS-CoV-2 RNA starts to increase but the patient does not show symptoms.</td>
</tr>
<tr>
<td>REASONING: If there is enough SARS-CoV-2 RNA present, then a molecular test should come back positive, and people currently infected with the virus can spread it to others.</td>
</tr>
</tbody>
</table>
SARS-CoV-2 RNA and Antigen Graph

Patient 1

Kelly is a 25 year old nurse working in an assisted living facility. Five people at her work have tested positive for COVID-19. Because Kelly did not work directly with anyone that tested positive and because she is fully vaccinated, her employer is not requiring her to have a test. Kelly has no symptoms and feels perfectly healthy, but worries that she may be an asymptomatic carrier. Worried about the safety of her elderly patients and her family, Kelly has decided to get tested for COVID-19.

OUR PREDICTION:
COVID-19 Test Results
CoV_N1__________________           CoV_N2 ____________________            RP_______________________

Is this patient currently infected with COVID-19?
Based on the COVID-19 Test Results and patient information, explain your diagnosis. Is the patient positive or negative for the virus? Do their symptoms match your diagnosis? Are your results inconclusive and require more testing?

________________________________________

________________________________________

Antibody Test Results
IgM _________________  IgG _____________________

Has this patient been infected with COVID-19 in the past?
Based on the antibody test results and patient information explain if this patient has had COVID-19 in the past?

________________________________________

________________________________________

Recommendations
Based on what you know about COVID-19 and the patient’s results, what would you recommend the patient, their family, or employer do to reduce the risk of spreading COVID-19?

________________________________________

________________________________________
Patient 2

Jason is a 43 year old medical researcher who has been working from home for the past three months. His state has begun to reopen and his lab is asking staff to return to work at the office. Jason and his partner had flu-like symptoms in late February 2020, but neither got tested for either the flu or COVID-19. Since then, he got the vaccine but his partner chose not to. Jason is interested in getting tested to see if he currently has COVID-19 or has had a COVID-19 infection in the past.

**OUR PREDICTION:**

**COVID-19 Test Results**

CoV_N1__________________           CoV_N2 ____________________            RP_______________________

*Is this patient currently infected with COVID-19?*

Based on the COVID-19 Test Results and patient information, explain your diagnosis. Is the patient positive or negative for the virus? Do their symptoms match your diagnosis? Are your results inconclusive and require more testing?

____________________________________________________________________________________

____________________________________________________________________________________

**Antibody Test Results**

IgM _________________  IgG _____________________

*Has this patient been infected with COVID-19 in the past?*

Based on the antibody test results and patient information explain if this patient has had COVID-19 in the past?

____________________________________________________________________________________

____________________________________________________________________________________

**Recommendations**

Based on what you know about COVID-19 and the patient’s results, what would you recommend the patient, their family, or employer do to reduce the risk of spreading COVID-19?

____________________________________________________________________________________

____________________________________________________________________________________
Patient 3

Samantha is a 19 year old college student who has been living at home since their college campus closed in March 2020. Samantha has been working at a grocery store for the summer where all employees and customers are required to wear a mask at all times. Samantha is interested in visiting their grandparents before returning to school in the fall, and wants to make sure it is safe to see them. Samantha has no symptoms and is vaccinated.

OUR PREDICTION:

COVID-19 Test Results

CoV_N1__________________           CoV_N2 ____________________            RP_______________________

Is this patient currently infected with COVID-19?

Based on the COVID-19 Test Results and patient information, explain your diagnosis. Is the patient positive or negative for the virus? Do their symptoms match your diagnosis? Are your results inconclusive and require more testing?

________________________________________________________________________

Antibody Test Results

IgM _________________  IgG _____________________

Has this patient been infected with COVID-19 in the past?

Based on the antibody test results and patient information explain if this patient has had COVID-19 in the past?

________________________________________________________________________

________________________________________________________________________

Recommendations

Based on what you know about COVID-19 and the patient’s results, what would you recommend the patient, their family, or employer do to reduce the risk of spreading COVID-19?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Patient 4

Terry is a 10 year old who has diabetes. Because of his diabetes, Terry is at a higher risk of developing serious complications from COVID-19. He is also unvaccinated because he is not eligible due to his age. Terry's school has been closed due to the pandemic for several months. Terry's mother works an essential job while Terry's father is responsible for remote schooling and takes care of him and his two siblings. Two week ago, one of his mom's co-workers tested positive for COVID-19. Since then, his mom had been staying with a different co-worker instead of being home with her family because she is afraid she might be infected and wants to keep Terry safe since he is high-risk. In the last week, Terry has been extra tired and easily becomes winded when playing outside. Terry's father is worried that Terry may be positive for COVID-19.

OUR PREDICTION:

COVID-19 Test Results

CoV_N1__________________           CoV_N2 ____________________          RP_______________________

Is this patient currently infected with COVID-19?
Based on the COVID-19 Test Results and patient information, explain your diagnosis. Is the patient positive or negative for the virus? Do their symptoms match your diagnosis? Are your results inconclusive and require more testing?

Antibody Test Results

IgM _________________  IgG _____________________

Has this patient been infected with COVID-19 in the past?
Based on the antibody test results and patient information explain if this patient has had COVID-19 in the past?

Recommendations

Based on what you know about COVID-19 and the patient's results, what would you recommend the patient or their family do to reduce the risk of spreading COVID-19?
**Patient 5**

Isabelle is a 32 year old high school science teacher. She had been teaching from home for the last three months of the 2019-2020 school year. Isabelle's partner has also been working from home. Isabelle does not remember being sick this year, but did some international travel in late January. Now it is summer. Isabelle's school district just announced their decision to reopen in-person instruction in Fall 2020 and are requiring all teachers to get vaccinated and get an antibody test before returning to school. She has scheduled to get her vaccine at the same time as her antibody test.

**OUR PREDICTION:**

**COVID-19 Test Results**

CoV_N1__________________           CoV_N2 ____________________            RP_______________________

*Is this patient currently infected with COVID-19?*

Based on the COVID-19 Test Results and patient information, explain your diagnosis. Is the patient positive or negative for the virus? Do their symptoms match your diagnosis? Are your results inconclusive and require more testing?

________________________________________________________________________________________________________________________________________________________________________

**Antibody Test Results**

IgM _________________  IgG _____________________

*Has this patient been infected with COVID-19 in the past?*

Based on the antibody test results and patient information explain if this patient has had COVID-19 in the past?

________________________________________________________________________________________________________________________________________________________________________

**Recommendations**

Based on what you know about COVID-19 and the patient's results, what would you recommend the patient, their family, or employer do to reduce the risk of spreading COVID-19?

________________________________________________________________________________________________________________________________________________________________________
Patient 6

Edward is a 56 year old business owner. He and his wife run a restaurant that has been doing take-out orders throughout the pandemic. Edward and his wife have been extremely cautious, wearing masks, regularly sanitizing any surface that customers have contact with, and consistently washing their hands. He and his wife are both fully vaccinated. Yesterday, Edward developed a cough. He also says that he has been experiencing fatigue and an itchy throat. Edward normally has seasonal allergies, but out of an abundance of caution for his family and customers he has decided to get tested for COVID-19.

**OUR PREDICTION:**

**COVID-19 Test Results**

<table>
<thead>
<tr>
<th>CoV_N1</th>
<th>CoV_N2</th>
<th>RP</th>
</tr>
</thead>
</table>

*Is this patient currently infected with COVID-19?*

Based on the COVID-19 Test Results and patient information, explain your diagnosis. Is the patient positive or negative for the virus? Do their symptoms match your diagnosis? Are your results inconclusive and require more testing?

**Antibody Test Results**

<table>
<thead>
<tr>
<th>IgM</th>
<th>IgG</th>
</tr>
</thead>
</table>

*Has this patient been infected with COVID-19 in the past?*

Based on the antibody test results and patient information explain if this patient has had COVID-19 in the past?

**Recommendations**

Based on what you know about COVID-19 and the patient's results, what would you recommend the patient, their family, or employer do to reduce the risk of spreading COVID-19?
Patient 7

Alan is a 19 year old part-time delivery driver who is not vaccinated. Throughout the pandemic Alan has been delivering packages. His company provides some personal protective equipment, but Alan has also been buying his own hand sanitizer and cleaning products to sanitize his vehicle. Alan admits that during especially hot days he does not wear a mask. Five days ago, Alan called his manager to let her know that he had developed mild symptoms including a cough and sore throat. He has not been to work since. Yesterday, Alan had a low-grade fever of 38.4°C (101.2°F). Alan’s company will only give paid-sick leave to part-time employees that can prove they have COVID-19 with a positive molecular test. Alan can not afford to take any unpaid time off and does not want to spread the disease if he has COVID-19, so he has come in for testing.

OUR PREDICTION:

COVID-19 Test Results

CoV_N1__________________           CoV_N2 ____________________            RP_______________________

Is this patient currently infected with COVID-19?

Based on the COVID-19 Test Results and patient information, explain your diagnosis. Is the patient positive or negative for the virus? Do their symptoms match your diagnosis? Are your results inconclusive and require more testing?

Antibody Test Results

IgM _________________  IgG _____________________

Has this patient been infected with COVID-19 in the past?

Based on the antibody test results and patient information explain if this patient has had COVID-19 in the past?

Recommendations

Based on what you know about COVID-19 and the patient’s results, what would you recommend the patient, their family, or employer do to reduce the risk of spreading COVID-19?
**Patient 8**

Tran is a 6 year old whose parents both work at a hospital. Because of his age, he is not eligible for the vaccine. He goes to a day care five days a week that is open to families of essential workers. The day care recently contacted all the parents to inform them that a parent of one of the children recently tested positive for COVID-19. Like many kids, Tran had a cold in early February but tested negative for the seasonal flu. He currently has no symptoms. Tran’s parents are interested in finding out if Tran currently has COVID-19 or has had COVID-19 in the past.

**OUR PREDICTION:**

**COVID-19 Test Results**

<table>
<thead>
<tr>
<th>CoV_N1</th>
<th>CoV_N2</th>
<th>RP</th>
</tr>
</thead>
</table>

*Is this patient currently infected with COVID-19?*

Based on the COVID-19 Test Results and patient information, explain your diagnosis. Is the patient positive or negative for the virus? Do their symptoms match your diagnosis? Are your results inconclusive and require more testing?

**Antibody Test Results**

<table>
<thead>
<tr>
<th>IgM</th>
<th>IgG</th>
</tr>
</thead>
</table>

*Has this patient been infected with COVID-19 in the past?*

Based on the antibody test results and patient information explain if this patient has had COVID-19 in the past?

**Recommendations**

Based on what you know about COVID-19 and the patient’s results, what would you recommend the patient, their family, and childcare provider do to reduce the risk of spreading COVID-19?
LESSON 2

Molecular Testing

Electrophoresis Lab

Overview: In this wet lab, students will examine patient samples to determine if their patient is positive, negative, or inconclusive for COVID-19 infection. To make this determination, students will perform gel electrophoresis on patient samples processed using the RT-PCR method for detecting the SARS-CoV-2 virus. Each team of students will run three samples from one patient in a gel (plus the 1kb DNA ladder). Afterwards, they will analyze their gels, measure their bands, and determine if their patient is positive, negative, or inconclusive for COVID-19 infection. Samples in this lab activity represent patient samples collected via nasal swab and processed via RT-PCR (reverse transcription polymerase chain reaction) to detect for SARS-CoV-2 RNA. Please see note about lab requirements.

Unit Progression

<table>
<thead>
<tr>
<th>#</th>
<th>LESSON TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>COVID-19 Diagnostic Testing Introduction</td>
</tr>
<tr>
<td>2</td>
<td>Molecular Testing</td>
</tr>
<tr>
<td>3</td>
<td>Antibody Testing</td>
</tr>
<tr>
<td>4</td>
<td>Bioethics and COVID-19</td>
</tr>
<tr>
<td>5</td>
<td>Health Inequities and COVID-19</td>
</tr>
<tr>
<td>6</td>
<td>Nextstrain Overview</td>
</tr>
<tr>
<td>7</td>
<td>Policies and the Nature of Science (Coming Soon!)</td>
</tr>
</tbody>
</table>

Remote Learning Adaptations

This wet lab requires students to be in-person to conduct the investigation, however adaptations have been included for remote learning contexts here.
**Student Understandings**

**WHAT STUDENTS FIGURE OUT**
- Viral tests tell you if you have a current viral infection by testing for the presence of the virus.
- Antibody tests tell you if you had a previous viral infection by testing for the antibodies produced by your immune system in response to the virus.
- No test is ever perfect. All tests occasionally result in false positive or false negative results.
- The viral load, the amount of virus present in an infected person, changes throughout the course of infection.
- The immune system begins antibody production a few days after infection.
- Gel electrophoresis is a laboratory technique that separates charged molecules (such as DNA, RNA, and proteins) according to their size.

**WHAT STUDENTS WILL DO**
- Use gel electrophoresis to analyze patient samples that were processed using RT-PCR.
- Practice making claims using evidence and reasoning to predict whether their patient has or has had COVID-19.
- Use argumentation to discuss their data and interpret group results.

**PREVIOUS KNOWLEDGE**
- Students should understand the basic concept of electrophoresis and have experience micropipetting.
- The SEP Electrophoresis Exploration and Intro to Micropipetting lessons can be used to help build these skills and understandings.

**Next Generation Science Standards**

This lesson builds toward the following Performance Expectation(s) from the NRC Framework and Next Generation Science Standards.

**PERFORMANCE EXPECTATIONS**

**HS-ETS1-3**: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

**STUDENT ASSESSMENT OPPORTUNITIES**
- Review the students’ answers from the pre-lab, the COVID-19 test results, and students’ explanation of diagnosis.
- Student Handout 2.1 and 2.2 can be collected for credit.
Lab Requirements

This lab requires that students have access to a gel box and power supply or the MiniOne Gel System. The lab protocol has been written for use with the MiniOne Gel System.

Note for SEP Teachers: If you ordered supplies from the Science Education Partnership’s Kit Loan Program, the freezer box will contain four tubes (three different markers and a tube of 1kb DNA ladder). These DNA markers will represent positive results for the three PCR primers issued by the CDC for COVID-19 testing.

Teacher Preparation

• Print copies of the materials listed in the Print & Digital Materials table or upload them to your classroom learning management system.
• Gather the reagents and gel electrophoresis supplies. Refer to the Inventory & Supplies Table.
• Prepare the COVID-19 samples and set up the student lab stations, using the directions provided in the Prepare COVID-19 Samples section that follows.

PRINT & DIGITAL MATERIALS

<table>
<thead>
<tr>
<th>Materials</th>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Handout 1.4: Patient Information</td>
<td>Includes descriptions of the patients that students will be testing and a place to record their results (from Lesson 1)</td>
<td>Each group should already have one from Lesson 1</td>
</tr>
<tr>
<td>Lesson 2 Slide Deck: COVID-19 Molecular Testing (Teacher)</td>
<td>Slide deck for teacher to use when enacting the lesson in-person or for student use for self-directed remote learning</td>
<td>N/A</td>
</tr>
<tr>
<td>Student Handout 2.1: Pre-Lab and Results</td>
<td>Pre-Lab Review Questions, Predictions, and Results for students</td>
<td>1 per student</td>
</tr>
<tr>
<td>Student Handout 2.2: Student Protocol</td>
<td>Gel electrophoresis protocol for the MiniOne Gel System</td>
<td>1 per student</td>
</tr>
<tr>
<td>Slide Deck: Molecular Test Results (Virtual Learning)</td>
<td>Slide deck with COVID-19 molecular test results for the 8 patient case studies to be used to adapt the activity for virtual learning</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Lesson 2: COVID-19 Molecular Testing Slide Deck

Download Slide Deck
Instructional Procedure

OVERVIEW

<table>
<thead>
<tr>
<th>Day</th>
<th>Activity</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Prepare COVID-19 Samples</td>
<td>(30 min)</td>
</tr>
<tr>
<td>1</td>
<td>Activity 2.1: Review</td>
<td>10 min</td>
</tr>
<tr>
<td>1</td>
<td>Activity 2.2: Gel Electrophoresis</td>
<td>Part 1</td>
</tr>
<tr>
<td>1</td>
<td>Activity 2.2: Gel Electrophoresis</td>
<td>Part 2</td>
</tr>
<tr>
<td>2</td>
<td>Activity 2.2: Gel Electrophoresis</td>
<td>Part 3</td>
</tr>
<tr>
<td>2</td>
<td>Activity 2.3: Results</td>
<td>15 min</td>
</tr>
</tbody>
</table>

INVENTORY & SUPPLIES

Freezer Reagents
- Marker pPSU1
- Marker pPSU2
- Marker pUC19
- SYBRsafe DNA dye
- 1 KB ladder

Gel Electrophoresis Supplies
- Loading dye
- 1% agarose gel with SYBRsafe
- LMW DNA ladder
- 1x TAE buffer
- Permanent marker
- Gloves
- P20 micropipette and tips
- Microcentrifuge (shared)
- Electrophoresis gel box
- Power supply or adapter
- UV/Blue LED transilluminator
- 0.5X TAE buffer (for MiniOne Gel Systems)

PREPARE COVID-19 SAMPLES (30 MINUTES)

1. **For this lesson, organize students into lab groups.** These directions assume that the SEP COVID lab kit is being used (available to teachers trained through the Science Education Partnership program). The SEP COVID lab kit provides enough supplies for eight groups per class.

2. **Give students copies of Student Handout 2.2: Student Protocol.** This can be given before class, to allow students to read through it and/or make flow charts.

3. **Organize Markers into Sample Tubes.** The SEP COVID lab kit will include three different markers with three different markers. Each marker will represent a positive result for one of three RT-PCR reactions that tests for either a part of the SARS-CoV-2 viral RNA or an mRNA found in all humans used as a control for successful nucleic acid extraction from tissue.

**TABLE 1: Sample Tubes For 8 groups (3 positive patients; 5 negative patients)**

<table>
<thead>
<tr>
<th>Name</th>
<th>Symbol</th>
<th>Details</th>
<th>Marker</th>
<th>Length</th>
<th># of Aliquots (4 µl each tube)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marker COV-N1</td>
<td>A</td>
<td>Tests for one part of the COVID-19 RNA sequence called N1</td>
<td>Marker pPSU2/Ndel</td>
<td>775 bp</td>
<td>3 (12 µl each)</td>
</tr>
<tr>
<td>Marker COV-N2</td>
<td>B</td>
<td>Tests for another part of the COVID-19 RNA sequences called N2</td>
<td>Marker pLemon/ NdeI</td>
<td>360 bp</td>
<td>3 (12 µl each)</td>
</tr>
<tr>
<td>RP</td>
<td>RP</td>
<td>Tests for human samples</td>
<td>Marker pUC19/NdeI</td>
<td>270 bp</td>
<td>8 (12 µl each)</td>
</tr>
<tr>
<td>Negative</td>
<td>–</td>
<td>For any negative test use sterile water</td>
<td>–</td>
<td>–</td>
<td>10 (12 µl each)</td>
</tr>
</tbody>
</table>
4. **Aliquot Markers into Sample Tubes**

Using a permanent marker, label microtubes according to Table 3: *Sample Microtube Labels and Contents*. Label one tube “1A” and another tube “1B” and so on. Then, add 12 µl of either the markers or sterile water depending on the reaction and result.

**Making a COVID-19 positive patient (Patients #1, 4, 7):**
1. Add 12 µl of **Marker A** to tube “#A”.
2. Then, add 12 µl of **Marker B** to tube “#B”.
3. Then, 12 µl of **Marker RP** to tube “#RP”.

---

**Making a COVID-19 negative patient (Patients #2, 3, 5, 6, 8):**
1. Add 124 µl **sterile water** to tube “#A” and “#B”.
2. Then, add 12 µl of **Marker RP** to tube “#RP”.

You will receive materials for 3 COVID-19 positive patients out of 8 total patients. In Table 2: *Patient COVID-19 Status Overall*, Patients 1, 4, and 7 are positive. Table 3: *Sample Microtube Labels and Contents* illustrates the corresponding reagents to set up the microtubes for all patients.

**TABLE 2: Patient COVID-19 Status Overall**

<table>
<thead>
<tr>
<th>Patient</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Result</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

**TABLE 3: Sample Microtube Labels and Contents**

<table>
<thead>
<tr>
<th>Label</th>
<th>1A</th>
<th>1B</th>
<th>1RP</th>
<th>2A</th>
<th>2B</th>
<th>2RP</th>
<th>3A</th>
<th>3B</th>
<th>3RP</th>
<th>4A</th>
<th>4B</th>
<th>4RP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marker</td>
<td>A</td>
<td>B</td>
<td>RP</td>
<td>H₂O</td>
<td>H₂O</td>
<td>RP</td>
<td>H₂O</td>
<td>H₂O</td>
<td>RP</td>
<td>A</td>
<td>B</td>
<td>RP</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Label</th>
<th>5A</th>
<th>5B</th>
<th>5RP</th>
<th>6A</th>
<th>6B</th>
<th>6RP</th>
<th>7A</th>
<th>7B</th>
<th>7RP</th>
<th>8A</th>
<th>8B</th>
<th>8RP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marker</td>
<td>H₂O</td>
<td>H₂O</td>
<td>RP</td>
<td>H₂O</td>
<td>H₂O</td>
<td>RP</td>
<td>A</td>
<td>B</td>
<td>RP</td>
<td>H₂O</td>
<td>H₂O</td>
<td>RP</td>
</tr>
</tbody>
</table>

An empty COVID-19 Sample Chart is available in the Appendix, if you would like to change the results for different classes.

5. **Aliquot Reagents**

Each group will need STE and sample loading dye. Table 4 describes the reagents needed for one class with 8 lab groups.

a. Label the colored tubes as shown in Table 3
b. Measure and aliquot the reagents as indicated.

c. Store at 4°C if prepped in advance.

**TABLE 4: Reagents Needed Per Class**

<table>
<thead>
<tr>
<th>Tubes, Quantity</th>
<th>Label</th>
<th>Reagent</th>
<th>Contents (each tube)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue tubes, 8</td>
<td>LD</td>
<td>Sample loading dye</td>
<td>12 µl</td>
</tr>
<tr>
<td>Orange tubes, 8</td>
<td>Ladder</td>
<td>1 KB ladder</td>
<td>9 µl</td>
</tr>
</tbody>
</table>

The contents of each tube is calculated with extra to account for pipetting error.
6. Solutions Recipe Guide
Dilute 50X TAE to a 1X TAE solution.

**TABLE 5: Solutions Recipe Guide**

<table>
<thead>
<tr>
<th>Diluted Solution</th>
<th>Amount Needed Per Class</th>
<th>Recipe</th>
</tr>
</thead>
</table>
| 1X TAE solution        | 2000 ml (200 ml for MiniOne) | • Measure 40 ml of 50X TAE into a 2L container.  
• Add 1960 ml of distilled water by filling up to the 2L mark. |
| 0.5X TAE               | 1200 ml                 | • Measure 12 ml of 50X TAE into a 2L container.  
• Add 1188 ml of distilled water by filling up to the 2L mark. |

***Only for MiniOne Protocol***

You will need 1X and 0.5X TAE solution if using the MiniOne Gel Systems.

7. Set up Shared Equipment/Reagent areas and Student Stations.

**Inventory for Each Student Station**
(Set up 8 stations total)
- Sample tubes
- Yellow tube (STE)
- Blue tube (LD)
- Orange tube (Ladder)
- P20 micropipette
- P20 tips
- Waste container

**Shared Reagents and Equipment**
- Minicentrifuges
- 1X TAE
- SYBRsafe DNA stain
- Agarose powder
- Hot gloves
- Scale/Balance (*Not provided in SEP kit)
- Glass bottles (100-50 ml) (*Not provided in SEP kit)
- Microwave (*Not provided in SEP kit)

Lesson Guide
Use the Lesson 2 Slide Deck: COVID-19 Molecular Testing (Teacher).

**ACTIVITY 2.1: REVIEW (10 MINUTES)**

1. (Slide #4) Remind students that during the last lesson they learned about COVID-19 testing. The following questions can be used to review either as a class or as a Turn & Talk partner discussion:

**Discussion Questions:**

a. What are the two types of diagnostic tests? *Antigen test and molecular (nucleic acid) tests.*

b. What do diagnostic tests tell us? *If a person currently has a COVID-19 infection.*

c. What does a molecular test detect? *Specific sequences of the viral RNA.*

d. What process is used during a molecular test? *RT-PCR.*
2. (Slide #5-7) Review the three RT-PCR primer sets provided by the CDC. Students can use their notes to review what each primer set detects.

3. (Slide #8) Review RT-PCR (reverse transcription polymerase chain reaction) as a method for copying RNA into DNA and making billions of copies of that DNA sequence.

4. Have students get into their lab groups. (The SEP COVID lab kit provides enough supplies for 8 groups per class).

5. (Slide #9) Group Work: Have students review the information about the patient that they were assigned in Lesson 1. Tell them that today we are going to analyze the patient samples using gel electrophoresis.

6. In their lab groups, have students work through the pre-lab questions on Student Handout 2.1: Pre-Lab and Results.

7. Pass out the patient samples to each group. Each group should get three tubes: a CoV_N1, CoV_N2, and RP with their patient number on it.

8. (Slide #11) Class Review:
   a. Swab samples are taken from the patient's nose.
   b. The genetic material RNA is extracted from the sample.
   c. RNA is turned into DNA in a process called reverse transcription.
   d. Specific sequences are amplified to make billions of copies in a process called PCR.

9. (Slides #12-14) Reiterate that the samples the students are using have already been processed using RT-PCR. They will be separating and measuring the bands to determine if their patient is currently infected with the SARS-CoV-2 virus.

10. (Slide #15) Turn & Talk:

**Discussion Question:**
What happens if there is no virus in the sample?
*Students should be able to answer that CoV_N1 and N2 will not amplify because there is no target DNA that is complementary to the PCR primers.*
ACTIVITY 2.2: GEL ELECTROPHORESIS LAB (75 MINUTES)

11. Pass out Student Handout 2.2: Student Protocol. This can be given before class to allow students to read through it and/or make flow charts.

12. Tell students to start by checking they have all the materials listed in the inventory or know where the shared materials are in the classroom.

13. Have students work through the protocol. They will make their gels first. Then, they will prep their samples by adding a loading buffer and STE.

14. There is an optional stopping point for Day 1 after students have prepped their samples. Part 3 of the Gel Electrophoresis protocol starts on Day 2.

ACTIVITY 2.3: RESULTS (15 MINUTES)

15. Have students record their gel data in the Results section of their Student Handout 2.1: Pre-Lab and Results or in their notebooks.

16. Have students answer the following questions from their Patient Information sheets (from Lesson 1). Students can record their answers in their notebooks or another sheet of paper to turn in later.

17. Share out and discuss each group’s results. The Data Analysis figure can be used to check students’ results from the lab. If a group’s results are different from the positive sample and negative sample shown in the figure, then the results are considered inconclusive.

FIGURE 1: COVID-19 Test Results from Student Handout 2.1

<table>
<thead>
<tr>
<th>COVID-19 TEST RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoV N1</td>
</tr>
</tbody>
</table>

Is this patient currently infected with COVID-19?

Based on the COVID-19 Test Results and patient information, explain your diagnosis. Is the patient positive or negative for the virus? Do their symptoms match your diagnosis? Are your results inconclusive, and require more testing? Make sure to reference the band’s size and/or specific references from the reading and your notes.

FIGURE 2: Data Analysis of Lab Results

<table>
<thead>
<tr>
<th>COVID-19 Positive Sample</th>
<th>COVID-19 Negative Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ladder</td>
<td>Ladder</td>
</tr>
<tr>
<td>CoV N1</td>
<td>CoV N1</td>
</tr>
<tr>
<td>CoV N2</td>
<td>CoV N2</td>
</tr>
<tr>
<td>RP</td>
<td>RP</td>
</tr>
</tbody>
</table>

All other results are considered inconclusive.
ADAPTATIONS FOR REMOTE INSTRUCTION

As an alternative to the in-person instructional procedure on the previous pages, the table below provides suggested instructional procedures adapted for remote learning settings. This lesson assumes students have computer and internet access at home.

<table>
<thead>
<tr>
<th>Learning Activity</th>
<th>Remote Instruction Procedure</th>
</tr>
</thead>
</table>
| Activity 2.1: Review (15 min) | 0. **Before the class:** Upload all handouts and the slide decks to your classroom learning management system. If you did not already assign students to patients in Lesson 1, do so now. There are eight patients total.  
1. Present the *Lesson 2 Slide Deck: COVID-19 Molecular Testing (Teacher)* during a synchronous video call. If that is not possible, students can review the slide deck on their own, taking notes in their lab notebook.  
2. Students should complete the pre-lab questions on *Student Handout 2.1: Pre-Lab and Results*.  
3. Ask students to fill in the blanks for the four statements on Slide #11. If students are accessing the slide deck on their own, they can be asked to complete the sentences in their lab notebooks or submit the answers to the teacher.  
   a. Swab samples are taken from the patient’s *nose*.  
   b. The genetic material *RNA* is extracted from the sample.  
   c. RNA is turned into DNA in a process called *reverse transcription*.  
   d. Specific sequences are amplified to make billions of copies in a process called *PCR*. |
| Activity 2.2: Gel Electrophoresis Lab (Time varies) | 4. **This activity is intended as an in-person, hands-on wet lab.** It has not been adapted for remote instruction. However, students can skip ahead to Activity 2.3 to engage in the data analysis and interpretation portions of the lab.  
5. **Students may be asked to review** *Student Handout 2.2: Student Protocol* even though they will not be conducting the wet lab to help them understand the process before moving on to analyzing the data. |
| Activity 2.3: Results (15 min) | 6. **Use Slide Deck: Molecular Test Results (Virtual Learning)** to allow students to engage in the data analysis and interpretation portions of the lab without having conducted the wet lab. The slide deck includes photos of the COVID-19 molecular test results for the eight patients.  
7. Have students record gel data for their patient in the Results section of *Student Handout 2.1: Pre-Lab and Results* and answer the questions on the handout.  
8. Ask students to submit their work for credit. |
Suggested Lesson Extensions

EXTENSIONS
The SEP Electrophoresis Exploration and Intro to Micropipetting lessons can be used to help build students’ lab techniques and understanding of the equipment needed for gel electrophoresis and its chemical properties.

OPPORTUNITIES FOR PRODUCTIVE UNCERTAINTY
Each patient profile provided in this lesson has a different potential exposure. Students will make predictions based on the patient information provided, but there is no certainty or guarantee that any of these exposure risks or symptoms are a 100% sign of infection. The molecular test will determine the status of the patient, but also no test is 100% accurate. Students will have to use their understanding of viral infection and their interpretation of the test results to determine the best course of action for their patient.

OPPORTUNITIES FOR PERSONAL CONNECTIONS TO STUDENTS
- The COVID-19 pandemic has affected everyone’s lives. This lesson allows students to better understand how the virus is detected and how to make informed decisions based on test results.
- The patients provided in this lesson have a wide range of ages, professions, reasons for getting tested, and exposure risks. This was done so that students could make connections between these fictional patients and the diverse real-world experiences of people affected by COVID-19.
**SCIENTIFIC VOCABULARY**

Students may need some support in understanding the terminology embedded within this lesson. This may be particularly true for emerging bilingual students and students with lower reading levels. Terms should be defined contextually as the lesson unfolds. The following list captures some of the terms used in the lesson materials.

- **Coronavirus (CoV):** A large family of viruses that cause illness ranging from the common cold to more severe diseases such as Severe Acute Respiratory Syndrome (SARS-CoV).
- **COVID-19:** The respiratory disease caused by the SARS-CoV-2 virus.
- **Diagnostic Test:** A test used to confirm or rule out conditions and diseases.
- **Exposure Event:** An event (time/moment) in which a person was exposed to a pathogen, or was potentially exposed.
- **Gel Electrophoresis:** A laboratory technique that separates charged molecules (such as DNA, RNA, and proteins) according to their size.
- **Molecular Test:** A test that detects the genomic material of a virus.
- **RT-PCR:** Reverse transcription polymerase chain reaction, a technology used to make billions of copies of a target sequence of RNA for detection.
  - **Primers:** Short fragments of DNA that recognize specific nucleic acid sequences.
  - **Probes:** Fluorescent tags used in PCR to show real-time amplification of the DNA.
  - **Reverse transcriptase:** The enzyme that builds a complementary DNA strand from RNA.
- **SARS-CoV-2:** The virus that causes COVID-19.
- **Virus:** An infectious agent that infects cells, replicates, and may cause disease.

**CAREER CONNECTIONS**

Career connections are not explicitly called out in the activities in this unit, however there are many careers related to COVID testing that teachers may wish to highlight. The career connection for Lesson 2 includes:

**Medical/Clinical Laboratory Technician:** A lab technician supports the daily operations of a medical lab that processes patient samples--such as blood, urine, saliva, and nasal swabs--to assist with the diagnosis of illnesses, diseases, or abnormalities. Technicians use microscopy or chemical analyses of patient samples, or may use other lab equipment (e.g., centrifuge, incubator, etc.). Responsibilities include preparing stock solutions or reagents, and managing the cleaning, maintenance, calibration, and documentation of glassware and equipment (e.g., incubator, hood, biosafety cabinet, etc.). Technicians also track inventories, order supplies, and maintain the cleanliness and safety of the lab environment. An associate’s degree or bachelor’s degree is required, depending on the job level and duties. Specialities include blood bank, hematology, microbiology, immunology, and clinical chemistry.

Additional careers are featured on the STEM Global - Pathways to Global Health Careers poster and accompanying fact sheets. Read more about each job by exploring these resources.
**PATIENT STORIES**

**Patient 1**
Kelly is a 25 year old nurse working in an assisted living facility. Five people at her work have tested positive for COVID-19. Because Kelly did not work directly with anyone that tested positive and because she is fully vaccinated, her employer is not requiring her to have a test. Kelly has no symptoms and feels perfectly healthy, but worries that she may be an asymptomatic carrier. Worried about the safety of her elderly patients and her family, Kelly has decided to get tested for COVID-19.

**Patient 2**
Jason is a 43 year old medical researcher who has been working from home for the past three months. His state has begun to reopen and his lab is asking staff to return to work at the office. Jason and his partner had flu-like symptoms in late February 2020, but neither got tested for either the flu or COVID-19. Since then, he got the vaccine but his partner chose not to. Jason is interested in getting tested to see if he currently has COVID-19 or has had a COVID-19 infection in the past.

**Patient 3**
Samantha is a 19 year old college student who has been living at home since their college campus closed in March 2020. Samantha has been working at a grocery store for the summer where all employees and customers are required to wear a mask at all times. Samantha is interested in visiting their grandparents before returning to school in the fall, and wants to make sure it is safe to see them. Samantha has no symptoms and is vaccinated.

**Patient 4**
Terry is a 10 year old who has diabetes. Because of his diabetes, Terry is at a higher risk of developing serious complications from COVID-19. He is also unvaccinated because he is not eligible due to his age. Terry’s school has been closed due to the pandemic for several months. Terry's mother works an essential job while Terry’s father is responsible for remote schooling and takes care of him and his two siblings. Two week ago, one of his mom’s co-workers tested positive for COVID-19. Since then, his mom had been staying with a different co-worker instead of being home with her family because she is afraid she might be infected and wants to keep Terry safe since he is high-risk. In the last week, Terry has been extra tired and easily becomes winded when playing outside. Terry’s father is worried that Terry may be positive for COVID-19.

**Patient 5**
Isabelle is a 32 year old high school science teacher. She had been teaching from home for the last three months of the 2019-2020 school year. Isabelle’s partner has also been working from home. Isabelle does not remember being sick this year, but did some international travel in late January. Now it is summer. Isabelle’s school district just announced their decision to reopen in-person instruction in Fall 2020 and are requiring all teachers to get vaccinated and get an antibody test before returning to school. She has scheduled to get her vaccine at the same time as her antibody test.

**Patient 6**
Edward is a 56 year old business owner. He and his wife run a restaurant that has been doing take-out orders throughout the pandemic. Edward and his wife have been extremely cautious, wearing masks, regularly sanitizing any surface that customers have contact with, and consistently washing their hands. He and his wife are both fully vaccinated. Yesterday, Edward developed a cough. He also says that he has been experiencing fatigue and an itchy throat. Edward normally has seasonal allergies, but out of an abundance of caution for his family and customers he has decided to get tested for COVID-19.

**Patient 7**
Alan is a 19 year old part-time delivery driver who is not vaccinated. Throughout the pandemic Alan has been delivering packages. His company provides some personal protective equipment, but Alan has also been buying his own hand sanitizer and cleaning products to sanitize his vehicle. Alan admits that during especially hot days he does not wear a mask. Five days ago, Alan called his manager to let her know that he had developed mild symptoms including a cough and sore throat. He has not been to work since. Yesterday, Alan had a low-grade fever of 38.4°C (101.2°F). Alan’s company will only give paid-sick leave to part-time employees that can prove they have COVID-19 with a positive molecular test. Alan can not afford to take any unpaid time off and does not want to spread the disease if he has COVID-19, so he has come in for testing.

**Patient 8**
Tran is a 6 year old whose parents both work at a hospital. Because of his age, he is not eligible for the vaccine. He goes to a day care five days a week that is open to families of essential workers. The day care recently contacted all the parents to inform them that a parent of one of the children recently tested positive for COVID-19. Like many kids, Tran had a cold in early February but tested negative for the seasonal flu. He currently has no symptoms. Tran’s parents are interested in finding out if Tran currently has COVID-19 or has had COVID-19 in the past.
**EMPTY COVID-19 SAMPLE CHART**

<table>
<thead>
<tr>
<th>Patient</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Result</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Label</th>
<th>1A</th>
<th>1B</th>
<th>1RP</th>
<th>2A</th>
<th>2B</th>
<th>2RP</th>
<th>3A</th>
<th>3B</th>
<th>3RP</th>
<th>4A</th>
<th>4B</th>
<th>4RP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marker</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Label</th>
<th>5A</th>
<th>5B</th>
<th>5RP</th>
<th>6A</th>
<th>6B</th>
<th>6RP</th>
<th>7A</th>
<th>7B</th>
<th>7RP</th>
<th>8A</th>
<th>8B</th>
<th>8RP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marker</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Add “A”, “B”, “RP”, or “H2O” for developing custom results.*
### CDC RESULT INTERPRETATION TABLE

The table below lists the expected results for the 2019-nCoV rRT-PCR Diagnostic Panel. If a laboratory obtains unexpected results for assay controls or if inconclusive or invalid results are obtained and cannot be resolved through the recommended re-testing, please contact CDC for consultation and possible specimen referral.

<table>
<thead>
<tr>
<th>2019 nCoV_N1</th>
<th>2019 nCoV_N2</th>
<th>RP</th>
<th>Result Interpretation</th>
<th>Report</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>+</td>
<td>±</td>
<td>2019-nCoV detected</td>
<td>Positive 2019-nCoV</td>
<td>Report results to CDC and sender.</td>
</tr>
<tr>
<td>If only one of the two targets is positive</td>
<td>±</td>
<td>Inconclusive Result</td>
<td>Inconclusive</td>
<td>Repeat testing of nucleic acid and/or re-extract and repeat rRT-PCR. If the repeated result remains inconclusive, contact your State Public Health Laboratory or CDC for instructions for transfer of the specimen or further guidance.</td>
<td></td>
</tr>
<tr>
<td>−</td>
<td>−</td>
<td>+</td>
<td>2019-nCoV not detected</td>
<td>Not Detected</td>
<td>Report results to sender. Consider testing for other respiratory viruses.</td>
</tr>
<tr>
<td>−</td>
<td>−</td>
<td>−</td>
<td>Invalid Result</td>
<td>Invalid</td>
<td>Repeat extraction and rRT-PCR. If the repeated result remains invalid, consider collecting a new specimen from the patient.</td>
</tr>
</tbody>
</table>

**a** Laboratories should report their diagnostic result as appropriate and in compliance with their specific reporting system.

**b** Optimum specimen types and timing for peak viral levels during infections caused by 2019-nCoV have not been determined. Collection of multiple specimens from the same patient may be necessary to detect the virus. The possibility of a false negative result should especially be considered if the patient’s recent exposures or clinical presentation suggest that 2019-nCoV infection is possible, and diagnostic tests for other causes of illness (e.g., other respiratory illness) are negative. If 2019-nCoV infection is still suspected, re-testing should be considered in consultation with public health authorities.

PRE-LAB
In this activity, we will be analyzing patients that have come into the clinic for COVID-19 molecular tests. Background about the patients are in your Patient Information sheet.

1. Record your group’s patient number and the patient’s first name. Then, take notes on any important facts.

<table>
<thead>
<tr>
<th>Patient #</th>
<th>Patient First Name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Symptoms:

- Potential exposure events:

- Risk factors:

- Prediction (Do you think your patient currently has COVID-19 and why?):

The samples we are using for this lab have been processed using a technology called reverse transcription polymerase chain reaction (RT-PCR). The process of reverse transcription is used to turn RNA into DNA. During PCR, primers find specific DNA sequences and an enzyme called Taq polymerase makes billions of copies of the target sequence. Each time a sample is processed using RT-PCR it is called an RT-PCR reaction. The COVID-19 molecular test is made up of three reactions. Each reaction uses a different primer set to find and amplify a specific sequence of RNA from the sample.
2. **Review your notes from Lesson One: Diagnostic Testing Intro.** Explain to your partner what each primer set will detect and what it tells us.

Once the RNA is turned into DNA, the **PCR primers** amplify (make billions of copies) of the target DNA sequence. Each primer set has a target sequence of different size. The size of the target sequences:

<table>
<thead>
<tr>
<th>PRIMER SET</th>
<th>TARGET SEQUENCE LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoV_N1</td>
<td>775 bp</td>
</tr>
<tr>
<td>CoV_N2</td>
<td>360 bp</td>
</tr>
<tr>
<td>RP</td>
<td>270 bp</td>
</tr>
</tbody>
</table>

We will be using gel electrophoresis to view the results of RT-PCR. Read through the instructions before starting.

If the reaction works and you can see the target DNA in your gel, the gel result is positive. If the reaction does not work and you can not see the target DNA in your gel, the gel result is negative.

3. **Circle whether you would expect positive or negative gel results** for each reaction primer set if the patient had COVID-19 or not.

<table>
<thead>
<tr>
<th>PATIENT STATUS</th>
<th>COV_N1</th>
<th>COV_N2</th>
<th>RP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Currently has COVID-19</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Does not have COVID-19</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

4. **Draw an example of what bands would look like in a gel if a patient had COVID-19 and if a patient did not have COVID-19.** Compare the DNA ladder to the reference image to estimate band sizes. *(Hint: A helpful place to start is by labelling the bright 3Kb (3,000 base pair) band on the ladder and comparing your sample bands to it.)*

<table>
<thead>
<tr>
<th>LADDER</th>
<th>PATIENT WITH COVID-19</th>
<th>PATIENT WITHOUT COVID-19</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNA Ladder</td>
<td>CoV_N1</td>
<td>CoV_N2</td>
</tr>
<tr>
<td>1000 bp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>800 bp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>600 bp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500 bp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>400 bp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300 bp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 bp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>150 bp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 bp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 bp</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RESULTS

1. Take a picture of your gel using your cell phone (or use the gel picture provided by your teacher).

2. Print your picture and estimate the size of your bands based on the DNA ladder. Or, use the table below to make a drawing of the gel by drawing the wells, the bands of the ladder, and the rest of the sample bands relative to the bands in the ladder.

<table>
<thead>
<tr>
<th>1KB DNA LADDER (NEB)</th>
<th>DNA SAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COV_N1</td>
</tr>
<tr>
<td></td>
<td>COV_N2</td>
</tr>
<tr>
<td></td>
<td>RP</td>
</tr>
</tbody>
</table>

3. Answer the following questions from the Patient Information sheet given in the previous lesson.

COVID-19 TEST RESULTS

CoV_N1_________________ CoV_N2_________________ RP_________________

Is this patient currently infected with COVID-19?

Based on the COVID-19 Test Results and patient information, explain your diagnosis. Is the patient positive or negative for the virus? Do their symptoms match your diagnosis? Are your results inconclusive, and require more testing? Make sure to reference the band’s sizes and/or specific references from the reading and your notes.
Student Protocol
Molecular Testing Electrophoresis Lab

Name: ____________________________ Date: ____________ Period: _____

Inventory for Each Student Station
- Sample tubes
- Yellow tube (STE)
- Blue tube (LD)
- Orange tube (Ladder)
- P20 micropipette
- P20 tips
- Waste container

Shared Reagents and Equipment
- Minicentrifuges
- 1X TAE
- SYBRsafe DNA stain
- Agarose powder
- Hot gloves
- Scale/Balance (*Not provided in SEP kit)
- Glass bottles (100-50 ml) (*Not provided in SEP kit)
- Microwave (*Not provided in SEP kit)

MiniOne Student Guide

PART 1: PREPARE AND SET UP 0.8% AGAROSE GEL WITH SYBRSAFE

These directions are for making two gels. Each group will need only one gel, so you should pair up with another group.

1. Weigh 0.26 g of agarose powder and pour it into a small glass bottle or microwaveable container.
2. Measure 30 ml 1X TAE using a graduated cylinder and add it to your agarose powder. Swirl to mix.
3. Place the lid loosely on the bottle and microwave for 30 seconds until boiling. Stop and swirl the bottle.
4. Microwave again for 20 seconds. Swirl and make sure all the agarose has melted. The solution should be entirely clear. If you still see particulates, microwave it again.
5. Using a P10 or P20 micropipette, add 3 µl SYBRsafe dye to the melted agarose solution. Swirl to mix.
6. Wait 5 mins for the agarose to cool before pouring.
7. While you wait, set up the gel casting system to make two 6-well gels for DNA.
   a. Make sure the clear gel trays are in both molds.
   b. Place the comb in the setting near the top of the gel tray. Make sure the large teeth are facing downwards.

8. Slowly pour half (~15 ml) of 0.8% agarose into each casting tray. There are two casting trays in one system.
9. Wait 15 min for the agarose to cool and solidify. Prepare your samples while you wait.
PART 2: PREPARE PATIENT SAMPLES

10. **Obtain your patient samples from your instructor.** Each tube contains 12 µl of DNA amplified from your patient.

11. **Record which sample numbers you have in your lab notebook.**

12. **Prepare your samples for gel electrophoresis by adding sample loading dye.** You do not need to add loading buffer to the DNA ladder.
   - a. Using a new tip add 2 µl LD (sample loading dye) to each sample.
   - b. Close the tube and gently flick the tube to mix the contents.

<table>
<thead>
<tr>
<th>REAGENT</th>
<th>AMOUNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNA sample</td>
<td>12 µl</td>
</tr>
<tr>
<td>LD (sample loading dye)</td>
<td>2 µl</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>14 µl</td>
</tr>
</tbody>
</table>

13. **Place the microtubes in a microcentrifuge.** Make sure the microcentrifuge is balanced. Spin for 3 seconds to pull all the liquid to the bottom of the microtubes.

**OPTIONAL STOPPING POINT**

*If your teacher tells you to stop at this point, follow these directions. If not, proceed to Part 3.*

Pour extra 1X TAE buffer over the gels. Then, cover the trays and store in a cool dark place (make sure that the gels do not freeze, or bubbles will appear in the gel) up to 2 days. Covering the trays in aluminum foil will prevent the SYBRsafe stain from degrading for longer storage. Samples can be stored in the refrigerator for up to 5 days.
PART 3: LOAD AND RUN THE DNA SAMPLES

14. Place the black gel plate into the buffer chamber. If it doesn’t fit, turn it around and match the ridges.

15. Check if your gels are solid by lightly brushing the top with a gloved finger. If it isn’t solid, wait longer until it is.

16. Remove the comb by gently pulling the comb upwards. If you remove the comb too quickly, you may break or collapse the wells.

17. Remove the gel tray and the gel from the casting system. Place it carefully into the gel box with the wells closest to the negative end.

18. Measure 140 ml of 0.5X TAE and pour it into one side of the tank until both sides of the tank are full. (Pouring the buffer into one side of the chamber helps to release any air bubbles trapped under the gel.) Add more buffer if the gel is not totally covered.

19. Using the table below, organize your samples before loading the gel by labeling the samples in the table with the label on the tube. (For example, if you have patient 1 you might put write “1A” below CoV_N1 because that is what is written on the tube.) You can refer to this table when you begin loading your samples.

<table>
<thead>
<tr>
<th>Well</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample</td>
<td>DNA Ladder</td>
<td>CoV_N1</td>
<td>CoV_N2</td>
<td>RP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

20. Place the gel box near the power source you will use. Once you have loaded your gel, you should not agitate or move the box.
   a. Load 8 µl of DNA ladder into the first well on the left.
   b. Load 12 µl of each sample according to your table.

21. Place the orange cover on the box.

22. Press power and record your start time. A small green power light should turn on if it is running. Wait 5 minutes.

23. After 5 minutes, turn on the high intensity blue light and check if your samples have moved.

24. Run your gel for 20 more minutes. Turn off the power once the lowest DNA band is at the 3 cm mark.

25. Turn off the power and take a picture of your results.

26. Measure your bands using the ladder image. Record your results in your notebook or on Student Handout 2.1: Pre-Lab & Results.
LEsson 3
Antibody Testing

*ELISA Lab*

**Overview:** In this lesson, students learn about how to test for past infections using an ELISA (enzyme-linked immunosorbent assay). During this activity, students learn about the body’s immune response to viral infection and how researchers use manufactured antibodies to detect viral antibodies produced by a patient’s immune system. Through a wet lab (or virtual) activity, students run an **indirect ELISA** to see if their patient has had a past SARS-CoV-2 infection. Students then compare what they know about the patients’ cases, their molecular test results, and their ELISA results to make a diagnosis and recommendation.

### Unit Progression

<table>
<thead>
<tr>
<th>#</th>
<th>Lesson Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>COVID-19 Diagnostic Testing Introduction</td>
</tr>
<tr>
<td>2</td>
<td>Molecular Testing</td>
</tr>
<tr>
<td>3</td>
<td><strong>Antibody Testing</strong></td>
</tr>
<tr>
<td>4</td>
<td>Bioethics and COVID-19</td>
</tr>
<tr>
<td>5</td>
<td>Health Inequities and COVID-19</td>
</tr>
<tr>
<td>6</td>
<td>Nextstrain Overview</td>
</tr>
<tr>
<td>7</td>
<td>Policies and the Nature of Science <em>(Coming Soon!)</em></td>
</tr>
</tbody>
</table>

**Remote Learning Adaptations**

Suggestions for adapting the activities for remote teaching and learning settings are included at the end of the lesson [here](#).
Student Understandings

WHAT STUDENTS FIGURE OUT

► Viral tests tell you if you have a current viral infection by testing for the presence of the virus.
► Antibody tests tell you if you had a previous viral infection by testing for the antibodies produced by your immune system in response to the virus.
► No test is ever perfect. All tests occasionally result in false positive or false negative results.
► The viral load, the amount of virus present in an infected person, changes throughout the course of infection.
► The immune system begins antibody production a few days after infection.

WHAT STUDENTS WILL DO

► Use an enzyme-linked immunosorbent assay (ELISA) to determine if the patient has IgG or IgM for SARS-CoV-2.
► Practice making claims using evidence and reasoning to predict whether their patient has or has had COVID-19.
► Use argumentation to discuss their data and interpret group results.

PREVIOUS KNOWLEDGE

► Students should understand that the body's immune system is made up of specialized cells that act and produce immune proteins to defend against disease-causing agents like bacteria and viruses.

Next Generation Science Standards

This lesson builds toward the following Performance Expectation(s) from the NRC Framework and Next Generation Science Standards.

PERFORMANCE EXPECTATIONS

HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

STUDENT ASSESSMENT OPPORTUNITIES

► Review students’ responses on Student Handout 3.1: Antibody Testing Pre-Lab and Results.
### Teacher Preparation

- Print copies of the materials listed in the Print & Digital Materials table or upload them to your classroom learning management system.
- Gather the supplies and prepare the reagents and aliquots. Refer to the Inventory & Supplies Table. Read the Background and Important Notes sections.
- Prepare the patient samples and set up the student lab stations, using the directions provided in the Teacher Lab Prep section below.

### PRINT & DIGITAL MATERIALS

<table>
<thead>
<tr>
<th>Materials</th>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Handout 1.4: Patient information</td>
<td>Includes descriptions of the patients that students will be testing and a place to record their results (from Lesson 1)</td>
<td>Each group should already have one from Lesson 1</td>
</tr>
<tr>
<td>Lesson 3 Slide Deck: COVID-19 Antibody Testing (Teacher)</td>
<td>Slide deck for teacher to use when enacting the lesson in-person or for student use for self-directed remote learning</td>
<td>N/A</td>
</tr>
<tr>
<td>Student Handout 3.1: Antibody Testing Pre-Lab and Results</td>
<td>Pre-Lab Review Questions, Predictions, and Results for students</td>
<td>1 per student</td>
</tr>
<tr>
<td>Student Handout 3.2: COVID-19 ELISA Lab Student Protocol</td>
<td>Student lab protocol for performing an ELISA</td>
<td>1 per student</td>
</tr>
<tr>
<td>Slide Deck: COVID-19 Antibody Test Results (Virtual Learning)</td>
<td>Optional slide deck with ELISA results to be used to adapt the activity for virtual learning</td>
<td>1 per student</td>
</tr>
<tr>
<td>Optional Extension: Specificity &amp; Sensitivity Slide Deck</td>
<td>Slide deck (from Lesson 1) for optional extension activity that explains how math and statistics are important in test development</td>
<td>N/A</td>
</tr>
</tbody>
</table>
In an indirect ELISA, there are four main parts: an antigen, a primary antibody (if present in the patient), a secondary antibody that is conjugated to a peroxidase enzyme, and a substrate that the peroxidase can act on.

In this lab, students will simulate running an ELISA on four patients (A, B, C, and D) presenting different symptoms, transmission events, or exposure conditions. We suggest having two patients that will test positive and two that will test negative.

Share with students the potential exposure conditions for each patient. Each condition allows for a discussion about transmission, viral load, and potential misconceptions. Create a patient sample table for your scenario. Assign your own letters to each patient. Before the lab, have students make a prediction individually or as a class.

Samples in this lab activity represent patient samples via blood draw.

This lab has a lot of reagents and aliquots. To reduce confusion, we have created a color system for your microtubes. Refer to the image below and the recipe guide for the color system. Clear tubes are used for the “patient samples”.

If you are using materials and reagents provided by the SEP Kit Loan Program, see the Recipe and Dilution Section at the end of this lesson plan for help with reagents, dilutions, and aliquots. If ordering a commercially available ELISA kit, follow the instructions provided by the company.

All reagents should be stored in the refrigerator (4° C). Do not freeze the antibodies. The primary antibody degrades when frozen.

TMB and Tween-20 are light sensitive. Store in a cool, dark place.

1xPBS+T (wash buffer) contains Tween-20 and is also slightly light sensitive.

Dilutions can be made ahead of time and stored in the fridge for up to 2 weeks. An increase in final incubation time and a reduction in signal (blue color) can be expected with longer storage.

NOTES TO TEACHER FOR PREPARING TO TEACH THIS LESSON:

Inventories & Supplies
The materials needed for the wet lab activity are available for SEP teachers through the SEP Kit Loan Program. The wet lab materials can also be purchased as a kit through BioRad or ordered as individual parts. If teaching 1-5 classes, we suggest ordering the BioRad ELISA Immuno Explorers Kit ($138/class). For more classes or multiple years, bulk ordering may be cheaper.

<table>
<thead>
<tr>
<th>Consumables</th>
<th>Refrigerator Reagents</th>
</tr>
</thead>
<tbody>
<tr>
<td>p200 or p100 micropipette with compatible tips (Small plastic transfer pipets can be used as a substitution)</td>
<td>Antibodies</td>
</tr>
<tr>
<td>Plastic Transfer Pipet</td>
<td>Chicken IgY</td>
</tr>
<tr>
<td>96 Well Plate</td>
<td>Rabbit Anti-IgY IgG</td>
</tr>
<tr>
<td>1.7 Ml Colored Microtubes</td>
<td>HRP-conjugated goat anti-rabbit IgG</td>
</tr>
<tr>
<td>Purple</td>
<td>TMB substrate</td>
</tr>
<tr>
<td>Green</td>
<td>Other Reagents</td>
</tr>
<tr>
<td>Pink</td>
<td>Tween 20</td>
</tr>
<tr>
<td>Yellow</td>
<td>1X PBS</td>
</tr>
<tr>
<td>Brown</td>
<td>Prep Supplies</td>
</tr>
<tr>
<td>Beaker</td>
<td>Graduated cylinder (for making wash buffer)</td>
</tr>
<tr>
<td>Paper Towels</td>
<td>P1000 &amp; P200 micropipettes with compatible tips</td>
</tr>
<tr>
<td>Gloves</td>
<td></td>
</tr>
</tbody>
</table>
Instructional Procedure

OVERVIEW

<table>
<thead>
<tr>
<th>Day</th>
<th>Activity</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Prepare reagents and aliquot them for each student station</td>
<td>(60 mins)</td>
</tr>
<tr>
<td>1</td>
<td>Activity 3.1: Antibody Review - Intro</td>
<td>20 mins</td>
</tr>
<tr>
<td>1</td>
<td>Activity 3.1: Antibody Review - Worksheet</td>
<td>25 mins</td>
</tr>
<tr>
<td>1</td>
<td>Activity 3.2: ELISA Lab - Antibody Testing Background</td>
<td>10 mins</td>
</tr>
<tr>
<td>2</td>
<td>Activity 3.2: ELISA Lab - Antibody Testing</td>
<td>30 mins</td>
</tr>
<tr>
<td>2</td>
<td>Activity 3.2: ELISA Lab - Antibody Testing Results</td>
<td>10 mins</td>
</tr>
</tbody>
</table>

PREPARE LAB REAGENTS (60 MINUTES)

1. **Label reagent microtubes** according to the Class Set of Aliquots Diagram.

   **FIGURE 1: Class Set of Aliquots Diagram**

   ![Class Set of Aliquots Diagram]

   16 aliquots of each per class

   - antigen (green)
   - positive control (pink)
   - negative control (purple)
   - $2^{nd}$ IgG antibody (yellow)
   - $2^{nd}$ IgM antibody (yellow)
   - TMB substrate (brown)

2. **For the IgG patient samples**, label **8 clear microtubes 1G through 8G** (i.e., 1G, 2G, etc.).
3. **For the IgM patient samples**, label **8 clear microtubes 1M through 8M** (i.e., 1M, 2M, etc.).
4. **Make all stock reagents and buffers using the Recipe and Dilution Guide at the end of this lesson plan.** Follow the guide to see how much of each reagent to aliquot into the labelled microtubes.
   a. Reagents can be made and aliquoted beforehand and stored in the refrigerator at around 4°C for up to 5 days. Do not allow any of the reagents to freeze, as it will destroy some of the antibodies.
   b. See **Patient Sample and Results Table** at the end of this lesson plan to see what reagent is needed for each patient sample.
5. **Set up student lab stations.** See the **Student Station Set-up** section at the end of this lesson plan.
Lesson Guide
Use the Lesson 3 Slide Deck: COVID-19 Antibody Testing (Teacher).

ACTIVITY 3.1: ANTIBODY REVIEW (45 MINUTES)

1. **(Slide #2)** Remind students that during the last lesson they did molecular testing on their patients to see if they currently have a SAR-CoV-2 infection. Review the following questions either as a class or in pairs:

   **Discussion Questions:**
   a. What are the two major types of COVID-19 tests? *Diagnostic Testing and Antibody Testing*
   b. What can each of these tests tell us about a patient? *Diagnostic tests tell us if a person is currently infected and the antibody tests tell us if a person has had a SARS-CoV-2 infection in the past.*

2. **(Slide #3)** Tell students that today we will be learning about antibody testing for COVID-19, which is different from diagnostic testing. Students will probably have heard about antibody testing in the news or known of somebody who has received an antibody test. Ask students what they may already know about antibody testing, if they have heard anything about it, or if they have any questions. Record answers on the board.

3. **(Slide #4)** Turn & Talk: Tell students to talk with a partner about what antibodies are. They should record their ideas on Student Handout 3.1: Antibody Testing Pre-Lab and Results.

4. **(Slide #5 & #6)** Watch: Tell students that they will be watching two videos on antibody testing. As they watch the videos, they should record important concepts or questions in the table for Question #2 on Student Handout 3.1.
   a. Roche video “How SARS-CoV-2 antibody tests work” (2:34 min), edited in EdPuzzle with built in notes and questions.
   b. (NEEDLE WARNING) New York Times video “How Does Coronavirus Antibody Testing Work?” (4:49 min) excerpt in EdPuzzle of the original video. This video is about the COVID-19 antibody testing being done at Stanford Hospitals. It shows ELISA being done with robots and introduces the concept of neutralizing antibodies.

**TURN & TALK:**
What are antibodies?

Write down what you know about antibodies in your Antibody Testing Pre-Lab & Results handout.
5. **(Slides #7-14)** Using the slide deck, present more information on IgG and IgM and their role in the immune response. As students learn new definitions, they can fill out the vocabulary section of **Student Handout 3.1**.

6. **(Slide #15)** Have students look at the “IgM and IgG Against SARS-CoV-2 Through Disease Progression Graph” on the handout and make predictions about whether or not their patients will test positive or negative for either immunoglobulin. Then, have them work through the Interpret the Graph section of **Student Handout 3.1**.

---

**ACTIVITY 3.2: ELISA LAB (50 MINUTES)**

7. **(Slides #16-22)** Walk students through the slides to demonstrate one type of antibody testing (indirect ELISA), that can be run to test for the two different types of antibodies (IgG and IgM) that are tested for COVID-19.
   a. **Optional** (Slide #23) Students can watch the protocol video, but note that the protocol demonstrated in the video has some different reagents than students will be using in the COVID ELISA lab.

8. Have students work through **Student Handout 3.2: COVID-19 ELISA Lab Student Protocol** for running an ELISA.

---

**STUDENT PROTOCOL OVERVIEW**

- This lab is set up for a class of 32 students working in groups of four.
- Each group will test one of the eight patient samples. Within the group the testing will be split between student pairs. Each student pair will run an IgG or IgM test for their patient.
- Each pair will run their samples (including controls) in triplicate.
  - 3 positive control wells
  - 3 negative control wells
  - 3 patient ___ wells
During each incubation period students should fill out the ELISA Lab section of Student Handout 3.1: Antibody Testing Pre-Lab and Results to tie what they are doing to what is happening in the wells.

a. **Optional:** (Slide #23) For virtual learning have students watch the protocol video and pause the video during each incubation period to fill out the Student Handout. Note that the protocol demonstrated in the video has some different reagents than students will be using in the COVID ELISA lab.

9. **(Slides #24-29)** Have students look at their test results and the “IgM and IgG Against SARS-CoV-2 Through Disease Progression Graph” and make sense of the results they obtained for their patient. Have them also refer back to their results from the molecular testing in Lesson 2 as well.

a. **Optional:** For virtual learning, have students look at the Slide Deck: COVID-19 Antibody Test Results (Virtual Learning) instead of their own results.

b. **Ask students:** Were their predictions correct? Were there any surprising results?

c. **Turn & Talk:** Have students turn and talk about the following questions:

**Discussion Questions:**

i. Is it possible to test negative but have had the diseases (be a true positive) with both tests? What happens if you test in that lag period?

ii. What are some other ways the test could have been incorrect?

10. **(Slide #30-31)** Explain to students what false positives and false negatives are and how they can be obtained. Emphasize that no test is perfect but usually tests are researched for how sensitive and specific they are to being able to detect disease.

a. **Optional:** Use the Optional Extension: Specificity & Sensitivity Slide Deck (from Lesson 1) to engage students in an extension activity that explains how math and statistics are important in test development.
ADAPTATIONS FOR REMOTE INSTRUCTION

Suggestions are summarized in the table below for synchronous and asynchronous teaching and learning settings. Teachers who can provide synchronous, live video conference meetings with students may sample from the original lesson plan or the synchronous remote instruction suggestions. This lesson assumes students have computer and internet access at home.

<table>
<thead>
<tr>
<th>Learning Activity</th>
<th>Adaptations for Synchronous Remote Instruction</th>
<th>Adaptations for Asynchronous Remote Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity 3.1: Antibody Review (45 min)</td>
<td>• Before the class: Upload all handouts and the slide decks to your classroom learning management system.</td>
<td>• Students can review the slide deck on their own, taking notes in their lab notebook or you can use a screen recording program to record yourself going over the slides. Students can work individually to watch the videos and complete the Student Handout to the best of their ability.</td>
</tr>
<tr>
<td></td>
<td>• Present the Lesson 3 Slide Deck: COVID-19 Antibody Testing (Teacher) during a synchronous video call. Students should work individually to watch the videos and complete the Student Handout to the best of their ability, and then compare answers during class.</td>
<td></td>
</tr>
<tr>
<td>Activity 3.2: ELISA Lab (Time varies)</td>
<td>• Students will not conduct the ELISA wet lab. Instead, they can skip ahead to analyzing and interpreting the results using Slide Deck: COVID-19 Antibody Test Results (Virtual Learning).</td>
<td>• Note: If you want students to experience an ELISA lab virtually, consider having students go through the interactive module on the HHMI BioInteractive - Immunology Virtual Lab website. Note that this interactive uses an ELISA to test for lupus, but the lab procedure is similar.</td>
</tr>
<tr>
<td></td>
<td>• Consider creating a digital bulletin board for students to use to respond to discussion questions, such as:</td>
<td>• For antibody testing results, student groups can work in breakout rooms during a class video meeting to interpret their results, or can work independently. Patient results can be shared during a class video meeting. Create a shared class table to compile all student results (molecular and antibody testing) and whether their predictions from Lesson 1 were correct. Have the students write their responses to the discussion questions on the Student Handout and turn it in.</td>
</tr>
<tr>
<td></td>
<td>− Is it possible to test negative but have had the diseases (be a true positive) with both tests? What happens if you test in that lag period?</td>
<td>• For the antibody testing results, have students groups work asynchronously in groups on the same Google Slide to interpret their results. Create a shared class table to compile all student results (molecular and antibody testing) and whether their predictions from Lesson 1 were correct. Have the students write their responses to the discussion questions on the Student Handout and turn it in.</td>
</tr>
<tr>
<td></td>
<td>− What are some other ways the test could have been incorrect?</td>
<td></td>
</tr>
</tbody>
</table>

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Suggested Lesson Extensions

EXTENSIONS
► Use the Optional Extension: Specificity & Sensitivity Slide Deck (from Lesson 1) to engage students in an extension activity that explains how math and statistics are important in test development.
► The General ELISA and HIV ELISA lessons from Fred Hutch SEP can be used to help build students’ lab techniques and understanding of the equipment needed for running an ELISA. In particular, the HIV ELISA lesson uses scenarios of patients concerned about HIV infection and connects well with this COVID-19 unit given the focus on the field of global health.
► Students who desire an extra challenge could research how ELISAs work and develop a presentation on the differences between direct, indirect, and sandwich assays. The HIV ELISA lesson from Fred Hutch SEP includes an antibody modeling activity and an ELISA slide deck that would be helpful for this purpose.

OPPORTUNITIES FOR PRODUCTIVE UNCERTAINTY
Each patient described in the scenarios has a different potential exposure. Students will make predictions based on the patient info provided, but there is no certainty or guarantee that any of these exposure risks or symptoms are a 100% sign of infection. The antibody test will tell us if the patient has had a COVID-19 infection in the past, but also no test is 100% accurate. Students will have to use their understanding of viral infection and their interpretation of the test results to determine the best course of action for their patient.

OPPORTUNITIES FOR PERSONAL CONNECTIONS TO STUDENTS
► COVID-19 pandemic has affected everyone’s lives. This lesson allows students to better understand how the virus is detected and how to make informed decisions based on test results.
► The patients provided have a wide range of ages, professions, reasons for getting tested, and exposure risks. This was done so that students could make connections between these fictional patients and the diverse real-world experiences of people affected by COVID-19.

CAREER CONNECTIONS
Career connections are not explicitly called out in the activities in this unit, however there are many careers related to COVID testing that teachers may wish to highlight. The career connection for Lesson 3 includes:

Phlebotomist: Also known as a phlebotomy technician. A person trained and certified to take blood samples from patients. A phlebotomist preps for the sample, maintains a clean work environment, labels vials/tubes/bags with patient information, enters information into databases, and draws blood specimens from the patient via a vein or finger stick. Phlebotomists may work in a medical or clinical lab, hospital, physician’s office, blood bank, or other healthcare setting. They may collaborate with physicians, nurses, and laboratory technicians. This job usually requires a high school diploma and completion of an accredited phlebotomy training from a community college or vocational/technical school.

Additional careers are featured on the STEM Global - Pathways to Global Health Careers poster and accompanying fact sheets. Read more about each job by exploring these resources.
Notes on Adaptations and Inclusivity

DIFFERENTIATION & ACCESSIBILITY SUGGESTIONS

► For schools that do not have access to the supplies and equipment needed for the ELISA wet lab, follow the directions in the Virtual Learning Options section. These directions can also be used for students who are absent during the lab day.

► This resource from the University of Washington’s DO-IT program includes suggestions for making science labs accessible to students with disabilities.

► If a student would benefit from reviewing the ELISA procedure before engaging in the wet lab, consider having them go through the interactive module on the HHMI BioInteractive - Immunology Virtual Lab website prior to the in-class lab day. Note that this interactive uses an ELISA to test for lupus, but the lab procedure is similar. See the Antibodies section at the end of this lesson plan for a list of the antibodies used in the COVID-19 ELISA lab to note differences with the virtual lab for Lupus testing.

► EdPuzzle videos allow for English closed captions. Students can review sections of the video more than once, and can pause the video while working on their student handout.

SCIENTIFIC VOCABULARY

Students may need some support in understanding the terminology embedded within this lesson. This may be particularly true for emerging bilingual students and students with lower reading levels. Terms should be defined contextually as the lesson unfolds. The following list captures some of the terms used in the lesson materials.

• Antibody: Also known as an immunoglobulin (Ig). An antibody is a part of the immune system that helps the body to recognize foreign molecules (antigens). Each antibody recognizes one particular antigen and then flags it for removal by other immune cells.

• Antigen: A molecule that normally triggers an immune response, including pieces of a virus.

• Coronavirus (CoV): A large family of viruses that cause illness ranging from the common cold to more severe diseases such as Severe Acute Respiratory Syndrome (SARS-CoV).

• COVID-19: The respiratory disease caused by the SARS-CoV-2 virus.

• Diagnostic Test: A test used to confirm or rule out conditions and diseases.

• ELISA: An enzyme-linked immunosorbent assay (ELISA) is a laboratory technique commonly used to detect and measure antibodies in blood samples as a way to diagnose certain viral infections and diseases. An ELISA can also be used to detect antigens, proteins, peptides, and hormones. There are three types of ELISAs: direct, indirect, and sandwich assays.

• False Negative: A test result which indicates that a person does not have a specific disease or condition when the person actually does have the disease or condition.

• False Positive: A test result which indicates that a person has a specific disease or condition when the person actually does not have the disease or condition.

• IgG: A type of antibody or immunoglobulin (Ig) that is found in the blood and other body fluids. It is the most common antibody in the blood. Its primary response function is the initial and secondary response to an antigen, making it both part of the first line of defense and part of the body’s long-term protection for re-infection.

• IgM: A type of antibody or immunoglobulin (Ig) that is found in the blood and lymph fluid. Its primary response function is the initial response to an antigen, making it the body’s first line of defense.

• Neutralizing Antibodies: As part of the immune system, neutralizing antibodies are antibodies that are responsible for defending cells from viruses (and other pathogens including bacteria and toxins) that can cause disease. They can be triggered by both infection with the virus and vaccines.

• SARS-CoV-2: The virus that causes COVID-19.

• Sensitivity: The percentage of sick people who are correctly identified as having the condition.

• Serum: A clear liquid that can be separated when blood clots. It includes proteins that do not play a role in clotting, antibodies, antigens, electrolytes, hormones, and foreign substances (pathogens, drugs, etc.). It does not include blood cells and clotting proteins. Serum is different from plasma, which is the clear liquid that can be separated from unclotted blood.

• Specificity: The extent to which a diagnostic test is specific for a particular condition determined by the percentage of healthy people who are correctly identified as not having the condition.

• Virus: An infectious agent that infects cells, replicates, and may cause disease.
ELISA LAB PROTOCOL - RECIPE & DILUTION GUIDE

Amounts given are for 1 class of 32 students working in pairs. Multiply the amounts for the number of classes you need. Make sure to centrifuge all of the stock reagent microtubes. Some tubes hold extremely small amounts ~4 µl.

Make solutions and dilutions before making aliquots. Refer to the Aliquot Summary Table on the next page as a quick guide.

### 1X PBS Dilution

<table>
<thead>
<tr>
<th>REAGENT</th>
<th>PER CLASS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>10X PBS</td>
<td>50 ml</td>
<td></td>
</tr>
<tr>
<td>Distilled water</td>
<td>450 ml</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>500 ml</td>
<td>Store at room temp</td>
</tr>
</tbody>
</table>

*1X PBS is used to make wash buffer and the antigen dilution. Do not use wash buffer for the antigen dilution.

### Wash Buffer (1X PBS+T)

<table>
<thead>
<tr>
<th>REAGENT</th>
<th>PER CLASS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1X PBS</td>
<td>400 ml</td>
<td></td>
</tr>
<tr>
<td>Tween-20</td>
<td>200.0 µl</td>
<td>Light sensitive</td>
</tr>
<tr>
<td>TOTAL</td>
<td>~ 400 ml</td>
<td>Store at room temp Protect from light if storing long-term.</td>
</tr>
</tbody>
</table>

### Antigen

<table>
<thead>
<tr>
<th>REAGENT</th>
<th>PER CLASS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1X PBS</td>
<td>10 ml</td>
<td></td>
</tr>
<tr>
<td>Stock Antigen</td>
<td>1.0 µl</td>
<td>Store in fridge</td>
</tr>
<tr>
<td>TOTAL</td>
<td>~ 10 ml</td>
<td></td>
</tr>
</tbody>
</table>

### Primary Antibody (1°Ab)

<table>
<thead>
<tr>
<th>REAGENT</th>
<th>PER CLASS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wash Buffer (1X PBS+T)</td>
<td>10 ml</td>
<td></td>
</tr>
<tr>
<td>Stock 1° Ab</td>
<td>5.0 µl</td>
<td>Store in fridge</td>
</tr>
<tr>
<td>TOTAL</td>
<td>~ 10 ml</td>
<td></td>
</tr>
</tbody>
</table>

### IgG and IgM Secondary Antibody (2°Ab [HRP])

<table>
<thead>
<tr>
<th>REAGENT</th>
<th>PER CLASS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wash Buffer (1X PBS+T)</td>
<td>30 ml</td>
<td></td>
</tr>
<tr>
<td>Stock 2° Ab (HRP)</td>
<td>1.5 µl</td>
<td>Store in fridge</td>
</tr>
<tr>
<td>TOTAL</td>
<td>~ 30 ml</td>
<td></td>
</tr>
</tbody>
</table>

### TMB (Brown Aliquots)

3,3',5,5'-Tetramethylbenzidine or TMB is a colorless substrate. When TMB is added to a solution with a peroxidase, such as a conjugated 2° antibody, TMB will reduce to a diimine, causing the solution to turn blue. This acts as the visualizing agent in an ELISA. TMB does not need to be diluted. It is light sensitive and should be stored in the fridge until ready to use. Aliquot 750 µl TMB into 16 brown tubes.

<table>
<thead>
<tr>
<th>REAGENT</th>
<th>PER CLASS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMB</td>
<td>750 µl</td>
<td></td>
</tr>
</tbody>
</table>

---

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ELISA LAB PROTOCOL - ALIQUOT SUMMARY TABLE

Fill in the table based on the number of classes you have. See the example on the first line of the Table. For the negative control, each class will need 16 purple microtubes with 175 μl of wash buffer. To prep for 3 classes, get 16 purple microtubes and add 525 μl (3 x 175 μl) of wash buffer into each. You will then have 16 tubes of negative control that can be used in all 3 classes. Make sure not to throw away the microtubes after each class and store in the fridge between classes.

<table>
<thead>
<tr>
<th>NAME</th>
<th># TUBES /CLASS</th>
<th>AMT/MICROTUBE FOR 1 CLASS</th>
<th># OF CLASSES</th>
<th>TOTAL AMT /MICROTUBE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WASH BUFFER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Example: Negative Control</td>
<td>Purple</td>
<td>16</td>
<td>3</td>
<td>175 μl x 3 = 525 μl</td>
</tr>
<tr>
<td>Wash buffer</td>
<td>50-ml falcon tube</td>
<td>16</td>
<td>20 ml</td>
<td></td>
</tr>
<tr>
<td>Negative Control</td>
<td>Purple</td>
<td>16</td>
<td>175 μl</td>
<td></td>
</tr>
<tr>
<td>(- IgG) patient sample #</td>
<td>Clear (labelled #G)</td>
<td>4</td>
<td>175 μl</td>
<td></td>
</tr>
<tr>
<td>(- IgM) patient sample #</td>
<td>Clear (labelled #M)</td>
<td>6</td>
<td>175 μl</td>
<td></td>
</tr>
<tr>
<td><strong>ANTIGEN</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antigen</td>
<td>Green</td>
<td>16</td>
<td>750 μl*</td>
<td></td>
</tr>
<tr>
<td><strong>PRIMARY ANTIBODY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive Control</td>
<td>Pink</td>
<td>16</td>
<td>175 μl</td>
<td></td>
</tr>
<tr>
<td>(+ IgG) patient sample #</td>
<td>Clear (labelled #G)</td>
<td>4</td>
<td>175 μl</td>
<td></td>
</tr>
<tr>
<td>(+ IgM) patient sample #</td>
<td>Clear (labelled #M)</td>
<td>2</td>
<td>175 μl</td>
<td></td>
</tr>
<tr>
<td><strong>SECONDARY ANTIBODY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2° Antibody</td>
<td>Yellow</td>
<td>32</td>
<td>750 μl*</td>
<td></td>
</tr>
<tr>
<td><strong>TMB SUBSTRATE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMB substrate</td>
<td>Brown</td>
<td>16</td>
<td>750 μl*</td>
<td></td>
</tr>
</tbody>
</table>

*If doing more than 2 classes, you will need to aliquot into more than one microtube. The microtubes provided fit a max of 1.7 ml.
### PATIENT SAMPLE AND RESULTS TABLE

<table>
<thead>
<tr>
<th>Patient</th>
<th>IgG or IgM</th>
<th>Tube Label</th>
<th>+/-</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IgG</td>
<td>1 G</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>IgM</td>
<td>1 M</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>IgG</td>
<td>2 G</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>IgM</td>
<td>2 M</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>IgG</td>
<td>3 G</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>IgM</td>
<td>3 M</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>IgG</td>
<td>4 G</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>IgM</td>
<td>4 M</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>IgG</td>
<td>5 G</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>IgM</td>
<td>5 M</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>IgG</td>
<td>6 G</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>IgM</td>
<td>6 M</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>IgG</td>
<td>7 G</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>IgM</td>
<td>7 M</td>
<td>+</td>
</tr>
<tr>
<td>8</td>
<td>IgG</td>
<td>8 G</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>IgM</td>
<td>8 M</td>
<td>-</td>
</tr>
</tbody>
</table>

### ANTIBODIES

The antigen and antibodies used in this lab are monoclonal chicken IgY, rabbit IgG, and horseradish peroxidase (HRP)-conjugated goat IgG. See the table for exact names. These can also be purchased as a kit from **BioRad**.

<table>
<thead>
<tr>
<th>Name</th>
<th>Reagent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antigen</td>
<td>Chicken IgY</td>
</tr>
<tr>
<td>1° Ab</td>
<td>Rabbit anti-IgY IgG</td>
</tr>
<tr>
<td>2° Ab (HRP)</td>
<td>HRP-conjugated goat anti-rabbit IgG</td>
</tr>
<tr>
<td>TMB substrate</td>
<td>TMB substrate of HRP</td>
</tr>
</tbody>
</table>

### STUDENT STATION SETUP

Each student station should have:
- 96-Well Plate
- Waste Container
- Wash Buffer
- Paper Towels
- Plastic Transfer Pipet
- Micropipet and Tips
- Reagents
  - Antigen
  - Positive Control
  - Negative Control
  - Patient _____ IgG Sample
  - Patient _____ IgM Sample
  - IgG Specific 2° Antibody
  - IgM Specific 2° Antibody
  - TMB Substrate

**FIGURE 4: Student Setup**

![Student Setup Diagram](image)
# RESULT INTERPRETATION TABLE

<table>
<thead>
<tr>
<th>Test Results</th>
<th>Clinical Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RT-qPCR</strong></td>
<td><strong>IgM</strong></td>
</tr>
<tr>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>–</td>
<td>+</td>
</tr>
</tbody>
</table>

Antibody Testing Pre-Lab & Results

Pre-lab worksheet

Name: ___________________________ Date: _____________ Period: _____

1. What do you know about antibodies?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

2. Watch the video “How Do SARS-CoV-2 antibody tests work?” by Roche and “How Does Coronavirus Antibody Testing Work?” by The New York Times. As you watch, fill in the table below with important facts and any questions you have.

<table>
<thead>
<tr>
<th>IMPORTANT CONCEPTS</th>
<th>QUESTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. **Use the information from your notes** to fill in the following charts.

<table>
<thead>
<tr>
<th>TERM</th>
<th>DEFINITION/ FACTS</th>
<th>DRAWING OR SKETCH (OPTIONAL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antibody</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutralizing Antibodies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IgG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IgM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ELISA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**INTERPRET THE GRAPH**

Using the graph, interpret what the different antibody test results could mean for the patient. Would we be able to tell if the patient had COVID-19 or not? Would we be able to tell how long it has been since they were infected? Are they at the beginning of their infection or near recovery?

**Graph: IgM and IgG Against SARS-CoV-2 Through Disease Progression**

**ANTIBODY TEST RESULTS**

<table>
<thead>
<tr>
<th>WHAT DOES IT TELL US?</th>
</tr>
</thead>
<tbody>
<tr>
<td>IgG +</td>
</tr>
<tr>
<td>IgM +</td>
</tr>
<tr>
<td>IgG -</td>
</tr>
<tr>
<td>IgM -</td>
</tr>
<tr>
<td>IgG +</td>
</tr>
<tr>
<td>IgM -</td>
</tr>
<tr>
<td>IgG -</td>
</tr>
<tr>
<td>IgM +</td>
</tr>
</tbody>
</table>
ELISA LAB

Record your patient number and first name. Mark which antibody you will be testing for.

Patient Number __________ Patient’s First Name ___________________________ IgM/IgG _________

Next, as you go through the ELISA protocol, fill in the diagram to represent what is happening at the molecular level inside the wells. Make sure to label which secondary antibody you are using.

- **STEP 1**: Add antigen
- **STEP 2**: Add patient serum
- **STEP 3**: Add secondary antibody
- **STEP 4**: Add TMB substrate

- **Negative Sample**: O = antigen, Y = 1° antibody
- **Positive Sample**: O = antigen, Y = 2° antibody-HRP, □ = TMB substrate, ▲ = cleaved substrate
COVID-19 ELISA Lab Student Protocol
*Enzyme Linked-Immunosorbent Assay*

**Name:** ____________________________ **Date:** ____________ **Period:** ______

**PURPOSE**
To use antibodies found in *simulated* patient serum to detect the presence of a particular infection through an ELISA protocol.

**BIG IDEA**
*Antibodies* are Y-shaped proteins used by the immune system to identify and help remove foreign objects like bacteria and viruses. Their specific shape helps them to recognize many different *antigens* (the unique parts of a molecule that causes an immune response).

An *ELISA (enzyme-linked immunosorbent assay)* uses scientifically designed antibodies to detect if a particular substance, such as a viral antigen, hormone, or another specific antibody, is present in a sample.

In this lab, you will use an indirect ELISA protocol to identify if a patient or sample is positive or negative for a specific antibody in response to infection. By comparing your patient results to positive and negative controls, you will be able to determine if the samples were positive or negative for a particular infection.

Your group will be testing your patient sample along with positive and negative controls. To ensure that your results are accurate, all your samples will be run in triplicate.

**MATERIALS PER STATION**

- Goggles/gloves
- Eppendorf rack
- Paper towels
- ELISA well strips
- Micropipet (P200)/tips
- Timer
- Tip waste container
- Transfer pipet
- Permanent marker
- 750µl antigen (green)
- 175µl positive control (pink)
- 175µl negative control (purple)
- 175µl each patient sample (clear)
  - IgG and IgM patient sample
- 50µl each secondary antibodies (yellow)
  - IgG and IgM secondary antibodies
- 750µl substrate (brown)
- Wash buffer
Procedures

PART 1: PLAN FOR LOADING THE ELISA STRIP

1. Each group will have 2 pairs that will each test for a specific antibody of a patient. You will run your samples in triplicate (3 wells per control and per sample with a well between to space each out).

2. On the Pre-lab handout or in your notebook, mark which patient and which antibody you and your partner will be testing.

3. Draw or tape a copy of Figure 3 into your lab notebook and record the location of your controls and patient samples. Run the samples near each other in a row so that the plate can be used again by the next class.

FIGURE 2: Student Setup

FIGURE 3: Location of Controls and Patient Samples

PART 2: PERFORM ELISA

4. Add 50µl of the antigen (green tube) to each of the 9 wells. Discard pipet tip.

5. Incubate for 5 minutes at room temperature. This allows for the antigen to bind to the plastic wells.

6. Remove the unbound antigen.
   a. Turn the well strip upside down on a stack of paper towels.
   b. Bang it forcefully several times to remove any unbound antigen.
   c. Discard the top layers of paper towels.
7. **Wash step.**
   a. Use a transfer pipet to fill each well with wash buffer. Be careful not to touch the sides of the wells with the tip. **Please keep the transfer pipet and use for future washes.**
   b. Remove the buffer by turning the well strip upside down on a stack of paper towels and banging. Discard the top layer of paper towels and keep the transfer pipet for future wash steps.

8. **Add controls and patient samples.** Add 50µl of the controls and patient samples to the wells designated in your template. Be sure to use a fresh pipet tip after pipetting a sample in triplicate.
   a. 3 well (+) control (pink tube)
   b. 3 well (-) control (purple tube)
   c. 3 wells patient ______ sample for Ig___ (clear tube)

9. **Incubate 5 minutes at room temperature.** This allows for antibodies, if present in the patient sample to bind to antigens.

10. **After 5 minutes, remove the sample** using the same technique you used to remove the antigen.
    a. Turn the well strip upside down on a stack of paper towels.
    b. Bang it forcefully several times to remove any unbound sample/control.
    c. Discard the top layers of paper towels.

11. **Repeat the wash step.**

12. **Add secondary antibody for the antibody you are testing for** (IgM secondary antibody for IgM test, IgG secondary antibody for IgG test). Add 50µl of IgG or IgM specific secondary antibodies (yellow tube) to all 9 wells. Change the pipet tip after each triplicate. The secondary antibody is bound to an enzyme. These enzyme-bound antibodies are called “conjugated”. This enzyme interacts with the substrate we will add next, allowing us to visualize whether the primary antibodies are present.

13. **Incubate for 5 minutes** at room temperature.

14. **Remove the secondary antibodies.**
    a. Turn the well strip upside down on a stack of paper towels.
    b. Bang it forcefully several times to remove any unbound antigen.
    c. Discard the top layers of paper towels.

15. **Repeat the wash step** 3 times to remove all unbound antibodies.

16. **Add substrate.** Add 50µl of peroxidase substrate (brown tube) to each well. Be careful not to touch the sides of the well with the tip.

17. **Incubate for 5-10 minutes** (until you see color change) then record your results.

**CLEAN UP**

- Dispose of used tips, microtubes, and used paper towels.
- Keep waste containers and transfer pipets.
- Wash your hands. Clean up your lab stations.
**PATIENT STORIES**

**Patient 1**
Kelly is a 25 year old nurse working in an assisted living facility. Five people at her work have tested positive for COVID-19. Because Kelly did not work directly with anyone that tested positive and because she is fully vaccinated, her employer is not requiring her to have a test. Kelly has no symptoms and feels perfectly healthy, but worries that she may be an asymptomatic carrier. Worried about the safety of her elderly patients and her family, Kelly has decided to get tested for COVID-19.

**Patient 2**
Jason is a 43 year old medical researcher who has been working from home for the past three months. His state has begun to reopen and his lab is asking staff to return to work at the office. Jason and his partner had flu-like symptoms in late February 2020, but neither got tested for either the flu or COVID-19. Since then, he got the vaccine but his partner chose not to. Jason is interested in getting tested to see if he currently has COVID-19 or has had a COVID-19 infection in the past.

**Patient 3**
Samantha is a 19 year old college student who has been living at home since their college campus closed in March 2020. Samantha has been working at a grocery store for the summer where all employees and customers are required to wear a mask at all times. Samantha is interested in visiting their grandparents before returning to school in the fall, and wants to make sure it is safe to see them. Samantha has no symptoms and is vaccinated.

**Patient 4**
Terry is a 10 year old who has diabetes. Because of his diabetes, Terry is at a higher risk of developing serious complications from COVID-19. He is also unvaccinated because he is not eligible due to his age. Terry's school has been closed due to the pandemic for several months. Terry's mother works an essential job while Terry's father is responsible for remote schooling and takes care of him and his two siblings. Two week ago, one of his mom's co-workers tested positive for COVID-19. Since then, his mom had been staying with a different co-worker instead of being home with her family because she is afraid she might be infected and wants to keep Terry safe since he is high-risk. In the last week, Terry has been extra tired and easily becomes winded when playing outside. Terry's father is worried that Terry may be positive for COVID-19.

**Patient 5**
Isabelle is a 32 year old high school science teacher. She had been teaching from home for the last three months of the 2019-2020 school year. Isabelle's partner has also been working from home. Isabelle does not remember being sick this year, but did some international travel in late January. Now it is summer. Isabelle's school district just announced their decision to reopen in-person instruction in Fall 2020 and are requiring all teachers to get vaccinated and get an antibody test before returning to school. She has scheduled to get her vaccine at the same time as her antibody test.

**Patient 6**
Edward is a 56 year old business owner. He and his wife run a restaurant that has been doing take-out orders throughout the pandemic. Edward and his wife have been extremely cautious, wearing masks, regularly sanitizing any surface that customers have contact with, and consistently washing their hands. He and his wife are both fully vaccinated. Yesterday, Edward developed a cough. He also says that he has been experiencing fatigue and an itchy throat. Edward normally has seasonal allergies, but out of an abundance of caution for his family and customers he has decided to get tested for COVID-19.

**Patient 7**
Alan is a 19 year old part-time delivery driver who is not vaccinated. Throughout the pandemic Alan has been delivering packages. His company provides some personal protective equipment, but Alan has also been buying his own hand sanitizer and cleaning products to sanitize his vehicle. Alan admits that during especially hot days he does not wear a mask. Five days ago, Alan called his manager to let her know that he had developed mild symptoms including a cough and sore throat. He has not been to work since. Yesterday, Alan had a low-grade fever of 38.4°C (101.2°F). Alan's company will only give paid-sick leave to part-time employees that can prove they have COVID-19 with a positive molecular test. Alan can not afford to take any unpaid time off and does not want to spread the disease if he has COVID-19, so he has come in for testing.

**Patient 8**
Tran is a 6 year old whose parents both work at a hospital. Because of his age, he is not eligible for the vaccine. He goes to a day care five days a week that is open to families of essential workers. The day care recently contacted all the parents to inform them that a parent of one of the children recently tested positive for COVID-19. Like many kids, Tran had a cold in early February but tested negative for the seasonal flu. He currently has no symptoms. Tran's parents are interested in finding out if Tran currently has COVID-19 or has had COVID-19 in the past.
LESSON 4

Bioethics and COVID-19

_Distributing Vaccines: Introduction to Biomedical Ethical Principles_

**Overview:** In this lesson, students learn about biomedical ethical principles and ethical reasoning. They then analyze a variety of bioethical issues related to the COVID-19 pandemic using those principles, including developing a policy recommendation for vaccine distribution when the supply is scarce.

### Unit Progression

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<td>Policies and the Nature of Science <em>(Coming Soon!)</em></td>
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**Remote Learning Adaptations**

Suggestions for adapting the activities for remote teaching and learning settings are included at the end of the lesson [here](#).
COVID TESTING — LESSON 4

Student Understandings

WHAT STUDENTS FIGURE OUT

► Ethics can help us decide on the best course of action, and provide reasons why that course is best.
► For ethical issues involving science, it is important to have a solid understanding of the scientific background as well as the ethical dimensions of the problem.
► Ethical reasoning relies on identifying an ethical question, considering the facts, identifying and analyzing the positions of various stakeholders, weighing different options, and justifying the best course of action.

WHAT STUDENTS WILL DO

► Learn about biomedical ethical principles.
► Apply principles to other ethical issues related to COVID-19.

PREVIOUS KNOWLEDGE

No special knowledge required.

STUDENT ASSESSMENT OPPORTUNITIES

The ways in which students invoke various ethical principles when applying them to new scenarios provides information about their understanding. An exit ticket can ask them to describe how principles are in tension in additional scenarios.

Next Generation Science Standards

This lesson builds toward the following Nature of Science - Crosscutting Concepts standards from the NRC Framework and Next Generation Science Standards.

PERFORMANCE EXPECTATIONS

Appendix H: Science is a Human Endeavor and Nature of Science

► Science is a Human Endeavor
► Science Addresses Questions About the Natural and Material World

Building Toward the Social Justice Education Standards

This lesson builds toward the following standards from Social Justice Standards: The Teaching Tolerance Anti-bias Framework from Learning for Justice:

► Justice 12 JU.9-12.12: I can recognize, describe and distinguish unfairness and injustice at different levels of society.
► Justice 13 JU.9-12.13: I can explain the short and long-term impact of biased words and behaviors and unjust practices, laws and institutions that limit the rights and freedoms of people based on their identity groups.
► Justice 15 JU.9-12.15: I can identify figures, groups, events and a variety of strategies and philosophies relevant to the history of social justice around the world.
Teacher Preparation
Print copies of the materials listed below or upload them to your classroom learning management system.

<table>
<thead>
<tr>
<th>Print &amp; Digital Materials</th>
<th>Description</th>
<th>Quantity</th>
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<tbody>
<tr>
<td>Lesson 4 Intro to Ethics Slide Deck (Teacher)</td>
<td>Includes ethics background</td>
<td>N/A</td>
</tr>
<tr>
<td>Bioethics Vaccine Policy Slide Deck (Students)</td>
<td>Includes directions for the bioethics vaccine policy activity</td>
<td>N/A</td>
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Instructional Procedure

OVERVIEW

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<td>Activity 4.1</td>
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<td>Activity 4.2</td>
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<td>Activity 4.3</td>
<td>Ethical Principles</td>
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<tr>
<td>Activity 4.4</td>
<td>Principle-based Ethical Reasoning &amp; COVID-19</td>
<td>20+ min</td>
</tr>
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Lesson 4: Intro to Ethics Slide Deck
Download Slide Deck
ACTIVITY 4.1: INTRO TO ETHICS (5 MINUTES)

1. **(Slides #1-4) Ethics Definition:** Ask students to first provide ideas about what ethics is. Then show the working definition. Highlight a few things from the definition on the slide:
   a. It asks us what we should do in a certain situation. The “should” conditional tips us off to a potential ethical issue. Of course, not all questions with “should” are ethical questions; only those that apply to ethical dilemmas.
   b. It arises because we need to act.
   c. It focuses on reasons; justifications are important in ethics. It’s not about opinions. Ethical reasoning relies on facts and ethical ideas.
   d. It arises out of living in a society or community where our actions impact others. It is part of thinking about the kind of communities we would want to live in.

2. **(Slide #5) Values and Morals:** Many students will likely put forth that morals are synonymous with ethics. Draw these distinctions for them:
   a. Values signify what is important and worthwhile (example: “honesty”).
   b. Morals help provide us with codes of conduct based on values (example: don’t lie).
   c. Ethics focuses on how to reason and provide answers for dilemmas where your values and morals might conflict (for example, values such as honesty may conflict with duties to a friend: Should I lie to avoid “telling on” my best friend?).

3. **(Slide #6) Ethics and Science:** Have students brainstorm topics in ethics and science. Then ask about how ethics and science are related to each other.
   a. Science asks testable questions about the natural world; Can be explored through inquiry and observation; Relies on empirical and measurable evidence.
   b. Like science, ethics relies on well-justified and careful reasoning. It is not simply our opinion as it draws on scientific facts as well as ethical principles and ideas.
   c. We need to draw on both sound science and ethics in formulating our decisions.
4. **(Slide #7) Ethics and Science** (broad groupings of different ways they relate):
   a. What science is done (what gets funded, what is considered important).
   b. How science is conducted (who gets to be a scientist, use of animals or human participants in research, the ethical conduct of research).
   c. How scientific discoveries are used (what we do with our ability to genetically engineer organisms).

5. **(Slide #8) Quote by Heinz Pagels:**
   a. “Science cannot resolve moral conflicts, but it can help to more accurately frame the debates about those conflicts.”
   b. Science can help us with our decision-making process by helping us get accurate information to work with.

6. **(Slide #9) Ethical Questions:**
   a. Ask us what we should or ought to do in the face of an ethical dilemma.
   b. Most of the time, a difficult dilemma will be not between “right” and “wrong” but between two “rights” or two “wrongs”.
   c. Identifying the ethical question is the first step in ethical reasoning.
   d. Reasonable people may disagree on how ethical issues are resolved, but ethical reasoning provides a way to have an evidence and principle-based argument on an ethical question.

**ACTIVITY 4.2: ETHICAL DILEMMAS IN COVID (10 MINUTES)**

7. **(Slide #10) Ask students to generate some ethical dilemmas/questions related to the COVID-19 pandemic**, using “should” as a starting point for their questions. This could be done in small groups.
   a. Encourage students to think of the different aspects of the pandemic (for example, mask mandates, social distancing, stay at home orders, vaccine mandates, border closures, travel restrictions, health care prioritization, supply chain issues especially with personal protective equipment, vaccine roll out/distribution, vaccine “passports”).
   b. Example possible answers include: How should ventilators be allocated in hospitals? How should a vaccine be distributed? Should vaccines be mandated at workplaces? Should vaccines be mandated at schools? Should people be forced to wear masks against their will? Should proof of vaccination be required for restaurants or for large events?
8. In debriefing, try to reframe students’ statements to foreshadow different ethical principles.
   a. Are they focused on beneficial outcomes?
   b. Are they concerned about being fair?
   c. Are they trying to take care of those who are vulnerable?
   d. Note that ethical questions involved in allocating scarce resources are fundamentally questions of justice.

9. (Slide #11) Share that the class will be exploring several of these ethical questions related to the COVID-19 pandemic during this lesson, including the question of how to distribute vaccines when there is a scarcity of supply.

ACTIVITY 4.3: ETHICAL PRINCIPLES (15 MINUTES)

10. (Slide #12) Ethical Reasoning: Show the slide and share that this is one approach for ethical reasoning. Read through the steps.
   a. Determine the ethical question.
   b. Identify the relevant facts. Facts include the scientific considerations.
   c. Consider stakeholders (who or what could be affected by how the question is resolved). Stakeholders have a stake in the outcome of how the issue is resolved. These stakeholders often prioritize different ethical principles or hold different values. When analyzing an issue, it’s helpful to try to see things from different stakeholder perspectives.
      i. For example, who are some of the main stakeholders in the vaccine ethics scenario?
      ii. (Answers can include health care providers, people with health conditions, decision-makers who are deciding on the distribution, etc.).
   d. Determine ethical considerations (more in coming slides).
   e. Generate possible options and evaluate the pros/cons of different options.
   f. Provide a reasoned justification.
11. (Slides #13-14) In order to evaluate ethical considerations, it is helpful to have the language of ethical ideas. One approach used frequently in biomedical ethics is “principle-based ethics”. Read through the list on Slide #14 and mention that these will be discussed more in the coming slides. Note that the principle-based approach is rooted in Western medicine and research. While Western ethics places a strong value on respecting the individual, other cultures, for example, might prioritize benefits to the broader community.

12. (Slide #15) Examples of Unethical Medical Research: Two examples of unethical biomedical research will be presented. It can be difficult to think about these cases, but it is important to recognize and learn from mistakes made in the past. Explain that after reviewing these examples, the principles of bioethics will be presented to help understand the protections now in place for research participants.

13. (Slides #16-17) Experiments on Nazi prisoners: While some of the ideas in the principles are from Ancient Greece, the articulation of the principles in this form came as a result of several examples of unethical medical research practices. These included the experiments performed on prisoners of war held by Nazi Germans. The doctors were prosecuted at the Nuremberg Trials after the war, and the atrocities committed led to the development of the Nuremberg code, which provided guidelines that included the importance of informed consent to participate in research.
14. (Slides #18-20) US Public Health Service Syphilis (PHS) Study (“Tuskegee”): This study spanned 40 years, from 1932-1972 and did not end until a reporter discovered the story and brought it to the attention of the public. Originally, investigators from PHS in conjunction with medical staff at the Tuskegee institute recruited 600 men (399 with syphilis and a control group of 201 without the disease) in Alabama to study how syphilis progressed in Blacks. They thought at the time that it was different in white people and Black people. The men were poor sharecroppers and were told that they had “bad blood”.

This study involved deception because the men thought they were being treated but they were not. Even when penicillin, an effective treatment, became available, the treatment was intentionally withheld from them so that the progression of untreated syphilis could continue to be observed. This was a vulnerable population that was not respected in the research process.

15. (Slides #21-22) Respect (also called “Respect for Persons”): This bioethical principle involves supporting, and not interfering with, people’s ability to make choices for themselves (supporting their “autonomy”). It means giving people enough information to make informed decisions (“informed consent”). It also involves honoring the dignity and worth of each individual and protecting those who are vulnerable.

16. (Slide #23) Maximizing benefits (“beneficence”) and minimizing harms (“nonmaleficeence”): Acting to lessen negative outcomes and promote positive ones. It also can be framed as “do good” and “avoid doing harm”.

a. The image shows a fragment of the Hippocratic oath. Hippocrates lived 460-370 BC. Sometimes the phrase, “first of all, do no harm” is attributed to him although it is not actually in the oath.
17. **(Slide #24) Justice:** Justice means treating a person fairly in light of what is due or owed them, and distributing benefits and burdens equitably across individuals.

18. **(Slide #25) Critical Perspectives:** In addition, we can add “critical" perspectives that try to address some of the things that the principles don’t (for example, ideas about ethics of care and feminist ethics). Critical perspectives ask us to look at:
   - Prioritizing relationships
   - Considering underlying power structures and consider who is benefiting/at whose expense
   - Elevating concerns of the broader community
   - Looking at more-than-human perspectives and our relationships with other animals and the environment (for example, indigenous approaches)

19. **(Slide #26) Summary Slide:** Provide a summary of a principle-based approach and the questions that this approach helps us ask of ethical issues
   a. **Respect:** What would be respectful of the dignity and worth of the individuals? What would support their autonomy? Are research participants giving informed consent?
   b. **Maximize Benefits (Beneficence)/Minimize Harms (Non-maleficence):** What would bring the most good? How can we avoid harm? Do benefits outweigh harms?
   c. **Justice:** What would be fair? How can we distribute resources equitably?
   d. **Critical Perspectives:** What honors our relationships with others and our community? What are the underlying power structures and assumptions?

20. **Note that often, ethical issues arise when principles are in tension with one another.** For example, your older grandparent may want to drive and insist that they are capable (they are demanding their autonomy) while your family may be concerned that they could cause harm to themselves and others. In this case, autonomy and respect for persons is in tension with minimizing harms.
ACTIVITY 4.4: PRINCIPLE-BASED ETHICAL REASONING & COVID-19 (20+ MINUTES)

21. Before the lesson:
   a. Break students into small discussion groups.
   b. Post the Bioethics Vaccine Policy Slide Deck (Students) to your learning management system.

22. In small groups, students will consider the ethical dilemmas associated with how to distribute vaccines when there is a scarcity of supply. When the COVID-19 vaccines first became available, policies had to be developed in order to decide what groups of people would first be eligible to receive the vaccine, and which groups would come next. Principle-based ethical reasoning can be applied to developing policies that affect groups of people differently.

23. Assign each small discussion group a number. Provide access to the Bioethics Vaccine Policy Slide Deck (Students) so that students can see the directions and add their responses to the slide for their group number. Allow time for students to meet in their groups to discuss the scenario and develop their policy recommendations.

24. Bring the class back together, asking someone from each group to share their recommendations and their ethical reasoning while you show their group’s slide to the class. Highlight the ethical principles that each group used to develop their policy recommendation. Reflect on the policies that were in place during the early phases of vaccine distribution in the U.S.

25. Optional Extension/Homework: Tell students, “We are now going to consider some other ethical dilemmas associated with the COVID-19 pandemic and think about how these ethical principles might apply”. Note that the discussion of the COVID ethical dilemmas can be conducted as a whole class, in small groups as a jigsaw activity, or as a homework assignment (details on next page).
a. (Slides #27-28) COVID vaccine challenge trials: In order to test whether a new vaccine is effective, some people are willing to be infected with SARS-CoV-2 after receiving a vaccine. This is called a "challenge trial".

Discussion Question:
What principles are in tension in this scenario?
*Autonomy vs. weighing risks and benefits*

b. (Slides #29-30) Diversity in clinical trial participants: Clinical trials for COVID-19 vaccines may not enroll people from different racial/ethnic groups or age groups, or people with underlying health conditions in a way that is representative of the populations who are most likely to be infected and experience serious disease or death. There are many reasons why an individual may or may not choose to enroll as a research participant.

Discussion Question:
What principles are in tension in this scenario?
*Individuals weighing their own risks and benefits to participation; honoring relationships to others and a sense of duty to participate; underlying power structures and historical inequities that may make some people wary of medical research.*

c. (Slides #31-32) Wearing face masks: What ethical issues does mask-wearing raise? What about when mask-wearing is mandated for entry to a space or participation in an event? There are those who believe being required to wear a mask interferes with their autonomy and their individual rights. They are prioritizing those rights above those of protecting the larger community and also those who are concerned about the harms that might come from increased viral spread.

Discussion Question:
What ethical issues does mask-wearing raise?
*Autonomy and individual “rights” vs. weighing risks and benefits, also honoring relationships or duties we may have to others and our broader community.*
d. **(Slides #33-34) Health Inequities and COVID-19:**
There are many ways that health inequities are made more extreme by the COVID-19 pandemic. This slide lists some of the dimensions of that inequity.

**Discussion Question:**
What ethical issues do health inequities raise? **Issues of justice and fairness predominate,** as Black people and Latinos are disproportionately exposed to COVID-19, are less protected, and have overall worse outcomes after infection. **Critical perspectives that ask what the underlying power structures and assumptions are that driving some of these issues are also important.** Issues of respect for persons and not actively doing harm to others also pertain.

26. **(Slide #35) CLOSURE:** Share with students that biomedical ethical principles are one way of invoking ethical ideas to try to reason through ethical dilemmas. Now students have some language to use when thinking about ethical issues in the future. In the next lesson, students will dive deeper into examining health inequities and COVID-19.
ADAPTATIONS FOR REMOTE INSTRUCTION

As an alternative to the in-person instructional procedure on the previous pages, the table below provides suggested instructional procedures adapted for remote learning settings. This lesson assumes students have computer and internet access at home.

<table>
<thead>
<tr>
<th>Learning Activity</th>
<th>Remote Instruction Procedure</th>
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</table>
| Activity 4.1: Intro to Ethics (5 min) | 0. Before the class: Upload all handouts and the slide deck(s) to your classroom learning management system.  
1. If you are able, present Slides #1-9 of the Lesson 4 slide deck during a synchronous class video call, following the instructions in the Procedure section. If not, students can be instructed to work through Slides #1-9 of the slide deck on their own. You might consider creating a digital bulletin board and posting questions for students to respond to, based on what they learned from the slide deck. |
| Activity 4.2: Ethical Dilemmas in COVID (10 min) | 2. If you are able, present Slide #10 of the Lesson 4 slide deck during a synchronous class video call and follow the directions in the Procedure section, having students meet in small groups in breakout rooms. If not, students can be instructed to follow the directions on Slide #10 of the slide deck on their own. You might consider creating a digital bulletin board for students to post their ideas of ethical dilemmas during the COVID pandemic. |
| Activity 4.3: Ethical Principles (15 min) | 3. If you are able, present Slide #12-25 of the Lesson 4 slide deck during a synchronous class video call and follow the directions in the Procedure section. If not, students can be instructed to work through Slides #12-25 of the slide deck on their own while taking notes. |
| Activity 4.4: Principle-Based Ethical Reasoning (15 min) | 4. Follow the directions in the Procedure section, having students work in small groups in breakout rooms during a synchronous class video call to discuss their ideas for a vaccine distribution policy, recording their group’s ideas on the slide for their group in the Bioethics Vaccine Policy Slide Deck (Students).  
5. If students will be working asynchronously, make additional duplicate slides in the Bioethics Vaccine Policy Slide Deck (Students) so there is one for each student to record their ideas as they work independently. Students could be asked to review one or more responses by other students and reflect in writing on how their recommendations were similar/different from their own. |
Suggested Lesson Extensions

EXTENSIONS
► To extend this lesson, students could research the policies that were in place during the early phases of vaccine distribution in the U.S. What groups of people were in the first and second tiers to be eligible for vaccination? What ethical principles may be in play to make these decisions? Students could also compare the U.S.’s vaccine distribution policy to those implemented in other countries.
► The Bill & Melinda Gates Discovery Center offers free virtual programs for middle and high school classes focused on COVID. The COVID-19 in Context program uses writing and drawing to help students reflect on the impacts of the pandemic on their own lives and their communities. The Science of COVID-19: Part I Virus/Testing and Part II Vaccine/Therapeutics could also extend students’ learning.

OPPORTUNITIES FOR PRODUCTIVE UNCERTAINTY
Ethical reasoning and decision-making requires marshalling both science facts and ethical principles to make a strong justification.

OPPORTUNITIES FOR PERSONAL CONNECTIONS TO STUDENTS
► The COVID-19 pandemic has affected everyone’s lives. This lesson provides an ethical reasoning framework that students may find helpful when reflecting on issues during the pandemic that may have felt confusing or stressful.
► Students can reflect on what kinds of ethical dilemmas they face in their lives, or what kinds of dilemmas they see playing out in their community. They can discuss how ethical principles can help clarify those dilemmas.
► Students could discuss ethical dilemmas they have encountered themselves during the pandemic, such as when to wear a mask or not or what sources of information to trust. Reminding your students of classroom discussions norms and to act with kindness could be helpful during this discussion.

CAREER CONNECTIONS
Career connections are not explicitly called out in the activities in this unit, however there are many careers related to COVID testing that teachers may wish to highlight. The career connection for Lesson 4 includes:

Bioethicist: Bioethicists are ethicists who specialize in examining the ethical, legal, and social implications of medicine (health care) and biomedical research. They wrestle with the philosophical implications of medical and biological procedures, treatments, and new technologies, as well as research studies involving humans. Bioethicists may teach and engage in scholarship as a professor, work at a hospital, help advise research studies, be involved in policy and advocacy, or serve as a member of an Institutional Review Board (IRB). To become a bioethicist requires an advanced degree (master’s or doctorate) in philosophy, medicine, nursing, genetics, law, or social work, with a specialization in bioethics.

Additional careers are featured on the STEM Global - Pathways to Global Health Careers poster and accompanying fact sheets. Read more about each job by exploring these resources.
Notes on Adaptations and Inclusivity

DIFFERENTIATION & ACCESSIBILITY SUGGESTIONS

► Students could be offered multiple forms of representation for sharing their vaccine distribution policy, such as: written text, verbal presentation, infographic/poster, or public service announcement.

► Emerging multilingual learners could be provided with the list of vocabulary words and definitions (see Vocabulary section below) to use during Activity 4.4 to assist them with using these new terms during small group discussions and when developing their policy recommendations.

► Students who need more challenge could investigate the other bioethical dilemmas presented at the end of Activity 4.4.

SCIENTIFIC VOCABULARY

Students may need some support in understanding the terminology embedded within this lesson. This may be particularly true for emerging bilingual students and students with lower reading levels. Terms should be defined contextually as the lesson unfolds. The following list captures some of the terms used in the lesson materials.

- **Beneficence/Nonmaleficence**: One of the fundamental principles of bioethics used to guide research with humans. Beneficence/Nonmaleficence means to maximize benefits while minimizing harms.

- **Bioethics (Biomedical Ethics)**: The field of ethics that is focused on medical and biological research. Bioethics is the study of the ethical, legal, and social implications of biomedical research. It includes the following fundamental principles to guide ethical and responsible research with humans: Beneficence/Nonmaleficence, Respect for Persons, and Justice.

- **COVID-19**: The respiratory disease caused by the SARS-CoV-2 virus.

- **Ethics**: How to reason and provide answers for dilemmas where your values and morals might conflict (e.g., values such as honesty may conflict with duties to a friend: Should I lie to avoid “telling on” my best friend?).

- **Justice**: One of the fundamental principles of bioethics used to guide research with humans. The principle of justice is focused on ensuring fairness and equity and guarding against exploitative procedures.

- **Morals**: Codes of conduct based on values of a group of people (e.g., don’t lie).

- **Pandemic**: An outbreak of a disease that is prevalent over multiple countries or continents across the world.

- **Respect for Persons**: One of the fundamental principles of bioethics used to guide research with humans. Respect for persons recognizes the autonomy of individuals and their rights to make their own decisions. This principle includes recognizing patient autonomy, protecting vulnerable individuals, and ensuring informed consent occurs.

- **Stakeholder**: People (or groups, organizations, industries, etc.) that could be affected by and who have a state in the outcome of how an ethical question is resolved. Stakeholders may prioritize different ethical principles or hold different values from one another.

- **Values**: Values signify what is important and worthwhile to a group of people (e.g., honesty).

Additional Ethics Resources

► See NWABR’s Ethics Primer for a general ethics resource. Additional information and a graphic organizer for Principle-based ethics can be found there. When discussing ethics and science and introducing their relationship, you may wish to engage students in the activity “Science and Ethics - Subjective or Objective?”

► In addition, NWABR’s curriculum features bioethics material on HIV Vaccine Trials, Stem Cell Research, Research with Animals and Human Participants, and the Social Nature of Scientific Research. Additionally, NWABR has resources related to Genetic Testing and Genetic Research.

► Practice Brief #44 from STEM Teaching Tools focuses on Addressing Controversial Science Topics in the K-12 Classroom and is an excellent resource for preparing to engage students in explorations of socio-scientific controversies.
LESSON 5

Health Inequities and COVID-19
*How Structural Racism Drives Health Inequities*

**Overview:** Students look at data related to COVID-19 health inequities and reflect on what drives those disparities. They engage with a seminar reading to deepen their understanding of the role of structural racism in exacerbating the effects of the pandemic in communities of color.

**Unit Progression**

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**Remote Learning Adaptations**

Suggestions for adapting the activities for remote teaching and learning settings are included at the end of the lesson [here](#).
Student Understandings

WHAT STUDENTS FIGURE OUT
► Collecting data about how COVID-19 is impacting certain communities disproportionately is important to being able to support those communities.
► “Race” is not itself a risk factor. The idea of “race”, while meaningful as a socio-political construct and marker of identity, is not biologically real. It is a “poor proxy” for shared ancestry and evolutionary/geographical origins of groups of humans.
► Structural racism is the deep underlying cause driving many of the inequities that result in health disparities.

WHAT STUDENTS WILL DO
► Examine COVID-19 data to examine the impacts of the pandemic on different communities.
► Conduct a Socratic Seminar to discuss the connections between race, racism, and health inequities.

PREVIOUS KNOWLEDGE
► No special knowledge required, although knowledge of the idea of structural racism and how it is distinct from personally mediated racism is extremely helpful (see SEP’s Implicit Bias and Structural Racism Lesson) and the Reference section at the end of this lesson plan.
► Students should read the seminar articles prior to class. You may ask them to interact with the text by asking them to consider a question as they are reading, to identify words or ideas that are unclear, or to highlight points that they want to discuss.

STUDENT ASSESSMENT OPPORTUNITIES
The ways in which students respond to questions about the data they examine and the readings they discuss provides information about their understanding. An exit ticket can ask them to describe their understanding of the sources of COVID-19 health inequities.

Next Generation Science Standards
This lesson builds toward the following Nature of Science - Crosscutting Concepts standards from the NRC Framework and Next Generation Science Standards.

PERFORMANCE EXPECTATIONS
Appendix H: Science is a Human Endeavor and Nature of Science
► Science is a Human Endeavor
► Science Addresses Questions About the Natural and Material World

Building Toward the Social Justice Education Standards
This lesson builds toward the following standards from Social Justice Standards: The Teaching Tolerance Anti-bias Framework from Learning for Justice:
► Justice 12 JU.9-12.12: I can recognize, describe and distinguish unfairness and injustice at different levels of society.
► Justice 13 JU.9-12.13: I can explain the short and long-term impact of biased words and behaviors and unjust practices, laws and institutions that limit the rights and freedoms of people based on their identity groups.
► Justice 15 JU.9-12.15: I can identify figures, groups, events and a variety of strategies and philosophies relevant to the history of social justice around the world.

Essential Question: How does the COVID-19 pandemic highlight and exacerbate already existing health inequities?
Teacher Preparation

1. Make copies of the COVID-19 data or upload them to your classroom learning management system.
2. Make copies of the Readings for Seminar or upload them to your classroom learning management system. **Students should read the articles prior to the class discussion.**

<table>
<thead>
<tr>
<th>Print &amp; Digital Materials</th>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesson 5 Health Inequities and COVID-19 Slide Deck (Teacher)</td>
<td>Slide presentation</td>
<td>N/A</td>
</tr>
</tbody>
</table>
| COVID-19 Data Slide Deck (Students) | • COVID-19 data related to health and impacts on communities of color  
• Data related to health inequities and impacts on communities of color (to show or print)  
• Includes Figures 5.1-5.4 and Student Handout 5.1 | The slides can be printed and distributed as handouts (1/student) or students can be given access to the slide deck. |
| Teacher Resource 5.1: Factors Contributing to Health Inequities | Student worksheet to accompany Activity 5.1. There are four sets of strips on this page. To be printed so that each small group receives one set of strips. | 1 set of strips/student (4 sets per page) |
| Readings for Socratic Seminar | There are two reading options which differ in focus and a third option which is a more challenging reading. Readings are found in the Readings Folder.  
• Yong, E., “How the Pandemic Defeated America,” *Atlantic*, 2020 (excerpt) - Focus on Health Inequities  
| Teacher Resource 5.2: Discussion Notes for Seminar Readings | Teacher notes for the Yong and Bouie seminar readings. | For teacher use |
1 DAY ONE

ACTIVITY 5.1: INTRO AND EXAMINING COVID-19 DATA (20 MINUTES)

1. **(Slides #1-2) Bridge:** Remind students that in the prior lesson, they looked at ethical questions raised by the COVID-19 pandemic. One important one was the issue of health inequities. As the slide diagram illustrates, many factors contribute to inequities.

2. **Acknowledge that COVID-19 has impacted all of us in different ways and that this may be a difficult topic for some students.** Let students know that if they are having difficulty with this topic for personal reasons, they should feel free to tell you in confidence. Remind students to be sensitive to the fact that others may have experienced loss.

3. **Ask students what they’ve heard in the news about how COVID-19 is impacting varied racial and ethnic groups differently.** Share that the class will be looking into these differences in this lesson.

4. **(Slide #3) COVID Racial Data Tracker:** Data on how the pandemic is impacting different populations has not always been easy to get.

5. **Distribute data handouts:** Break students into small groups. Distribute printed copies of Figures 5.1-5.4 from COVID-19 Data Slide Deck (Students) or have students review the slides on a computer.

Discussion Question:

Why might it be important to gather data about impacts about COVID-19 on different groups? Understanding the impact of a pandemic on certain racial and ethnic groups requires a counting of people who consider themselves part of that group.
a. It may be easiest to distribute one of each of the figures to different groups, so that students only look at one graph and then share their results later. However, you could also assign all of the figures to each group.

b. Optional: Use Figure 5.5 for groups that finish early or need a challenge.

c. Note: The teacher slide deck has slides featuring these same figures (see Slides #5-9).

6. (Slide #4) Small group discussion:

   **Small Group Questions:**
   
   a. What are the graphs showing/demonstrating?
   
   b. Imagine you were going to write a news headline to accompany the graphs (your claim). What would you write for the headline? What would a big take-away be?
   
   c. What evidence supports that claim?
   
   d. What questions do the data raise? What else do you want to know?

7. Ask students to consider (if they have not raised this as a question themselves): Why do these differences exist between different groups? What do you think is responsible for these differences?

   a. Ask students to brainstorm in their small groups first and then share with the larger class.
   
   b. Write students’ ideas in a place where they can all be seen.

8. Distribute cut-outs from Teacher Resource 5.1 (1 set of strips per group) and have students organize them in order:

   a. Sort the strips into order from what elements you think are most responsible to what you think is least responsible for the disparities you observed in the data.
   
   b. Which factors do you think are most important? Less important? Which factors are under an individual’s control? Which are less so?

9. Ask each group to share their top factors with the class. These may differ depending on which graph they looked at.

10. Work with the class to try to come to a consensus on the most important factors.
11. Ask students “What underlies these factors? Particularly the ones where an individual may have less immediate control?” These may be the “proximal” or closely observable causes, but what are the root causes? For example, if students say “limited access to health care,” ask them to push a little further and ask “Why might people have limited access to health care?” or, “Why might some people be more exposed to environmental toxins?” Help students to see that the underlying reasons often rely on, or are connected to, structural racism. See note.

Note: Ideally, students will have participated in SEP’s lesson about Implicit Bias and Structural Racism, which discusses different types of racism, before this one. However, if students have not been exposed to the distinction previously, now would be a good time to mention the difference between personally mediated, individualized racism (calling racist names, someone burning a cross in someone’s yard) and structural, systemic racism (policies/structures in systems/institutions such as medicine, education, real estate, government, and business, which were originally shaped by racist beliefs, and which perpetuate and justify racist ideas). Additionally, racism may be internalized. For an excellent reading on types of racism, see the Levels of Racism: A Theoretical Framework and a Gardener’s Tale by Camara Jones.

12. Ask students, “Why is race often used when analyzing data around health outcomes?”
   a. Students may mention the idea of race as a poor proxy for ancestry/genetics/biology if they have already experienced SEP’s Race and Genetics Lessons. Such data can also help identify inequities that result from the socio-political idea of race. As noted previously, understanding the impact of a pandemic on certain racial groups requires a counting of people who consider themselves part of that group.
   b. It is important to recognize that counting people in that way (with reference to their socio-political identification with a racial group) is separate from identifying those individuals who share common biology. Because of this tendency to conflate socio-political identification with ancestry/genetics/biology, some health professionals advocate for using other measures than race for health outcomes data.

13. (Slide #10) Share the slide showing The Telegraph article about Native Americans and COVID-19 and facts from the article:
   a. Native Americans are dying at a rate five times that of their white counterparts, according to the US Centers for Disease Control (CDC).
   b. The disparities could be even higher, because in the first months of the pandemic states collecting data on COVID cases didn’t track Native Americans (there was no box).
   c. In exchange for their lands, many tribes signed treaties that guaranteed healthcare and certain rights to ensure their well-being.
   d. People in the Navajo Nation have to go great distances to get water, due in part to water overuse from mining and drought.
   e. 58 out of every 1,000 Native households lack plumbing, compared to three out of every 1,000 white households. The lack of indoor plumbing and access
to potable water was found to be the most important determinant of the increase in COVID-19 cases, more so than overcrowded living conditions or language barriers.

f. Almost 25% of the most toxic waste sites are on Indian lands and the Navajo Nation is a prime example of this.

14. (Slide #11) Share the slide from the New York Times Interactive (The Fullest Look Yet at the Racial Inequity of Coronavirus). Encourage students to explore this on their own time as it breaks down information by county level across the US (see Extensions section).

Transition to the next activity by telling students that they will further examine what contexts might be important to consider when looking at health inequity data.

**ACTIVITY 5.2: SOCRATIC SEMINAR (30 MINUTES)**

Use Teacher Resource 5.2: Discussion Notes for Seminar Readings for this activity.

15. Share with students that they will discuss the articles “How the Pandemic Defeated America” and “Why the Coronavirus is Killing African-Americans More Than Others”, and that they should try to make connections with the ideas in this lesson as well as in the lesson series overall.


16. Review Socratic Seminar Procedures and Norms

a. Remind students that the purpose of a seminar is to come to a deeper understanding of the ideas in a text through discussion together.

b. Students should look for evidence in the text when making claims about the author’s perspective. They should refer to the text by line number or page/paragraph.

17. Create a circle so students can see each other. If they do not know each other well, consider using nametents. Sit in the circle with them (if they are experienced in this format, you may also wish to stay outside the circle).
Large groups can make inside/outside circles with students inside consulting their outside partners during the seminar. Alternatively, students on the outside can take notes about what their partner and others said during the seminar.

18. **Start off by leading students through any background and fact-based questions** so everyone understands the basics.

19. **Then, move into the interpretive questions requiring students to make claims using evidence from the text.** Once you have asked a question, make sure to give ample wait time for students to respond. This may take longer than usual, but be patient. Let the conversation continue among students as long as it is productive. You may wish to redirect them to another question if they get off track.
   a. The larger questions connecting text to student experiences will yield interesting and important conversations, but tend to not be as grounded in the perspective of the text and author.
   b. Continue to ensure students stay on a **positive discussion track** and remind them of norms if necessary.

20. **Other factors for teachers to consider:**
   a. Try to not make excessive eye contact with students when they are talking to encourage them to speak to other students and not seek your validation.
   b. You may wish to take notes about who has spoken or what main ideas arise in conversation.
   c. Sample questions include, “Would anyone like to add on? Does anyone have a different view? Can someone summarize the main ideas you heard? Where do you see evidence for that in the text?”
   d. You can also invite students to share by saying, “Now I’d like to open it up for someone who hasn’t had the chance to share yet.”
   e. Be careful not to overly dominate the conversation, this is an opportunity for a message to be conveyed that students’ thoughts matter and are worthy of discussion.

21. **Always end a seminar with a few minutes of reflection about the process.** Did the seminar serve its purpose in terms of students understanding the text better? How did the group do in terms of adhering to the norms? These questions help students see the value of a seminar and also help improve the discussion in the future.

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**DAY TWO**

**ACTIVITY 5.3: CLOSURE - STRUCTURAL RACISM AND HEALTH OUTCOMES (15 MINUTES)**

These ideas are further explored in SEP’s Race, Racism, and Genetics unit.

22. **(Slide #12-21) Share the idea of the reinforcing circle of “race.”**
   a. **(Slide #12) Share the graphic organizer** of the “Reinforcing Circle” in the slide deck.
   b. **(Slide #13) Start with racism driving the “race idea.”**
      The idea of “race” was constructed in order to justify, and benefit from, the subjugation and oppression of enslaved people, indigenous people, and others. Remind students of the role that some scientists have played in reinforcing that idea.
   c. **(Slide #14) Share the quote from Ta-Nahisi Coates** in the slide deck (“race is the child of racism, not the father”) and discuss what it means relative to the idea of the “reinforcing circle” (racism driving the idea of race) as well as the idea of race being primarily created to serve hierarchical purposes.
d. (Slide #15) Note how the manifestation of racism in the idea of “race” has resulted in health inequities through behaviors, practices, and policies. This includes practices as broad as the stress of worrying about personal safety (such as from biased or racist actions from others, including police) to being exposed to more toxins because of environmental hazards being sited in areas of poverty. For more information on structural and historical factors related to the racial character of health inequities in America, see Bouie, 2020.

e. (Slide #16) Share the quote from Dr. Gravlee (from the seminar reading):

> ...If we assume that people who are racialized as “black” or “white” are fundamentally different and treat them accordingly, the paradoxical result is that it will produce the very biological differences we presumed to exist in the first place. But it’s not because of any deep-seated differences in our DNA. It’s because our social structures and attitudes promote the well-being of some and devalue others.”
> ~ Clarence Gravlee, Scientific American, 2020

f. (Slide #17) Moving around the circle, note how health researchers and providers use the category of “race” to try to analyze those disparities and inequities and how this reinforces or strengthens the idea that “race” is biologically meaningful. It also suggests that something about the “race” of individuals is the cause of the inequities. We have to take care when talking about racial categories.

g. (Slide #18) Share the quote from Dr. Fulwiley:

> Medical anthropologist Duana Fulwiley explains how the potential for racialization of medical genetics has been institutionalized because “you can’t get a grant from the NIH unless you recruit in racial groups, label people by census category, and then report back the data in terms of outcomes by racial type.” The original intent—to counter the widespread use of the white male body as the working research norm—is “fine and good,” she says, but there “ought to be some flexibility to these race categories, and some thinking about what they mean.”
> ~ Harvard Magazine, 2008

h. (Slide #19) Note that arrows can actually flow both directions in this diagram.
i. (Slide #20) Emphasize that some inequities/disparities are CORRELATED with “race” categories, but that does not mean that they are either CAUSED by them or that “race” is biologically real. It speaks to the fact that many people in a “race” category experience the world in similar ways (for example, through increased stress from discrimination and micro-aggressions) and not that the people within a particular “race” category are more genetically similar.

j. (Slide #21) Sometimes, of course, people in the same “race” category may have greater genetic similarity in particular areas of their genome IF their recent ancestors are from the same geographic area and have been exposed to the same evolutionary history and pressures. However, this is not something that can be inferred from a broad socio-political grouping such as “race”.

23. (Slide #22) Share the slide showing the Business Insider article and note that the seminar reading explored the idea that racism, not race, is the risk factor for health inequity (see Resources section).

24. (Slide #23) Show the slide that shows another article in Scientific American on the topic: “Why Racism, Not Race is a Risk Factor for Dying of COVID-19.” This article features an interview with Dr. Camara Jones (see Resources section).

25. (Slides #24-25) Share the slides that summarize the arguments in that article:

<table>
<thead>
<tr>
<th>Exposure to virus:</th>
<th>Outcomes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black, brown and indigenous people are...</td>
<td>Black, brown and indigenous people are more likely to...</td>
</tr>
<tr>
<td>• More likely to be more exposed—through frontline jobs—and less protected—through lack of appropriate personal protective equipment (PPE) protection.</td>
<td>• Have a poor outcome or die once infected.</td>
</tr>
<tr>
<td>• More often in “essential” jobs that can’t be done remotely. This is tied to residential and educational segregation, which results in limited educational and employment opportunities.</td>
<td>• Have chronic diseases which contribute to poor outcomes (Black people have 60% more diabetes and 40% more hypertension).</td>
</tr>
<tr>
<td>• Overrepresented in prisons and detention centers, and also more likely to be living in tight quarters with many family members.</td>
<td>• Have health problems due to chronic stress and trauma of racism and of living in “food deserts” and polluted areas.</td>
</tr>
<tr>
<td>• Have less access to healthcare and experience bias in medical treatment.</td>
<td>• Have less access to healthcare and experience bias in medical treatment.</td>
</tr>
</tbody>
</table>
26. (Slide #26) Share the slide that notes that COVID-19 outcomes reveal a legacy of structural discrimination. COVID-19 has just put into clearer focus the health inequities that have been present previously and that have deep historical roots.

27. (Slide #27) Share the Black Doctor Covid-19 Consortium Video (2:59 minutes, Bloomberg, May 3, 2020). This video is about a doctor (@alastanford) who organized testing in Philadelphia, where 44% of the cases are in the hardest-hit African American population.

Discussion Question:
What kinds of barriers are members of the community facing in accessing health care, as described in the video?
Possible answers include:
a. Access to testing and supplies
b. Health care providers who are empathetic
c. Lack of resources including staff and financial resources
d. Lack of infrastructure to support the kinds of efforts she is undertaking.

28. Share how important it is that community members take action, but also that the larger social and political systems support an integrated approach that doesn’t leave people behind when addressing health needs.

29. CLOSURE: Ask students to reflect how what they learned in the ethics lesson connects to health inequities.

30. Share that, in this lesson, students have seen that health inequities exist and they predominate in communities of color. These are inequities that have been present for a long time; COVID-19 has just “pulled back the curtain” to reveal them more starkly. The equitable allocation of health resources is fundamentally an issue of justice, although many other ethical issues also arise related to health inequities.

31. They have also touched on the fact that this is not due inherently to something biological about the “race” of certain groups, but rather to the ways those members of those groups have been treated over time through oppressive systems that have existed to benefit some groups at the expense of others.

32. Ask students to think about what potential solutions might be to help address some of the issues that were raised in this lesson. What can be done in their own local communities? What should be done at a larger scale in our states and country? This can be assigned as homework or can be discussed during class time (see Extensions section).
ADAPTATIONS FOR REMOTE INSTRUCTION

As an alternative to the in-person instructional procedure on the previous pages, the table below provides suggested instructional procedures adapted for remote learning settings. This lesson assumes students have computer and internet access at home.

<table>
<thead>
<tr>
<th>Learning Activity</th>
<th>Remote Instruction Procedure</th>
</tr>
</thead>
</table>
| Activity 5.1: Intro and Examining COVID-19 Data (20 min) | 0. Before the class: Upload all handouts and the slide deck(s) to your classroom learning management system.  
1. If you are able, present the slides and intro information during a synchronous class video call, following the instructions in the Procedure section. Student groups can be assigned to breakout rooms to discuss one of the figures in the slide deck. If a video call is not possible, students can be instructed to work through the slide deck on their own. You might consider creating a digital bulletin board and posting questions for students to respond to, based on what they learned from the slide deck. This can include prompting them to create a news headline and to share their observations on their assigned data figure.  
2. For the activity using Student Handout 5.1, students can write or type up a list that shows their organization of the factors and their reasoning for choosing that particular order. Another option is to organize sticky notes or slips of paper with the factor names and then take a photo of the final list. This can be submitted to the teacher for credit. The students’ lists could also be shared with each other via a digital bulletin board. The list of factors to be sorted includes: Factors Contributing to Health Inequities  
  - Access to medical care  
  - Chemical and physical exposure (toxins)  
  - Diet  
  - Genetics/biological factors  
  - Stress  
  - Physical activity  
  - Socioeconomic factors (housing, income) |
| Activity 5.2: Socratic Seminar (30 min) | 3. If you are able, hold the Socratic seminar during a synchronous class video call, either as a whole class or as small group discussions in breakout rooms. Alternatively, if asynchronous instruction is required, students could be challenged to read one of the articles and respond in writing to reflection questions. |
| Activity 5.3: Closure (20 min) | 4. If you are able, present the slides and closure discussion during a synchronous class video call, following the instructions in the Procedure section. Alternatively, if asynchronous instruction is required, consider using a screencast program to record a video of yourself presenting the slides. It is not recommended that the slide deck be assigned for students to explore on their own without facilitation from the teacher. |
Suggested Lesson Extensions

EXTENSIONS

► In addition to the readings for the seminar (Young, 2020 and Bouie, 2020), a third reading is offered as a challenge/extension activity. This one has a more difficult reading level: Chowkwanyun, M., and Reed, A., “Racial Health Disparities and COVID-19 - Caution and Context,” NEJM, 2020.

► See SEP’s resources from the unit Race, Racism, and Genetics for a general lesson on health inequities and another option for a seminar.


► Have students explore some of the additional resources listed below, particularly the TED talks by Dr. Roberts and Dr. Williams.

► The Bill & Melinda Gates Discovery Center offers free virtual programs for middle and high school classes focused on COVID. The COVID-19 in Context program uses writing and drawing to help students reflect on the impacts of the pandemic on their own lives and their communities. The Science of COVID-19: Part I Virus/Testing and Part II Vaccine/Therapeutics could also extend students’ learning.

OPPORTUNITIES FOR PRODUCTIVE UNCERTAINTY

Students have opportunities to make claims and support their claims with evidence (either data or text evidence) and reasoning.

OPPORTUNITIES FOR PERSONAL CONNECTIONS TO STUDENTS

This may be a very personal topic for students. COVID-19 is impacting all of us, and some people bear additional burdens and losses due to the pandemic. Students should be able to share how the pandemic is impacting them and their loved ones, but also be permitted to refrain from participating in discussions that are too personal or uncomfortable for them.

CAREER CONNECTIONS

Career connections are not explicitly called out in the activities in this unit, however there are many careers related to COVID testing that teachers may wish to highlight. The career connection for Lesson 5 includes:

Health Outcomes Researcher: A health outcomes researcher is typically a professor, clinician (e.g., physician, pharmacist), staff scientist, or research fellow with an interest in health outcomes and/or health inequities. They may have expertise in a wide variety of disciplines, including public health or economics, or a specific area of medicine, such as medical oncology, pulmonary medicine, critical care medicine, or pediatrics. Health Outcomes Researchers investigate a variety of questions including looking for patterns in the way that people are screened, diagnosed, or treated for diseases. They may look at patients’ access and barriers to treatment and care, patients’ experiences and outcomes, and financial impacts related to the cost and quality of care. In particular, Health Outcomes Researchers are interested in health inequities in patients’ experiences and outcomes.

Additional careers are featured on the STEM Global - Pathways to Global Health Careers poster and accompanying fact sheets. Read more about each job by exploring these resources.
Notes on Adaptations and Inclusivity

SUPPORTING COMMUNITIES DURING THE COVID-19 PANDEMIC

► The Fred Hutch Office of Community Outreach and Engagement (OCOE) has started a PPE Supply Drive in collaboration with University of Washington’s Seven Directions, and the Indigenous Wellness Research Institute to support health care facilities and programs of Indigenous Communities here in Washington state. You can purchase and send items to OCEO directly through their Amazon Wish List. Items will be reviewed and updated. Items can be shipped directly to OCEO offices. If you have items that you would like to donate via shipping, please email OCEO at enddisparities@fredhutch.org for the mailing address.

► For other communities in need, the Urban League of Metropolitan Seattle is also providing great resources for underserved communities of color, as well as a list of emergency services for those who have been impacted by the COVID-19 pandemic.

► In addition, the City of Seattle has compiled “COVID-19 Resources for Community.” This page contains information and web links for the City of Seattle, King County, Washington State, federal, and community programs and services that help residents significantly impacted by the COVID-19 pandemic. Some of these programs and services are available to everyone regardless of where they live. All Seattle residents regardless of immigration status are eligible for City of Seattle programs and services unless noted otherwise. Keep checking back because that page will be continually updated as more resources develop.

SCIENTIFIC VOCABULARY

Students may need some support in understanding the terminology embedded within this lesson. This may be particularly true for emerging bilingual students and students with lower reading levels. Terms should be defined contextually as the lesson unfolds. The following list captures some of the terms used in the lesson materials.

- **COVID-19**: The respiratory disease caused by the SARS-CoV-2 virus.
- **Health Inequities**: “Systematic differences in the health status of different population groups. These inequities have significant social and economic costs both to individuals and societies” (Definition by WHO, 2018).
- **Health Outcomes**: The results of the health care interventions or resources received by a patient.
- **Pandemic**: An outbreak of a disease that is prevalent over multiple countries or continents across the world.
- **Race**: “A socially constructed taxonomy based on perceived skin color (and sometimes culture), with no scientific or biological determinacy. Used as a tool to allocate resources.” (Definition by Edwin Lindo, 2019, presentation at Fred Hutchinson Cancer Research Center).
- **Racism**: “A system of structuring opportunity and assigning value based on the social interpretation of how one looks (which is what we call ‘race’).” (Definition by Dr. Camara Jones).
Additional Information & Resources

COVID-19 INEQUITY RESOURCES

► Gravlee, C., *Racism, not genetics, explains why Black Americans are dying of COVID-19*, *Scientific American*, June 2020 (link to full article).
► CDC COVID Data Tracker (Accessed 03/2021).
► COVID in Black YouTube series from the COVID 19 Prevention Network at Fred Hutch. This series features honest conversations/discussions about the disproportionate impacts of COVID-19 on the Black community.

Indigenous Communities:

► Hosea, L., *They say wash your hands but the nearest water source is 25 miles away*: America’s hidden virus victims, *The Telegraph*, July 2020.
► Dooley, S. (Traditional Dine’ storyteller/elder): *Coronavirus is attacking the Navajo because we have built the perfect human for it to invade*, *Scientific American*, 2020 (Accessed 8/12/20).

General Health Inequity Resources

ARTICLES

► How Racism Impacts Health: *Racism has a toxic effect*, *Science Daily*, 2019.
► Moral Determinants of Health: *The Moral Determinants of Health*, *Journal of the American Medical Association* (JAMA), 2020. A Doctor calls for thinking about not just the “social determinants” of health but the moral ones as well. A strong connection to the earlier ethics lesson.
► Racism as a Root of Health Inequities: *On racism: A new standard for publishing on racial health inequities*, *Health Affairs Blog*, 2020. Very aligned with the ideas in this lesson. Oriented to public health and medical researchers. Also a good resource for teachers.
► Review of Research into Racism and Health: *Racism and Health: Evidence and Needed Research*, *Annual Review of Public Health*, 2019. Outstanding review of research into ways in which racism can adversely affect health. Dr. Williams (see video below) is the primary author.

* These resources are more challenging in terms of reading level.

VIDEOS/TED TALKS

► Camara Jones: The Cliff of Good Health. Dr. Jones uses an analogy of a “cliff of good health” to illustrate the importance of social determinants of health and equity (5:18 minutes).
► Dorothy Roberts: The Problem with Race-Based Medicine. Dr. Roberts discusses the idea of social identity vs. ancestry, how science has reinforced ideas of race and contributed to oppression, and how race is a “bad proxy” for biology (14:28 minutes).
► David Williams: How Racism Makes Us Sick. Dr. Williams developed a tool to measure racism/discrimination and mapped that against health. He discusses how other factors, such as racial segregation in housing, impact health. He also shares some stories of health programs that have been successful in combating racism (17:20 minutes).
## Factors Contributing to Health Inequities

**Teacher Resource**

Distribute cut-outs (1 set of strips per group) and have students organize them in order:

a. Sort the strips into order from what elements you think are most responsible to what you think is least responsible for the disparities you observed in the data.

b. Which factors do you think are most important? Less important? Which factors are under an individual's control? Which are less so?

<table>
<thead>
<tr>
<th>Access to Medical Care</th>
<th>Access to Medical Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical and Physical Exposure (toxins)</td>
<td>Chemical and Physical Exposure (toxins)</td>
</tr>
<tr>
<td>Diet</td>
<td>Diet</td>
</tr>
<tr>
<td>Genetics/Biological Factors</td>
<td>Genetics/Biological Factors</td>
</tr>
<tr>
<td>Stress</td>
<td>Stress</td>
</tr>
<tr>
<td>Physical Activity</td>
<td>Physical Activity</td>
</tr>
<tr>
<td>Socioeconomic Factors (housing, income)</td>
<td>Socioeconomic Factors (housing, income)</td>
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<thead>
<tr>
<th>Access to Medical Care</th>
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<td>Chemical and Physical Exposure (toxins)</td>
<td>Chemical and Physical Exposure (toxins)</td>
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<td>Diet</td>
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<td>Physical Activity</td>
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<td>Socioeconomic Factors (housing, income)</td>
<td>Socioeconomic Factors (housing, income)</td>
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Discussion Notes for Seminar Readings
Teacher Resource

Reading 1: How the Pandemic Defeated America
(Yong, 9/2020, The Atlantic)

TEACHER FACILITATION QUESTIONS

Comprehension Questions requiring evidence from the text:

► Q: What groups, according to the author, have been particularly hard hit by the pandemic?
- Elderly, women, people with dementia/disabilities, Latinos, (lines 8-19) Black people, Native Americans (lines 63-68).
Asian Americans also have faced racist abuse (line 17).

► Q: What, according to the author, are some ways states have hampered access of Black people to adequate medical care since the Civil War?
- Building hospitals away from Black communities; segregating Black patients in separate hospital wings; blocking Black students from attending medical schools; creating a system of private, employer-based medical insurance; Medicare, Medicaid, and ACA (lines 25-31); low investments in public health and low quality of medical care in former slave states (lines 32-34).

► Q: What are some factors that have made combatting the pandemic challenging for the Navajo Nation?
- Inability to regularly wash hands due to lack of water, as water may be unavailable or contaminated. They may live in crowded multi-generational homes, and live far from hospitals. Thus, these types of factors have accounted for higher rates of members of the Navajo Nation than in any U.S. state (lines 63-68).

Interpretive Questions requiring evidence from the text:

► Q: What examples does the author provide of both systemic and personally-mediated racism in health care?
- When Black people go to hospitals: Black mothers die at higher rates during pregnancy; Black people are less likely to be treated at hospitals or more likely to receive lower quality care (lines 41-44).
- Black people may be hesitant to seek aid for COVID-19 symptoms and end up at the hospital in sicker states (lines 44-46).

► Q: How does the author connect policies and economic factors with health-related ones?
- Black people were left with less income and higher unemployment during the pandemic. They were more likely to work as low-paid “essential workers” without the less risky option of teleworking. Hourly paying jobs didn’t provide sick leave. Risky commutes on crowded public transportation (lines 51-59).

► Q: What does the author mean by “existing inequities stack the odds in favor of the virus” (line 62)?
- “There's nothing about Blackness that makes you more prone to COVID” but “existing inequities stack the odds in favor of the virus” (line 59-62). This means that though there is no genetic basis for Black as a race, systemic racism and bias in society, including in health care, jobs, and government policies left Black people more vulnerable to getting exposed to the virus and less likely to get high quality health care to treat infection.

► Q: The author quotes Nicollette Louissaint, the executive director of a health-related nonprofit, as saying “There’s nothing about Blackness that makes you more prone to COVID” (lines 59/60). What do you think she is trying to say? Does the author agree with her? What other parts of the essay back up your claims?
- “There's nothing about Blackness that makes you more prone to COVID” but “existing inequities stack the odds in favor of the virus” (line 59-62). This means that though there is no genetic basis for Black as a race, systemic racism and bias in society, including in health care, jobs, and government policies left Black people more vulnerable to getting exposed to the virus and less likely to get high quality health care to treat infection. It seems that the author agrees with Louissaint, as the author builds the case that social, economic, and government policies left Black people more vulnerable to infection, severe disease, and death. See lines 51-62).
Q: The author notes that “Americans often misperceive historical inequities as personal failures” (line 69). What do you think he means by that?
- Government officials have made public statements that erroneously places the blame for these higher rates of infection and poorer health outcomes for people from certain groups as something caused by an individual’s behavior (like not washing their hands frequently or having chronic underlying diseases) rather than looking at the underlying systemic factors and patterns (lines 69-75).

Q: What do you think is the main point the author is trying to make? Or, what is the most important point the author makes?
- Answers may vary, in general the theme is the connection between historical and deeply-rooted systems of racial inequity and the current health of Black Americans - probe for specific examples in the text.

Q: What do you think is the most important sentence in the article in terms of understanding the author’s argument? Why?
- Answers may vary.

Larger Questions connecting the text to student perspectives and experiences:
Use either bullet points or numbered questions for analyzing the seminar articles.

- What was the main take-away for you?
- What other factors could be contributing to racial health inequity?
  - Possible answers include toxic stress from enduring racism, food deserts, living near toxic sites
- (If students have studied bioethics) Did this article connect to any ethical principles and ideas?
- Do you agree/disagree with the author? Explain your position.
- Did this information change any of your thinking?

---

Reading 2: Why Coronavirus is Killing African-Americans More Than Others
(Bouie, 4/14/2020, New York Times)

TEACHER FACILITATION QUESTIONS

Background Vocabulary:

- (Line 24) **Comorbidities**: Diseases or conditions that coexist in one person at the same time.
- (Line 30) **Ex nihilo**: “Out of nothing” (Latin).
- (Line 38) **Sharecropping**: System where landlord/planter allows tenants to live on land in exchange for a share of the crop. A system that exploited former slaves after the Civil War.
- (Line 83) **Agrarian**: Related to farmers/rural communities.

Comprehension Questions requiring evidence from the text:

- Q: Does the author believe that individual behavior or social systems are more responsible for COVID-related disparities?
  - In truth, black susceptibility to infection and death...has everything to do with the racial character of inequality in the US (lines 13/14).

- Q: The author acknowledges that white workers may have had difficult lives, but that black workers faced additional challenges. What kinds of challenges does the author describe?
  - Many listed in lines 51-55 including denial of political rights, social exclusion, state-sanctioned violence, being restricted to substandard housing/neighborhoods, exclusion from unions/guilds and professions.
Q: What, according to the author, did New Deal policies do to racial inequalities?
- They deepened disparities by excluding the occupation that African-Americans worked in and by institutionalizing racist practices for the administration of those policies (lines 65-71).

Q: In the post-WWII boom, what other kinds of policies helped deepen inequity?
- Opportunities for state-subsidized education (GI Bill), low-interest home loans and continuing segregation of cities benefitted whites. The author notes that working class ethnic Europeans became a middle class of ‘whites’ (lines 75-77).

Interpretive Questions requiring evidence from the text:

Q: What do you think is the main point the author is trying to make? Or, what is the most important point the author makes?
- Answers may vary, in general the theme is the connection between historical and deeply-rooted systems of racial inequity and the current health of Black Americans - probe for specific examples in the text.

Q: What do you think is the most important sentence in the article in terms of understanding the author’s argument? Why?
- Answers may vary.

Q: How does the author connect what is happening with the pandemic to past events?
- One example: Wealth disparities and concentration in service-sector jobs are connected to a history of racially segmented labor markets and housing discrimination (lines 20-26).

Q: What does the author mean that “racialized inequality isn’t a mistake - it isn’t a flaw in the system?” (lines 26/27)
- The author believes that the system of American capitalism maintained racial hierarchy after the Civil War (line 33). He asserts that the system is designed to perpetuate racialized inequality (lines 27/28). As it developed, “industrial capitalism retained a caste system with whites as the dominant social group” (lines 43/44).

Q: What does the author mean when he notes that the “mass of white workers may have been attached to a ‘psychological wage’ of racial entitlement, but it’s also true that racially divided labor suited the owners of capital, who took advantage of racism when it suited their interests” (lines 80-83).
- White workers could feel superior to Black workers even if their own conditions were not very good - and such divisions could be useful if they helped create more money for those who controlled jobs and the means of production.

Q: What does the author mean by “Race...still answers the question of who”? (line 96)
- Race is still a determining factor in where someone will live, what kinds of environmental exposures they might suffer.

Larger Questions connecting the text to student perspectives and experiences:
Use either bullet points or numbered questions for analyzing the seminar articles.

What was the main take-away for you?

What other factors could be contributing to racial health inequity?
- (Possible answers include toxic stress from enduring racism, differential access to health care, past medical abuses contributing to a fear of doctors/hospitals).

(If students have studied bioethics) Did this article connect to any ethical principles and ideas?

Do you agree/disagree with the author? Explain your position.

Did this information change any of your thinking?
LESSON 6

Nextstrain Overview
COVID-19 Tracking and Genomic Data

Overview: Students will explore COVID-19 genomic data using the Nextstrain tool to analyze the viral evolution as well as spread of SARS-CoV-2.

Unit Progression

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<td>Antibody Testing</td>
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<td>Bioethics and COVID-19</td>
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<td>Health Inequities and COVID-19</td>
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<td>6</td>
<td>Nextstrain Overview</td>
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<tr>
<td>7</td>
<td>Policies and the Nature of Science (Coming Soon!)</td>
</tr>
</tbody>
</table>

Remote Learning Adaptations
Suggestions for adapting the activities for remote teaching and learning settings are included at the end of the lesson here.
Essential Question:
How has the virus spread and how has it changed during that spread?

Student Understandings

WHAT STUDENTS FIGURE OUT
► Genomic data like that available through Nextstrain can be used to understand complex behaviors of viruses and outbreaks.
► Bioinformatics can help us make sense of big data sets.

WHAT STUDENTS WILL DO
► Learn about bioinformatics and viral evolution tracking.
► Explore Nextstrain to answer some questions about the current pandemic.

PREVIOUS KNOWLEDGE
No special knowledge required.

Next Generation Science Standards

This lesson builds toward the following Nature of Science - Crosscutting Concepts standards from the NRC Framework and Next Generation Science Standards. Note that connections to the Biological Evolution Performance Expectations can be strengthened through deeper exploration of Nextstrain and study of viral mutations and evolution.

PERFORMANCE EXPECTATIONS

HS-LS1-1: From Molecules to Organisms: Structures and Processes. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.

HS-LS4-2: Biological Evolution: Unity and Diversity. Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

HS-LS4-3: Biological Evolution: Unity and Diversity. Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.

HS-LS4-4: Biological Evolution: Unity and Diversity. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

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STUDENT ASSESSMENT OPPORTUNITIES

► In-class observations and questions/wonderings from the Nextstrain animation.
► Students’ responses to questions on the student handout.

Teacher Preparation

1. Make copies of the student handout, or upload it and the slide deck to your classroom learning management system. Each student group will need one copy of the handout.
2. This is a computational lab. Each student group should have one computer that is able to access Nextstrain.org.

<table>
<thead>
<tr>
<th>Print &amp; Digital Materials</th>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesson 6 Intro to Nextstrain Slide Deck (Teacher)</td>
<td>Information on navigating Nextstrain as well as some guiding questions for student exploration.</td>
<td>N/A</td>
</tr>
<tr>
<td>Student Handout 6.1: Exploring Nextstrain</td>
<td>Student worksheet with guiding questions. Students can paste in screen shots or main takeaways from their exploration.</td>
<td>1/student group</td>
</tr>
</tbody>
</table>

Lesson 6: Intro to Nextstrain Slide Deck
Download Slide Deck

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Instructional Procedure

OVERVIEW

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<tr>
<th>Day of Instruction</th>
<th>Activity</th>
<th>Description</th>
<th>Approx. Time</th>
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<tr>
<td>Day One</td>
<td>Activity 6.1</td>
<td>Examining COVID-19 Data with Nextstrain</td>
<td>50 min</td>
</tr>
<tr>
<td>Day Two</td>
<td>Optional Extension - Activity 6.2</td>
<td>Answer a Question Using Nextstrain</td>
<td>20–30 min</td>
</tr>
</tbody>
</table>

1 DAY ONE

ACTIVITY 6.1: EXAMINING COVID-19 DATA WITH NEXTSTRAIN (50 MINUTES)

1. (Slide #3) Ask your students “What are viral mutations and why are they important?” Have students discuss this question with a partner and ask some pairs to share out.

   Discussion Question: What are viral mutations and why are they important?

2. (Slide #4) Show students the *New York Times* image of the SARS-CoV-2 coronavirus (the virus that causes the disease COVID-19). Point out the different viral parts and highlight how those parts are coded in different sections of the viral genome.

3. (Slide #5) Show students the next image that highlights the different mutations of the coronavirus. Emphasize how mutations in different areas of the genome affect the structure and/or function of the virus. Some of these mutations can give the virus an advantage.

   a. (Slide #6) For example, the *N501Y mutation* helps the virus latch on more tightly to human cells, and the *p681H mutation* may help infected cells create new spike proteins more efficiently. These are both mutations to the spike protein.

4. (Slide #7) RNA viruses have high mutation rates that can result in several different versions of the viral genome when the virus replicates. This creates a population of viruses with diverse genomes, known as quasispecies. The SARS-CoV-2 virus that causes COVID-19 is also mutating over time. Advantageous mutations allow certain viral genomes to spread more effectively. These different forms of the SARS-CoV-2 virus contain...
only a few genetic differences and are often referred to as different COVID strains, or more scientifically, as variants or clades.

5. **(Slide #8)** The Bedford Lab at Fred Hutch works to understand how viruses like SARS-CoV-2 mutate over time. Using computational tools and statistics, the Bedford team analyzes big data sets to forecast changes and monitor the expansion of different variants. One of the projects at the Bedford lab is called Nextstrain.

6. **(Slides #9-12)** The next few slides contain background information on Nextstrain. Importantly, Nextstrain utilizes phylogenetic trees to visualize viral data.

7. **(Slides #13-16)** Ask your students what they know about phylogenetic trees.
   a. Explain to them that viruses mutate rapidly and these mutations can be used to track the lineages of specific strains of virus.
   b. This information can be used to track the evolution of the virus as well as the movement.

8. **(Slide #17)** The data used for Nextstrain is composed of publicly shared SARS-CoV-2 genomes. Each point on Nextstrain represents one COVID patient’s SARS-CoV-2 viral sequence. Not all COVID positive patients have their viral genome sequenced. Actually, only a very small fraction of positive cases are sequenced. Sequencing can be a costly process that requires specialized labs. Sequencing a random sampling of infections and sharing that data (in a confidential but openly shared way), allows researchers like those in the Bedford Lab to track the progression of the pandemic.

9. **(Slides #18-22)** Have students use their computers to go to the Nextstrain website and help them navigate to the Latest Global SARS-CoV-2 analysis. Follow the directions on the slides. You should see something like this:
10. (Slide #23) Show students the three main data visualizations that Nextstrain offers: phylogenetic trees, maps, and genomic diversity.

a. **Phylogenetic trees**
   i. Nextstrain uses genomic sequencing to track the evolution of viruses.
   ii. As viruses mutate, they accumulate different mutations that allow them to be tracked and traced to create these phylogenetic trees.

b. **Map**
   i. Using the sequenced genomes, you can also track the movement of the virus over a geographical space. You can change the scope that you are looking at to specific countries or globally.
   ii. These viral mutations are logged as well as the location the sample was taken to be able to extrapolate the movement of a specific strain of virus across the globe.
   iii. Show students an example by pressing play to see the phylogenetic tree and the map move.
   iv. The colors of the dots and lines are represented by the country of origin for that strain.

c. **Diversity**
   i. At the bottom there is also a diagram of the viral genome and the diversity that has been found in their samples.
   ii. This data can be viewed to show diversity at the nucleotide or amino acid level.
   iii. You can look at this section by entropy or events. Entropy shows the amount of uncertainty inherent in the nucleotides of that position while events show the count of the nucleotide or codon position.

11. (Slides #24-27) **Watch and observe**: Have students follow the directions on the Watch and Observe slide. This will allow students to watch an animation of the pandemic from a phylogenetic and geographic perspective. Students should record any observations or questions they have about the animation.

   a. Students should be able to see the legend for the different colors in the corner of the map.
12. **(Slides #28-36) Navigating the data:** Show students the different parts of Nextstrain. Explain the different parts including Diversity (Slides #34-35) and Frequencies (Slide #36).

13. **(Slide #37) Using the data:** With their group or partner, have students think of 2-3 questions that Nextstrain might help answer. Have students share their questions with the class.

14. **Have students work through the guiding questions on** Student Handout 6.1: Exploring Nextstrain.

15. **Bring the class back together to discuss answers.**

---

**DAY TWO**

**ACTIVITY 6.2: ANSWER A QUESTION USING NEXTSTRAIN (20–30 MINUTES)**

16. **Optional extension:** If time allows, have students select one of their questions to answer. Allow time for students to explore Nextrain in order to find the answer(s) to their question(s).

17. **Students must provide a screenshot** to explain their conclusion.

18. **Have students write out their answer and the evidence they used** to obtain that answer and turn it in or share with the class.

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Students could be asked to create a slide in a shared slide deck for the class in order to share their responses. Alternatively, these questions and answers could be shared in a “gallery walk”.

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ADAPTATIONS FOR REMOTE INSTRUCTION

As an alternative to the in-person instructional procedure on the previous pages, the table below provides suggested instructional procedures adapted for remote learning settings. This lesson assumes students have computer and internet access at home.

<table>
<thead>
<tr>
<th>Learning Activity</th>
<th>Remote Instruction Procedure</th>
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</table>
| Activity 6.1: Examining COVID-19 Data with Nextstrain (50 min) | 0. **Before the class:** Upload the handout and the slide deck to your classroom learning management system.  
1. **If you are able, present the slides and intro information during a synchronous class video call,** following the instructions in the Procedure section. Go through multiple examples with Nexstrain so that students will feel comfortable working on the handout on their own, if needed. Student groups can be assigned to breakout rooms to work on the activity together. If a video call is not possible, use a screencast program to create a screen recording of yourself going over the slides with multiple demonstrations on Nextstrain. If that isn’t possible, students can be instructed to work through the slide deck on their own.  
2. **You might consider creating a digital bulletin board and posting questions for students to respond to,** based on what they learned from the slide deck.  
3. **Students should complete** [Student Handout 6.1: Exploring Nextstrain](#) **and submit it to the teacher for credit.** |
| Activity 6.2: Answer a Question Using Nextstrain (20–30 min) | 4. **This optional activity could be completed asynchronously,** having students work independently from home rather than in groups.  
5. **Provide a platform for students to share their questions and answers with each other,** either during a live class video call or asynchronously. You might consider using a shared slide deck, digital bulletin board, Flipgrid, or other mode for sharing. |
Suggested Lesson Extensions

EXTENSIONS
Students who need an extra challenge can engage in the optional Activity 6.2 or explore the Additional Nextstrain & COVID-19 Resources (see below).

OPPORTUNITIES FOR PRODUCTIVE UNCERTAINTY
Students can develop questions that they think can be answered using Nextstrain. As an extension activity, students can use Nextstrain to answer one of the questions they came up with and give supporting evidence.

OPPORTUNITIES FOR PERSONAL CONNECTIONS TO STUDENTS
This may be a very personal topic for students. Students may know someone who has had COVID-19, and may even know if the person had a particular genetic strain, like the Delta variant that is the primary strain circulating in the U.S. in 2021.

CAREER CONNECTIONS
Dr. Trevor Bedford, who is highlighted in this lesson, is a computational virologist (a speciality within computational biology) who works in the Vaccine and Infectious Disease Division at Fred Hutchinson Cancer Research Center. Teachers may wish to highlight careers related to this lesson. The career connections for Lesson 6 include:

- **Data Scientist:** A data scientist applies deep expertise in statistics, mathematics, and computer science (e.g., machine learning, programming, database systems, software engineering) to collect, analyze, and/or interpret large data sets. They may design computer programs that model, analyze, or visualize data. Can also be called a data technician or information research scientist. Entry level jobs may only require a bachelor’s degree, but more advanced positions will require a Master of Science in Data Science. Data scientists may work at universities, research institutions, or private companies (e.g., biotech, pharmaceutical, etc.).

- **Computational Biologist:** Professionals with strong backgrounds in computer science, biology, and/or bioinformatics who work in the fields of biological or biomedical research. Computational biologists use computational thinking and tools to understand scientific phenomena and problems. They are also called bioinformatics scientists. Computational biologists may work at universities, research institutions, or private companies (e.g., biotech, pharmaceutical, etc.). Additional careers are featured on the STEM Global - Pathways to Global Health Careers poster and accompanying fact sheets. Read more about each job by exploring these resources.

Additional Information & Resources

REFERENCES

ADDITIONAL NEXTSTRAIN & COVID-19 RESOURCES
- Global Health: Tracking a Pandemic, Fred Hutch
- COVID-19 Research Information, Fred Hutch
- COVID-19 Timeline, Fred Hutch
- Bedford Lab at Fred Hutch
- Dr. Trevor Bedford @trvrb and #COVID19pandemic on Twitter
- MacArthur Foundation: Trevor Bedford (Award Class of 2021)
ADDITIONAL TEACHER RESOURCES ABOUT COMPUTATIONAL THINKING

- **Practice Brief #56**: Engaging Students in Computational Thinking During Science Investigations (STEM Teaching Tools, 2019)
- **Practice Brief #2**: Why Should Students Investigate Contemporary Science Topics—and Not Just “Settled” Science? (STEM Teaching Tools)
- **NGSS Science and Engineering Practices: Using Mathematics and Computational Thinking** (NGSS@NSTA)
- **NGSS Appendix F**: Science and Engineering Practices in the NGSS (see Practice 5).

Notes on Adaptations and Inclusivity

- Consider how to thoughtfully group students so those who have more computational/data experience may work with those who have less expertise.
- The Nextstrain website’s Help section may be helpful for students who need additional background. See the About section in particular.

SCIENTIFIC VOCABULARY

Students may need some support in understanding the terminology embedded within this lesson. This may be particularly true for emerging bilingual students and students with lower reading levels. Terms should be defined contextually as the lesson unfolds. The following list captures some of the terms used in the lesson materials.

- **Clades**: Advantageous mutations allow certain viral genomes to spread more effectively. These different forms of the SARS-CoV-2 virus contain only a few genetic differences and are often referred to as different COVID strains, or more scientifically variants or clades.
- **COVID-19**: The respiratory disease caused by the SARS-CoV-2 virus.
- **Entropy**: (Nextstrain diversity panel) Measuring the “uncertainty” inherent in the possible nucleotides or codons at a given position.
- **Events**: (Nextstrain diversity panel) Represents a count of changes in the nucleotide or codon at that position across the (displayed) (sub-)tree.
- **Mutation**: A change in the genome of an organism or virus. For SARS-CoV-2, mutations in different areas of the genome affect the structure and/or function of the virus.

- **Pandemic**: An outbreak of a disease that is prevalent over multiple countries or continents across the world.
- **Pathogen**: A virus, bacterium, or other microorganism that is capable of causing disease. The SARS-CoV-2 virus is a pathogen that can cause the disease COVID-19.
- **Phylogenetic Tree**: (Phylogeny) A diagram that represents evolutionary relationships. It shows lines of evolutionary descent of species, organisms, viruses, or genes from a common ancestor.
- **SARS-CoV-2**: The virus that causes COVID-19.
- **Variants**: Advantageous mutations allow certain viral genomes to spread more effectively. These different forms of the SARS-CoV-2 virus contain only a few genetic differences and are often referred to as different COVID strains, or more scientifically, as variants or clades.
- **Viral Genome**: The complete set of genetic material present in a virus. The viral genome can be quite diverse and can include DNA (single-stranded or double-stranded) or RNA (single-stranded or double-stranded).
- **Virus**: An infective agent that infects cells, replicates, and may cause disease.
Exploring Nextstrain

1. What are the 3 types of data visualizations that are available on Nextstrain and what do they show?

<table>
<thead>
<tr>
<th>DATA VISUALIZATION</th>
<th>WHAT IT SHOWS</th>
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2. Use the information from your notes to fill in the following chart.

<table>
<thead>
<tr>
<th>TERM</th>
<th>DEFINITION/FACTS</th>
<th>DRAWING OR SKETCH (OPTIONAL)</th>
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<tbody>
<tr>
<td>Genomic Data</td>
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<tr>
<td>Phylogeny</td>
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<tr>
<td>Entropy</td>
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</table>
EXPLORATION QUESTIONS

Using Nextstrain, work to answer these questions below. Take a screenshot of what you found or explain it in your own words.

3. How many SARS-CoV-2 genome samples are in Nextstrain?

4. Approximately how large is the SARS-CoV-2 genome?

5. a. What site has the highest entropy in the spike protein?

b. How many separate times across the phylogenetic tree has it mutated?

6. If you were to choose a section of the SARS-CoV-2 genome to look for in diagnostic testing (like the test you performed earlier), what part of the genome would you choose and why?
LESSON 7

Policies and the Nature of Science

Overview: Students will analyze the evolving recommendations around COVID-19 guidelines, think critically about how the types of news reporting can influence an individual's level of precaution taken during the pandemic, and realize how different pieces of information can vary from source to source, impacting the public's understanding of COVID-19 guidelines.

Unit Progression

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</tbody>
</table>
Diagnostic Detective: HIV ELISA

FRED HUTCHINSON CANCER RESEARCH CENTER’S SCIENCE EDUCATION PARTNERSHIP

Time:
Approx. 6 50-minute class periods

Subject & Grade Level(s):
High School Biology, Grades 9-10

Brief Overview: In this short unit, students investigate the importance of HIV testing and how scientists have designed tests that utilize natural immune proteins called antibodies. Students develop questions around why it is that 25% of people infected with HIV do not know they are infected. Students investigate the societal pressures that inform these decisions. Students can also challenge their own assumptions about HIV. Through learning about HIV and HIV testing, students develop an understanding of the immune system and protein structure and function, as well as developing the scientific practice of planning out an investigation.

www.fredhutch.org
Lesson Structure

This mini-unit includes an antibody modeling activity and an ELISA lab activity. In the Antibody Modeling Activity, students use chenille stems and beads to show how structure and function relates to the variability and specificity of antibodies. The concept of antibodies is an important piece in understanding how doctors test for HIV infection and how the body’s immune system is made up of specialized proteins for protecting the body.

In the next activity, a scenario is presented in which four patients need to be tested for HIV. Background information for each patient reveals different potential exposure risks. This provides a great opportunity for discussion about common misconceptions around HIV transmission. ELISA, Enzyme-Linked Immunosorbent Assay, is a method of testing for infection by identifying the presence of antigens or antibodies in a person’s blood serum. For the HIV rapid-test, a paper form of ELISA is used to identify if HIV-antibodies are present as evidence of the body responding to infection. In this simulation, the ELISA is performed on a well-plate or well strips. Each component is added separately to reinforce the specificity of antibodies and their usefulness in diagnostic biotechnology. An alternate version of this lab that requires less reagents is available that uses pH; this adaption may be better suited for middle school students.

Student Understandings

WHAT STUDENTS FIGURE OUT

By the end of the unit, students develop ideas about the physiology of multicellular organisms and the complexity of solving real world issues including:

- Multicellular organisms have an immune system consisting of specialized cells and proteins.
- How to plan an investigation and construct explanations and solutions based on evidence.
- Use models to understand the structure and function relationship in proteins.
- Understand how science is an important part in designing solutions to real world issues.

ANCHORING PHENOMENON

HIV, the virus that can cause AIDS (acquired immunodeficiency syndrome) if left untreated, is one of the world’s most serious public health challenges. Since the beginning of the AIDS epidemic, more than 70 million people have been infected and about 35 million have died due to HIV/AIDS. While the number of new infections is steadily decreasing, approximately 37 million people are still living with HIV. Lina’s story, as told through a short video from the World Health Organization, provides a personal look at the impacts of an HIV positive diagnosis. Lina is a woman who lives in Malaysia who learns that her ill husband has been diagnosed with HIV and tuberculosis, only to learn that she and her child were also HIV positive. Using the following graph, students generate questions about HIV.

Remote Learning Adaptations

Adaptations for remote instruction are included, including a self-guided Google Site, a variety of options for creating antibody models, and an online animated simulation of the ELISA lab protocol.
Driving Question:
25% of people living with HIV do not know they are infected. Why?

WHAT WE FIGURE OUT

In 2017, it’s estimated that 25% (over 9 million people) of people living with HIV are unaware of their HIV status. The development of quick and effective HIV tests has saved countless lives through treatment and by preventing further spread of the virus.

HIV infects immune cells called T cells in the body. It spreads through contact with bodily fluids like blood that contains those infected T cells. Although HIV can affect anyone, some groups are at higher risk of infection. The four main routes of HIV transmission today are unprotected sex, sharing IV drug needles, mother to child transmission and infected blood transfusions or other medical procedures. People who engage in behaviors that involve these routes of exposure are often considered high risk. Among them the largest percentage of cases are made up of men who engage in sex with other men, followed by people who inject drugs, children born to HIV positive mothers, and sexual partners of HIV positive people.

These populations are known as key affected populations and are communities in which a lot of HIV work is occurring. Seattle is home to the HIV Vaccine Trials Network located at the Fred Hutchinson Cancer Research Center where they conduct research surrounding preventing and curing HIV. Some of the most promising work has been in HIV vaccine development as well as other prevention methods. (More information on the HIV Vaccine Trials Network and current research can be found in the Teacher Resources section).

There are a variety of HIV tests used to detect the virus at different stages of infection. The most rapid and easily accessible uses the body’s natural immune response as a detection tool. These tests check for HIV antibodies in blood. These antibodies are disease fighting proteins naturally produced by the body to identify and help remove foreign objects like bacteria and viruses. Their specific shape helps them to recognize many different antigens that cause immune responses. An Enzyme-Linked Immunosorbent Assay (ELISA) is a laboratory test that uses scientifically designed antibodies to detect if a particular substance, such as a viral antigen, is present in a patient’s blood sample.
Next Generation Science Standards

The activities in this unit build toward the following bundle of Performance Expectations from the NRC Framework and Next Generation Science Standards. Dimensions of learning not explicitly covered in these materials are indicated by strike-through text. Additional dimensions of learning featured in this unit but not integrated into the target Performance Expectations are indicated with an asterisk.

TARGET PERFORMANCE EXPECTATIONS

**HS-LS1-2:** Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

**HS-ETS1-3:** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

SUPPORTING PERFORMANCE EXPECTATION

**HS-LS1-6:** Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.
# Teacher Preparation

<table>
<thead>
<tr>
<th>Materials</th>
<th>Description</th>
</tr>
</thead>
</table>
| Handouts, Teacher Resources, and Slide Decks | - Teacher Resource 1: Barriers to HIV Care  
- Student Handout 1: Barriers to HIV Care  
- ELISA Slide Deck |
| Antibody Modeling Activity (chenille stems) | - Student Handout 2: Modeling Antibody Variety Specificity  
- 64 chenille stems of the same color (per class of 32 students)  
- 32 chenille stems of a second color (per class)  
- 32 “sparkle” chenille stems of a third color (per class)  
- 320 colored beads in 10 colors (per class) |
| HIV ELISA Wet Lab | Materials and prep procedures needed for the ELISA lab can be found under Activity IX, Option A  
- Student Handout 3: Lab Scenario  
- Student Handout 4: HIV ELISA Lab Student Protocol  
- Student Handout 5: Data & Analysis |
| Optional pH Indicator Alternative Lab | Materials and prep procedures needed for the pH indicator alternate to the ELISA lab can be found in the pH Indicator ELISA: Alternative Activity.  
- Teacher Guide: pH Indicator ELISA - Lab Protocol  
- Student Guide: pH Indicator ELISA - Lab Protocol |
| Optional Remote Instruction Materials | Materials for activities adapted for remote instruction can be found in the Remote Instruction section.  
- Teacher Guide: Remote Instruction Adaptations  
- Google Site: Testing for HIV (Virtual)  
- Antibody Coloring Activity (Virtual)  
  - Antibody Modeling Coloring Template slide deck (Google Slides or PowerPoint version; found in this Google folder)  
  - Student Handout: Antibody Coloring (Google Slides or PowerPoint version)  
- Modeling Antibodies with Everyday Materials Activity (Virtual)  
  - Modeling Antibodies with Everyday Materials Slide Deck  
- HIV ELISA Online Simulation Activity (Virtual)  
  - Student Handout: Online ELISA Lab Simulation |

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**ELISA Slide Deck**

[Download Slide Deck](#)

**Types of ELISA**

1. Direct
2. Indirect
3. Sandwich
4. Competitive

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About this lesson: Diagnostic Detective — Lesson 141

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NOTES TO TEACHER FOR PREPARING TO TEACH THIS LESSON:

1. Make copies of student handouts or upload to your classroom learning management system.

2. Prepare materials for the Modeling Antibody Variety Specifications activity. For each class of 32 students, each student will need:
   • 2 whole chenille stems of the same color (heavy chain segments) (64 total)
   • 1 chenille stem cut into 2 pieces (light chain segments) (32 total)
   • 1 “sparkle” chenille stem cut into 4 pieces (disulfide bonds) (32 total)
   • Small container of colored beads (need 10 colors) to use as VDJ segments (320 total)

3. Prepare materials, reagents, and equipment for the ELISA wet lab.

STUDENT ASSESSMENT OPPORTUNITIES:
A variety of assessment opportunities are integrated into this mini-unit, including ideas for formative assessment for each activity that makes up the unit. Additional opportunities include:

► Students' participation in class and small group discussions and/or responses to Exit Tickets.
► Students' responses on the multiple handouts.
► The accuracy and completeness of the antibody models that students create (chenille stems and beads, or digitally).
► Students' active participation and engagement in the HIV ELISA wet lab investigation, including following the lab protocol and safety guidelines.
► The final activity includes a summative assessment opportunity in which students develop a written argument in response to a series of prompts.

Scenario
The global health context for this unit is developed through a scenario:

You are a healthcare provider at a clinic in Uganda, a country in East Africa. A community health advisor brings four people to see you that may have been exposed to HIV. You have a nurse talk to each of them and she comes back with information on each of their suspected modes of exposure to HIV.

PATIENT A CASE STUDY
Lydia met her husband David during her fourth year of medical school. They got married soon after graduation and both started jobs in a large hospital. After a few years of marriage, they were both making enough money to support them and their two children while sending some back to her family. Around this time, David was tested and they discovered he is HIV positive. Now Lydia is worried about herself and came to the clinic today to be tested.

PATIENT B CASE STUDY
Alice is a nurse at a clinic that has been counselling and treating HIV patients for decades. She is the nurse in charge of the program that is focused on getting HIV positive people onto treatment to prevent further spread of the virus. She recently had an incident involving an accidental needle prick and would like to be tested today.

PATIENT C CASE STUDY
Anna is a 24 year old woman who recently had unprotected sex with a man she met through a friend. She has had sex with other men before but has never been tested for HIV or other sexually-transmitted infections (STIs). She has come into the clinic today for an STI check including an HIV test. Her other STI test results have come back negative.

PATIENT D CASE STUDY
Zack is a gay man who recently met his boyfriend who is HIV positive. They have kissed but he has not had sex with him. He is not sure if he is at risk for HIV. He would like to be tested today and also possibly receive counselling on prevention methods.
Instructional Procedure

OVERVIEW

<table>
<thead>
<tr>
<th>Day</th>
<th>Activity</th>
<th>Details</th>
<th>Approx. Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day One</td>
<td>Activity I: Introduction: Lina’s Story - Video</td>
<td>Introduces background information with a video</td>
<td>10 min</td>
</tr>
<tr>
<td></td>
<td>Activity II: Living with HIV/AIDS - What Is HIV/AIDS?</td>
<td>Explore the biological and societal impacts of living with HIV/AIDS</td>
<td>40 min</td>
</tr>
<tr>
<td>Day Two</td>
<td>Activity III: Share Findings - Societal Dimensions of HIV/AIDS</td>
<td>Explore the societal dimensions of having HIV/AIDS, including social stigma</td>
<td>30 min</td>
</tr>
<tr>
<td></td>
<td>Activity IV: Interpreting a Table from Literature</td>
<td>Explore a table that presents data on barriers to care for people with HIV living in the rural U.S.</td>
<td>10 min</td>
</tr>
<tr>
<td>Day Three</td>
<td>Activity V: How Do We Test for HIV?</td>
<td>Examine a chart to learn about different types of tests for HIV</td>
<td>20 min</td>
</tr>
<tr>
<td></td>
<td>Activity VI: The Modeling Antibody Activity</td>
<td>Create physical models of antibodies to show antibody variety specificity</td>
<td>30 min</td>
</tr>
<tr>
<td>Day Four</td>
<td>Activity VII: How Can We Use Antibodies to Detect HIV?</td>
<td>Introduce various types of ELISA tests</td>
<td>20 min</td>
</tr>
<tr>
<td></td>
<td>Activity VIII: HIV Testing Scenario: Predictions</td>
<td>Make predictions about a patient’s risk of contracting HIV based on their behaviors</td>
<td>Homework</td>
</tr>
<tr>
<td>Day Five</td>
<td>Activity IX: HIV ELISA Lab Protocol - Gaining Evidence for HIV Infection</td>
<td>Three options: 1) an indirect ELISA wet lab; 2) an alternative lab using pH indicator; 3) remote instruction options</td>
<td>50-100 min</td>
</tr>
<tr>
<td>Day Six</td>
<td>Activity X: Why Do People Avoid Getting Tested?</td>
<td>Discussion of different types of HIV tests, barriers to testing, and societal impacts</td>
<td>20 min</td>
</tr>
<tr>
<td></td>
<td>Activity XI: Summative Assessment - Written Argument</td>
<td>Written responses to answer the unit driving question and to examine how to mitigate social and cultural impacts on disease prevention</td>
<td>30 min</td>
</tr>
</tbody>
</table>

1 DAY ONE

ACTIVITY I: LINA’S STORY (10 MINUTES)

Watch this 2:22 minute video clip: Lina’s Story: Hope for Women Living with HIV in Malaysia, World Health Organization Regional Office for the Western Pacific, YouTube, (2:22 minutes).

The video introduces Lina, a woman from Malaysia who was devastated when she learned that her critically-ill husband was diagnosed with HIV and tuberculosis. Lina and her child are HIV positive too. This video shows the depth of the HIV crisis and the common misconceptions about the disease.

► Use the video to elicit questions about HIV/AIDS.
► Develop an idea board about what students already know about HIV/AIDS.

What We Figure Out:
- Many people living with HIV do not know it.
- HIV is a global issue.
- HIV/AIDS-related stigma affects the well-being and health choices of people living with HIV.

Connection to Phenomenon:
- Helps students generate questions and previous knowledge around HIV/AIDS.
- Establishes a reason to care about the phenomenon.
- Emphasizes the need for testing.

Learning Targets:
- Through understanding the societal dimensions of HIV/AIDS students learn that not all questions can be answered by science.

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ACTIVITY II: LIVING WITH HIV/AIDS (40 MINUTES)

What is HIV/AIDS?

Use NAT.org/uk Teaching Resources to expand on students’ existing knowledge of HIV and to answer any questions that may have come up.

Elicit ideas on how living with HIV/AIDS could affect an individual biologically and socially using the NAT.org HIV Teaching Resources linked below. Assign student groups with the different Prompt cards.

NAT.org/uk Teaching Resources (Tell students to replace UK with US in Prompt Cards)

What We Figure Out:

• HIV is the virus that can cause AIDS. It is spread through contact with infected bodily fluids like blood, semen and breast milk.
• Individuals have varying degrees of risk of becoming infected based on their behaviors.
• 25% of people living with HIV do not know their status.

Connection to Phenomenon:

• Understand the basics of HIV.

Learning Targets:

• Through understanding the societal dimensions of HIV/AIDS students learn that not all questions can be answered by science.
• Through understanding AIDS, students acquire knowledge about the immune system and white blood cells.
• Students construct an explanation based on evidence from their own investigations.

Formative Assessment Day 1:

► What question do you have about HIV/AIDS that you would most like answered?
► What is the most surprising thing you learned from the video, Lina’s Story?
► Why do you think only 25% of people living with HIV do not know their status? What might be barriers to them getting tested?
ACTIVITY III: SHARE FINDINGS - SOCIETAL DIMENSIONS TO THE HIV/AIDS CRISIS (30 MIN)

What are the societal dimensions to the HIV/AIDS crisis?

Based on the Lina’s Story video from the World Health Organization from Day 1, have students, in pairs or groups, discuss the societal dimensions of having HIV/AIDS.

► Why was Lina afraid to tell her family and friends that she had HIV?
► How do you think income in different areas around the world affects whether a person would get tested?
► What other factors do you think affect how a community feels about HIV?

Formative Assessment: Have the students regroup and generate an idea board or concept map about the societal dimensions discussed. This might cover issues about poverty, education, religion, and misinformation as they relate to HIV/AIDS.

Have students consider Lina and how she found out she had HIV by asking:

► How did Lina find out she was positive for HIV?
► How do other people know that they are at higher risk and should be tested?

What We Figure Out:

• Social stigma around sexual activity and HIV are often barriers for individuals when considering testing.
• There are also other social and economic barriers to HIV testing and treatment.

Connection to Phenomenon:

• Help students grasp the value of people getting tested for HIV.
• Understand why people are not getting tested

Learning Targets:

• Understand that science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.
• Through understanding the societal dimensions of HIV/AIDS students learn that not all questions can be answered by science.
• Many decisions surrounding healthcare are heavily impacted by the social and cultural context.

ACTIVITY IV: INTERPRETING A TABLE FROM LITERATURE (10 MIN)

As another option for exploring the societal dimensions of HIV/AIDS, students can interpret a data table from a Literature Review published in the Journal of the Association of Nurses in HIV Care.

This figure reviews different barriers to care for those with HIV in the rural US. Students can spend time analyzing the table, generating questions and forming questions. The teacher resource contains questions to aid in discussion. Most importantly, address: “How do you think these barriers to care compare/apply to other areas of the world, especially resource-poor regions?” Use the following resources:

• Teacher Resource 1: Barriers to Care for Rural People Living with HIV
• Student Handout 1: Barriers to Care for Rural People Living with HIV

Address different risk behaviors and how that relates to the transmission of disease.

Formative Assessment: Assign one or more of the discussion questions from the Teacher Resource as an exit ticket.
ACTIVITY V: HOW DO WE TEST FOR HIV? (20 MIN)

Use the chart at Avert.org to introduce the different types of HIV tests.

Give students time to look at the chart. Together, address what information the chart is providing (column titles).

Formative Assessment: Ask students to answer the following questions in writing or through discussion:

► If a person uses the rapid test but gets inconclusive results, which test would probably be recommended?
► Analyze the cost and benefits of the different types of testing.

What We Figure Out:

• The first step in diagnosis is the rapid test.
• The rapid test is cheap, fast, and 99% accurate.
• The rapid test uses the body’s immune response to test for HIV.

Connection to Phenomenon:

• Students learn how people know that they are infected with HIV.

Learning Targets:

• Students analyze the costs and benefits as a critical aspect of decisions about technology.

ACTIVITY VI: MODELING ANTIBODY VARIETY (30 MIN)

Modeling Antibody Variety Specificity

Go through the Student Handout 2: Modeling Antibody Variety Specificity to help students develop an understanding of antibodies and their structure. The model uses chenille stems to show the basic layout of an antibody: the 2 heavy chains, 2 light chains, and the disulfide bonds that hold those polypeptides together. Colored beads are used to represent VDJ segments. The model is then used to demonstrate the vast diversity in the variable regions of antibodies using VDJ recombination.

Creating the Antibody Model Structure using Chenille Stems

Preparation: Cut the chenille stems into pieces, as indicated on the materials list.

Part One: Building the heavy and light chains

1. Select 4 chenille stems:
   a. Two of the same color (heavy chains)
   b. One of a color different from the heavy chains (will become light chains)
   c. One “sparkle” pipe cleaner (will become disulfide bonds)

2. Lay the two same-colored pipe cleaners side by side on a desk.

3. Cut the third pipe cleaner in half and lay alongside the outside of the two large ones aligned at the top.

4. Cut the “sparkle” pipe cleaner into 4 even pieces – use two pieces to join the heavy chains together at the lower half (the “constant region”) of the pipe cleaners, and one to join each light chain to a heavy chain.

5. Bend the heavy chains apart in a “Y” shape.

Part Two: Modeling VDJ recombination

What We Figure Out:

• Antibodies are highly specific to the antigen and are naturally developed by an individual’s immune system after exposure to said antigen.
• The importance of an antibody’s structure/function relationship

Connection to Phenomenon:

• Connect antibodies with HIV testing.

Learning Targets:

• The Modeling Antibody Variety Activity is a system model used to simulate the immune system and interactions between antigens and antibodies.
• Understand the structure and function relationship that makes antibodies varied and specific.
6. Randomly choose three colored beads from the container, then select the same three colors again so they have a pair of each. Each colored bead represents one V, one D, and one J segment on the heavy chain.

7. Place three of the beads (of different colors) in a row on the variable region of one of the heavy chains, then create the same pattern of beads on the other heavy chain variable region.

8. Randomly choose two more beads from the container (these represent the V and J segments on the light chain), place them on the end of the light chain. Repeat with the same two colors for the second light chain variable region so that both light chains match.

Part Three: Discussion

- Are there any two groups of students who have the exact same colored beads on their model? (the color of the pipe cleaners does not matter in this model)
- There are only 10 different colors of beads. How many varieties of antibody might you be able to create?
  - **Heavy chain:** (10 V segments) X (10 D segments) X (10 J segments) = 1000 possible combinations
  - **Light chain:** (10 V segments) X (10 J segments) = 100 possible combinations
  - (1000 possible heavy chains) X (100 possible light chains) = 100,000 possible antibody variations
- Now about the real thing:
  - **Heavy chain:** (51 V)(25 D)(6 J) = 7650 possible combinations
  - **Light chains:** (40 V)(5 J) + (31V)(4 J) = 324 possible combinations
  - (7650 possible heavy chains) X (324 possible light) = 2,478,600 possible combinations
  - **BUT WAIT!!** Because of additional recombination events and mutations during mitosis, the actual number of possible antibody variations is potentially much greater than 1X10⁸.

Formative Assessment: Assign one or more of these prompts as an exit ticket for Day 3:

- What is an antibody? Where is it found? What is its purpose within the immune system?
- What is an antigen?
- Draw a picture of your antibody model. Label its parts and their functions.
- Explain how the relationship between the structure and function of an antibody allows it to recognize specific antigens.

Optional: For more details about DNA recombination and Immunology, see G.J.V Nossel’s 2003 article in Nature, “The Double Helix and Immunology.”

Note: This activity can be extended by completing activities from the Protein Data Bank. Check out the Learn and Teach tabs.

Remote Instruction: Adaptations for remote instruction are available for this activity here. In particular, use the following resources:

- Teacher Guide: Remote Instruction Adaptations
- Google Site: Testing for HIV (Virtual)
- Antibody Coloring Activity (Virtual)
- Modeling Antibodies with Everyday Materials Activity (Virtual)
ACTIVITY VII: HOW CAN WE USE ANTIBODIES TO DETECT HIV? (20 MIN)

The ELISA Slide Deck goes through the steps for various types of ELISA tests. The slides can be edited or shortened depending on your goals for these activities. Note that the HIV ELISA test we will be simulating in the web lab is an example of an indirect ELISA.

Formative Assessment: Ask students to answer the following questions in writing or through discussion:

► Why are antibodies so specific to an antigen?
► When are they produced by the body?

ACTIVITY VIII: HIV TESTING SCENARIO: PREDICTIONS (HOMEWORK)

As a homework assignment (or in-class if you have time), have students look over Student Handout 3: Lab Scenario and discuss what behaviors they believe are higher risk for contracting HIV.

Go over possible routes of transmission for each patient.

What We Figure Out:
- Antibodies only develop after exposure to the antigen and after the body mounts an immune response.

Connection to Phenomenon:
- Understand that when testing doctors are looking for an immune response to HIV.

Learning Targets:
- ELISAs were developed based on the assumption that scientific knowledge about the nature of antibodies in the immune system will continue to work for diagnostic tests.
- As we gain a deeper understanding of the immune system new technologies and treatments can be developed.
ACTIVITY IX: HIV ELISA - GAINING EVIDENCE FOR HIV INFECTION (50-100+ MIN)

There are three options for the HIV ELISA Lab:

A. An indirect ELISA wet lab (outlined below)
- Students work through the lab activity protocol in Student Handout 4: HIV ELISA Lab Student Protocol. Have students fill out Student Handout 5: Data & Analysis as they work.
- See Appendix for required set of aliquots, Recipe and Dilution Guide, and Aliquot Summary Table.

B. An alternative lab using pH indicator, which can be found in the pH Indicator ELISA: Alternative Activity

C. Activities adapted for remote instruction
- Teacher Guide: Remote Instruction Adaptations
- Google Site: Testing for HIV (Virtual)
- HIV ELISA Online Simulation Activity (Virtual)

What We Figure Out:
- Student’s ELISA test results.

Connection to Phenomenon:
- Understand that testing provided strong evidence for potential infection.

Learning Targets:
- Students learn that scientific inquiry is characterized by a common set of values including logical thinking, objectivity, and open-mindedness.

Diagnostic Detective: HIV ELISA Wet Lab

Enzyme Linked-Immunosorbent Assay Lab Protocol

OVERVIEW

This ELISA (Enzyme-Linked Immunosorbent Assay) protocol simulates an indirect ELISA for detection of particular antibodies in a person’s blood as markers for infection. In an indirect ELISA, there are 4 main parts: an antigen, a primary antibody (if present in the patient), a secondary antibody that is conjugated to a peroxidase enzyme, and a substrate that the peroxidase can act on.

In this lab, students will simulate running an ELISA on four patients (A, B, C, and D) presenting different symptoms, transmission events, or exposure conditions. Potential exposure conditions for each patient are provided in the Student Handout 3: Lab Scenario. Each condition allows for a discussion about transmission, viral load, and potential misconceptions. As shown in the table below, two patients will test positive and two will test negative.

Before the lab, have students make a prediction individually or as a class. Remember that HIV is not transmitted through sweat, saliva, or coming into contact with an HIV positive person.

<table>
<thead>
<tr>
<th>PATIENT</th>
<th>RESULT</th>
<th>POTENTIAL EXPOSURE CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>+</td>
<td>Female with a partner who is HIV-positive partner</td>
</tr>
<tr>
<td>B</td>
<td>+</td>
<td>Nurse who had an accidental needle prick</td>
</tr>
<tr>
<td>C</td>
<td>-</td>
<td>Sexually-active female</td>
</tr>
<tr>
<td>D</td>
<td>-</td>
<td>18-year-old who kissed HIV-positive partner</td>
</tr>
</tbody>
</table>

TABLE 1: HIV Patient Scenarios

FIGURE 1: Indirect ELISA. In an indirect ELISA, the primary antibody within a patient sample is the target. The presence of the primary antibody within a patient can be evidence of a past or present infection.
STUDENT PROTOCOL OVERVIEW

- This lab is set up for a class of 32 students working in pairs (16 groups).
- Each group will test two of the four patient samples.
- Each group will run their samples (including controls) in triplicate.
  - 1 positive control well
  - 1 negative control well
  - 3 patient ____ wells
  - 3 patient ____ wells
- Each student group should get their own well strip.

ANTIBODIES

The antigen and antibodies used in this lab are monoclonal chicken IgY, rabbit IgG, and horseradish peroxidase (HRP)-conjugated goat IgG. See the table for exact names. These can also be purchased as a kit from BioRad.

IMPORTANT NOTES

- This lab has a lot of reagents and aliquots. To reduce confusion, we have created a color system for your microtubes. Refer to the image below and the recipe guide for the color system. Clear tubes are used for the “patient samples” and should be labelled A, B, C, or D.
- See the Recipe and Dilution Section in the Appendix for help with reagents, dilutions, and aliquots.
- All reagents should be stored in the refrigerator (4°C). Do not freeze the antibodies. The primary antibody degrades when frozen.
- TMB and Tween-20 are light sensitive. Store in a cool, dark place.
- 1xPBS+T (wash buffer) contains Tween-20 and is also slightly light sensitive.
- Dilutions can be made ahead of time and stored in the fridge for up to 2 weeks. An increase in final incubation time and a reduction in signal (blue color) can be expected with longer storage.

CLASS SET OF ALIQUOTS

![FIGURE 2: Example ELISA Well Strip](image)

![TABLE 2: Reagents Needed for Lab](table)

![FIGURE 3: Color System for Microtubes. Clear tubes should be used for the “patient samples” and labelled A, B, C, or D.](image)
STUDENT SETUP
Each student station should have:
- Goggles/gloves
- Eppendorf rack
- Paper towels
- ELISA well strips
- Micropipet (P200)/tips
- Timer
- Tip waste container
- Transfer pipet
- Permanent marker
- 750µl antigen (green)
- 175µl positive control (pink)
- 175µl negative control (purple)
- 175µl each patient sample (clear)
- 750µl secondary antibodies (yellow)
- 750µl substrate (brown)
- Wash buffer

PROCEDURE
Students work through the lab activity protocol in Student Handout 4: HIV ELISA Lab Student Protocol.
Have students draw, photograph, or model each step as they do it during incubation periods. They can also describe the purpose of each step in their lab notebooks. Have students complete data tables and reflection questions in Student Handout 5: Data & Analysis as they work.

DISCUSS RESULTS
- Analyze results. Compare data on “patient samples”.
- Discuss issues or differences in data between students.
- Connect to pathology, viruses, common ELISA tests, and/or public health.
DAY SIX

ACTIVITY X: WHY DO PEOPLE AVOID GETTING TESTED?

Use rapid test experience to discuss other barriers to getting tested. (*Rapid tests are fast, accurate and relatively cheap*).

Elicit more ideas on the stigma and the current status of this global health problem.

Optional: Show video produced by Sumanas, Inc. of a lateral flow ELISA test - [How a Pregnancy Test Works](#).

Read through and discuss the UN [90-90-90 goals](#) and the [third Sustainable Development Goal](#) set by UNAIDS.

ACTIVITY XI: SUMMATIVE ASSESSMENT - WRITTEN ARGUMENT

As a summative assessment for this lesson, challenge students to respond to the following questions in writing:

► How can communities ensure that more people are tested for HIV?
► How can scientists help more people get tested for HIV?
► Model how an ELISA could be used for testing other viral diseases like ebola?
► Use all information gathered to answer the question: Why are 25% of people living with HIV unaware of their status?
► Optional: Use resources about different programs (local and global) and their success throughout the decades long HIV/AIDS epidemic to see how these programs and interventions could be translated to other viral diseases.

What We Figure Out:
- The speed and ease of running an ELISA test for HIV.
- A look at the specificity and sensitivity of HIV ELISA tests.
- The goals set by UNAIDS.

Connection to Phenomenon:
- Return to the phenomena / driving question: “25% of those living with HIV do not know they are infected. Why?”

Learning Targets:
- HIV/AIDS testing technologies have deep impacts on society, including some that are not anticipated. Societal values also impact testing technologies in unanticipated ways.

What We Figure Out:
- Different HIV testing and education programs around the world.

Connection to Phenomenon:
- Discuss how scientists can help mitigate the social and cultural impacts on disease prevention, not just HIV.
- Return to the anchoring phenomena / driving question: “25% of those living with HIV do not know they are infected. Why?”

Learning Targets:
- Use all information gathered to answer the question: Why are 25% of people living with HIV unaware of their status?
Teacher Resources

ADDITIONAL INFORMATION ON HIV

- Information on HIV
  Avert.org

- History of HIV and AIDS
  Avert.org

- HIV Stigma and Discrimination
  Avert.org

- Prevalence of HIV Graph
  The World Bank

- Global HIV/Aids Overview
  HIV.gov

- The Global Health Observatory: HIV/AIDS
  World Health Organization

- The Global HIV/AIDS Epidemic
  KFF.org

FINANCIAL BARRIERS TO HIV TESTING

- HIV Testing in the U.S.
  KFF.org

CURRENT RESEARCH

- HIV Vaccine Trials Network: About
  Fred Hutchinson Cancer Research Center

- HIV Vaccine Trials Network: Science
  Fred Hutchinson Cancer Research Center

CAREER CONNECTIONS

The activities in this unit connect to several careers in global health. These three relevant careers are featured on the STEM Global - Pathways to Global Health Careers poster and accompanying fact sheets. Read more about each job by exploring these resources.

- Public Health Nurse (see the Health Sciences section)
- Community Health Advisor (see the Human Services, Education & Training section)
- Biomedical Lab Technician (see the STEM section)

ADDITIONAL INFORMATION ON ELISA

- How a Pregnancy Test Works
  (Video), Sumanas Inc.
REFERENCES


ELISA LAB PROTOCOL - RECIPE & DILUTION GUIDE

Amounts given are for 1 class of 32 students working in pairs. Multiply the amounts for the number of classes you need. Make sure to centrifuge all of the stock reagent microtubes. Some tubes hold extremely small amounts ~4 µl. Make solutions and dilutions before making aliquots. Refer to the Aliquot Summary Table on the next page as a quick guide.

1X PBS Dilution

<table>
<thead>
<tr>
<th>REAGENT</th>
<th>PER CLASS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>10X PBS</td>
<td>50 ml</td>
<td></td>
</tr>
<tr>
<td>Distilled water</td>
<td>450 ml</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>500 ml</td>
<td>Store at room temp</td>
</tr>
</tbody>
</table>

*1X PBS is used to make wash buffer and the antigen dilution. Do not use wash buffer for the antigen dilution.

Wash Buffer (1X PBS+T)

<table>
<thead>
<tr>
<th>REAGENT</th>
<th>PER CLASS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1X PBS</td>
<td>400 ml</td>
<td></td>
</tr>
<tr>
<td>Tween-20</td>
<td>200.0 µl</td>
<td>Light sensitive</td>
</tr>
<tr>
<td>TOTAL</td>
<td>~ 400 ml</td>
<td>Store at room temp Protect from light if storing long-term.</td>
</tr>
</tbody>
</table>

Purple Aliquots / - Patient Samples (clear)

Aliquot 175 µl of wash buffer into 16 purple microtubes for the negative control.
Label 16 clear tubes with the letter corresponding to negative patients. You will need 8 tubes per patient sample. Aliquot 175 µl of wash buffer into each tube.

Antigen

<table>
<thead>
<tr>
<th>REAGENT</th>
<th>PER CLASS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1X PBS</td>
<td>10 ml</td>
<td></td>
</tr>
<tr>
<td>Stock Antigen</td>
<td>1.0 µl</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>~ 10 ml</td>
<td>Store in fridge</td>
</tr>
</tbody>
</table>

Green Aliquots

Aliquot 750 µl of the antigen dilution into each of the 16 green microtubes needed per class.

Primary Antibody (1°Ab)

<table>
<thead>
<tr>
<th>REAGENT</th>
<th>PER CLASS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wash Buffer (1XPBS+T)</td>
<td>10 ml</td>
<td></td>
</tr>
<tr>
<td>Stock 1° Ab</td>
<td>5.0 µl</td>
<td>Store in fridge</td>
</tr>
<tr>
<td>TOTAL</td>
<td>~ 10 ml</td>
<td></td>
</tr>
</tbody>
</table>

Pink Aliquots / + Patient Samples (clear)

Aliquot 175 µl of primary antibody into 16 pink microtubes for positive control.
Label 16 clear tubes with the letter corresponding to positive patients. You will need 8 tubes per patient sample. Aliquot 175 µl of primary antibody into each tube.

Secondary Antibody (2°Ab [HRP])

<table>
<thead>
<tr>
<th>REAGENT</th>
<th>PER CLASS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wash Buffer (1XPBS+T)</td>
<td>30 ml</td>
<td></td>
</tr>
<tr>
<td>Stock 2° Ab (HRP)</td>
<td>1.5 µl</td>
<td>Store in fridge</td>
</tr>
<tr>
<td>TOTAL</td>
<td>~ 30 ml</td>
<td></td>
</tr>
</tbody>
</table>

Yellow Aliquots

Aliquot 750 µl of secondary antibody into each of the 16 yellow microtubes needed per class.

TMB (Brown Aliquots)

3,3',5,5'-Tetramethylbenzidine or TMB is a colorless substrate. When TMB is added to a solution with a peroxidase, such as a conjugated 2° antibody, TMB will reduce to a diimine, causing the solution to turn blue. This acts as the visualizing agent in an ELISA. TMB does not need to be diluted. It is light sensitive and should be stored in the fridge until ready to use. Aliquot 750 µl TMB into 16 brown tubes.
ELISA LAB PROTOCOL - ALIQUOT SUMMARY TABLE

Fill in the table based on the number of classes you have. See the example on the first line of the Table. For the negative control, each class will need 16 purple microtubes with 175 μl of wash buffer. To prep for 3 classes, get 16 purple microtubes and add 525 μl (3 x 175 μl) of wash buffer into each. You will then have 16 tubes of negative control that can be used in all 3 classes. **Make sure not to throw away the microtubes after each class and store in the fridge between classes.**

<table>
<thead>
<tr>
<th>NAME</th>
<th>MICROTube COLOR</th>
<th># TUBES /CLASS</th>
<th>AMT/MICROTUBE FOR 1 CLASS</th>
<th>___ # OF CLASSES</th>
<th>TOTAL AMT / MICROTUBE</th>
</tr>
</thead>
<tbody>
<tr>
<td>WASH BUFFER</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Example: Negative Control</td>
<td>Purple</td>
<td>16</td>
<td>175μl</td>
<td>3</td>
<td>175 μl x 3 = 525 μl</td>
</tr>
<tr>
<td>Wash buffer</td>
<td>50-ml falcon tube</td>
<td>16</td>
<td>20 ml</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative Control</td>
<td>Purple</td>
<td>16</td>
<td>175 μl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(-) Patient Sample ___</td>
<td>Clear (labelled ___)</td>
<td>8</td>
<td>175 μl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(-) Patient Sample ___</td>
<td>Clear (labelled ___)</td>
<td>8</td>
<td>175 μl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANTIGEN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antigen</td>
<td>Green</td>
<td>16</td>
<td>750 μl*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRIMARY ANTIBODY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive Control</td>
<td>Pink</td>
<td>16</td>
<td>175 μl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(+) patient sample ___</td>
<td>Clear (labelled ___)</td>
<td>8</td>
<td>175 μl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(+) patient sample ___</td>
<td>Clear (labelled ___)</td>
<td>8</td>
<td>175 μl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SECONDARY ANTIBODY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2° Antibody</td>
<td>Yellow</td>
<td>16</td>
<td>750 μl*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMB SUBSTRATE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMB substrate</td>
<td>Brown</td>
<td>16</td>
<td>750 μl*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*If doing more than 2 classes, you will need to aliquot into more than one microtube. The microtubes provided fit a max of 1.7 ml.
### BARRIERS TO CARE

**for People Living with HIV in Rural Areas of the United States**

<table>
<thead>
<tr>
<th>Barriers to Care</th>
<th>Duran et al., 2000</th>
<th>Goicoechea-Balbona, 1997</th>
<th>Henderson et al., 1998</th>
<th>Kempf et al., 2010</th>
<th>Maimon et al., 1997</th>
<th>Mainey et al., 2004</th>
<th>McKinney, 1998</th>
<th>Rhodes et al., 2010</th>
<th>Roeder, 2002</th>
<th>Sarquis et al., 2011</th>
<th>Sutton et al., 2010</th>
<th>Vyasvihari et al., 2008</th>
<th>Walker, 2002</th>
<th>Whetten-Goldstein et al., 2001</th>
<th>Number of Articles That Address Each Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>11</td>
</tr>
<tr>
<td>Long distances to care</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>5</td>
</tr>
<tr>
<td>Personal health: Limitations</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
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<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>3</td>
</tr>
<tr>
<td>Lack of childcare</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>5</td>
</tr>
<tr>
<td>Insurance issues (lack of or difficulties applying for benefits)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>5</td>
</tr>
<tr>
<td>Affordability/Lack of financial resources</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
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<td>X</td>
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</tr>
<tr>
<td>Housing issues</td>
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<td>X</td>
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<td>X</td>
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<td></td>
<td></td>
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<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>4</td>
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<tr>
<td>Legal matters/Incarceration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>2</td>
</tr>
<tr>
<td>Employment or workplace issues</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>4</td>
</tr>
<tr>
<td>Lack of or inadequate HIV-trained health professionals</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>5</td>
</tr>
<tr>
<td>Lack of or inadequate HIV-specific services</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>X</td>
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<td>X</td>
<td>X</td>
<td>1</td>
</tr>
<tr>
<td>Long waits for appointments</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>3</td>
</tr>
<tr>
<td>Inflexibility in scheduling/Inconvenient hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>3</td>
</tr>
<tr>
<td>Bureaucracy/Red tape</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>3</td>
</tr>
<tr>
<td>Lack of knowledge about available services</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>5</td>
</tr>
<tr>
<td>Lack of mental health workers</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>3</td>
</tr>
<tr>
<td>Lack of drug treatment facilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>1</td>
</tr>
<tr>
<td>Organization did not provide the right referrals to the services needed or services were unhelpful</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>2</td>
</tr>
<tr>
<td>Denial of problem/Attitudes about HIV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>5</td>
</tr>
<tr>
<td>Lack of social support, networks, and groups</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>4</td>
</tr>
<tr>
<td>Community stigma</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>5</td>
</tr>
<tr>
<td>Religious/Sociocultural factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>4</td>
</tr>
<tr>
<td>Fear of being reported to authorities/Deportation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>2</td>
</tr>
<tr>
<td>Provider discrimination/Stigma</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>7</td>
</tr>
<tr>
<td>Confidentiality</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>7</td>
</tr>
<tr>
<td>Perceived lack of sensitivity of the organization regarding issues and concerns</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>2</td>
</tr>
<tr>
<td>Communication with provider/Quality of patient-provider relationship</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>3</td>
</tr>
</tbody>
</table>

**Caption:** Review of 15 HIV studies in the United States that identified a total of 27 distinct categories of barriers to care. Each of these barriers encompassed its own concerns and points of interest in understanding why individuals might not have engaged in treatment. Figure from: Pellowski, J. A. *“Barriers to Care for Rural People Living With HIV: A Review of Domestic Research and Health Care Models.”* Journal of the Association of Nurses in AIDS Care 24, 422–437 (2013).
BACKGROUND

Historically, the availability of healthcare in rural areas has been sparse. Specialized care for people living with HIV has been especially problematic. Rural patients are faced with significantly greater barriers to care than their urban counterparts.

In this review, we analyzed 15 studies concerning barriers to care among patients infected with HIV in rural areas of the United States. Among the 27 barriers identified, the most commonly discussed were transportation needs, provider discrimination and stigma, confidentiality concerns, and affordability and lack of financial resources. Barriers to care must be addressed in conjunction with one another in order to alleviate their impacts.

BIG IDEAS, NOTES & QUESTIONS

**How to Use this Resource:** Review the following table and caption with your students. The Student Handout provides space for observations, notes, and questions. Next to the Background information there is also a space for students to write big ideas, notes, and questions. Discussion questions are listed below.

**BACKGROUND**

Historically, the availability of healthcare in rural areas has been sparse. Specialized care for people living with HIV has been especially problematic. Rural patients are faced with significantly greater barriers to care than their urban counterparts.

In this review, we analyzed 15 studies concerning barriers to care among patients infected with HIV in rural areas of the United States. Among the 27 barriers identified, the most commonly discussed were transportation needs, provider discrimination and stigma, confidentiality concerns, and affordability and lack of financial resources. Barriers to care must be addressed in conjunction with one another in order to alleviate their impacts.

**CONCEPTS TO REVIEW WITH STUDENTS**

- **Barriers to Care** - Real world issues that prevent people from seeking or receiving treatment.
- **Literature Review** - A peer-reviewed report that analyzes multiple studies on a single topic to reveal patterns across all studies.
- **Literature Citation** - Duran et al., 2000 refers to a study whose author has the last name Duran. “Et al.” means that there are multiple authors including Duran. 2000 refers to the year it was published. The hyperlink allows readers to find these papers easily.

**DISCUSSION QUESTIONS**

- What barriers to care are addressed the most?
- Which study addresses the most barriers?
- Why do you think that different studies on barriers to care in the rural US address identify only a few barriers?
- Are barriers to care for treating HIV different from barriers for other illnesses or diseases? Why might that be?
- Are there certain barriers that you were surprised to see?
- How do you think “Housing issues” might be a barrier to care?
- How do you think “Employment or Workspace Issues” might be a barrier to care?
- How do you think these barriers to care compare/apply to other areas of the world, especially resource-limited regions?
Modeling Antibody Structure using Chenille Stems

OBJECTIVE
This activity describes a way to model the basic structure of antibodies. The model uses chenille stems to show the basic layout of an antibody: the 2 heavy chains, 2 light chains, and the disulfide bonds that hold those polypeptides together. Colored beads are used to represent VDJ segments. The model is then used to demonstrate the vast diversity in the variable regions of antibodies using VDJ recombination.

ESTIMATED TIME
20-30 minutes

MATERIALS NEEDED
► 2 whole chenille stems of the same color (heavy chain segments)
► 1 chenille stem cut into 2 pieces (light chain segments)
► 1 “sparkle” chenille stem cut into 4 pieces (disulfide bonds)
► Container of colored beads to use as VDJ segments

PREPARATION
Cut the chenille stems into pieces, as indicated on the materials list.

IMPORTANT CONCEPTS
► Antibodies are made of 2 heavy chain polypeptides (blue in the diagram) and 2 light chain polypeptides (red in the diagram). Each chain is a polymer of amino acids.
► Disulfide bonds (S-S bonds between cysteine residues) hold the 4 chains together. Two disulfide bonds connect the heavy chains together, while one disulfide bond connects each light chain to the nearest heavy chain.
► The antibody takes on a Y-shape when all 4 chains interact.
► The trunk of the “Y” makes up the constant region of the antibody and is specific to each species. The arms of the “Y” on the antibody make up the variable region and form a specific shape that recognizes and binds to one unique epitope (specific region of an antigen).
► Each mature B cell produces antibodies that recognize only one target. There are only about 21,000 human genes total, so how are millions of different antibodies created when there aren’t millions of different genes?
► Our B cells create tremendous variety in antibody structure from three genes (two that code for light chains, one that codes for heavy chains) using a special mechanism called VDJ recombination. Remember that each gene has 2 alleles.
When a B cell is immature, the heavy chain gene contains multiple V segments, D segments, and J segments, and the light chain gene contains multiple V and J segments.

As immature B cells mature, one V segment, one D segment, and one J segment are selected at random and recombined into a revised, shorter heavy chain gene. A similar process occurs in the light chain gene. (There is no D segment present in the light chain genes).

In mature B cells, these shorter genes will provide the instructions for producing the heavy and light chain polypeptides that comprise the structure of the unique antibody. [Note that “Con” stands for “Constant Region.”]

### Heavy chain DNA in immature B cell:

- **V<sub>1</sub>** Variable segments
- **V<sub>2</sub>**
- **V<sub>3</sub>**...
- **V<sub>51</sub>**
- **D<sub>1</sub>** Diversity segments
- **D<sub>2</sub>**...
- **D<sub>27</sub>**
- **J<sub>1</sub>** Joining segments
- **J<sub>2</sub>**...
- **J<sub>6</sub>**
- **C** Constant segment

---

**CREATING THE ANTIBODY MODEL**

**Part One: Building the heavy and light chains**

1. **Select 4 chenille stems:**
   - a. Two of the same color (heavy chains)
   - b. One of a color different from the heavy chains (will become light chains)
   - c. One “sparkle” pipe cleaner (will become disulfide bonds)

2. **Lay the two same-colored pipe cleaners side by side on a desk.**

3. **Cut the third pipe cleaner in half and lay alongside the outside of the two large ones aligned at the top.**

4. **Cut the “sparkle” pipe cleaner into 4 even pieces** – use two pieces to join the heavy chains together at the lower half (the “constant region”) of the pipe cleaners, and one to join each light chain to a heavy chain.

5. **Bend the heavy chains apart in a “Y” shape.**

**Part Two: Modeling VDJ recombination**

6. **Randomly choose three colored beads from the container,** then select the same three colors again so they have a pair of each. Each colored bead represents one V, one D, and one J segment on the heavy chain.

7. **Place three of the beads (of different colors) in a row on the variable region of one of the heavy chains,** then create the same pattern of beads on the other heavy chain variable region.

8. **Randomly choose two more beads from the container (these represent the V and J segments on the light chain), place them on the end of the light chain.** Repeat with the same two colors for the second light chain variable region so that both light chains match.
Part Three: The Discussion

9. Are there any two groups of students who have the exact same colored beads on their model? (the color of the pipe cleaners does not matter in this model)

10. There are only 10 different colors of beads. How many varieties of antibody might you be able to create?

   Heavy chain: (10 V segments) x (10 D segments) x (10 J segments) = ________ possible combinations

   Light chain: (10 V segments) x (10 J segments) = ________ possible combinations

   (________ possible heavy chains) x (________ possible light chains) = ________ possible antibody variations

11. Now how about the real thing:

   Heavy chain: (51 V)(25 D)(6 J) = ________ possible combinations

   Light chains: (40 V)(5 J) + (31V)(4 J) = ________ possible combinations

   (________ possible heavy chains) x (________ possible light) = ________ possible combinations

   BUT WAIT!! Because of additional recombination events and mutations during mitosis, the actual number of possible antibody variations is potentially much greater than 1X10^8.
**Lab Scenario**

_HIV ELISA_

Name: ____________________________ Date: ___________ Period: ______

**SCENARIO**

You are a healthcare provider at a clinic in Uganda, a country in East Africa. A community health advisor brings 4 people to see you that may have been exposed to HIV. You have a nurse talk to each of them and she comes back with information on each of their suspected modes of exposure to HIV.

**Patient A**

Lydia met her husband David during her fourth year of medical school. They got married soon after graduation and both started jobs in a large hospital. After a few years of marriage, they were both making enough money to support them and their two children while sending some back to her family. Around this time, David was tested and discovered that he is HIV positive. Now Lydia is worried about herself and came to the clinic today to be tested.

**Patient B**

Alice is a nurse at a clinic that has been counselling and treating HIV patients for decades. She is the nurse in charge of the program that is focused on getting HIV positive people onto treatment to prevent further spread of the virus. She recently had an incident involving an accidental needle prick and would like to be tested today.

**Patient C**

Anna is a 24 year old woman who recently had unprotected sex with a man she met through a friend. She has had sex with other men before but has never been tested for HIV or other sexually-transmitted infections (STIs). She has come into the clinic today for an STI check including an HIV test. Her other STI test results have come back negative.

**Patient D**

Zack is a gay man who recently started dating someone who is HIV positive. They have kissed but have not had sex. He is not sure if he is at risk for HIV but would like to be tested today and also possibly receive counselling on prevention methods.

You and the nurse both believe that all four patients should all take the HIV rapid test. According to the Ministry of Health, the prevalence of HIV has been increasing in this community recently and they have been working hard to diagnose more patients to get them into treatment to prevent further transmissions. You ask the nurse to collect blood samples from each patient and prepare the samples for the ELISA test.

---

Student Guide: HIV ELISA Lab Student Protocol

Enzyme Linked-Immunosorbent Assay

Name: ____________________________ Date: _____________ Period: ______

PURPOSE
To use antibodies found in simulated patient serum to detect the presence of a particular infection through an ELISA protocol.

BIG IDEA
Antibodies are Y-shaped proteins used by the immune system to identify and help remove foreign objects like bacteria and viruses. Their specific shape helps them to recognize many different antigens (the unique parts of a molecule that causes an immune response).

An ELISA (enzyme-linked immunosorbent assay) uses scientifically designed antibodies to detect if a particular substance, such as a viral antigen, hormone, or another specific antibody, is present in a sample.

In this lab, you will use an indirect ELISA protocol to identify if a patient or sample is positive or negative for a specific antibody in response to infection. By comparing your patient results to positive and negative controls, you will be able to determine if the samples were positive or negative for a particular infection.

DIRECTIONS
1. Read the Student Handout 3: Lab Scenario.
2. Your medical lab has been given four blood serum samples from patients who suspect may be at risk for HIV:
   - Patient A: _______________________________
   - Patient B: _______________________________
   - Patient C: _______________________________
   - Patient D: _______________________________
3. Copy Table 1 in your lab notebook and write down which patients you think are at high risk for testing positive and provide your reasoning.

   TABLE 1. Experimental Prediction. Mark high or low risk for each patient based on what you know.

<table>
<thead>
<tr>
<th>Patient Sample</th>
<th>Low Risk</th>
<th>High Risk</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Your group will be testing two of the four patient samples along with positive and negative controls. To ensure that your results are accurate, all your samples will be run in triplicate.
MATERIALS PER STATION

- Goggles/gloves
- Gloves
- Eppendorf rack
- Paper towels
- ELISA well strips
- Micropipet (P200)/tips
- Timer
- Tip waste container
- Transfer pipet
- Permanent marker
- 750µl antigen (green)
- 175µl positive control (pink)
- 175µl negative control (purple)
- 175µl each patient sample (clear)
- 750µl secondary antibodies (yellow)
- 750µl substrate (brown)
- Wash buffer

Procedures

PART 1: PLAN FOR LOADING THE ELISA STRIP

1. Each group will have 2 of the 4 patient samples. You will run your samples in triplicate (1 well per control and 3 wells per sample. 8 wells total.)

2. In your notebook mark which samples you will be testing.

3. Draw a copy of Figure 2 into your lab notebook and record the location of your controls and patient samples. Run the samples near each other in a row so that the plate can be used again by the next class.

PART 2: PERFORM ELISA

Note: As you go through these steps, draw in what is happening on the Well Diagram on the last page of the Student Handout: Data & Analysis.

4. Add 50µl of the antigen (green tube) to each of the 8 wells. Discard pipet tip.

5. Incubate for 5 minutes at room temperature. This allows for the antigen to bind to the plastic wells.

6. Remove the unbound antigen.
   a. Turn the well strip upside down on a stack of paper towels.
   b. Bang it forcefully several times to remove any unbound antigen.
   c. Discard the top layers of paper towels.

7. Wash step.
   a. Use a transfer pipet to fill each well with wash buffer. Be careful not to touch the sides of the wells with the tip. Please keep the transfer pipet and use for future washes.
   b. Remove the buffer by turning the well strip upside down on a stack of paper towels and banging. Discard the top layer of paper towels and keep the transfer pipet for future wash steps.

8. Add controls and patient samples. Add 50µl of the controls and patient samples to the wells designated in your template. Be sure to use a fresh pipet tip after pipetting a sample in triplicate.
   a. 1 well (+) control (pink tube)
   b. 1 well (-) control (purple tube)
   c. 3 wells patient ______ sample (clear tube)
   d. 3 wells patient ______ sample (clear tube)

FIGURE 2: Example ELISA well

FIGURE 3: Samples and controls
9. **Incubate 5 minutes at room temperature.** This allows for antibodies, if present in the patient sample, to bind to antigens.

10. **After 5 minutes, remove the sample** using the same technique you used to remove the antigen.
    a. Turn the well strip upside down on a stack of paper towels.
    b. Bang it forcefully several times to remove any unbound sample/control.
    c. Discard the top layers of paper towels.

11. **Repeat the wash step.**

12. **Add secondary antibodies.** Add 50µl of secondary antibodies (yellow tube) to all 8 wells. Change the pipet tip after each triplicate. The secondary antibody is bound to an enzyme. These enzyme-bound antibodies are called “conjugated”. This enzyme interacts with the substrate we will add next, allowing us to visualize whether the primary antibodies are present.

13. **Incubate for 5 minutes** at room temperature.

14. **Remove the secondary antibodies.**
    a. Turn the well strip upside down on a stack of paper towels.
    b. Bang it forcefully several times to remove any unbound antigen.
    c. Discard the top layers of paper towels.

15. **Repeat the wash step** 3 times to remove all unbound antibodies.

16. **Add substrate.** Add 50µl of peroxidase substrate (brown tube) to each well. Be careful not to touch the sides of the well with the tip.

17. **Incubate for 5-10 minutes** (until you see color change) then record your results.

### CLEAN UP

- **Dispose** of used tips, microtubes, and used paper towels.
- **Keep** waste containers and transfer pipets.
- **Wash** your hands. Clean up your lab stations.
FIGURE 5: Positive ELISA Schematic. The p24 antigens are attached to the surface of the well. Next, HIV antibodies from the patient's serum attach to the antigen. Enzyme-linked anti-HIV antibodies then bind to the patient's antibodies. Once the substrate is added, the HRP enzyme will convert the non-colored substrate to a colored product.

FIGURE 6: Negative ELISA Schematic. The p24 antigens are attached to the surface of the well. Next, HIV-negative sample is added. Because there are no HIV antibodies from the patient's sample, the enzyme-linked anti-HIV antibodies cannot bind and are washed out. Without the HRP enzyme, the substrate is not converted into the visible blue product.
Results

1. In your lab notebook, record your results by copying Results Table 1. Mark which patient sample you tested (A, B, C, or D). Then record whether your results were positive (color change), negative (no color change) or inconclusive (slight color change).

<table>
<thead>
<tr>
<th></th>
<th>Positive Control</th>
<th>Negative Control</th>
<th>Patient Sample ___</th>
<th>Patient Sample ___</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well 2</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Well 3</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

2. Collaborate with another group that tested the other two patient samples. Be sure to include their group name, sample data, and controls. Combine their data with yours in Results Table 2.

<table>
<thead>
<tr>
<th>Patient</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Collaborating Group Negative Control</th>
<th>Collaborating Group Positive Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Well 2</td>
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<tr>
<td>Well 3</td>
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</tbody>
</table>

Analysis

Write your analysis questions and answers in your lab notebook.

3. If a well is blue, is the target antibody present? Explain.

4. Did any of the blood serum samples contain the antibody against the HIV p24 antigen? How do you know?

5. Were your predictions correct?
Well Diagram

Use this diagram of the wells to draw what is happening as you go through the ELISA protocol. Draw in each well as you wait during each incubation step.
Code Cracking: Decoding Cancer Causing Mutations

NWABR

Time:

3 or more 50-minute class periods, if taught during synchronous in-person instruction. Adaptations for remote learning may change this time estimate.

Subject & Grade Level(s):

High School Biology, Grades 9-10

Brief Overview: This lesson is intended to be integrated into a High School Biology genetics unit and allows students to investigate and understand that cancer is a result of an accumulation of mutations in the genes that control cell proliferation. Cancer has a global impact, impacting lives around the world. However, cancer (both rates of incidences and cancer related deaths) disproportionately affects people in different countries of the globe. Students will learn about risk factors and prevention strategies to help them unpack some of the reasons for these disparities. In the culminating mini-project, students will conduct online research on the global disparities of cancer by investigating either a type of cancer across multiple countries/regions or the rates of different types of cancer in a single country/region. Optional extension activities are included.

nwabr.org

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Lesson Structure

This lesson plan is divided up into three parts which can be enacted over three class periods. Day One is focused on cancer as a molecular disease. Day Two is focused on mutations and the cell cycle. Day Three engages students in examining global disparities of cancer incidences and rates.

Teachers may choose to use this lesson as a launch event and puzzling scientific phenomenon for their genetics unit, using cancer as an authentic case for understanding different concepts in genetics. Alternatively, teachers may choose to leverage these activities as a culminating project for their genetics unit, where students will be challenged to apply their foundational understanding of genetics to a cancer related phenomenon. Regardless of how teachers opt to position it, these activities will engage students in an exploration of the global burden of cancer.

Student Understandings

ANCHORING PHENOMENON

Cancer has a global impact, impacting lives around the world. However, cancer (both rates of incidences and cancer related deaths) disproportionately affects people in different countries of the globe.

DNA is a molecule that contains all the information that allows an organism to develop, live, and reproduce. Genes are the areas of DNA that code for proteins, which are the workhorses of the cell. Cancer is a result of the accumulation of mutations in the genes that control cell proliferation. While a small number of these mutations are inherited, the majority are acquired either spontaneously or caused by external agents. Because cancer is a result of uncontrolled cell division, its development is linked to mutations in cells that control cell proliferation.

DRIVING QUESTIONS

Anchoring Question for the Lesson: How can an understanding of genetics help us investigate why cancer (both rates of incidences and cancer related deaths) disproportionately affects people in different countries of the globe?

Day One Investigative Questions:

► What causes cancer?
► What are the exposures and events that lead to cancer?
► Are there preventative measures that can help reduce cancer risks?

Day Two Investigative Questions:

► What are genetic mutations?
► What types of genes are mutated in cancer cells?

Day Three Investigative Questions:

► What factors might account for disparities in cancer types and rates in different countries around the world?
► Given the limited funding dedicated to non-communicable diseases around the world, how could those resources best be spent?

Remote Learning Adaptations

Integrated into this lesson plan are suggestions for adapting the activities for remote teaching and learning settings. For remote instruction, this lesson assumes students have computer and internet access at home.
Next Generation Science Standards

This lesson builds toward the following bundle of high school level Performance Expectations (PEs). Hyperlinks direct to relevant sections of the Next Generation Science Standards and A Framework for K-12 Science Education.

PERFORMANCE EXPECTATIONS

**HS-LS1-1: From Molecules to Organisms—Structures and Processes.** Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.

**HS-LS1-4: From Molecules to Organisms—Structures and Processes.** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

**HS-LS3-2: Heredity—Inheritance and Variation of Traits.** Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations from meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

<table>
<thead>
<tr>
<th>Science and Engineering Practices (SEPs)</th>
<th>Disciplinary Core Ideas (DCIs)</th>
<th>Crosscutting Concepts (CCCs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Developing and Using Models</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Engaging in Argument from Evidence</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>LS1.A: Structure and Function</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>LS1.B: Growth and Development of Organisms</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>LS3.B: Variation of Traits</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Structure and Function</td>
<td></td>
<td>●</td>
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<tr>
<td>Systems and Systems Models</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Cause and Effect</td>
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<td></td>
</tr>
</tbody>
</table>

## Teacher Preparation

### MATERIALS:

<table>
<thead>
<tr>
<th>Material</th>
<th>Description/Source</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom computer</td>
<td>Computer with internet access, projector, and speakers (for live, in-class instruction).</td>
<td>1</td>
</tr>
<tr>
<td>Student computers</td>
<td>Computers need to have internet access. For remote instruction, this lesson assumes students have computer and internet access at home.</td>
<td>1/student or small group</td>
</tr>
</tbody>
</table>
| Student Handouts          | Make copies of the Student Handouts -OR- make digital copies of handouts available to students via your learning management system:  
  • Student Handout 1: Code Cracking Vocabulary Terms (Optional)  
  • Student Handout 2: Cancer: True or False?  
  • Student Handout 3: Protein Synthesis  
  • Student Handout 4: Mutation Practice  
  • Student Handout 5: The Eukaryotic Cell and Cancer  
  • Student Handout 6: Socioeconomic Status & Cancer  
  • Student Handout 7: Global Cancer Disparities (Optional)  
  • Student Handout 8: Global Cancer Mini-Project  
  • Student Handout 9: Global Health Careers (Extension Activity) | 1/student or small group |
| Teacher Resources         |  
  • Code Cracking Slide Deck (main slide deck used throughout lesson)  
  • Cancer True or False Slide Deck (for use with live in-person or videoconference presentations)  
  • Cancer True or False: Teacher Answer Key  
  • Protein Synthesis: Teacher Answer Key  
  • Say It with DNA Messages (alternate Google doc for remote instruction)  
  • Say It with DNA Messages: Teacher Answer Key  
  • Mutation Practice: Teacher Answer Key  
  • Global Cancer Disparities: Teacher Answer Key (Optional)  
  • Global Cancer Mini-Project: Scoring Rubric | N/A |

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**Code Cracking:**  
Decoding Cancer Causing Mutations Slide Deck  
[Download Slide Deck](#)
NOTES TO TEACHER FOR PREPARING TO TEACH THIS LESSON:

1. Internet-enabled computers are required for several activities in this lesson. Students will need to work individually or in small groups on computers.

   Remote instruction: This lesson assumes students have computer and internet access at home.

2. Make copies of the Student Handouts. Determine if/how you will use the optional handouts, Student Handout 1: Code Cracking Vocabulary Terms and Student Handout 7: Global Cancer Disparities.

   Remote instruction: Make digital copies of handouts available to students via your learning management system.

3. Review the slide deck and speaker’s notes.

   Remote instruction: Consider recording a video of you presenting the slides (i.e., by using Peardeck for Google Slides or ScreenCast O Matic) for students to view from home.

4. Consider if you want to incorporate any of the alternative or extension activities.

5. You will need to have the following materials prepped for each day of instruction.

   - Day One:
     i. Code Cracking Slide Deck
     ii. Cancer True or False Slide Deck (Optional)
     iii. Student Handout 1: Code Cracking Vocabulary Terms (Optional)
     iv. Student Handout 2: Cancer: True or False?
     v. Student Handout 3: Protein Synthesis

   - Day Two:
     i. Code Cracking Slide Deck
     ii. Student Handout 4: Mutation Practice
     iii. Student Handout 5: The Eukaryotic Cell and Cancer
     iv. Student computers/tablets

   - Day Three:
     i. Code Cracking Slide Deck
     ii. Student Handout 6: Socioeconomic Status & Cancer
     iii. Student Handout 7: Global Health Disparities (Optional)
     iv. Student Handout 8: Global Cancer Mini-Project
     v. Student computers/tablets

   - Extensions:
     i. Student Handout 9: Global Health Careers (Optional)

STUDENT ASSESSMENT OPPORTUNITIES:

- The Student Handouts provide opportunities for formative assessment. Teacher Answer Keys are provided for many of these handouts.
- Whole class discussions also provide opportunities for teachers to check-in on students’ developing understanding of the lesson’s anchoring phenomenon and daily driving questions.
- In addition, teachers could assign daily Exit Tickets to check student understanding of key concepts.
- The Global Cancer Mini-project serves as the summative assessment for this lesson. A scoring rubric is provided.
Instructional Procedure

Assuming synchronous, live, in-class instruction

This lesson plan is divided up into three parts which can be enacted over three class periods (assuming 50-55 minute periods). Day One is focused on cancer as a molecular disease. Day Two is focused on mutations and the cell cycle. Day Three engages students in a research project looking at global disparities of cancer incidences and rates.

OVERVIEW

<table>
<thead>
<tr>
<th>Day of Instruction</th>
<th>Activity</th>
<th>Approx. Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day One</td>
<td>Activity I: Introduction to Cancer</td>
<td>10 min</td>
</tr>
<tr>
<td></td>
<td>Activity II: Cancer Causes and Prevention</td>
<td>10 min</td>
</tr>
<tr>
<td></td>
<td>Activity III: Cancer as Molecular Disease</td>
<td>10 min</td>
</tr>
<tr>
<td></td>
<td>Activity IV: Exploring the Genetic Code</td>
<td>20 min</td>
</tr>
<tr>
<td>Day Two</td>
<td>Activity V: Intro to Mutations</td>
<td>20 min</td>
</tr>
<tr>
<td></td>
<td>Activity VI: Cancer-causing Mutations</td>
<td>10 min</td>
</tr>
<tr>
<td></td>
<td>Activity VII: The Eukaryotic Cell and Cancer</td>
<td>20 min</td>
</tr>
<tr>
<td>Day Three</td>
<td>Activity VIII: Socioeconomics of Cancer</td>
<td>15 min</td>
</tr>
<tr>
<td></td>
<td>Activity IX: Culminating Mini-Project</td>
<td>35+ min</td>
</tr>
</tbody>
</table>

1 DAY ONE

ACTIVITY I: INTRODUCTION TO CANCER (10 MINUTES)

1. Open the activity by asking students what they know about cancer and why they think they will be studying it. Students give feedback (Code Cracking Slide Deck, Slides #1-2).

   Ask students:
   a. Why is cancer such an important topic?
   b. Why do you think we are talking about cancer?
   c. Do you know anyone who has cancer?

2. Present key facts about the impact of cancer (Slide #3), emphasizing that these numbers represent human lives and community resources. In the US alone, people die of cancer at a rate greater than one per second. These numbers represent parents, children, our relatives, friends, and perhaps even our future selves. The human and financial burden of cancer is enormous and impacts us all.
3. Inform students that we might not always have accurate ideas about cancer (Slide #4). Divide students into groups to answer T/F questions (Student Handout 2: Cancer—True or False?) followed by whole class discussion in which students share their responses. The optional Cancer True or False Slide Deck can be used as a discussion tool after students have completed the handout. It includes the correct answers to each prompt, which can be revealed to encourage student discussion.

4. The last question on the handout introduces cancer as a result of mutations. Return to the Code Cracking Slide Deck, Slide #5 to emphasize a key point: Cancer is caused by changes in genes that normally control the growth and death of cells. Certain lifestyle and environmental factors can change, or mutate, normal genes into genes that allow and promote the growth of cancer.

5. Introduce the overall driving question that students will be investigating during this lesson, which will extend for three days. Then, introduce the investigative questions for today (Slides #6-7).

Day One Investigative Questions:

a. What causes cancer?

b. What are the exposures and events that lead to cancer?

c. Are there preventative measures that can help reduce cancer risks?

ACTIVITY II: CANCER CAUSES AND PREVENTION (10 MINUTES)

6. Ask students to brainstorm about what types of events might cause mutations. Explain to students that these cancer risk factors fall into 3 categories: physical, chemical and biological. Have students identify which category each type of event falls into (Slides #8-11).

7. Ask students to brainstorm about things they can do to prevent cancer, and ask how people can protect themselves from these exposures and events.
8. **Slide #12 asks: Are there some things that are more difficult to prevent/protect against than others?** Does where you live have anything to do with these factors? Do they think that people around the world have the same risk factors for cancer? Why or why not? What percent of cancers do students think could be prevented if these risk factors could be avoided? Discuss these questions with students.

9. **Show Slide #13 with key facts:**
   - Around one third of deaths from cancer are due to the five leading behavioral and dietary risks: high body mass index, low fruit and vegetable intake, lack of physical activity, tobacco use, and alcohol use.
   - Tobacco use is the most important risk factor for cancer and is responsible for approximately 22% of cancer.
   - Cancer causing infections, such as hepatitis and human papilloma virus (HPV), are responsible for up to 25% of cancer cases in low- and middle-income countries.

10. **Ask students why certain risk factors might vary in high and low resource countries?** Based on just these key facts, students might note that the five leading behavioral risks are more prevalent in high resource countries, and that lower resource countries have more limited access to vaccines and antibiotics.

**ACTIVITY III: CANCER AS MOLECULAR DISEASE (10 MINUTES)**

11. **Use Slides #14-15.** Note that students will need a basic understanding of DNA transcription and translation as a foundation for the rest of the unit. The following videos can serve either as a review or a brief introduction to these topics.

   - What is DNA and how does it work? (5:23 minutes)
     Stated Clearly, 2012
   - What is a gene? (4:56 minutes)
     Stated Clearly, 2012
   - These exposures increase the risk of cancer because of their capacity to cause: DNA Damage
     - Chemical
     - Biological
     - Physical
ACTIVITY IV: EXPLORING THE GENETIC CODE (20 MINUTES)

12. Introduce students to the coding activity and give a brief explanation of the central dogma, using Slides #16-19. Remind students that proteins are made up of amino acid sequences. The specific amino acid sequence for each unique protein is determined by the sequence of DNA bases. These DNA bases are read in triplets, or “codons” and each codon, or set of three bases codes for a specific amino acid.

13. Distribute copies of Student Handout 3: Protein Synthesis as well as DNA strips cut from Teacher Resource: Say it With DNA Messages. Ask students to work alone or in small groups to decode the DNA sequence strips using the handout, and then use the codon dictionary to come up with their own words or sentences.

14. Optional: (Slide #20). Redistribute the DNA strips cut from Teacher Resource: Say it With DNA Messages for students to decode using a simple bioinformatics database that translates DNA to mRNA to an amino acid sequence. Students can then translate the amino acid abbreviation given to its single letter symbol. (Students click on DNA, enter their DNA sequence, click on “Convert” and then scroll down to see the results.

Example:
AGA ACA TAA CTC TAA AGA CCA CTC CGA TGA
Decodes to: Science is great

DNA Translator (DNA to mRNA to Protein Converter)
NucleiAcidicConverter, 2016 (built by a high school student)
https://skaminsky115.github.io/nac/
ACTIVITY V: INTRO TO MUTATIONS (20 MINUTES)

15. (Slide #21). Begin class with a quick review of the previous day’s decoding activities. Introduce today’s investigative questions:

Day Two Investigative Questions:
- What are gene mutations?
- What types of genes are mutated in cancer cells?

16. Ask students what they think would happen if there was a mutation (mistake in sequence resulting in a permanent change in the DNA’s code.) Students can brainstorm responses and teacher helps them to understand that mutations can lead to a change in the cell’s structure, function, or regulation.

17. Review the three types of mutations using Slides #22-24.

18. Distribute copies of Student Handout 4: Mutation Practice for students to complete. Provide about 15 minutes for students to complete the activity.

ACTIVITY VI: CANCER-CAUSING MUTATIONS (10 MINUTES)

19. Use Slides #25-28 to explain to students that of the approximately 35,000 genes in the human genome, only a small number are associated with cancer. Ask students to brainstorm about what kinds of genes these might be. Remind students that cancer is out of control cell growth. The discussion should end with students understanding that the mutations associated with cancer are mutations to the genes that regulate the cell cycle.
ACTIVITY VII: THE EUKARYOTIC CELL AND CANCER (20 MINUTES)

20. Use Slides #29-31 to introduce the eukaryotic cell and cancer. Ask students explore the cell cycle online using the interactive website listed below, along with Student Handout 5: The Eukaryotic Cell and Cancer. The HHMI BioInteractive website provides cell cycle fundamentals and explains how cancer causing mutations affect cell cycle regulation.

Note: If students need an extra challenge, use the in-depth version of the worksheet available from HHMI BioInteractive. A Spanish language version of Student Handout 5 or the more in-depth version is also available at this website.

ACTIVITY VIII: SOCIOECONOMICS OF CANCER FACILITATED DISCUSSION (15 MINUTES)

21. Use Slide #32 to introduce today’s investigative questions:

Day Three Investigative Questions:

a. What factors might account for disparities in cancer types and rates in different countries around the world?

b. Given the limited funding dedicated to non-communicable (not infectious) diseases around the world, how could those resources best be spent?

22. What factors can impact a person’s health and cancer risk? Distribute copies of Student Handout 6: Socioeconomic Status & Cancer for students to read. Then, use Slide #33 to facilitate a discussion about how socioeconomic status (SES) factors can impact a person’s health. Students could Turn and Talk first before holding a whole class discussion. What do students wonder about? What data would they need to answer those questions?
Note that additional information on cancer disparities and contributing factors is available from the National Cancer Institute. This would make a great additional student reading if you would like to go into more depth on this topic: Cancer Disparities (National Cancer Institute, 2019)

23. How might SES impact global rates of cancer?
   Expand the discussion to include a global perspective on socioeconomic factors and cancer and introduce the culminating mini-project.

ACTIVITY IX: CULMINATING MINI-PROJECT (35+ MINUTES)

24. (Slide #34). A mini-project extends students’ focus from cancer as a molecular disease to thinking about the global burden of cancer as a disease. This project can be extended to an additional class period, if desired, by providing additional time for in-class research and/or by asking students to also complete the optional Student Handout 7: Global Health Disparities. This handout engages students in activities that are a great lead-in to the mini-project.

25. Students should work in pairs or small teams and use Student Handout 8: Global Cancer Mini-Project. The mini-project serves as the summative assessment for this lesson.

MINI-PROJECT DESCRIPTION

In this mini-project, student teams either: (a) investigate a specific type of cancer (i.e., stomach) across different countries/regions or (b) investigate a country/region and examine rates of different types of cancer (i.e., brain, breast, stomach, lung, etc.) in that country or region.

Teams will engage in sensemaking of statistics, articles, data, and data visualizations from multiple sources (e.g., WHO, IHME Global Burden of Disease, Gapminder, Globocan). They will develop an explanatory model—using their understanding of the genetics of cancer—to develop an evidence-based explanation for these disparities. They will also develop a list of recommendations for how to best spend limited resources to reduce cancer rates.
ADAPTATIONS FOR REMOTE INSTRUCTION

This lesson plan has been updated to include adaptations for remote instruction settings. As written, the lesson is intended for in-person, live, classroom-based instruction. Suggestions are summarized in the table below for hybrid and fully remote teaching and learning settings. **Hybrid instruction** assumes several days each week of live, in-person, classroom-based instruction paired with several days of asynchronous, home-based, remote learning. **Asynchronous remote instruction** assumes no in-person, class-based instruction with all learning taking place remotely in students’ own homes. Suggestions focus on asynchronous learning. Teachers who can provide synchronous, live video conference meetings with students may sample from the original lesson plan or the hybrid setting suggestions. The adaptations described below should be considered in addition to the directions in the Procedure section of the lesson plan.

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<tr>
<td><strong>Teacher Prep for Lesson</strong></td>
<td>• Decide what students will do during in-class days and what they will do from home during remote days. • Make digital copies of handouts available to students via your learning management system. • Focus in-person time in the classroom on group work, group discussion, and interaction between students.</td>
<td>• Consider recording a video of you presenting the slides (i.e., by using Peardeck for Google Slides, Screencastify or ScreenCast O Matic) for students to view from home. • Make digital copies of handouts available to students via your learning management system. • Consider using digital bulletin boards (i.e., Padlet, Google Jamboard app, or FlipGrid) as a way for students to communicate, share, and increase interaction. • Consider curating all web links that students will need to access in one place (i.e., Wakelet, LinkTree, Google Doc, etc.). An example has been provided in this LinkTree page <a href="https://linktr.ee/LaughingCrowLLC">https://linktr.ee/LaughingCrowLLC</a>, but you may want to create your own in order to customize it.</td>
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**Day One: Intro to Cancer** (Slides #1-7)

1. **For remote, synchronous live instruction:**
   - If you will present the slide deck during a live videoconference, consider using a digital poll (i.e., poll function in Zoom Meeting, PollEverywhere, DirectPoll, etc.) in lieu of the **Student Handout 2: Cancer—True or False?** to elicit, view, and discuss responses in real time. Alternatively, consider using the Cancer—True or False? Slide Deck to run through each response with the class, allowing students to vote using the chat or hand raise function in the videoconference app.

2. **For fully remote, asynchronous instruction:**
   - (Slides #1-4) Have students review Slides #1-4 of the Code Cracking Slide Deck and speaker’s notes or view a video of you presenting the slide deck (preferable).
   - After reviewing Slides #1-4, students should answer the T/F questions on **Student Handout 2: Cancer—True or False?**. Students can be asked to complete their work on the digital version of the handout to submit to the instructor, or to submit answers to the instructor in some other format through the classroom learning management system. Alternatively, an online auto-corrected quiz could be created using a tool like Peardeck for Google Slides.
   - (Slides #5-7) Have students review Slides #5-7 of the Code Cracking Slide Deck and speaker’s notes or view a video of you presenting the slide deck.

**Day One: Cancer Causes & Prevention** (Slides #8-13)

1. **For remote, synchronous live instruction:**
   - If you will present the Code Cracking Slide Deck during a live videoconference, consider how to use digital bulletin boards so students can see and respond to each other’s responses. Breakout rooms may provide an opportunity for smaller group discussion.

2. **For fully remote, asynchronous instruction:**
   - Have students review Slides #8-13 of the Code Cracking Slide Deck. Digital bulletin boards allow students to respond to prompts, re-organize and categorize responses, and respond/react to each other’s answers. Some examples include Padlet, Google Jamboard app, or FlipGrid. Use a digital bulletin board for students to post their responses for the following discussion prompts.
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| 1 Day One: Cancer Causes & Prevention, cont. (Slides #8-13) | • Alternatively, you may have students type their answers and submit them to you using your classroom learning management system.  
  − (Slides #8-11) What types of events might cause mutations? Identify or sort which category each cancer risk factor falls into: physical, chemical and biological.  
  − What are some things you can do to prevent cancer? How can people protect themselves from these exposures and events?  
  − (Slide #12) Are there some things that are more difficult to prevent/protect against than others? Does where you live have anything to do with these factors. Do they think that people around the world have the same risk factors for cancer? Why or why not? What percent of cancers do students think could be prevented if these risk factors could be avoided?  
  − (Slide #13) Why might certain risk factors might vary in high and low resource countries? | |
| 1 Day One: Cancer as a Molecular Diseases (Slides #14-15) | • This video-based activity would work in-person or at-home. If you will present the slide deck in class, follow the instructions as written in the Procedure. For remote instruction, see the column to the right. | • (Slides #14-15) Have students review Slides #14-15 of the Code Cracking Slide Deck. Links to the two videos, "What is DNA and how does it work?" and "What is a gene?" have been included in the sample LinkTree for this lesson to make it easy for students to access them from home. |
| 1 Day One: Exploring the Genetic Code (Slides #16-19) | • This activity works well as a small group, in-person activity as described in the lesson Procedure.  
  • For remote instruction, the activity can be adapted for individual, at-home learning using the instructions provided in the column to the right. | • (Slides #16-19) Have students review Slides #16-19 of the Code Cracking Slide Deck, which provide a brief explanation of the central dogma. It is important for students to understand that proteins are made up of amino acid sequences. The specific amino acid sequence for each unique protein is determined by the sequence of DNA bases. These DNA bases are read in triplets, or “codons” and each codon, or set of three bases codes for a specific amino acid.  
  • After reviewing the slides, students should work on Student Handout 3: Protein Synthesis. You will need to assign each student a different number (1-30) that will correspond to a DNA message available on the Say It with DNA Messages Google doc. You can make a copy of the Google doc and post to your learning management system or email each student their unique DNA message. Their task is to decode the DNA sequence strips using the handout, and then use the codon dictionary to come up with their own words or sentences. Students can be asked to complete their work on the digital version of the handout to submit to the instructor, or to submit answers to the instructor in some other format through the classroom learning management system.  
  • See the lesson Procedure for an optional, fully online extension activity that has students decode DNA messages using an online bioinformatics database. |
| 2 Day Two: Intro to Mutations (Slides #20-24) | • This activity could be done in-person or at-home. If you will present the slide deck and mutation practice activity in class, follow the instructions as written in the Procedure.  
  • If students will review the slide deck and complete the handout on their own during a remote instruction day, follow the instructions in the column to the right. | • (Slides #20-24) Have students review Slides #20-24 of the Code Cracking Slide Deck which covers what happens when there is a mutation and reviews the three types of mutations.  
  • Students then complete Student Handout 4: Mutation Practice. Students can be asked to complete their work on the digital version of the handout to submit to the instructor, or to submit answers to the instructor in some other format through the classroom learning management system. |
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| **2** Day Two: Cancer-causing Mutations (Slides #25-28) | • This activity is discussion dependent and would work best in-person. If you will present the slide deck and discussion in class, follow the instructions as written in the Procedure.  
• If students will review the slide deck on their own during a remote instruction day, follow the instructions in the column to the right. | • (Slides #25-28) Have students review Slides #25-28 of the Code Cracking Slide Deck which explains that of the approximately 35,000 genes in the human genome, only a small number are associated with cancer.  
• Consider using a digital bulletin board (i.e., Padlet) to allow students to answer prompts and respond/react to each other's answers. Alternatively, you may have students type their answers and submit them to you using your classroom learning management system.  
  - What kinds of genes might be associated with cancer? (The mutations associated with cancer are mutations to the genes that regulate the cell cycle.) |
| **2** Day Two: The Eukaryotic Cell and Cancer (Slides #29-31) | • This activity is accomplished completely online, so it is a good match for a remote learning day. In this case, follow the instructions in the column to the right.  
• If you will present the slide deck and activity in class, follow the instructions as written in the Procedure. | • (Slide #29) Have students review Slide #29 of the Code Cracking Slide Deck, which introduces the eukaryotic cell and cancer.  
• Students can then explore HHMI BioInteractive’s Eukaryotic Cell and Cancer Online Activity, as described in the lesson Procedure. For the HHMI online activity, students will need access to Student Handout 5: The Eukaryotic Cell and Cancer. |
| **3** Day Three: Socioeconomics of Cancer Facilitated Discussion (Slides #32-33) | • This activity is discussion-based and serves to launch the mini-project; it would work best in-person.  
• If you will present the slide deck and discussion in class, follow the instructions as written in the Procedure.  
• If students will review the slide deck on their own during a remote instruction day, follow the instructions in the column to the right | • (Slide #30) Have students review Slide #30 of the Code Cracking Slide Deck which introduces the day’s investigative questions. They then investigate what factors can impact a person’s health and cancer risk using a reading.  
• After reviewing Slide #30, students should read Student Handout 6: Socioeconomic Status & Cancer.  
• (Slide #31) Students review Slide #31 and then respond to prompts. Consider using a digital bulletin board (i.e., Padlet) to allow students to answer prompts and respond/react to each other's answers. Alternatively, you may have students type their answers and submit them to you using your classroom learning management system.  
  - How might socioeconomic factors impact a person’s health?  
  - What do you wonder about this topic?  
  - What data would you need to answer those questions?  
• An optional reading from the National Cancer Institute is provided in the Procedure section that would allow students to go into more depth on the topic.  
• (Slide #32) Students review the slide, which expands the topic to a global perspective on socioeconomic factors and cancer, while introducing the culminating mini-project. |
| **3** Day Three: Culminating Mini-Project (Slide #34) | • If conducted in-class, the mini-project allows for students to work in groups and present their projects to the class. This is encouraged—especially the presentations—because it allows for collaboration and discussion.  
• If students will work on the project in groups in class, follow the instructions as written in the Procedure.  
• However, the project is entirely computer-based, so it could translate well to at-home learning. If students will work on the project independently during a remote instruction day, follow the instructions in the column to the right. | Research Project:  
• If working in pairs or small groups, consider what technologies are available to your school/district that would allow students to virtually meet-up to complete the assignment together and discuss their results. Otherwise, students will have to work on the project independently. See the Procedure for a description of the mini-project.  
• Students will need access to a digital version of Student Handout 8: Global Cancer Mini-Project and will need to be able to access multiple websites from home. You may also want to use the optional Student Handout 7: Global Health Disparities, which serves as an excellent lead-in to the project.  
• The links for research sources that are included in the project’s handout have also been included in the sample LinkTree for this lesson to make it easy for students to access them from home.  
• Whether accomplished in groups (meeting virtually) or independently, the mini-project challenges students to develop an explanatory model and a list of recommendations for how to best spend limited resources to reduce cancer rates. }
### Day Three: Culminating Mini-Project, cont. (Slide #34)

#### Project Presentations:
- Consider what technologies are available to your school/district that would allow students to virtually meet-up to share and discuss their results. Another option could be using FlipGrid or Google slides to allow for each group to share their presentations with one another. For example, each group could record a video presentation or audio narration and upload it to FlipGrid for everyone to view.

The mini-project serves as the summative assessment for this lesson.

Consider assigning an extension activity that focuses on careers in the global health field. See the Lesson Extensions section for a full description. Students are introduced to the field of global health using Student Handout 9: Global Health Careers which provides a reading about careers in this field. Students could then investigate different global health careers of interest using the poster and fact sheets offered online by the Washington Global Health Alliance. All materials are provided online and amendable to remote learning.

To further deepen students’ career exploration, see the Exploring Pathways to Global Health Careers lesson plan.

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Suggested Lesson Extensions

GLOBAL HEALTH CAREERS READING AND RESEARCH

Introduce students to the field of global health using Student Handout 9: Global Health Careers which provides a reading about careers in this field.

The following careers are related to cancer research and global health, linked to the Occupational Outlook Handbook on the U.S. Bureau of Labor Statistics website.

- Epidemiologist
- Biostatistician
- Oncologist
- Biomedical Research Scientist
- International Aid Worker
- Social Worker

Students could then investigate different global health careers of interest using the STEM Global - Pathways to Global Health Careers poster and fact sheets. The careers of Epidemiologist, Biostatistician, International Aid Worker, and Social Worker are included in these resources.

ALTERNATIVE ACTIVITIES

The following resources provide activities that can be used as alternatives to the ones presented in the instructional procedure or can be used as lesson extensions, in particular for students who desire more depth of content. All materials are provided online and amendable to remote learning.

DNA Translator
DNA to mRNA to Protein Converter
NucleiAcidicConverter, 2016
(built by a high school student)

Alternate Cell Cycle Activity: BioNinja
BioNinja, 2016

Gene Card Activity: Classifying Cancer Genes and Examining Patient Data
HHMI BioInteractive
Notes on Adaptations and Inclusivity

INCLUSIVITY FOR ALL LEARNERS
Consider how the lesson activities may need to be adapted to be accessible for all learners. For example, what accommodations may a student with a visual or mobility impairment need to engage in these activities? How might you elicit, build connections with, and leverage students’ everyday expertise with genetics, cancer, and global health? How might you group students with diverse expertise and learning needs into teams so that they can support each other?

VIDEO CAPTIONING
The suggested review videos have a closed captioning option. Choose the “CC” option on the YouTube menu.

SPANISH VERSION
A Spanish language version of Student Handout 5, as well as a more in-depth version of the worksheet, are available from HHMI BioInteractive.

SCIENTIFIC VOCABULARY
Students may need some support in understanding the terminology embedded in this lesson. This may be particularly true for emerging bilingual students and students with lower reading levels. Terms should be defined contextually as the lesson unfolds. A list of vocabulary terms and definitions is provided in the optional Student Handout 1: Code Cracking Vocabulary Terms. The following list captures some of the terms used in the lesson materials.

- Age adjusted
- Amino acid
- Apoptosis
- Base
- Cancer
- Cancer deaths
- Cancer rate
- Cell cycle
- Central Dogma
- Codon
- Deletion mutation
- Disparity
- DNA (Deoxyribonucleic acid)
- Frameshift mutation
- Gene
- Global disease burden
- High-income country
- Highly developed country (HDC)
- Human Development Index (HDI)
- Insertion mutation
- Least developed country (LDC)
- Low-income country
- Mitosis
- Mutation
- Nucleotide
- Oncogene
- Point mutation
- Protein
- Protein synthesis
- Proto-oncogenes
- RNA
- Socioeconomic status (SES)
- Tumor suppressor genes
- Upper middle-income country
Teacher Resources

BACKGROUND INFORMATION

Cancer Key Facts
World Health Organization, 2018

Cancer as a Genetic Disease
Cancer.net, 2018

Cancer and the Cell Cycle
Khan Academy

Oncogenes and Tumor-Suppressor Genes
Cancer.org, 2014

Oncogenes, Tumor-Suppressor Genes, and DNA Repair Genes
CISN, 2013

What is Statistics?
ThoughtCo., Courtney Taylvor, 2018

Cancer Disparities and Contributing Factors
National Cancer Institute, 2019

ADDITIONAL INSTRUCTIONAL RESOURCES TO USE WITH STUDENTS

What is DNA and how does it work?
(5:23 minutes) Stated Clearly, 2012

What is a gene?
(4:56 minutes) Stated Clearly, 2012

Cancer and the Cell Cycle
Khan Academy

Types of Mutations
Understanding Evolution, 2019, University of California Museum of Paleontology

DNA Translator (DNA to mRNA to Protein Converter)
NucleiAcidicConverter, 2016 (built by a high school student)

Alternate Cell Cycle Activity:
BioNinja
BioNinja, 2016

Gene Card Activity: Classifying Cancer Genes and Examining Patient Data
HHMI BioInteractive

Authorship Credit: The Code Cracking lesson plan and associated materials were developed by Wendi Russac of the Northwest Association for Biomedical Research, a non-profit organization located in Seattle, WA and adapted for a STEM Global Educator Workshop in November 2019. Lesson plan development, editing, and adaptations for remote instruction provided by Kristen Bergsman of Laughing Crow Curriculum LLC.

The protein synthesis sentences on Student Handout 3: Protein Synthesis are from the activity Say It with DNA: Protein Synthesis Tutorial, developed by Larry Flammer, 2004, Evolution & the Nature of Science Institute.

Student Handout 5 is an adaptation of The Eukaryotic Cell Cycle and Cancer Overview Student Worksheet developed by HHMI BioInteractive as part of their Click and Learn activity.
**Vocabulary Terms**

Name: ___________________________  Date: ___________  Period: ______

**Age adjusted:** (Also called “age standardization”). A way of comparing age-related disease rates in populations with different age profiles and life expectancies.

**Amino acid:** The basic unit of a protein, sometimes called the “building blocks of life”. Amino acids combine to make proteins.

**Apoptosis:** The process of programmed cell death (also called “cell suicide”). Apoptosis is a controlled mechanism for ridding the body of old, abnormal, or irreparably damaged cells. One of the hallmarks of cancers is that cancer cells are able to avoid apoptosis.

**Base:** The differentiating component of nucleotides, the basic units of nucleic acids like DNA and RNA.

**Cancer:** A group of diseases distinguished by uncontrolled cell division as a result of an accumulation of mutations in the genes that regulate the cell cycle.

**Cancer deaths:** The mortality rate from cancer. Usually given as number of deaths per year per 100,000 males and females.

**Cancer rate:** Number of new cancer diagnoses. Usually given as number of diagnoses per year per 100,000 males and females.

**Cell cycle:** Pattern of growth, DNA replication, and cell division. The cell cycle is very closely regulated in normal cells.

**Central Dogma:** Describes the process by which the information on DNA is used to code for proteins via transcription and translation. Summarized as DNA → RNA → Protein.

**Codon:** A sequence of three DNA or RNA nucleotides that corresponds with a specific amino acid or stop signal during protein synthesis.

**Deletion mutation:** A gene mutation that results from the deletion of a base, or bases, in a DNA sequence.

**DNA (Deoxyribonucleic acid):** The molecule that carries the genetic information in almost all organisms. DNA uses four different bases (Adenine, Cytosine, Thymine, and Guanine) that pair together in specific ways that enable it to accurately pass on the information it contains to create proteins as well as to self-replicate. The sequence of bases on a particular section of DNA determines the sequence of amino acids that result in a unique protein.

**Frameshift mutation:** A mutation that shifts the reading frame of the genetic code because of an insertion or deletion.

**Gene:** A sequence of bases or nucleotides in DNA or RNA that codes for the synthesis of a functional gene product, either RNA or protein.

**Global disease burden:** A quantification of the risks and consequences of diseases in different populations of the world.

**High-income country:** The World Bank defined a high-income country as one that has a gross national income (GNI) per capita of $12,696 (US dollars) or more in 2020. Sometimes used as a simplified measure of a country’s development.

**Highly developed country (HDC):** A stable country with a high standard of living and per capita income that also has advanced levels of infrastructure and industrialization. HDCs score high on the Human Development Index compared to other countries.
**Human Development Index (HDI):** A statistical composite index used to rank countries into levels of development. It is based on indicators such as gross national income, standard of living, industrialization, level of education, political stability, childbirth mortality, and other factors.

**Insertion mutation:** A gene mutation that results from the insertion of a base, or bases, in a DNA sequence.

**Least developed country (LDC):** Least developed countries are those confronting significant and long-term barriers to sustainable development. They have low levels of human assets and are economically vulnerable. They have a low Human Development Index compared to other countries.

**Low-income country:** The World Bank defined a low-income country as one that has a gross national income (GNI) per capita less of $1,045 (US dollars) or less in 2020. Sometimes used as a simplified measure of a country's development.

**Lower middle-income country:** The World Bank defined a lower middle-income country as one that has a gross national income (GNI) per capita between $1,046 and $4,095 (US dollars) in 2020. Sometimes used as a simplified measure of a country’s development.

**Mitosis:** The process where a single cell divides into two identical daughter cells (cell division).

**Mutation:** A change that occurs in our DNA sequence, either due to mistakes when the DNA is copied or as the result of environmental factors.

**Nucleotide:** A molecule consisting of a nitrogen-containing base (adenine, guanine, thymine, or cytosine in DNA; adenine, guanine, uracil, or cytosine in RNA), a phosphate group, and a sugar.

**Oncogene:** The mutated form of a proto-oncogene. Proto-oncogenes are genes whose normal roles include stimulating cell growth by signaling cell division and regulating cell death. Mutations that cause proto-oncogenes to get “stuck on” and can lead to cancer.

**Point mutation:** A mutation where a single nucleotide is changed to another. Sometimes called a substitution mutation.

**Protein:** The major molecular component of cells. Proteins consist of a linear chains of amino acids arranged in a specific sequence. They are the workhorses of the cell and are required for the regulation, structure and function of all of the body’s tissues and organs.

**Protein synthesis:** The process by which the information encoded on DNA is transcribed and translated into a protein.

**Proto-oncogenes:** Proto-oncogenes are genes whose normal roles include stimulating cell growth by signaling cell division and regulating cell death. Mutations that cause proto-oncogenes to get “stuck on” can lead to cancer.

**RNA:** RNA has many complex functions. One of its most important roles is as a molecule that acts as a messenger in converting the genetic information encoded on DNA into a functional protein. RNA uses four different bases: adenine, guanine, uracil, and cytosine to code for the specific amino acids that make up a unique protein.

**Socioeconomic status (SES):** A measure of a person’s income, education, and occupation. These factors are often closely tied to other factors such as race, language skills, geography, and access to resources. A low SES is linked to a wide range of health problems, including low birth weight, cardiovascular disease, hypertension, arthritis, diabetes, and cancer.

**Tumor suppressor genes:** Tumor suppressor genes are normal genes that slow down cell division, repair DNA mistakes or tell cells when to die (apoptosis). Mutations in tumor suppressor genes can allow uncontrolled cell proliferation, which can lead to cancer.

**Upper middle-income country:** The World Bank defined an upper middle-income country as one that has a gross national income (GNI) per capita between upper middle-income economies are those between $4,096 and $12,695 (US dollars) in 2020. Sometimes used as a simplified measure of a country’s development.
Cancer: True or False?

Circle T for true or F for false for each statement.

1. Cancer deaths in the United States are increasing. T F
2. Cancer is contagious. T F
3. Lunchmeat can cause cancer. T F
4. There are over one hundred types of cancer. T F
5. Unhealthy lifestyle choices when you are young don’t affect your chances of getting cancer when you are older. T F
6. Cancer cells can grow forever. T F
7. Cancer cells grow and divide in a controlled fashion. T F
8. We currently have cures for cancer, but the medical industry keeps them from the public because they make so much money treating cancer patients. T F
9. Cancer develops because of changes in our DNA that result in abnormal gene function. T F
1. Cancer deaths in the United States are increasing.  
   **False.** According to annual statistics reporting from the American Cancer Society, the death rate from cancer in the US has declined steadily over the past 25 years. As of 2016, the cancer death rate for men and women combined had fallen 27% from its peak in 1991. This decline translates to about 1.5% per year and more than 2.6 million deaths avoided between 1991 and 2016. Although cancer diagnoses have increased, survival rates have increased at an even greater rate.  
   **Sources:** Cancer.org, Cancer Research UK

2. Cancer is contagious.  
   **False.** You cannot “catch” cancer. Cancer does not spread from one person to another. However, certain contagious viruses such as HPV or hepatitis, or bacteria such as *Helicobacter pylori*, can cause diseases that increase your risk of developing cancer.  
   **Sources:** Cancer.gov

3. Lunchmeat can cause cancer.  
   **True.** Research shows that eating processed meats like bacon and cold cuts can increase your chances for stomach and colorectal cancer. Processed meat includes hot dogs, ham, bacon, sausage, and some deli meats. It refers to meat that has been treated in some way to preserve or flavor it. Processes include salting, curing, fermenting, and smoking.  
   **Sources:** Cancer.gov

4. There are over one hundred types of cancer.  
   **True.** Any replicating cell can become cancerous. Different cancer types are named after the type of tissue where they arise.  
   **Sources:** WebMD.com

5. Unhealthy lifestyle choices when you are young don’t affect your chances of getting cancer when you are older.  
   **False.** Cancer is usually the result of years of exposure to a variety of risk factors. Avoiding some of these risk factors reduces your overall cancer risk.  
   **Sources:** NCBI
6. Cancer cells can grow forever.
   
   **True.** Cancer cells are considered immortal. Unlike normal cells, cancer cells have acquired mutations that allow them to divide indefinitely.

   **Sources:** Oxford Academic

7. Cancer cells grow and divide in a controlled fashion.
   
   **False.** Cancer is the uncontrolled growth of abnormal cells.

   **Sources:** Cancer.gov

8. We currently have cures for cancer, but the medical industry keeps them from the public because they make so much money treating cancer patients.
   
   **False.** Doctors and their loved ones also get cancer and would benefit from a cure. If there were a cure for cancer sharing it would bring enormous positive publicity and probable financial gain.

   **Sources:** How Stuff Works

9. Cancer develops because of changes in our DNA that result in abnormal gene function.
   
   **True.** Cancer is a genetic disease caused by changes in genes that normally control the growth and death of cells.
Protein Synthesis: Instructions

Name: ________________________  Date: ___________  Period: _____

**Overview:** In this activity, you will translate segments of DNA into their respective amino acid sequences and record the one letter amino acid symbol that corresponds to the correct translation of each codon. If you have accurately translated each DNA segment, the resulting amino acid sequence will spell out a word or phrase. A codon wheel is included to assist you in translation.

1. **Locate the codon wheel below.** You will need to use this to translate the RNA sequence.

2. **Start by transcribing the DNA sequence into mRNA.** Remember that DNA bases pair together in specific ways: C with G, and A with T. Your RNA sequence will pair U with A instead of T.

3. **Record your RNA sequence.**

4. **Remember that the cell reads the DNA code in groups of three bases.** Each triplet of bases, also called a codon, specifies which amino acid will be added next during protein synthesis. (Putting dashes or lines between each triplet, or circling each group of 3 bases can make translation easier.)

5. **Using the codon wheel, find the first base letter of the codon at the center of the wheel**, the second base letter in the next circle out and finally the last base in the third circle.

6. **Record the amino acid indicated outside the colored wheel.** Find and record its one letter symbol from the symbol table.

7. **If you have accurately synthesized your protein, the amino acid symbols should spell out a word or phrase in English.**

**Example:**

- **DNA sequence:** C C A C T C T T A C T T
- **mRNA sequence:** G G U-G A G-A A U- G A A
- **Amino acid:** GLY-GLU-ASN-GLU
- **Letter symbol:** GENE

**NOW YOU TRY IT!**
DNA Decoding (Protein Synthesis)
Practice Sheet

Name: ______________________ Date: ___________ Period: ______

1. DNA: C T T C C A C C T
   mRNA: _____________________________
   AA: _______________________________
   Symbol: __________________________

2. DNA: G G T C G T A C C
   mRNA: _____________________________
   AA: _______________________________
   Symbol: __________________________

3. DNA: G T G C T T T T A
   mRNA: _____________________________
   AA: _______________________________
   Symbol: __________________________

4. DNA: T C G T T C T A A
   mRNA: _____________________________
   AA: _______________________________
   Symbol: __________________________

TRY A LONGER SENTENCE

5. Following the same procedure, decode the message your teacher gives you below. (Note: the stop codons are used as spaces.)
   _____________________________
   _____________________________
   _____________________________
   _____________________________
   _____________________________
   _____________________________
   _____________________________
NOW CREATE YOUR OWN MESSAGE!

6. Create your own message. (Letters not available: B J O U X Z)

Decoded Message (English word or words): 

AMINO ACID SEQUENCE (three-letter abbreviations are okay):

mRNA: 

DNA: 

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>Three-Letter Abbreviation</th>
<th>One-Letter Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alanine</td>
<td>Ala</td>
<td>A</td>
</tr>
<tr>
<td>Arginine</td>
<td>Arg</td>
<td>R</td>
</tr>
<tr>
<td>Asparagine</td>
<td>Asn</td>
<td>N</td>
</tr>
<tr>
<td>Aspartate</td>
<td>Asp</td>
<td>D</td>
</tr>
<tr>
<td>Cysteine</td>
<td>Cys</td>
<td>C</td>
</tr>
<tr>
<td>Glutamate</td>
<td>Glu</td>
<td>E</td>
</tr>
<tr>
<td>Glutamine</td>
<td>Gln</td>
<td>Q</td>
</tr>
<tr>
<td>Glycine</td>
<td>Gly</td>
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<td>Histidine</td>
<td>His</td>
<td>H</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>Ile</td>
<td>I</td>
</tr>
<tr>
<td>Leucine</td>
<td>Leu</td>
<td>L</td>
</tr>
<tr>
<td>Lysine</td>
<td>Lys</td>
<td>K</td>
</tr>
<tr>
<td>Methionine</td>
<td>Met</td>
<td>M</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>Phe</td>
<td>F</td>
</tr>
<tr>
<td>Proline</td>
<td>Pro</td>
<td>P</td>
</tr>
<tr>
<td>Serine</td>
<td>Ser</td>
<td>S</td>
</tr>
<tr>
<td>Threonine</td>
<td>Thr</td>
<td>T</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>Trp</td>
<td>W</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>Tyr</td>
<td>Y</td>
</tr>
<tr>
<td>Valine</td>
<td>Val</td>
<td>V</td>
</tr>
</tbody>
</table>
1. DNA: CTTCCACCT
   mRNA: GAA GGU GGA
   AA: Glu Gly Gly
   Symbol: EGG

3. DNA: GTGCTTTTA
   mRNA: CAC GAA AAU
   AA: His Glu Asn
   Symbol: HEN

2. DNA: GTCGTACC
   mRNA: CCA GCA UGG
   AA: Pro Ala Trp
   Symbol: PAW

4. DNA: TCAGTCTAA
   mRNA: AGC AAG AUU
   AA: Ser Lys Iso
   Symbol: SKI

TRY A LONGER SENTENCE

5. Following the same procedure, decode the message your teacher gives you below. (Note: the stop codons are used as spaces.)

   Students will decode one message using the paper strips given to them by their teacher. Codes (to be cut into strips) are provided on the next page. Answers for each decoded message are also provided.

NOW CREATE YOUR OWN MESSAGE!

6. Create your own message. (Letters not available: B J O U X Z)

   Check that students accurately create a decoded message.

Decoded Message (English word or words):
AMINO ACID SEQUENCE (three-letter abbreviations are okay):
mRNA:
DNA:
Say it with DNA Messages

TEACHER RESOURCE

Instructions: Cut each DNA message into a strip and give one message to each student. Thirty messages are provided. Note that some messages are longer and may take longer to decode. Strip #11 has the initials of a high school (EVHS) as part of the message, so you might consider creating your own message or just skipping this strip.

1. CCT CTT TGC ACT CGG ATC GTA CGC TAT TCT ATG ATT ACA CGG TTG CGA TCC ATA

2. AGA TAC TAG GAC CTT ACT CGA TTG CTG ATT GCG CGA CTA TAA CGG TGC CTC ACT CGG ATT AAC TAG TGC TGA AAT CTT ATT ACG GTA CTT CTC GCC ATC

3. TCC CTT GGG GAA TAT ACA CGC TGG CTT ACT CGA ATT TGA CTC CGT ACG GTA CTC GCC ATC

4. AGA ACA TAA CTC TTA ACA CTC TAA AGA CCA GCA CTC CGA TGA

5. TAA ACT CGG TAC ATT CTA GCT TAG CAC TAA TTA CCC ATC

6. TAC CGT TTC ATT GAT CGC GCC CCA CTC ATT CTT CGG TCT AGG ATC

7. CTA GCC CTC CGT TAC TAG TTA CCT ACT TAT TCA ATT TTG TAA AGC CTC ATC CGA ACC CGC TTT TAA TTG CCC ACT TAG TCG ATT ACC CGT TTA TGT TAA TTA CCT ATC

8. ACC GTG ATA ACT CGT GCT CTT ATT ACC CTC ACT AAT CTC CGG TCC TTA TGT AGC ATT CCT TTA TCA ATC

9. TAC CGA TTT CTT ACT AGT GGC TCC TAT TTA CCT ATA ATT ACAGTG TAA ACG TTC CTC TTA TCA ATC

10. CTA TTA CGA ACT TAG AGC ATT GAA TAG AAA CTT ATC

11. CTC CAC GTG AGA ATT CAC CGA TCA TAG TGG ATG ATT AGA ACC TAT TAC TAT TTG CCT ATC

12. ACC GTG ATA ACT CGA GCA CTC ATT GGC AAC CGC TTA TGT AGC ATT CCT TCT CTC CTT TTG ATC

13. ACG GCT CTC CGT TGT CTC ACT CGA TTG ATT CTC ATG CTT ATC

14. CTG CTT AGT TAT CCA TTG ACT CGA ATT GTG CGC TTG CTG ATC

15. ACA GCC CTT CGC TGC CTC ACT CGA ATT AAA TAT TTG CCA CTC GCT ATC
16. AAA TAT TTA CTA ACT TGG GTA CTT ATT AGC CTC ACG GCG CTT TGT ATT TAC CTC AGA AGC CGA CCA CTC ATC

17. CTT CGA TGA ATT CCA GCC CTC CTT TTG ATC CTT CCT AGC ACT CGA TTG CTA ACT GTA CGC ATC

18. AGT TAC TAA GAA CTT ACT TAG TGT TCA ATC GTA CTT CGA GAG TGG GTA ATG

19. ACC CGA TGG CTC TCT ATC TAT AGC ATT ACA AAC CTC CGA GCG

20. ACG CTT GAA AAT AGG ACT CGA TCT CTC ATC CCG TCC CTG CGC TGC ATT TGT GTA TAG TTA CCC AGG

21. GAA CTC CGA TCT TTG TAT CCG ACT CTA TTA CGG ATC TAA AGC ATT CCT TCC CTT CGT TGT

22. TAC ATA ACT TAC TAG TTA CTA ATC TAT AGA ATT TAC CGA CCC TTG TAT AAA TAG ACG CTT TTA TGC ATC

23. TAA ACT GTG CGA CAC CTC ATT CGT ATC CTA CGG CTT CGT TAC ATC

24. AGA CGG CAA CTC ATT TGG GTG CTT ACT TGT TCT CTC AGT ATC

25. CCG GCA CTC CTT CTA ATT GCT CTT TAG CCA TTA AGT ACT TAA TTG ATC ACC CGA AAT GAG ATT AGG TGT TCC CTC CTT TGC ATC

26. GAT TAA AAA CTC ACT TAG AGC ATT AGT GGG CTT ACA TAA CGG GAA ATC

27. ACC GTA ATG ATT TAG AGG ATC CTG TTA CGA ACT TTG CTC ACA CTT AGC ACT GTA CGG TCC ATA ATC

28. GTA CGA GGA GGA ATG ATC CAA CGA AAC CTC TTA TGA TAA TTA CTC AGG ATC CTA CGA ATA ATC

29. AAT CTC CGA GCT TTG TAG TTA CCC ATT TAG AGT ATC TAG TTG TGT CTC CTT CTC AGG TAT TGG CCT ACT

30. CGA ACT AGA TAA CCC TTA TAG AAA TAT ACA CGC TTG TGA AAC ATA ATC CGG CTT CAA CGT TTA ACA CTC CTA ATT AGG ACA TAA CTC TTG ACA CTT ACT TAG AGA ACT CTC CGC TCA TAG GAG ATA ATT TAC TAA AGA TGA CGG TTC TCT TTG ACT CGA AGC ATT TAC CGC CCC TAG ATC
Say it with DNA Messages

ANSWER KEY

1. CCT CTT TGC ACT CGG ATC GTA CGC TAT TCT ATG ATT ACA CGG TTG CGA TCC ATA
   Get a hairy canary

2. AGA TAC TAG GAC CTT ACT CGA TTG CTG ATT GCG CGA CTA TAA CGG TGC CTC ACT CGG ATT AAC TAG TGC TGA AAT CTT
   ATC ACG GTA CTT CTC GCC ATC
   Smile and radiate a little cheer

3. TCC CTT GGG AAT ACA CGC TGG CTT ACT CGA ATT TGA CTC CGT ACG GTA CTC GCC ATC
   Replicate a teacher

4. AGA ACA TAA CTC TTA ACA CTC TAA AGA CCA GCA CTC CCA TGA
   Science is great

5. TAA ACT CGG TAC ATT CTA GCT TAG CAC TAA TTA CCC ATC
   I am driving

6. TAC CGT TTC CTT ATT GAT CGC GCC CCA CTC ATT CTT CGG TCT AGG ATC
   Make large ears

7. CTA GCC CTC CGT TAC TAG TTA CCT ACT TAT TGC TAA TAT TGG TAA ACG CTC ATC CGA ACC CGC TTT TAA TTA CCC ACT TAG
   TGC ATT ACC GTG TTA TGT TAA TTA CTT ATC
   Dreaming is nice. Awaking is wanting.

8. ACC GTG ATA ACT CGT GCT CTT ATT ACC CTC ACT AAT CTC CGG TCC TTA TAT TTG CCT ATT TGC GTA TAG TCG ATC
   Why are we learning this

9. TAC CGA TTT CTT ACT AGT GGC TCC TAT TTA CCT ATA ATT ACAGTG TAA ACG TCC CTC TTA CCA ATC
   Make a springy chicken

10. CTA TTA CGA ACT TAG AGC ATT GAA TAG AAA CTT ATC
    DNA is life

11. CTC CAC GTG AGA ATT CAC CGA TCA TAG TGG ATG ATT AGA ACC TAT TAC TAT TTG CCT ATC
    EVHS Varsity swimming

12. ACC GTG ATA ACT CGA GCA CTC ATT GGC AAC CGC TTA TGT AGC ATT CCT TCT CTC CTT TTG ATC
    Why are plants green

13. ACG GCT CTC CGT TGT CTC ACT CGA TTG ATT CTC ATG CTT ATC
    Create an eye

14. CTG CTT AGT TAT CCA TTG ACT CGA ATT GTG CGC TTG CTG ATC
    Design a hand
15. ACA GCC CTT CGC TGC CTC ACT CGA ATT AAA TAT TTG CCA CTC GCT ATC
   Create a finger

16. AAA TAT TTA CTA ACT TGG GTA CTT ATT AGC CTC ACG GCG CTT TTG ATT TAC CTC AGA AGC CGA CCA CTC ATC
   Find the secret message

17. CTT CGA TGA ATT CCA GCC CTC CTT TTG ATC CTT CCA CCT AGC ATC CGA TTG CTA ACT GTA CGC ATC
   Eat green eggs and ham

18. AGT TAC TAA GAA CTT ACT TAG TGT TCA ATC GTA CTT CGA GAG TGG GTA ATG
   Smile it's healthy

19. ACC CGA TGG CTC TCT ATC TAT AGC ATT ACA AAC CTC CGA GCG
   Water is clear

20. AGC CTT GAA AAT AGG ACT CGA TCT CTC ATC CCG TCC CTG CGC TGC ATT TGT GTA TAG TTA CCC AGG
   Cells are great things

21. GAA CTC CGA TCT TTG TAT CCG ACT CTA TTA CGG ATC TAA AGC ATT CCT TCC CGT TGT
   Learning DNA is great

22. TAC ATA ACT TAG TTA CTA ATC TAT AGA ATT TAC CGA CCC TTG TAT AAA TAG ACG CTT TTA TGC ATC
   My mind is magnificent

23. TAA ACT GTG CGA CAC CTC ATT CGT ATC CTA GCG CTT CGT TAC ATC
   I have a dream

24. AGA CGG CAA CTC ATT TGG GTG CTT ACT TGT CCT TCT AGT ATC
   Save the trees

25. CCG GCA CTC CTT TAG CTA ATT CGG ACT CTA TTA CGG ATC TAA TTG ATC ACC AGA ATT TGG TCC CTC CTG ATC
   Greed reigns in Wall Street

26. GAT TAA AAA CTC ACT TAG AGC ATT AGT GGG CTT ACA TCG GAA ATC
   Life is special

27. ACC GTA ATG ATT TAG AGG ACT CTG TTA CGA ACT TTG CTC ACA CTG AGT CGG TCC ATA ATC
   Why is DNA necessary

28. GTA CGA GGA GGA ATG ATC CAA CGA AAC CTC TTA TGA TAA TTA CTC AGG ACT CTA CGA ATA ATC
   Happy Valentines Day

29. AAT CTC CGA GCT TTG TAG TTA CCC ATT TAG AGT ATC TAG TTG TGT CTC GCT ATC GCG TAC TTG CCT ACT
   Learning is interesting

30. CGA ACT AGA TAA CCC TTA TAG AAA TAT ACA CGC TTG TGA AAC ATA ATC CGG CTG CAA CGT TTA ACA CTC CTA ATT AGG
   ACA TAA CTC TTG ACA CTT ACT TAG AGA ACT CTC CGC TCA TAG GAG ATA ATT TAC TAA AGA TGA CGG TTT CTT TTG ACT
   CGA AGC ATT TAC CGC CCC TAG ATC
   A significantly advanced science is easily mistaken as magic

**Credit:** These sentences are from the activity Say It with DNA: Protein Synthesis Tutorial, developed by Larry Flammer, 2004, Evolution & the Nature of Science Institute. [https://ensiweb.bio.indiana.edu/index.html](https://ensiweb.bio.indiana.edu/index.html)
Mutation Practice

Name: ___________________________ Date: ___________ Period: ______

REVIEW

Three of the most common types of mutations are:

1. **POINT MUTATION** (one base is substituted for another)
   - If a point mutation changes the amino acid, it's called a **MISSENSE mutation**.
   - If a point mutation does not change the amino acid, it's called a **SILENT mutation**.
   - If a point mutation changes the amino acid to a “stop,” it’s called a **NONSENSE mutation**.

2. **INSERTION** (an extra base, or bases, is inserted)

3. **DELETION** (a base, or bases, is lost)
   - Deletion and insertion may cause what's called a **FRAMESHIFT**, meaning the reading frame changes. These are typically one of the most serious types of mutations.

DIRECTIONS

Following the same procedure you followed during the decoding activity (DNA to mRNA to Amino Acid), decode the original and mutated sequences and identify them as one of the three types of mutations listed above. If it is a point mutations, include whether it is a missense, silent, or nonsense mutations.

1. The original DNA sequence is:

   DNA: TGC GTG CTT AAG CGG TGT ACA CGT TGC

   mRNA: ____________________________________________

   Amino acid: ______________________________________

   Symbol: _________________________________________

   Now decode the following mutated sequences:

2. TGC GTG CTT AAG CGA TGT ACA CGT TGC

   What kind of mutation is this? ____________________________

   Do you think it will affect the protein’s function? Why?
   ____________________________________________________
   ____________________________________________________
   ____________________________________________________
   ____________________________________________________
   ____________________________________________________
   ____________________________________________________
3. TGC GTG CTT AAG CGG TGT GCA CGT TGC
   What kind of mutation is this?
   Do you think it will affect the protein's function? Why?

4. TGC GTG CTT AAG TAG TGT ACA CGT TGC
   What kind of mutation is this?
   Do you think it will affect the protein's function? Why?

5. TGC GTG CTT ACT CGG TGT GCA CGT TGC
   What kind of mutation is this?
   Do you think it will affect the protein's function? Why?

6. GCG TGC TTA AGC GGT GTA CAC GTT GC
   What kind of mutation is this?
   Do you think it will affect the protein's function? Why?
EXTENSION QUESTIONS

7. Do any of the amino acids only have one codon? Which ones?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

8. Many of the amino acids have more than one codon. Do you think this is an advantage or disadvantage? Why?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

9. If your DNA sequence is 96 bases long. How long will the resulting amino acid sequence be?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

10. If a mutation doesn’t cause any change to the resulting protein, what type of mutation do you think this most likely is?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Three of the most common types of mutations are:

1. **POINT MUTATION** (one base is substituted for another)
   - If a point mutation changes the amino acid, it's called a **MISSENSE** mutation.
   - If a point mutation does not change the amino acid, it's called a **SILENT** mutation.
   - If a point mutation changes the amino acid to a “stop,” it's called a **NONSENSE** mutation.

2. **INSERTION** (an extra base, or bases, is inserted)

3. **DELETION** (a base, or bases, is lost)

Deletion and insertion may cause what's called a **FRAMESHIFT**, meaning the reading frame changes. These are typically one of the most serious types of mutations.

**DIRECTIONS**

Following the same procedure you followed during the decoding activity (DNA to mRNA to Amino Acid), decode the original and mutated sequences and identify them as one of the three types of mutations listed above. If it is a point mutation, include whether it is a missense, silent, or nonsense mutations.

1. **The original DNA sequence is:**
   - DNA: TGC GTG CTT AAG CGG TGT ACA CGT TGC
   - mRNA: ACG CAC GAA UUC GCC ACA UGU GCA ACG
   - Amino acid: Thr  His  Glu  Phe  Ala  Thr  Cys  Ala  Thr
   - Symbol: The fat cat

   Now decode the following mutated sequences:

2. **TGC GTG CTT AAG CGA TGT ACA CGT TGC**  The fat cat
   - What kind of mutation is this? **Point mutation, silent**.
   - Do you think it will affect the protein's function? Why?
     - No. The amino acid and thus the protein sequence is unchanged.

3. **TGC GTG CTT AAG CGG TGT GCA CGT TGC**  The fat rat
   - What kind of mutation is this? **Point mutation, missense**.
   - Do you think it will affect the protein's function? Why?
     - Unable to predict. The amino acid and protein are changed. The protein may or may not be functional.
4. TGC GTG CTT AAG TAG TGT ACA CGT TGC  The fit cat

What kind of mutation is this? **Point mutation, missense.**

Do you think it will affect the protein's function? Why?
Unable to predict. The amino acid and protein are changed. The protein may or may not be functional.

5. TGC GTG CTT ACT CGG TGT GCA CGT TGC  Rtn sph vq

What kind of mutation is this? **Deletion, frameshift.**

Do you think it will affect the protein's function? Why?
Yes. The reading frame was changed, and the protein is non-functional.

6. GCG TGC TTA AGC GGT GTA CAC GTT GC  The flat cat

What kind of mutation is this? **Insertion, frameshift, missense.**

Do you think it will affect the protein's function? Why?
Unable to predict. Because the insertion was 3 base pairs, an extra amino acid was added and the protein may still be functional.

**EXTENSION QUESTIONS**

7. Do any of the amino acids only have one codon? Which ones?
Yes. Tryptophan and Methionine only have one codon.

8. Many of the amino acids have more than one codon. Do you think this is an advantage or disadvantage? Why?
This is an advantage to the organism because if there is a mistake during translation via a mutation, there is a higher chance that the altered codon will still code for the same amino acid. Note that the redundant codons are usually different at the third base.

9. If your DNA sequence is 96 bases long. How long will the resulting amino acid sequence be?
96/3 = 32 amino acids

10. If a mutation doesn't cause any change to the resulting protein, what type of mutation do you think this most likely is?
Although there are other possibilities, the most likely mutation would be a silent point mutation where a single base is changed, but the changed codon still codes for the same amino acid.
The Eukaryotic Cell and Cancer: An Overview

About this Handout
This handout is an adaptation of “The Eukaryotic Cell Cycle and Cancer Overview Student Worksheet” developed by HHMI Biointeractive and is intended as a straightforward introduction to the cell cycle and how it relates to cancer.

Procedure
Go to https://www.hhmi.org/biointeractive/eukaryotic-cell-cycle-and-cancer and click the “Launch Interactive” button to learn about the cell cycle. Then, if it is not open by default, click on the “Background” tab on the right side. Read the information in the 4 slides, watch the videos, and answer the questions below.

1. Why is cell division important for both unicellular and multicellular organisms?

2. Why does cell division remain important to an adult organism even after it is fully developed?

3. Cells divide, differentiate, or die. What is differentiation?

4. What is apoptosis? What is its purpose?

5. What are cell cycle regulators?

6. What happens if cell cycle regulators don’t function properly?
Click on the purple section labeled “Cell Cycle Phases” as well as the words “Mitosis” and “Interphase” to read an overview of the cell cycle. You can also click on the various phases.

7. Cells go through periods of growth and division. Cell division occurs during ______. The rest of the cell cycle is called interphase, during which (complete the sentence):

8. Fill in the details about what happens during the three phases of interphase labeled in the diagram.

9. In general, what is the purpose of a checkpoint in the cell cycle?

10. What is the G0 phase of the cell cycle?
   a. Which factors determine whether a cell enters G0?
   b. Can cells leave G0?
Click on “Cell Cycle Regulators and Cancer” in the center purple circle. Read the Regulators Overview and then read through the Cancer Overview and watch the videos.

11. **What are cell cycle regulators?**

   a. Stimulatory proteins are encoded by: ____________________________
   
   b. Examples include: ____________________________
   
   c. Inhibitory proteins are encoded by: ____________________________
   
   d. Examples include: ____________________________

12. **Cancer is the result of an improperly regulated cell cycle. Describe two reasons why cells can form tumors.**

13. **In some types of colon cancer, stem cells have a mutation in the APC gene. What happens if the APC gene is mutated?**

14. **Normally, proto-oncogenes stimulate the cell cycle. What are oncogenes and how do they affect the cell cycle?**

   To cause cancer, proto-oncogenes require _______ allele(s) to be mutated and therefore are considered _______. The mutation results in a _______ of function.

15. **Normally, tumor suppressor genes inhibit the cell cycle. How do mutated tumor suppressor genes affect the cell cycle?**

   To cause cancer, tumor suppressor genes require _______ allele(s) to be mutated and therefore are considered _______. The mutation results in a _______ of function.
WHAT IS SOCIOECONOMIC STATUS?

Socioeconomic status (SES) measures a person's social, economic, and work status.

- **Social status** is measured by how many years a person spent in school.
- **Economic status** is measured by how much money a person earns each year.
- **Work status** is measured by whether a person has a job.

For example, a person with a high SES may have a college degree, earn an above-average income, and have a full-time job that pays well. A person with a low SES may not have finished high school, doesn’t earn enough money to live comfortably, and may be unemployed or have a low-paying job.

HOW SES IS RELATED TO HEALTH

A person's SES may affect their ability to get health care. A person with more education is more likely to get a job that pays well and provides health insurance and paid sick leave. People who have higher incomes and health insurance are more likely to get tests that can find cancer early, and get the right treatment if cancer is found. So people with a higher SES often have higher cancer survival rates.

ACCESS TO HEALTH CARE SERVICES

People with a low SES are less likely to get cancer screening tests because they may not have health insurance. So their cancer is often found at a later stage, when it causes symptoms. Even if their cancer is treated, patients are less likely to survive cancer that is found after it has advanced. People with a low income may not get health care for other reasons. For example—

- They may not have health insurance to cover the costs of tests, care, and treatment.
- They may not speak English well.
- They may be worried about the screening test.
- They may not be able to take time off from work to go to the doctor.
- They may not have transportation to go to the doctor.
- Other reasons.

BEHAVIORS

People may engage in behaviors that are related to a higher risk of getting cancer, like smoking cigarettes, eating unhealthy food, not getting enough physical activity, and engaging in risky sexual activity.

Smoking cigarettes increases the risk for many kinds of cancer including cancers of the lip, mouth, throat, pancreas, larynx (voice box), lung, uterine cervix, urinary bladder, and kidney.

Eating unhealthy food and not getting enough physical activity can cause a person to become overweight or obese. Obesity increases the risk for breast cancer after menopause, colorectal cancer, endometrial cancer, esophageal adenocarcinoma (a type of throat cancer), and cancers of the kidney and pancreas.

Risky sexual activities like unprotected sex and sex with multiple partners can make a person more likely to get human papillomavirus (HPV), the most common cause of cervical cancer.
SOCIAL AND BUILT ENVIRONMENTS

The social environment describes the social conditions in which people work and live. A good social environment helps a person make good decisions, like living a healthy lifestyle. For example, in a good social environment, a person’s friends and family members encourage him or her to eat healthy foods, exercise, and go to the doctor regularly.

The built environment refers to physical objects like buildings, neighborhoods, cities, and roads. A good built environment has a lot of parks, playgrounds, and sidewalks that make it easy to get exercise. A good built environment also provides transportation that makes it easy for people to go to good jobs and schools, doctors, and stores that sell healthy food.

Cities tend to have better transportation systems and sidewalks, but may lack parks, playgrounds, and other places for recreation. Cities may have high crime rates, and people may be less likely to exercise when neighborhoods are unsafe. Country (rural) areas are usually more spread out, making people more likely to drive cars rather than walk or bicycle.

In the United States, rural residents have a higher risk of type 2 diabetes, obesity, dental problems, suicide, and tobacco use. People who live in the country are more likely to be lower-income than people who live in cities. Going to the doctor may be a greater barrier for people living in rural areas for a variety of reasons. Because of this, they may be more likely to treat the health problems they know they have, instead of getting screening tests to find other health problems early or making lifestyle changes to prevent future health problems.

EXPOSURE TO CARCINOGENS

A carcinogen is a substance that causes cancer. People have a higher risk of getting cancer if they live near places where carcinogens are produced and emitted, like smelters, foundries, chemical factories, and coal mines. In part due to the history of housing inequities and redlining in this country, members of racial and ethnic minorities are more likely to live near such places. In addition, workers in some jobs are exposed to carcinogens at work (such as chemical factory workers, miners, fire fighters, and more).

A person’s age group can make him or her more likely to be exposed to carcinogens. Because of laws against smoking in public and work places, adults are much less likely to be exposed to secondhand smoke today than in the late 1980s. But people still smoke at home often, so children who are 4 to 11 years old are exposed to secondhand smoke at a high rate.

CANCER TREATMENT

Generally, patients get better cancer treatment at a hospital that sees a lot of cancer patients, or by a doctor who does a lot of cancer surgeries (called high-volume surgeons or hospitals). Patients treated in low-volume hospitals are more likely to be members of racial or ethnic minorities, live in rural areas, have a low SES, and live far away from a high-volume hospital.

In these ways, a person’s social economic status, social environment, built environment, job, neighborhood, personal behaviors, and access to medical care may be related to health and cancer incidences. Can you think of other social, economic, physical, or structural factors that might be important to consider as well?


GO TO THE WORLD HEALTH ORGANIZATION (WHO) CANCER FACT SHEET:
https://www.who.int/news-room/fact-sheets/detail/cancer

Read the text and answer the following questions.

1. Cancer rates are highest in high resource countries. Why do you think that is?

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________

2. Low resource countries have comparatively low rates of cancer, but the rates are on the rise and expected to continue to increase dramatically in the coming years. How would you explain this?

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________

3. Why are most cancer deaths considered preventable?

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________

4. Looking at the factors that contribute to “preventable” cancers, what types of actions and interventions do you think would have the most impact on cancer rates worldwide?

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
GO TO THE AMERICAN INSTITUTE OF CANCER RESEARCH CANCER RATE COMPARISON SITE:  
https://www.wcrf.org/dietandcancer/cancer-trends/comparing-more-and-less-developed-countries

Then, review the statistics and answer the following questions.

This organization uses the Human Development Index (HDI) instead of income levels to rank a country’s development level. The United Nations defines the HDI as “a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable, and have a decent standard of living.” You can read more about what statistics (i.e., life expectancy, years of schooling, gross national income, etc.) are used for each of the three dimensions in the HDI here: http://hdr.undp.org/en/content/human-development-index-hdi.

5. **What three key factors do they consider in assigning this ranking?**

6. **Are these three indexes objective or subjective?**

7. **The cancer rate chart has been “age standardized.” Why do you think this is important?**

8. **Do all the cancer rate comparisons follow the same trend? What is the exception? Why do you think this is?**

9. **Click on and explore the Interactive Cancer Risk Matrix. Do the risk factor rankings support your conclusions for Questions 1-4?**
GO TO THE WORLD HEALTH ORGANIZATION (WHO) CANCER FACT SHEET:
https://www.who.int/news-room/fact-sheets/detail/cancer

Read the text and answer the following questions.

1. Cancer rates are highest in high resource countries. Why do you think that is?
   
   This can be largely attributed to behavioral risk factors such as tobacco use, alcohol use, unhealthy diet, physical inactivity, and high body mass index—activities that are more common in high resource countries.

2. Low resource countries have comparatively low rates of cancer, but the rates are on the rise and expected to continue to increase dramatically in the coming years. How would you explain this?

   Students' answers will vary. Example responses provided below.

   Lifestyle risk factors such as tobacco use, alcohol use, unhealthy diet changes, and physical inactivity are on the rise in low resource countries. Low resource countries will also continue to see challenges in access to vaccinations like those for HPV and hepatitis B.

   Globally, people are living longer and exposure to risk factors is growing.

3. Why are most cancer deaths considered preventable?

   About 30–50% of cancers overall could be avoided with lifestyle changes and healthier behaviors as well as by implementing prevention strategies, but the majority of cancer deaths are linked to tobacco: every year 1.5 million people die from cancer linked to tobacco. Early detection and proper treatment of cancer is critical.

4. Looking at the factors that contribute to “preventable” cancers, what types of actions and interventions do you think would have the most impact on cancer rates worldwide?

   Students’ answers will vary. A few examples are provided below.

   Widespread education about risk factors and access to vaccinations could have an enormous impact.

   • There are safe and effective vaccines against the human papilloma virus (HPV) that causes cervical cancer and against the hepatitis B virus (HBV) that causes liver cancer.

   • Early screening for some of the most common cancers (i.e. breast, colon, prostate, and skin) could help detect cancer while it is still treatable.

   • Lung cancer is the leading type of cancer and the leading cause of deaths from cancer. Smoking cessation programs could help reduce the number of people who smoke. Improvements in air quality could also help.
GO TO THE AMERICAN INSTITUTE OF CANCER RESEARCH CANCER RATE COMPARISON SITE:
https://www.wcrf.org/dietandcancer/cancer-trends/comparing-more-and-less-developed-countries

Then, review the statistics and answer the following questions.

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5. What three key factors do they consider in assigning this ranking?

According to this website: “The Human Development Index (HDI) measures average achievement in three key dimensions of human development: a long and healthy life, knowledge and a decent standard of living.”

6. Are these three indexes objective or subjective?

This question is designed to encourage students to take an analytical look at the HDI definition used by this site. Students might note that factors like life span can be measured and quantified and are objective measurements, but a “decent” standard of living could be a subjective measure. Students might be encouraged to research how other global organizations define HDI and if there are ways of quantifying a “decent standard of living”.

7. The cancer rate chart has been “age standardized.” Why do you think this is important?

Cancer rates are strongly correlated with age. The longer a person lives the more likely they are to acquire and accumulate mutations that can lead to cancer. If rates aren’t standardized one might assume that the higher cancer rates in high resource countries with a longer life expectancy could be explained by an older population. By comparing age standardized rates, however, we know that this isn’t true and that there are other factors contributing to the higher cancer rates.

8. Do all the cancer rate comparisons follow the same trend? What is the exception? Why do you think this is?

Almost all cancer rates are higher in HDI countries with the biggest exception being cervical cancer. Students might remember two key facts from the WHO statistics to create an explanatory hypothesis:

• There are effective vaccines against the human papilloma virus (HPV) that causes cervical cancer.
• Cervical cancer is the second most common cancer in women worldwide. Cost-effective and accessible screening programs to detect cervical cancer or pre-cancer combined with prompt treatment can reduce deaths in women.

Esophageal cancer is also very slightly higher in low HDI countries.

9. Click on and explore the Interactive Cancer Risk Matrix. Do the risk factor rankings support your conclusions for Questions 1-4?

The Risk Cancer Matrix graphically illustrates the impact of behavioral risk factors on cancer rates and should support the student’s findings.
Description: In this mini-project, you will work in a small team to either investigate a specific type of cancer across different countries/regions, or investigate a country/region and examine rates of different types of cancer in that area.

Your team will engage in sensemaking of statistics, articles, data, and data visualizations from multiple online sources. Your team will develop an explanatory model—leveraging your understanding of the genetics of cancer—to develop an evidence-based explanation for these disparities. You will also develop a list of recommendations for how to best spend limited resources to reduce cancer rates.

Write down the names of your team members:

_________________________  __________________________
_________________________  __________________________
_________________________  __________________________

PART I: DETERMINE YOUR PROJECT FOCUS

With your teammates, choose between these two options:

► Investigate a specific type of cancer (i.e., stomach cancer) across different countries/regions
► Investigate a country/region and examine rates of different types of cancer (i.e., brain, breast, stomach, lung, etc.)

Circle your option above and then list the type(s) of cancer and the country(ies)/region(s) you will focus on for your research project. Explain why you chose these as your focus.

_________________________
_________________________
_________________________

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PART II: BEGIN YOUR ONLINE RESEARCH

Here are a few websites to start your research, but don't feel limited by these suggestions. Take notes and be sure to keep track of your citations.

- World Health Organization (WHO) Cancer Facts
  https://www.who.int/health-topics/cancer#tab=tab_1

- Cancer Control Opportunities in Low and Middle-Income Countries
  https://www.ncbi.nlm.nih.gov/books/NBK54028/

- Global Cancer Data

- GLOBAL Cancer Observatory
  https://gco.iarc.fr/

- IHME Global Burden of Disease (GBD)
  http://www.healthdata.org/gbd

- Gapminder Global Cancer Statistics (videos)
  https://www.gapminder.org/videos/
  Scroll down to the Factpods & Answers section, then look for the Cancer Statistics videos for lung, prostate, breast, liver, colon, stomach, and cervical cancer.

- Gapminder Global Data Visualization Tool
  You can change the variables for the x- and y-axis by clicking on the small triangle on each axis. For the x-axis, choose Health, then Cancer, and the specific statistics you want to view. You can experiment with different choices for the y-axis, such as Time or Income. Push the play button. The color of the animated bubbles is specific to different regions of the world. Specific countries can be chosen to feature using the menu at the right. The size of the bubble can be changed using the menu.
  https://www.gapminder.org/tools/#$chart-type=bubbles

PART III: DEVELOP YOUR EXPLANATORY MODEL

Work with your teammates to write an explanatory model that describes the findings from your online research and includes an evidence-based explanation for any disparities you found between higher and lower-income countries. Leverage your understanding of the genetics of cancer, risk factors, and prevention strategies in your explanation. Your teacher will tell you if this should be handwritten or typed and submitted electronically.

Your explanatory model should answer this question, using your research findings as a specific example: How can an understanding of genetics help us investigate why cancer (both rates of incidences and cancer related deaths) disproportionately affects people in different countries of the globe?

WORD BANK:
- DNA
- Gene
- Protein
- Mitosis
- Mutation
- Risk Factor
- Hereditary/Non-Hereditary
- Socioeconomic Status
- Prevention

PART IV: MAKE A PUBLIC HEALTH RECOMMENDATION

Develop a list of 2-3 recommendations for how the country(ies) you chose to research could best spend their limited financial resources to reduce cancer rates. Support each recommendation with evidence.
Global Cancer Mini-Project: SCORING RUBRIC

Group Members' Names: ____________________________

Country(ies) or Region(s): ____________________________

Type(s) of Cancer: ____________________________

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<thead>
<tr>
<th>CONCERNS</th>
<th>CRITERIA</th>
<th>ADVANCED</th>
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<tbody>
<tr>
<td><strong>Areas that need work</strong></td>
<td><strong>Standards for this performance</strong></td>
<td>Evidence of exceeding standard</td>
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<td><strong>Project Focus</strong></td>
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<tr>
<td>Focus of the project was on either:</td>
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<td>a. A specific type of cancer across different countries/regions.</td>
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<td>b. Rates of different cancers in a specific country/region.</td>
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<td><strong>Evidence-based Explanation</strong></td>
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<td>The project included an evidence-based explanation for any disparities found.</td>
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<td><strong>Understanding of Cancer Genetics, Risks, and Prevention</strong></td>
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<tr>
<td>The explanation incorporated an understanding of the genetics of cancer, risk factors and prevention strategies and used this understanding to investigate why people in different parts of the globe are disproportionately affected by cancer.</td>
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<td><strong>Country's Development Levels</strong></td>
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<td>The project demonstrated an understanding of how a country/region’s level of development impacts these disparities.</td>
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<tr>
<td><strong>Recommendations/Strategies</strong></td>
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<tr>
<td>The project gave 2 -3 recommendations for how a country’s limited resources could best be used to reduce cancer rates and supported these recommendations with evidence.</td>
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Notes:

Grade: __________
GLOBAL PUBLIC HEALTH
Infectious and non-communicable diseases and epidemics are a major concern, and one of the greatest challenges to the health of major populations:

- **AIDS** has claimed the lives of more than 35 million people since its discovery.
- **Tobacco-related deaths** are expected to account for nearly 10 percent of all deaths globally by 2030.
- **Chronic diseases** that result from high blood pressure account for 13 percent of all deaths globally.
- **Cancers** figure among the leading causes of death worldwide, accounting for 9.6 million deaths in 2018.

Another major scope of global health involves non-communicable diseases, which are among the leading causes of disability worldwide, such as:

- Diabetes
- Obesity
- Substance abuse
- Tobacco use
- Mental illness

WHAT IS GLOBAL HEALTH?
As the world becomes more globalized, and as international travel and commerce becomes more extensive, public health must be considered in a global context. A complex international distribution chain has also resulted in potential international outbreaks from contaminated consumer goods, poor-quality pharmaceuticals, and foodborne illnesses, just to name a few.

Infectious diseases and other health threats have prompted the United States to enhance its capability to respond to infectious diseases globally by developing a real-time infectious disease surveillance system.

**Global health efforts in the U.S. help to:**
- Promote health around the world
- Prevent the international spread of disease
- Protect the health of the U.S. population

MAJOR PLAYERS IN GLOBAL HEALTH PROGRAMS AND INITIATIVES
The goal of global health is to improve public health and strengthen U.S. national security through global disease detection, response, prevention, and control strategies. The work of public health professionals in global health is vital for researching and containing diseases and working toward eradication. They also craft policies that help prepare for disease outbreaks and oversee programs that educate communities about effective treatment for diseases.
For example, public health professionals actively work to fight HIV/AIDS in developing countries by educating populations about HIV prevention and transmission, distributing condoms, increasing access to antiretroviral medications, and encouraging healthy behaviors that help prevent the spread of the virus.

Public health professionals work for U.S. government agencies, public health agencies, nonprofit organizations, advocacy groups, academic institutions, and private businesses. These public health employers may provide education, funding, resources, and technical support for global health initiatives, and many of these organizations combine their efforts and provide assistance to international organizations.

For example, the U.S.-based Global Initiative invested more than $63 billion in 2010 to help partner countries improve health outcomes through strengthened health systems.

**JOBS IN GLOBAL HEALTH**

Global health affects everyone. Therefore, professionals in global health are directly responsible for the study and practice of population-level health interventions in communities around the world.

These specialists are focused on health within all countries, across borders, across boundaries, and across all socio-economic statuses. In other words, global health professionals are focused on health issues that transcend boundaries and that are important both domestically and internationally.

Global health professionals may study large-scale epidemics, vaccines, treatments, and other methods of mitigating the spread of these diseases. They may also collaborate with community leaders, governmental agencies, relief organizations, and other groups to promote global health and medical awareness.

**Some jobs in global health include:**

**HIV/AIDS Research Associates**

HIV/AIDS research associates work with other researchers and study participants to implement an organized HIV/AIDS research agenda. Their work includes managing research grant portfolios, monitoring and evaluating grantee progress, and working with senior-level directors and researchers to design and implement modifications to grant programs.

Other job responsibilities of HIV/AIDS research associates include:

► Assisting in the development of strategic plans that support research  
► Assisting with communications and fundraising endeavors  
► Helping design plans that raise the profile of a company or organization’s research efforts  
► Monitoring and analyzing research issues in a swiftly changing environment

Some of the largest supporters of global health in the U.S. include:

- Centers for Disease Control (CDC)
- World Health Organization (WHO)
- Global Health Council
- Task Force for Global Health
- Bill & Melinda Gates Foundation
- Care International
- American Red Cross
- Save the Children
- William J. Clinton Foundation
- World Vision
- National Institutes of Health

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- Bill & Melinda Gates Foundation
- Care International
- American Red Cross
- Save the Children
- William J. Clinton Foundation
- World Vision
- National Institutes of Health
International NGO Aid Workers

International aid workers in non-governmental aid organizations (NGO) serve as first responders during times of crisis. They are the frontline workers who bring relief to places devastated by war, disease, famine, or natural disasters. They must adhere to safety and health regulations and create programs to respond to emergencies that require budgetary constraints and the work of local staff and volunteers.

Job responsibilities of international NGO aid workers in director/manager positions include:

► Managing, monitoring, and evaluating projects
► Conducting needs assessments
► Organizing fundraising efforts
► Researching and writing grant proposals and reports
► Engaging in strategic planning for long-term development and/or disaster management to reduce the need for crisis intervention
► Managing budgets and allocating resources
► Recruiting, managing, and training staff and volunteers
► Developing relationships with partner organizations
► Implementing security procedures to ensure the safety of workers in unstable areas

Global Infectious Disease Analysts

Global infectious disease analysts are responsible for collecting, interpreting, and analyzing epidemiological data and research regarding global infectious diseases. The epidemiology of infectious diseases involves studying risk factors of infectious diseases, as well as their prevalence and incidence.

Global infectious disease analysts implement and evaluate interventions at both the individual and community levels to prevent primary infection, prevent disease-associated deaths and disabilities, and prevent diseases from developing further.

These professionals are called upon to answer a number of questions, such as:

► How can treatment best be delivered and health systems strengthened?
► How can treatment regimens be optimized and the quality of care improved?
► How can resistance and transmission be prevented?
► How does poverty and disease impact global policy?

Global infectious disease analysts use the results of their research to improve healthcare delivery and to guide the design and implementation of health policies.
Some of the areas frequently explored in global health graduate programs include:

- Biomedical research
- Chronic diseases
- Climate change
- Global medicines safety
- Global trauma and violence
- Health metrics and evaluation
- Implementation science
- Infectious diseases
- Mental health
- Women, children, and adolescent health
- Workforce development

**DEGREE OPTIONS FOR A CAREER IN GLOBAL HEALTH**

Those interested in working in the global health field often pursue undergraduate degrees in the social sciences, public health, or in the allied health fields. One of the most widely held graduate degrees among global health professionals is the Master of Public Health (MPH) with a concentration in global health. Similar program concentrations include global health communications, global health program design, global health policy, and global environmental health.

An MPH in Global Health provides study in the social, economic, and political determinants of health, as well as the history of global responses to health problems. Graduates of MPH in Global Health programs possess the skills necessary to pursue careers in academia, industry, government, foundations, and non-governmental organizations.

**Courses in an MPH degree that are focused on global health include:**

- Issues in global health
- Global health policy and delivery
- Program evaluation in public health

**LEARN MORE!**

Want to explore more jobs and career pathways in the field of global health? Check out the Pathways to Global Health Careers Poster and Fact Sheets from the Washington Global Health Alliance's STEM Global program.

**Poster: Pathways to Global Health Careers:**
https://www.wghalliance.org/resource/global-health-career-poster/

**Fact Sheet: Pathways to Global Health Careers:**
https://www.wghalliance.org/resource/global-health-career-fact-sheets/

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Text sourced from: [https://www.publichealthcareeredu.org/global-health](https://www.publichealthcareeredu.org/global-health) and [https://www.who.int/cancer/about/facts/en](https://www.who.int/cancer/about/facts/en)
Earth Sciences/Data Literacy

IHME

Data Driven: Investigating the Human Health Effects of Air Pollution in Washington State, High School Version

3 50-minute class periods | Grades 9-12

IHME

Data Driven: Investigating the Human Health Effects of Air Pollution in Washington State, Middle School Version

3 50-minute class periods | Grades 6-8
Data Driven: Investigating the Human Health Effects of Air Pollution in Washington State, High School Version

**Brief Overview:** This lesson explores past, current, and future trends of air pollution in Washington State and provides opportunities for students to better understand the phenomenon through intensive interaction and manipulation of data using spreadsheet software. Through this lesson, students will develop an understanding of foundational data science principles and recognize techniques for manipulating and analyzing data. In particular, students will develop skills in vetting data quality and generating basic descriptive statistics, including calculating mean, median, min, and max. Students will also gain skills in interpreting trends and patterns in data and making informed and evidence-based conclusions. In addition, students will gain an understanding of how air pollution affects human health and the global epidemiology of outcomes attributed to air pollution.

This lesson was developed by the Institute for Health Metrics and Evaluation (IHME), an institute affiliated with the University of Washington focused on health metrics sciences. As such, this lesson attempts to introduce students to fundamental data sciences practices that are the work of scientists across fields, including global health.

healthdata.org
Exposure to outdoor (ambient) air pollution is a major risk factor for disease for people around the world. There is a wide array of health effects which are believed to be associated with air pollution exposure. Among them are respiratory diseases (including asthma and changes in lung function), cardiovascular diseases, adverse pregnancy outcomes (such as preterm birth), and even death. While air pollution is a global phenomenon, it has very local impacts that can profoundly affect communities in unique and profound ways. In Washington State for instance, increasing temperatures, rapid urbanization, increased manufacturing, and natural disasters can affect the region’s air quality which, in turn, can contribute to poorer health outcomes for residents. In order to alleviate/mitigate the consequences of air pollution in Washington State, we must assess and understand levels and trends of exposure to air pollution to better identify solutions and interventions.

**LEARNING OBJECTIVES**

By the time students complete these activities, they will be able to:

- Recognize and explain how air pollution affects human health.
- Evaluate and examine the quality of data including its completeness, outliers, consistency, and accuracy.
- Generate basic descriptive statistics using a set of data including mean, median, min, and max.
- Interpret trends and patterns of health outcomes related to air pollution by using various forms of data visualization.
- Iterate through assorted designs using lessons learned via hands-on tinkering/discovery.

**MADEHATICAL AND COMPUTATIONAL THINKING**

This lesson was designed to introduce students to data science. It engages students in fundamental data science practices, including manipulating, analyzing, and visualizing data. For each of these steps, students are encouraged to engage in sensemaking around why it is important and what meaningful work it does with the data. In this lesson, students will use a spreadsheet as a computational tool for finding patterns and trends. The underlying assumption for this lesson is that students have not yet used spreadsheets, therefore scaffolding is provided in the student handouts. Students with prior expertise with spreadsheets could be challenged to engage with the data in more complex ways. See the Suggested Lesson Extensions section for ideas. The following teacher resource may be helpful for framing your approach to computational thinking in the science classroom:

**STEM Teaching Tools Practice Brief #56: Engaging Students in Computational Thinking During Science Investigations**

**Remote Learning Adaptations**

Integrated into this lesson plan are suggestions for adapting the activities for remote teaching and learning settings. For remote instruction, this lesson assumes students have computer and internet access at home.

**Student Understandings**

**ANCHORING PHENOMENON**

Exposure to outdoor (ambient) air pollution is a major risk factor for disease for people around the world. There is a wide array of health effects which are believed to be associated with air pollution exposure. Among them are respiratory diseases (including asthma and changes in lung function), cardiovascular diseases, adverse pregnancy outcomes (such as preterm birth), and even death. While air pollution is a global phenomenon, it has very local impacts that can profoundly affect communities in unique and profound ways. In Washington State for instance, increasing temperatures, rapid urbanization, increased manufacturing, and natural disasters can affect the region’s air quality which, in turn, can contribute to poorer health outcomes for residents. In order to alleviate/mitigate the consequences of air pollution in Washington State, we must assess and understand levels and trends of exposure to air pollution to better identify solutions and interventions.

**DRIVING QUESTIONS**

- How can data be used to understand changing levels of air pollution exposure in the State of Washington?
- What are health effects from outdoor air pollution exposure to Washington residents?
- How can data be used to make predictions and recommendations about air pollution and human health?
Next Generation Science Standards

This lesson builds toward the following bundles of middle and high school level Performance Expectations (PEs) from the NRC Framework and Next Generation Science Standards. Standards marked with an asterisk (*) are concepts or practices aligned to this lesson, but not included in the PE bundle. The lesson materials are written to support the high school level PEs; therefore adaptations should be made to the lesson to make it appropriate for middle school students (e.g., scientific vocabulary, scaffolds for data analysis, etc.).

PERFORMANCE EXPECTATIONS

**HS-ESS3-3**: Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

**HS-ESS3-6**: Use a computational representation to illustrate the relationship among Earth systems and how those relationships are being modified due to human activity.

Connections to Common Core State Standards

Connections to Common Core State Standards in Mathematics include the following mathematical practices:

**MP.2**: Reason abstractly and quantitatively

**MP.4**: Model with mathematics
### Teacher Preparation

<table>
<thead>
<tr>
<th>Material</th>
<th>Description/Source</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom/Teacher Computer</td>
<td>Computer with internet access, projector, and speakers (for live, in-class instruction).</td>
<td>1</td>
</tr>
<tr>
<td>Student Computers</td>
<td>Computers need to have access to spreadsheet software: Google Sheets or Microsoft Excel. For remote instruction, this lesson assumes students have computer and internet access at home.</td>
<td>1/student or pair of students</td>
</tr>
</tbody>
</table>
| Student Handouts             | Make copies of the student handouts, one of each handout for each group of students -OR- make digital copies of handouts available to students via your learning management system.  
  - Student Handout 1: Instructions: Data Science in Global Health (1/student or group)  
  - Student Handout 2: Time Series Plot for Washington State Data (1/group)  
  - Student Handout 3a-i: City Comparison Plots (1/group to match city assignment)  
  - Student Handout 4: Washington State Map of PM2.5 Mean Values (1/group)                                                                                     | 1 for each group/pair of students |
| Teacher Slide Deck           | Air Pollution in WA State (HS) Slide Deck (elements of slide deck below)  
  - Part I: Introduction to Air Pollution (Slides #1-6)  
  - Part II: Data Science and Air Pollution in Washington State (Slides #7-12)  
  - Part III: Air Pollution and Human Health (Slides #13-26)  
  - Part IV: How Air Pollution is Measured (Slides #27-34)  
  - Part V: Data Quality Assessment (Slides #35-40)  
  - Part VI: Basic Descriptive Statistics (Slides #41-50)  
  - Part VII: City Comparisons (Slides #51-62)                                                                                                               | Teacher resource |
| Video: Data Analysis Example | Data Driven: Data Analysis Example Video  
  Short video that demonstrates the data analysis process using Pullman as the example dataset. Teacher should watch this to help them understand the process and to decide if they want students to watch this prior to working on their own dataset. If so, load the video to your learning management system. | Teacher resource |
| Data: Instructor Version     | Spreadsheet_WA_Air_Pollution_Teacher (HS).xlsx  
  (Includes an answer key)                                                                                                                                       | Teacher resource |
| Data: Student Version        | Spreadsheet_WA_Air_Pollution_Student.xlsx                                                                                                                      | 1        |

### Air Pollution in WA State (HS) Slide Deck

**Download Slide Deck**
NOTES TO TEACHER FOR PREPARING TO TEACH THIS LESSON:

1. **Computers are required for this lesson.** Students must also have access to the internet and Google Sheets (preference) or Microsoft Excel. All directions on Student Handout 1 are included for Google Sheets. If students will be using Excel instead, you may need to adapt some of the instructions for filtering and sorting data.

2. **Make copies of the student handouts,** as indicated in the materials table above. Student Handouts 2-4 should be printed in color or viewed digitally for students to be able to accurately analyze the color-coded data.

3. **Review the slide deck and speaker’s notes.**

4. **Watch the Data Driven: Data Analysis Example Video** to help you understand the data analysis procedure. You may also want to go through the data analysis process, as demonstrated in the video, by using the Pullman data provided in the data spreadsheet.

5. **Decide if you want students to view the video before beginning data analysis.**

6. **An important component of engaging in data practices is having students pause during their computational work to engage in sensemaking together.** This teacher resource on science talk and the embedded Student Talk Flow Chart provides ideas of how to structure student-to-student talk and teacher-student talk in equitable ways.

### Remote instruction:

- **Remote instruction:** Make digital copies of handouts available to students via your learning management system.

- **Remote instruction:** Consider recording a video of you presenting the slides (i.e., by using Peardeck for Google Slides or ScreenCast O Matic) for students to view from home.

- **Remote instruction:** Consider recording a video of you presenting the slides (i.e., by using Peardeck for Google Slides or ScreenCast O Matic) for students to view from home.

- **Remote instruction:** Consider how you might be able to use breakout rooms to allow for small group talk during live, synchronous remote instruction. Also consider using digital bulletin boards (i.e., Padlet, Google Jamboard app, or FlipGrid) as a way for students to communicate, share, and increase interaction.

### STEM Teaching Tools Practice Brief #35: How Can I Foster Curiosity and Learning in my Classroom? Through Talk!

### STUDENT ASSESSMENT OPPORTUNITIES

Students’ thoughtful participation during class discussions, group share-outs, and exit ticket, as well as responses on **Student Handout 1:** Data Science in Global Health, can all be used for assessment purposes.
# Instructional Procedure

**ASSUMING SYNCHRONOUS, LIVE, IN-CLASS INSTRUCTION**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Teaching Activities</th>
<th>Student Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction to Air Pollution and Data Science</strong></td>
<td><strong>1.1</strong> Teacher asks students what they know about air pollution or where they have observed air pollution in their community.</td>
<td><strong>1.1</strong> Students provide answers to this question.</td>
</tr>
<tr>
<td></td>
<td><strong>1.2</strong> Mini-presentation on air pollution using slide deck Part I: Introduction to Air Pollution (Slides #1-6). Define air pollution and describe why we are talking about it.</td>
<td><strong>1.2</strong> Students listen and ask questions.</td>
</tr>
<tr>
<td></td>
<td><strong>1.3</strong> Mini-presentation on data science using the slide deck Part II: Data Science and Air Pollution in Washington State (Slides #7-12). What data science is and how using it can help us better understand air pollution and its effects on human health.</td>
<td><strong>1.3</strong> Students listen and ask questions.</td>
</tr>
<tr>
<td><strong>How Air Pollution Affects Human Health (defining the problem of air pollution)</strong></td>
<td><strong>2.1</strong> Teacher asks students what they know about how air pollution affects human health. Can the students think of any specific instance/event they know of where air pollution impacted human health?</td>
<td><strong>2.1</strong> Students answer the question by sharing their understanding of air pollution and human health.</td>
</tr>
<tr>
<td></td>
<td><strong>2.2</strong> Mini-presentation on how air pollution affects human health (biological symptoms) using slide deck Part III: Air Pollution and Human Health (Slides #13-26).</td>
<td><strong>2.2</strong> Students listen and ask questions.</td>
</tr>
</tbody>
</table>
| | • Play the video about PM 2.5 (1:18 minutes)  
• Ask students if they have any questions/thoughts.  
• Include a discussion about what makes air quality bad and good (present examples from data or cities/countries). | |
| **The Science of Measuring Air Pollution** | **3.1** Mini-presentation on how air pollution is measured using slide deck Part IV: How Air Pollution is Measured (Slides #27-34). Include a discussion about the different sources of air pollution (natural/human/rural/urban) and how scientists track/monitor air pollution (description of different instruments, measures). | **3.1** Students will listen and ask questions. |
### Exercise Prep

<table>
<thead>
<tr>
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</tr>
</thead>
</table>
| **4.1** | Teacher asks students to divide into groups of 2 or 3 students. Teacher can count off by numbering students 1 through 3 if necessary. Each student group will need their own computer. If there are limited computers in the classroom, then groups can be larger than 2 to 3 students. Limit the # of groups to 19 as there are only 19 cities in the monitoring dataset.  
*Note:* If you choose to show students the Data Analysis Example video, limit the number of groups to 18 and do not include Pullman data (as the answers are provided in the video). | **4.1** Once students have their numbers, they can divide themselves into groups. |

**4.2** Teacher instructs students to log-on to computers and go to Google Sheet with data. Teacher makes a copy of the student version of the Google Sheet data and saves it to their own folder, then directs students to the class version of the spreadsheet:
- Student version of Google Sheet data: [Spreadsheet_WA_Air_Pollution_Student (HS).xlsx](#)
- Instructor version of Google Sheet data: [Spreadsheet_WA_Air_Pollution_Teacher (HS).xlsx](#)

Teacher will assign a city to each group. Cities can be assigned at random or students can choose based on interest. A state map could be shown to students to help them choose their city of interest. There is a total of 19 cities (18 if you do not include Pullman).

*Note:* If you will assigning less than 19 cities, it will be important to look at the group assignments below and Slide #52 in the slide deck, which show how student groups will later pair up to compare two cities. Make sure that you assign cities so that you will be able to form these pairings later in the lesson. Given the uneven number of cities, Pullman does not have a comparison city, therefore, if you do not need 19 cities for your class size, this one can be skipped.

1. Anacortes (Group E)
2. Bellingham (Group H)
3. Bremerton (Group C)
4. Bremerton-Silverdale (Group C)
5. Darrington (Group G)
6. Forks (Group D)
7. Kent (Group A)
8. Marysville (Group F)
9. Methow (Group G)
10. Mount Vern-Anacortes (Group B)
11. Mountlake Terrace (Group D)
12. Pullman
13. Scotch Basin (Group A)
14. Seattle (Group B)
15. Seattle-Tacoma-Bellevue (Group H)
16. Spokane (Group I)
17. Tacoma (Group E)
18. Walla Walla (Group F)
19. Yakima (Group I)

**4.3** Instructor asks students to create their own version of the data in a new Google Sheet. Instructions for creating a new database:
- Click the **File** tab.
- Click on the **New** tab.
- Select spreadsheet.
- Go to **air pollution student sheet**.
- Press **Control + A** to select all cells in the data set.
- Press **Control + C** to copy the data set.
- Press **File > New > Spreadsheet.**
- Press **Control + V** to paste data into a new sheet.

**4.3** Student-groups will create their own version of the Google Sheet in order to make changes during the analysis.
<table>
<thead>
<tr>
<th>Topic</th>
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<th>Student Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise Part 1:</td>
<td>5.1 Mini-presentation on data assessment (what is data quality) and why it is so important in data science using the slide deck Part V: Data Quality Assessment (Slides #35-40). Teacher will define the criteria which the air pollution data will be assessed: (a) accuracy, (b) completeness, (c) representation, (d) recency (description and examples included in slides and on student handout).</td>
<td>5.1 Students will listen and ask questions. Students will answer 3+ questions.</td>
</tr>
<tr>
<td>Assessing Data Quality</td>
<td>5.2 Teacher will distribute copies of Student Handout 1: Instructions: Data Science in Global Health to students (1 copy per group of students). Instructor will ask students to spend 5 minutes reviewing the raw dataset in the Google Sheet for the criteria mentioned above: (a) accuracy, (b) completeness, (c) representation, (d) recency. Students can write down findings, insights, and discoveries on a loose-leaf sheet of paper.</td>
<td>5.2 Students will assess and analyze data and complete the handout.</td>
</tr>
<tr>
<td></td>
<td>5.3 Teacher will then distribute copies of Student Handout 2: Time Series Plot for Washington State Data to each group. Students will spend 10 to 15 minutes looking at the graphs and identifying (a) accuracy, (b) completeness, (c) representation, and (d) recency.</td>
<td>5.3 Students will analyze graph and plots and write down their findings in the handout.</td>
</tr>
<tr>
<td></td>
<td>5.4 Teacher will bring students back together and ask them report out to the entire class about their findings. • Teacher will project Slide #40: Washington State Air Pollution Data Time Series onto the screen. Teacher will identify the data points that are questionable and describe why (teachers will have notes in the notes section of the slide deck—reproduced below—about the data points that have potential issues).</td>
<td>5.4 Students will report out about their findings and answer instructor questions.</td>
</tr>
<tr>
<td></td>
<td>Answers to the data assessment exercise (included on Slide #40) • <strong>Completeness:</strong> Does missingness appear to be random? (in the case of Marysville, data is missing each summer aka not random). • <strong>Accuracy:</strong> Are there any invalid values (aka 0, negatives, extreme values – a number that is very high or low). One artifact that students should notice is that data from Kent in 2015 were reported in the wrong units and need to be multiplied by 100. Students should also notice very high values in 2016 for the Pullman data point. Given this strange time trend and that this is a student run station, we will need to remove it. Extreme values were seen in Methow Valley and Scotch Basin in 2014/2015. Students should be guided to observe that these reflect very large forest fires during that time period and are not invalid data points. • <strong>Recency:</strong> Students should note that several monitors do not have data after 2014 and this should be taken into account in later analysis. • <strong>Representativeness:</strong> Some data points (i.e., Forks, Methow Valley, Scotch Basin, Walla Walla) are located away from major population centers and as such, may not tell us much about health impacts.</td>
<td></td>
</tr>
<tr>
<td>Exercise Part 2:</td>
<td>6.1 Mini-presentation on basic descriptive statistics using slide deck Part VI: Basic Descriptive Statistics (Slides #41-50). Teacher introduces the concepts of mean, median, min, max, and variance. Teacher will ask students if they understand what “average” means and how it is used to describe things (give examples).</td>
<td>6.1 Students will listen and ask questions.</td>
</tr>
<tr>
<td>Generating Descriptive</td>
<td>6.3 Teachers instructs students to find the mean, median, min, max, and variance in the data for their city. Instructions on how to do this are available on Student Handout 1. Students will document the findings for each metric on their handout.</td>
<td>6.3 Students will generate mean, median, min, max, and variance. Students will write metrics on the handout.</td>
</tr>
<tr>
<td>Statistics</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Exercise Part 3: Comparing Metrics Across Cities

#### 7.1 Teaching Activities
Teacher will ask students to join groups with their other city group, as shown in the list below (forming groups of 4 to 5 students). Teacher will ask students to compare and contrast findings across the two cities. Students will need copies of Student Handout 3a-i: City Comparison Plots, with each group getting a copy of the handout that is specific to their group. Teacher will instruct students to document the findings on Part III of Student Handout 1. Teacher will ask students to discuss their findings and evaluate the reasons for any differences and/or similarities. City comparison groups are listed below:

- Group A: Kent vs. Scotch Basin
- Group B: Mount Vernon-Anacortes vs. Seattle
- Group C: Bremerton vs. Bremerton-Silverdale
- Group D: Forks vs. Mountlake Terrace
- Group E: Anacortes vs. Tacoma
- Group F: Marysville vs. Walla Walla
- Group G: Darrington vs. Methow
- Group H: Bellingham vs. Seattle-Tacoma-Bellevue
- Group I: Spokane vs. Yakima

**Note:** Due to the odd number of cities, Pullman does not have a comparison.

#### 7.2 Teaching Activities
Teacher will bring class back together and ask students to present their findings by city comparison groups to the class. Teachers will project the city comparison plots as a backdrop found in the slide deck for each city comparison group. Use the slide deck Part VII: City Comparisons (Slides #51-62).

#### 7.3 Teaching Activities
After all student groups present, teacher will ask the entire class to compare and contrast results. Students can generate their own questions to guide comparisons. In addition, teacher will ask the following questions:

- Which city had the highest maximum? Which city had the lowest minimum?
- What city had the highest mean? What city had the lowest mean?
- What city had the highest median? What city had the lowest median?
- What is the variance across the cities?

**Note:** Answers to these questions are found in the instructor version of the Google Sheet on the sheet titled “stats key.”

For each question, the teacher will challenge students to answer why they think those are the findings. Teacher will ask students what the general trends and patterns are for each metric.

#### 7.4 Teaching Activities
Students will turn in their handouts to the teacher for grading.

### Exercise Part 4: Comparing Washington State Results with Global Results

#### 8.1 Teaching Activities
Teacher will ask students probing questions:

- How have you been impacted by air pollution?
- Have you been impacted by any of the events found in the data? How did the event impact you (please explain why and how)?
- What is the general trend for air pollution in Washington State (is it decreasing, increasing, staying stable)?
- Why is this the case and what could be contributing to these trends/patterns?
- What has been the impact/effect of wildfires on air pollution in Washington State?
- How could wildfires affect human health in the Washington State?

**Note:** Due to the odd number of cities, Pullman does not have a comparison.
<table>
<thead>
<tr>
<th>Topic</th>
<th>Teaching Activities</th>
<th>Student Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise Part 4: Comparing Washington State Results with Global Results, cont.</td>
<td>8.2 Instructor will ask students to access the State of Global Air webpage and tell students to identify three countries: one that has lower, one that has higher, and one that has equivalent values to the maximum value across Washington State. <a href="http://www.stateofglobalair.org/air#PM">http://www.stateofglobalair.org/air#PM</a>.</td>
<td>8.2 Students will go to the State of Global Air webpage and explore the map view.</td>
</tr>
</tbody>
</table>
|  | 8.3 Teacher will instruct students to go to the data plot view to compare time series: [http://www.stateofglobalair.org/data/#/air/plot](http://www.stateofglobalair.org/data/#/air/plot)  
• Students will need Student Handout 4: Washington State Map of PM2.5 Mean Values.  
• Teacher will ask students to compare results for each country selected against the maximum value in Washington State (or each city). | 8.3 Students will go to the State of Global Air webpage and explore the plot view. Students will discuss the findings. |
| Discussion & Wrap-up | 9.1 Students will share if they found any interesting results from their exploration on the State of Global Air webpage. An Exit Ticket could be assigned at this point asking students to summarize what they learned from exploring the State of Global Air webpage. | 9.1 Students will report out about what they found and discuss further. |
|  | 9.2 Teacher will ask students what we can do with this data and results to improve air quality/pollution in the state. Teacher asks students to generate ideas in their groups. Students will report out and teacher will write ideas on the board. Teacher will ask students to critique the ideas being shared. | 9.2 Students will ask each other questions and debate/discuss their ideas. |
ADAPTATIONS FOR REMOTE INSTRUCTION

This lesson plan has been updated to include adaptations for remote instruction settings. As written, the lesson is intended for in-person, live, classroom-based instruction. Suggestions are summarized in the table below for hybrid and fully remote teaching and learning settings. **Hybrid instruction** assumes several days each week of live, in-person, classroom-based instruction paired with several days of asynchronous, home-based, remote learning. **Asynchronous remote instruction** assumes no in-person, class-based instruction with all learning taking place remotely in students’ own homes. Suggestions focus on asynchronous learning. Teachers who can provide synchronous, live video conference meetings with students may sample from the original lesson plan or the hybrid setting suggestions. The adaptations described below should be considered in addition to the directions in the Procedure section of the lesson plan.

<table>
<thead>
<tr>
<th>Learning Activity</th>
<th>Adaptations for Hybrid Instruction</th>
<th>Adaptations for Asynchronous Remote Instruction</th>
</tr>
</thead>
</table>
| **Teacher Prep for Lesson** | • Decide what students will do during in-class days and what they will do from home during remote days.  
• Make digital copies of handouts available to students via your learning management system.  
• Load the Data Analysis Example video on your learning management system so students can view from home.  
• Focus in-person time in the classroom on group work, group discussion, and interaction between students. | • Consider recording a video of you presenting the slides (i.e., by using Peardeck for Google Slides or ScreenCast O Matic) for students to view from home.  
• Make digital copies of handouts available to students via your learning management system.  
• Load the Data Analysis Example video on your learning management system so students can view from home.  
• Consider using digital bulletin boards (i.e., Padlet, Google Jamboard app, or FlipGrid) as a way for students to communicate, share, and increase interaction. |
| **Introduction: Air Pollution and Data Science**  
(1.1 – 3.1) | • If you will present the slide deck in class, follow the instructions as written in the Procedure.  
• If students will review the slide deck on their own during a remote instruction day, follow the instructions in the column to the right. Discussion questions could be reviewed together during the next in-class session. | • Optional: As an optional way to open the lesson which leverages that students are engaged in learning from home, students could be asked to engage in a self-documentation activity around sources of ambient air pollution in their own community and lives. Students could take photos using a cell phone and/or add text to a collaborative digital space using technology such as Padlet, Google Jamboard app, FlipGrid or Google Slides. This resource provides an overview of how to engage in this kind of culturally-responsive launch to the lesson.  
- STEM Teaching Tools Practice Brief #31: How to Launch STEM Investigations That Build on Student and Community Interests and Expertise.  
- (Slides #1-34) Have students review the slide deck and speaker’s notes or view a video of you presenting the slide deck (preferable). See Procedure section as written for more information about the mini-presentations in the slide deck.  
• At the end of each mini-presentation, engage students in sensemaking. They could be asked to respond in writing to the following questions to submit to the teacher. Another option to promote student interaction is to use a digital bulletin board for students to post responses to the prompts and comment on each other’s responses.  
- **Beginning of Intro to Air Pollution and Data Science:**  
  What do you know about air pollution? Where have you observed air pollution in their community?  
- **End of Intro to Air Pollution and Data Science:**  
  How can using data science help us better understand air pollution and its effects on human health? |
### Learning Activity | Adaptations for Hybrid Instruction | Adaptations for Asynchronous Remote Instruction
--- | --- | ---

**Exercise Prep (4.1 – 4.3)** | • If students will be able to work in groups on data analysis during an in-classroom day, follow the instructions as written in the Procedure. Divide students into groups of 2 or 3. You will need one computer per student or group for classroom work.  • If students will need to work on data analysis from home during a remote instruction day, follow the instructions in the column to the right. | • Decide if students will be able to work remotely in pairs, or if they will need to work individually on the data analysis project. If working in pairs, consider what technologies are available to your school/district that would allow students to virtually meet-up to complete the assignment together.  • **Option A: Working Remotely in Pairs**  Follow the directions in the Exercise Prep section of the Procedure. Do not assign anyone to the Pullman dataset.  • **Option B: Working Remotely as Individuals**  Follow the directions in the Exercise Prep section of the Procedure except do not break students into groups. Assign each individual student to a data set. Do not assign anyone to the Pullman dataset. Not counting Pullman, there are 18 available datasets. As needed, you may assign multiple students to a dataset. It will be important to look at the group assignments in the Procedure and Slide #52 in the slide deck, which show how students will later pair up to compare their data from two cities. Make sure that you assign cities so that you will be able to form these pairings later in the lesson.

**Exercise Part 1: Assessing Data Quality (5.1 – 5.6)** | • If students will be able to work in groups on data analysis during an in-classroom day, follow the instructions as written in the Procedure. This is encouraged if possible because it allows for collaborative group work and also makes the instructor available for just-in-time troubleshooting assistance.  • If students will need to work on data analysis from home during a remote instruction day, follow the instructions in the column to the right. | • Have students review the slide deck Part V: Data Quality Assessment (Slides #35-40), which focuses on data assessment, what is data quality, and why it is so important in data science.  • Students will need access to a digital version of Student Handout 1: Instructions: Data Science in Global Health. In Part I of the handout, students can be asked to complete their work on the digital version of the handout to submit to the instructor, or to submit answers to the instructor in some other format through the classroom learning management system.  • Ask students to review the raw dataset in the Google Sheet for the (a) accuracy, (b) completeness, (c) representation, (d) recency.  • Students will need access to a digital version of Student Handout 2: Time Series Plot for Washington State Data with the Washington State air pollution plot graphs. Students will examine the graphs and identify (a) accuracy, (b) completeness, (c) representation, and (d) recency. Consider if students should submit their observations of the plot graphs to the instructor.  • Direct students to Slide #40: Washington State Air Pollution Data Time Series to identify the data points that are questionable and why (information is provided in the notes section of the slide deck).
<table>
<thead>
<tr>
<th>Learning Activity</th>
<th>Adaptations for Hybrid Instruction</th>
<th>Adaptations for Asynchronous Remote Instruction</th>
</tr>
</thead>
</table>
| Exercise Part 2: Generating Descriptive Statistics (6.1 – 6.3) | • If students will be able to work in groups on data analysis (encouraged) during an in-classroom day, follow the instructions as written in the Procedure.  
• If students will need to work on data analysis from home during a remote instruction day, follow the instructions in the column to the right. | • Have students review the slide deck mini-presentation on basic descriptive statistics, Part VI: Basic Descriptive Statistics (Slides #41-50). This will introduce the concepts of mean, median, min, max, and variance.  
• Individual students, from home, will use the dataset for their assigned city to find the mean, median, min, max, and variance in the data for their city. Instructions on the data analysis task are provided in Part II of Student Handout 1: Instructions: Data Science in Global Health. Students will document the findings for each metric on their handout.  
• If working in pairs, consider what technologies are available to your school/district that would allow students to virtually meet-up to complete the assignment together and discuss their results.  
• Also consider how students will get help if they encounter problems while engaged in data analysis from home. Consider if drop-in office hours via videoconference are a possibility on the day(s) students are likely to work on Part II of Student Handout 1.  
• Optional: For assessment purposes, each student could be asked to submit their city’s filtered/sorted/analyzed dataset to the instructor. |
| Exercise Part 3: Comparing Metrics Across Cities (7.1 – 7.4) | Whether students engaged in data analysis in class or at home, having students present their group comparison data in class is a great option for interaction and collaborative sensemaking. In this case, follow the instruction as written in the Procedure. | • Consider what technologies are available to your school/district that would allow students to virtually meet-up to share and discuss their results. Another option could be using FlipGrid or Google Slides to allow for each group (Groups A-I) to share and compare their results. For example, a Google Slide could be created for students who make up Group A to input their results for Kent and Scotch Basin for comparison. Alternatively, FlipGrid allows for students to upload short, informal videos (could be filmed on a cell phone) of themselves presenting their data. Each group (A-I) could also integrate the city comparison plots using their group slide from the slide deck Part VII: City Comparisons (Slides #51-62).  
• Students will need access to a digital version of Student Handout 3: City Comparison Plots (specific to their group).  
• Depending on how students share their comparison plots and data in a virtual environment, ask all students to compare and contrast the results across all of the group’s data. Ask students to respond to the following questions and submit to the instructor.  
  • Which city had the highest maximum? Which city had the lowest minimum?  
  • What city had the highest mean? What city had the lowest mean?  
  • What city had the highest median? What city had the lowest median?  
  • What is the variance across the cities?  
  • *Note that answers to these questions are found in the instructor version of the Google Sheet on the sheet titled “stats key.” |
<table>
<thead>
<tr>
<th>Learning Activity</th>
<th>Adaptations for Hybrid Instruction</th>
<th>Adaptations for Asynchronous Remote Instruction</th>
</tr>
</thead>
</table>
| **Exercise Part 4: Comparing WA and Global Results**  
(8.1 – 8.3) | • Part 4 of the lesson should work well for students to complete at home on a remote learning day. If so, follow the instructions in the column to the right.  
• If students will be able to work on Part 4 during an in-classroom day, follow the instructions as written in the Procedure. | • Engage students in sensemaking focused on the first three parts of the exercise and to prepare them for comparing Washington State results with those from other countries. Students could be asked to respond in writing to the following questions to submit to the teacher. Another option to promote student interaction is to use a Padlet, Google Slides, or FlipGrid for students to post responses to the prompts and comment on each other’s responses.  
  - How have you been impacted by air pollution?  
  - Have you been impacted by any of the events found in the data? How did the event impact you (please explain why and how)?  
  - What is the general trend for air pollution in Washington State (is it decreasing, increasing, staying stable)?  
  - Why is this the case and what could be contributing to these trends/patterns?  
  - What has been the impact/effect of wildfires on air pollution in Washington State?  
  - How could wildfires affect human health in the Washington State?  
• Students will need access to a digital version of **Student Handout 4: Washington State Map of PM2.5 Mean Values**.  
• Adapt the activity by having students work individually from home, rather than together in small groups in the classroom, to complete Part IV of **Student Handout 1: Instructions: Data Science in Global Health**. The handout will prompt students to access the State of Global Air webpage and to identify three countries: one that has lower, one that has higher, and one that has equivalent values to the maximum value across Washington State. The handout will also guide students in exploring the data plot view to compare time series. Finally, students will record their observations and summarize their ideas for how the data could be used to improve air quality. |
| **Discussion & Wrap-up**  
(9.1 – 9.2) | • If the discussion will be happening during a live, in-class day, engage the students in a whole class discussion to wrap-up what they have learned about air pollution and human health, both locally, across our region, and globally. Ask students what we can do with this data and results to improve air quality/pollution in the state (from their responses to Part IV on **Student Handout 1**). Student groups can report out and teacher can record ideas on the board.  
• An Exit Ticket could be assigned at this point asking students to summarize what they learned from exploring the State of Global Air webpage. In addition, ask students to submit their completed **Student Handout 1** for grading/credit.  
• If the wrap-up will occur during a remote instruction day, follow the instructions in the column to the right. | • One option for remotely wrapping up the lesson is to ask students to look through the posts (i.e., via Padlet, Google Jamboard app, FlipGrid, etc.) made by other students about what they found on the State of Global Air webpage.  
• A digital Exit Ticket could be assigned at this point asking students to:  
  - Summarize what they have learned about air pollution and human health, both locally, across our region, and globally.  
  - Summarize what they learned from exploring the State of Global Air webpage and reviewing other students’ posts. Did they see any patterns or trends?  
• In addition, ask students to submit their completed **Student Handout 1** for grading/credit through your classroom learning management system. For accountability purposes, you could also ask students to submit their spreadsheet that shows the data analysis that they completed for the lesson. |
Suggested Lesson Extensions

SELF-DOCUMENTATION
For the Introduction, students could be asked to engage in a self-documentation activity around sources of ambient air pollution in their own community and lives. This resource provides an overview of how to engage in this kind of culturally-responsive launch to the lesson.

EXPLORING HEALTH IMPACTS
This lesson could be extended to focus additional time on understanding the health impacts of air pollution on different body systems (pulmonary, cardiac, vascular, and neurological) as well as connections between air pollution, cancer, and other diseases.

SCIENTIFIC & COMPUTATIONAL VOCABULARY
Students may need some support in understanding the terminology embedded in this lesson. This may be particularly true for emerging bilingual students and students with lower reading levels. The following list captures some of the scientific, mathematical, and computational terms used in the lesson materials.

- **Mean**: The mean or average that is used to derive the central tendency of the data in question. It is determined by adding all the data points in a population and then dividing the total by the number of points.

- **Median**: A simple measure of central tendency. To find the median, we arrange the observations in order from smallest to largest value. If there is an odd number of observations, the median is the middle value. If there is an even number of observations, the median is the average of the two middle values.

- **Minimum**: The smallest observation (number) in a sample of data.

- **Maximum**: The largest observation (number) in a sample of data.

- **Data assessment**: The process of scientifically and statistically evaluating data in order to determine whether they meet the quality required for projects or business processes and are of the right type and quantity to be able to actually support their intended use.

- **Accuracy**: The extent to which the result of a measurement, calculation, or specification conforms to the correct value or a standard.

- **Completeness**: The extent to which there are any gaps in the data from what was expected to be collected, and what was actually collected.

- **Recency**: The extent to which the data contains observations from recent time periods.

- **Representativeness**: The extent to which the data provides insight into what is happening with the broader population of interest.

- **PM2.5**: Refers to atmospheric particulate matter (PM) that have a diameter of less than 2.5 micrometers, which is about 3% the diameter of a human hair.
Teacher Resources

BACKGROUND INFORMATION ON AIR POLLUTION IN GLOBAL HEALTH

- **Our World in Data: Air Pollution**
  Hannah Ritchie and Max Roser, October 2017

- **State of Global Air Report Card**
  IHME, 2020

- **Health Impacts of Air Pollution**
  European Environment Agency, April 2016

- **Air Pollution, Climate, and Health**
  Breathe Life; Climate & Clean Air Coalition; WHO, 2016

- **The Weight of Numbers: Air Pollution and PM2.5**
  UnDark Magazine & the Pulitzer Center on Crisis Reporting, 2018

CAREER CONNECTIONS

The following careers are related to data sciences and global health. Read more about each job by following the links.

- **Biostatistician**
  [https://www.careersinpublichealth.net/careers/biostatisticians/](https://www.careersinpublichealth.net/careers/biostatisticians/)

- **Data Analyst**


Authorship Credit: This activity was originally developed by the Institute for Health Metrics and Evaluation (IHME), a global health organization located in Seattle, WA and adapted for a STEM Global Teacher Workshop in April 2019. Authors include: Austin Carter, Doctoral Candidate and Researcher, IHME; Joseph Frostad, Doctoral Candidate and Researcher, IHME; Sean Lassiter, Senior Education Program Manager. Revisions in July 2020 by Sarah Wozniak and Justin Lo of IHME. Lesson plan development, editing, and adaptations for remote instruction provided by Dr. Kristen Bergsman of Laughing Crow Curriculum LLC.

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PART I: ASSESSING DATA QUALITY

Data Quality Dimensions

**Accuracy** – The extent to which the result of a measurement, calculation, or specification conforms to the correct value or a standard.

**Completeness** – The extent to which there are any gaps in the data from what was expected to be collected, and what was actually collected.

**Recency** – The extent to which the data contains observations from recent time periods.

**Representativeness** – The extent to which the data provides insight into what is happening with the broader population of interest.

Answer the following questions about data accuracy based on the presentation and the data set provided.

1. **Accuracy**: What are some potential sources of bias in the way the data is collected? Are there any data points different from the others? Which ones?

2. **Completeness**: Is there any data missing that does not seem to be random? If so, which data points appear to be missing?

3. **Recency**: How recent were the latest observations in our dataset?

4. **Representativeness**: Can we make conclusions about air quality in all of Washington with observations we have in our data?
PART II: GENERATING DESCRIPTIVE STATISTICS USING A SPREADSHEET

STEP 1: CREATING A NEW DATA SET IN GOOGLE SHEETS

2. Press Control + A to select all cells in the data set.
3. Press Control + C to copy the data set.
5. Press Control + V to paste data into a new sheet.

STEP 2: FINDING YOUR CITY

6. Create a filter on the cell titled “city”.
7. Select your city and filter out all other cities.

STEP 3: IDENTIFYING AND REMOVING OUTLIERS

8. Based on observations from Part I, identify outliers for your city.
   • Examples: negative values, missing values ("NA"), or very large values.
   • Mark them “1” in the “outlier” column.
9. Create a filter on the cell titled “outlier”.
10. Filter out any values which are outliers.
    • 1 = outlier
    • 0 = not an outlier
11. We now have a clean dataset!

STEP 4: CREATING A CLEAN DATASHEET

12. Press Control + A to select all cells in the clean data set.
13. Press Control + C to copy the clean data set.
14. Press the + button at the bottom left of the spreadsheet to “Add Sheet”.
15. Press Control + V to paste data into the new “Sheet2”.

STEP 5: FINDING THE MINIMUM

16. In “Sheet2”, sort the PM2.5 column from largest to smallest (or smallest to largest) and find the minimum value for their city.
    • Hint: you might have to create a new filter.
17. Or, use the minimum function.
    • In a new blank cell type the following function:
      a. = min (highlight all the cells for their city)
      b. Press enter

TIP #1:
How to Filter Your Data in Google Docs

1. Select a range of cells by clicking on them.
2. Click Data > Create a filter.
3. To see filter options, go to the top of the range and click Filter.
   • Filter by condition: Choose from a list of conditions or write your own. For example, if the cell is empty, if data is less than a certain number, or if the text contains a certain letter or phrase.
   • Filter by values: Uncheck any data points that you want to hide and click OK. If you want to choose all data points, click Select all. You can also uncheck all data points, by clicking Clear.
   • Search: Search for data points by typing in the search box. For example, typing “P” will shorten your list to just the names that start with P.
4. To turn the filter off, click Data > Turn off filter.
PART II: GENERATING DESCRIPTIVE STATISTICS USING A SPREADSHEET, CONT.

STEP 6: FINDING THE MAXIMUM
18. Sort the PM2.5 column from largest to smallest (or smallest to largest) and find the maximum value for their city.
19. Or, use the maximum function.
   • In a new blank cell type the following function:
     a. = max (highlight all the cells for their city)
     b. Press enter

STEP 7: FINDING THE MEDIAN
20. Sort all values by largest to smallest and find the middle value.
21. Or, use the median function.
   • In a new blank cell type the following function
     a. = median (highlight all the cells for their city)
     b. Press enter

STEP 8: CALCULATING THE MEAN
22. Add together all the values by hand.
   • Take a calculator and add up all the values.
   • Divide by the number of values (or rows).
23. Or, use the average function.
   • In a new blank cell type the following function:
     a. = average (highlight all the cells for their city)
     b. Press enter

STEP 8: CALCULATING VARIANCE
24. In a new blank cell type the following function:
   a. = var (highlight all the cells for their city)
   b. Press enter

TIP #2:
How to Sort a Range of Data in Google Docs
1. Highlight the group of cells you would like to sort.
2. Click Data > Sort range.
3. If your columns have titles, click Data has header row.
4. Select the column you would like to be sorted first and whether you would like that column sorted in ascending or descending order. This also sorts numbers.
   • If needed, click +Add another sort column to add another sorting rule. Sorting will be done according to the order of your rules.
   • To delete a rule, click Close [X].
5. Click Sort. Your range will be sorted.
PART III: COMPARING METRICS ACROSS TWO CITIES

Definitions

Minimum – The smallest observation.
Maximum – The largest observation.
Median – The middle observation in a ranked list of observations.
Mean – The sum of the observations over the number of observations.
Variance – The sum of the squared differences between each observation and the mean of all observations.

Fill out the table and answer the questions that follow:

<table>
<thead>
<tr>
<th>CITY 1 NAME:</th>
<th>CITY 2 NAME:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>Minimum</td>
</tr>
<tr>
<td>Maximum</td>
<td>Maximum</td>
</tr>
<tr>
<td>Median</td>
<td>Median</td>
</tr>
<tr>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td>Variance</td>
<td>Variance</td>
</tr>
</tbody>
</table>

1. What interesting differences between cities can you identify?

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

2. What do these differences in the data mean? What might they imply about air quality in these two cities?

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

3. What are some possible explanations for these differences?

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
PART IV: COMPARING WASHINGTON STATE AND GLOBAL AIR QUALITY

Now that you have examined air quality data for specific cities/areas of Washington State and compared data across different regions, let's take a global look at air quality. In this section, you will be examining air quality data for different countries of your choosing using a website called State of Global Air.

Exploring air quality in different countries

1. First, examine the air quality of different countries around the world. You will want to find three countries with lower, higher, and equivalent values as compared to the maximum value in Washington State. You will first need to go back to the original Washington State dataset and find the maximum value of PM2.5.

2. Next, check out the “map view” option of the State of Global Air website: http://www.stateofglobalair.org/air#PM
   - Move cursor over countries to view levels of PM2.5
   - Write down the three countries you chose:

   | Lower: ____________________________ | PM2.5: ____________ |
   | Higher: ____________________________ | PM2.5: ____________ |
   | Equivalent: ____________________________ | PM2.5: ____________ |

3. Now, explore one of the countries you identified in more detail. To do this, check out the “plot view” option of the State of Global Air website: http://www.stateofglobalair.org/data/#/air/plot
   - Go to the “Choose a country” tab:
     a. In the drop-down menu, pick one of the countries you identified from the map view.
     b. Click on that country's name.
   - The plot should generate a yellow line representing PM2.5 levels between 1990 and 2015.
   - To compare the PM2.5 of the three countries in a time series, you can add a country by selecting them in the “+Add countries” drop down menu. Compare the data across all three countries.

4. Record some observations of the data for the three countries of your choice. What do you notice? What do you wonder about?

   __________________________________________
   __________________________________________
   __________________________________________

5. What can we do with your Washington State data and this global data? How might it help inform policy, action, or education in order to improve air quality/pollution across Washington State and globally? Record your thoughts and ideas below.

   __________________________________________
   __________________________________________
   __________________________________________
Time Series Plot for Washington State Data

Name: ___________________________ Date: ___________ Period: ______

WASHINGTON PM2.5

Anacortes

Bellingham

Bremerton

Bremerton-Silverdale

Darrington

Forks

Kent

Marysville

Methow

Mount Vernon-Anacortes

Mountlake Terrace

Pullman

Scotch Basin

Seattle

Seattle-Tacoma-Bellevue

Spokane

Tacoma

Walla Walla

Yakima

TIME

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City Comparison Plots
GROUP A: KENT VS. SCOTCH BASIN

City Comparison Plots
GROUP B: MOUNT VERNON-ANACORTES VS. SEATTLE

City Comparison Plots
GROUP C: BREMERTON VS. BREMERTON-SILVERDALE
City Comparison Plots
GROUP D: FORKS VS. MOUNTLAKE TERRACE

City Comparison Plots
GROUP E: ANACORTES VS. TACOMA

City Comparison Plots
GROUP F: MARYSVILLE VS. WALLA WALLA
City Comparison Plots
GROUP G: DARRINGTON VS. METHOW

City Comparison Plots
GROUP H: BELLINGHAM VS. SEATTLE-TACOMA-BELLEVUE

City Comparison Plots
GROUP I: SPOKANE VS. YAKIMA
Washington State Map of PM2.5 Mean Values

Name: ___________________________ Date: __________ Period: ______

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Data Driven: Investigating the Human Health Effects of Air Pollution in Washington State, Middle School Version

IHME

Brief Overview: In this data science lesson, students practice analyzing and interpreting data in order to answer an investigative question about air pollution in Washington State. Student groups first collaborate to graph air pollution data from a city in Washington. They then compile data as a class in order to observe trends and patterns across cities to make a claim about whether the time of year affects the amount of air pollution in Washington. Through this lesson, students will develop an understanding of foundational data science principles and recognize techniques for manipulating and analyzing data. Students will also gain skills in interpreting trends and patterns in data and writing evidence-based claims. In addition, students will gain an understanding of how air pollution affects human health and the global epidemiology of outcomes attributed to air pollution.

The high school version of this lesson was originally developed by the Institute for Health Metrics and Evaluation (IHME), an institute affiliated with the University of Washington focused on health metrics sciences. As such, this lesson attempts to introduce students to fundamental data sciences practices that are the work of scientists across fields, including global health. This middle school adaptation of the lesson was created by Laughing Crow Curriculum.

healthdata.org

Time:

3 50-minute class periods, if taught during synchronous in-personal instruction. Adaptations for remote learning may change this time estimate.

Subject & Grade Level(s):

Middle School Earth and Space Sciences (Grades 6-8). This lesson incorporates mathematics and computational thinking concepts and practices.
Exposure to outdoor (ambient) air pollution is a major risk factor for disease for people around the world. There is a wide array of health effects which are believed to be associated with air pollution exposure. Among them are respiratory diseases (including asthma and changes in lung function), cardiovascular diseases, adverse pregnancy outcomes (such as preterm birth), and even death. While air pollution is a global phenomenon, it has very local impacts that can profoundly affect communities in unique and profound ways. In Washington State for instance, increasing temperatures, rapid urbanization, increased manufacturing, and natural disasters can affect the region's air quality which, in turn, can contribute to poorer health outcomes for residents. In order to alleviate/mitigate the consequences of air pollution in Washington State, we must assess and understand levels and trends of exposure to air pollution to better identify solutions and interventions.

**LEARNING OBJECTIVES**

By the time students complete these activities, they will be able to:

- Recognize and explain how air pollution affects human health.
- Graph data in order to observe trends and patterns.
- Make a claim about whether the time of year affects the amount of air pollution in Washington and support it with data.
- Generate basic descriptive statistics using a set of data including mean, median, min, and max.
- Interpret trends and patterns of health outcomes related to air pollution by using various forms of data visualization.

**MATHEMATICAL AND COMPUTATIONAL THINKING**

This lesson was designed to introduce students to data science. It engages students in fundamental data science practices, including manipulating, analyzing, and visualizing data. For each of these steps, students are encouraged to engage in sensemaking around why data is important and how graphing and doing statistical analyses of data extracts meaning from it. The following teacher resource may be helpful for educators in thinking about how to frame their approach to computational thinking in the science classroom:

**Remote Learning Adaptations**

Integrated into this lesson plan are suggestions for adapting the activities for remote teaching and learning settings. For remote instruction, this lesson assumes students have computer and internet access at home.

**Student Understandings**

**ANCHORING PHENOMENON**

Exposure to outdoor (ambient) air pollution is a major risk factor for disease for people around the world. There is a wide array of health effects which are believed to be associated with air pollution exposure. Among them are respiratory diseases (including asthma and changes in lung function), cardiovascular diseases, adverse pregnancy outcomes (such as preterm birth), and even death. While air pollution is a global phenomenon, it has very local impacts that can profoundly affect communities in unique and profound ways. In Washington State for instance, increasing temperatures, rapid urbanization, increased manufacturing, and natural disasters can affect the region's air quality which, in turn, can contribute to poorer health outcomes for residents. In order to alleviate/mitigate the consequences of air pollution in Washington State, we must assess and understand levels and trends of exposure to air pollution to better identify solutions and interventions.

**DRIVING QUESTIONS**

- How can data be used to understand changing levels of air pollution exposure in Washington State?
- How can we present air pollution data in a way that reveals patterns or relationships?
- What are the health effects from outdoor air pollution exposure to Washington residents?
- How can data be used to make predictions and recommendations about air pollution and human health?
Next Generation Science Standards

This lesson builds toward the following bundles of middle and high school level Performance Expectations (PEs) from the NRC Framework and Next Generation Science Standards. Standards marked with an asterisk (*) are concepts or practices aligned to this lesson, but not included in the PE bundle.

MIDDLE SCHOOL BUNDLE OF PERFORMANCE EXPECTATIONS

**MS-ESS3-3**: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

<table>
<thead>
<tr>
<th><strong>Science and Engineering Practices (SEPs)</strong></th>
<th><strong>Disciplinary Core Ideas (DCIs)</strong></th>
<th><strong>Crosscutting Concepts (CCCs)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Using Mathematics and Computational Thinking</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Influence of Science, Engineering, Technology, and Applications of Science</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td><em>Analyzing and Interpreting Data</em></td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>ESS3.C: Human Impacts on Earth Systems</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Systems and Systems Models</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td><em>Patterns</em></td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td><em>Stability and Change</em></td>
<td>•</td>
<td>•</td>
</tr>
</tbody>
</table>


Connections to Common Core State Standards

Connections to Common Core State Standards in Mathematics include the following mathematical practices:

**MP.2**: Reason abstractly and quantitatively

**MP.4**: Model with mathematics
## Teacher Preparation

<table>
<thead>
<tr>
<th>Material</th>
<th>Description/Source</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom/Teacher Computer</td>
<td>Computer with internet access, projector, and speakers (for live, in-class instruction).</td>
<td>1</td>
</tr>
<tr>
<td>Student Computers</td>
<td>Computers need to have access to internet for the last topic/step of the lesson.</td>
<td>1/student or group of students</td>
</tr>
<tr>
<td>Student Handout: Lesson</td>
<td>Make copies of <a href="#">Student Handout: Data Science in Global Health</a>, one of each handout for each group of students.</td>
<td>1/student or group of students</td>
</tr>
<tr>
<td>Student Handout: Excel Spreadsheet</td>
<td>Print the Excel spreadsheet <a href="#">WA_Air_Pollution_Student (MS).xlsx</a> and cut out the different cities so that each group can have the data for just their city. If you want a more simplified version of the data, use the Air Pollution by City Spreadsheet offered as a resource for remote learning.</td>
<td>1/student or group of students</td>
</tr>
<tr>
<td>Teacher Slide Deck</td>
<td><a href="#">Air Pollution in WA State Slide Deck (MS)</a> (elements of slide deck below)</td>
<td>Teacher resource</td>
</tr>
<tr>
<td>Student Slide Deck (remote only)</td>
<td><a href="#">Remote Instruction</a>: For remote learning contexts, students will need collaborative access to the slide deck <a href="#">Data Driven_Part IV_Slides_Remote (MS).pptx</a> and the ability to edit it, for Part IV of the Student Handout.</td>
<td>1</td>
</tr>
<tr>
<td>Data: Instructor Version</td>
<td><a href="#">Spreadsheet_Teacher - Full Dataset (MS)</a></td>
<td>Teacher resource</td>
</tr>
</tbody>
</table>

### Air Pollution in WA State - MS Slide Deck

**Download Slide Deck**

---

**An Investigative Question**

Is there a relationship between the time of year (or season) and the amount of air pollution in Washington?

**Two variables:**

- What is your hypothesis? Why do you think that?
- What kinds of data do you think we would need to answer the question?

**Air Pollution and Human Health**

- Causes both acute (short-term) and chronic (long-term) health effects.
- Can be linked to cardiovascular disease, cancer, asthma, and neurological impairment.
- High-risk groups are infants, infants and children of young age, persons with pre-existing conditions.
- Relative risk of asthma.
NOTES TO TEACHER FOR PREPARING TO TEACH THIS LESSON:

1. Computers are required for the last topic/step of this lesson.
   Remote instruction: Students will need computers and internet access throughout this lesson in order to access the digital versions of the student handouts and to submit their work to the teacher.

2. Make copies of the student handouts, as indicated in the materials table above.
   Remote instruction: Make digital copies of handouts available to students via your learning management system.

3. Print out the Excel spreadsheet "WA_Air_Pollution_Student (MS).xlsx" (Data for Students tab) and cut out the different cities so that each student group will have the data for just their city.
   Remote instruction: Post the spreadsheet file "Air Pollution by City_Remote (MS).xlsx" to your learning management system. Each tab in the file has the data for one of the nine cities.

4. Decide how to divide the class into groups of 2 or 3 students. Each group will be assigned a city. There are 9 cities, so divide groups accordingly:
   - Anacortes
   - Bremerton
   - Darrington
   - Kent
   - Methow
   - Mountlake Terrace
   - Scotch (Creek) Basin
   - Seattle
   - Tacoma

5. Review the slide deck and speaker’s notes.
   Remote instruction: Upload copies of the two slide decks to your learning management system.
   Consider recording a video of you presenting the slides in the Air Pollution slide deck (i.e., by using Peardeck for Google Slides or ScreenCast O Matic) for students to view from home.

6. An important component of engaging in data practices is having students pause during their computational work to engage in sensemaking together. This teacher resource on science talk and the embedded Student Talk Flow Chart provides ideas of how to structure student-to-student talk and teacher-student talk in equitable ways.

STEM Teaching Tools Practice Brief #35: How Can I Foster Curiosity and Learning in my Classroom? Through Talk!

STUDENT ASSESSMENT OPPORTUNITIES
Students’ thoughtful participation during class discussions, group share-outs, as well as responses on the Student Handout can all be used for assessment purposes.
## Instructional Procedure

### ASSUMING SYNCHRONOUS, LIVE, IN-CLASS INSTRUCTION

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<tr>
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<th>Student Activities</th>
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</table>
| **Warm-up Questions and Investigative Question #1** | 1.1 Teacher asks students:  
• What they know about air pollution or where they have observed air pollution in their community.  
• What they know about how air pollution affects human health. Can the students think of any specific instance/event they know of where air pollution impacted human health?  
• Ideas students have about how they think air pollution might be measured. | 1.1 Students provide answers to the warm-up questions. |
|  | 1.2 Teacher reads aloud investigative question (#1) on Slide #1 and has students Turn and Talk to discuss their hypotheses and ideas. | 1.2 Students listen and ask questions. |
| **Presentation on Air Pollution** | 2.1 Presentation on air pollution using the slide deck Parts I – IV:  
Part I: Introduction to Air Pollution (Slides #1-6)  
Part II: Air Pollution and Human Health (Slides #7-9)  
Part III: Data Science and Air Pollution in Washington State (Slides #10-12)  
Part IV: How Air Pollution is Measured (Slides #13-16) | 2.1 Students listen and ask questions. |
| **Investigable Questions and Identifying Variables** | 3.1 Teacher divides class into groups of 2 or 3 students (there are 9 cities, so divide groups accordingly) and assigns a city to each group. Distribute copies of the Student Handout: Data Science in Global Health. | 3.1 Students sit with their groups. |
|  | 3.2 Read overview for Part I on the Student Handout as a class. Give groups a few minutes to write answers to the questions for Part I. Depending on students’ familiarity with variables, the teacher may need to provide more support in identifying variables, possible controls, and making a hypothesis. Part I could be done as a class, if necessary. | 3.2 Groups write their answers to the questions for Part I on the handout. |

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*DATA DRIVEN: MIDDLE SCHOOL — LESSON

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| **Graphing Data to See Patterns** | 4.1 Teacher distributes hard copies of city data from the Excel spreadsheet: WA_AirPollution_Student (MS), making sure to give each group only the data for their assigned city. Read overview for Part II as a class.  
*Note:* Optional Slide #31 provides a Washington State map with an approximate plot of each city/region's location. Optional Slide #32 provides descriptions of the codes in the dataset.  
Teacher emphasizes that it is difficult to see patterns/trends or relationships in raw data. By graphing the data, we can more easily observe any patterns. Depending on students' familiarity with graphing data, the teacher may need to provide more support in discussing the different types of graphs and which graph might be most appropriate to represent this data and answer the investigative question. Teacher might consider using Excel to show a few different graph types and help students reason through which type of graph might best represent the air pollution data. A line graph would be best, but a bar graph would also work. Groups will also need to decide whether they will make a double or triple line graph (depending on how many years they have data for their city), either using three different colors or make separate graphs for each year.  
4.2 Groups make a graph (or graphs) to represent the amount of air pollution per month for their city across all years using the Excel spreadsheet: WA_AirPollution_Student (MS). Once groups have finished making their graph(s), they should answer the graph analysis questions in Part II of the Student Handout as a group.  
4.3 Teacher brings students back together and asks them report out to the entire class about their findings for their city.  
  - Teacher shares Slide #17 and reads aloud the topic and the question: Why do we need to analyze data from across cities in order to make a claim about whether the time of year affects the amount of air pollution in Washington?  
  - Teacher solicits ideas from students about why we need to analyze data from across cities in order to make a claim about whether the time of year affects the amount of air pollution in Washington State. Students should say that since the question is about whether there is a relationship between the time of year and the amount of pollution in Washington, they need to analyze data from multiple cities, not just their assigned city. The more data (air pollution from different cities) they analyze, the more reliable their claim will be.  
4.4 Groups share out the months with the highest air pollution and the months with the lowest air pollution for each year. Teacher tallies these months in the table on Slide #18.  
4.5 Teacher reads aloud questions on Slide #18 and solicits students' responses:  
  - Does there appear to be a trend in the highest amount of air pollution and the month(s) across cities?  
  - Does there appear to be a trend in the lowest amount of air pollution and the month(s) across cities?  
4.6 Teacher projects Slide #19 and allows students time to do Turn and Talk for the question, then calls on a couple of students to share their thinking with the class.  
4.6 Students do Turn and Talk for question on Slide #19. | 4.1 Groups use Excel spreadsheet of Washington air pollution for their city to make a graph.  
4.2 Students analyze and interpret the data represented in their graph by answering the graph analysis questions on the handout.  
4.3 Student-groups will create their own version of the Google Sheet in order to make changes during the analysis.  
4.4 Groups share out the months with the highest and lowest air pollution for each year. Teacher tallies these months in the table on Slide #18.  
4.5 Students discuss questions with their group, then a few students share out with the class.  
4.6 Students do Turn and Talk for question on Slide #19. |
Making a Claim and Supporting it with Data

5.1 Read overview Part III on the Student Handout as a class. Groups are given a few minutes to write a claim that answers Investigative Question #1 and support their claim with data from the table on Slide #18. Leave Slide #18 projected so that students can reference it and include quantitative details in their evidence statement from the table.

Depending on students’ skill level with writing claims and evidence, sentence frames written on the whiteboard might be helpful:

- **CLAIM:** There _____[is/is not] a relationship between the time of year and the amount of air pollution in Washington.
- **EVIDENCE:** Our evidence comes from data on the amount of air pollution each month, measured in 9 cities in Washington during 2014, 2015, and 2016. Of the 9 cities, _______ cities had the highest air pollution in August, followed by _______ cities in September and _______ cities in July.

Generating Basic Statistics to Answer a New Investigative Question

6.1 Teacher projects Slide #23 and reads aloud the topic and question.

- **How do basic statistics help us interpret and gain additional meaning from the data?**

6.1 Teacher projects Slide #24, reads aloud Investigative Question #2 and gives students a minute to discuss the Turn and Talk questions.

- **How does location affect the amount of air pollution in Washington?**

6.2 Students Turn and Talk to discuss the questions.

6.3 Teacher explains that in addition to graphing data, another way that scientists organize and interpret data in order to find meaning is through statistical analysis. Next, groups will find some basic statistics for their city’s air pollution and then compare those statistics with another group in order to answer Investigative Question #2: How does location (city) affect the amount of air pollution?

Continue with the slidedeck presentation on basic statistics using Slides #25-29. Introduce the concepts of statistics, mean, median, minimum, and maximum.
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| Generating Basic Statistics to Answer a New Investigative Question, cont. | **6.4** Read overview for Part IV on the Student Handout as a class. Groups complete Student Handout Part IV. First they generate basic statistics for their city. Once most groups are finished calculating statistics for their city, teacher shares Slide #30. Each group then pairs up with another group and compares statistics for their city and the other group's city in order to answer Investigative Question #2 and the additional questions on the handout. Teacher might consider providing sentence frames on the whiteboard for the claim and evidence statements:  
  - **CLAIM:** [city] has a higher mean (or median) level of air pollution than [city].  
  - **EVIDENCE:** Our evidence is that the mean (or median) air pollution for all three years (or each separate year) was [value]. The mean (or median) air pollution for [city] was [value]. | **6.4** Groups calculate mean, median, min, and max. After the statistics have been generated and compared with another group, the two groups collaborate to write a claim that answers Investigative Question #2 and support it with statistics.  
  
**6.5** Teacher leads a discussion about which statistics the groups thought were most relevant to support their claim. Groups should have cited the median and/or mean and, possibly, the maximum. Students should come away from the discussion with the understanding that the median is less sensitive to outliers, so if one of the city's data set had some extreme air pollution measures, the group could have used the median. If both cities had a fairly standard set of measurements, the mean is fine to use. | **6.5** Students actively participate in discussion.  
  
**6.6** After groups are finished writing their claims to answer Investigative Question #2, teacher will ask the entire class to compare and contrast results. For each question, the teacher will challenge students to answer why they think those are the findings. Teacher will ask students what the general trends and patterns are for each metric.  
  - Which city had the highest maximum? Which city had the lowest minimum?  
  - What city had the highest mean? What city had the lowest mean?  
  - What city had the highest median? What city had the lowest median? | **6.6** Students actively participate in discussion, basing their comments on the data. |
| Observing and Asking Questions about the State of Global Air Pollution | **7.1** Read overview for Part V on the Student Handout as a class. Have individual students or groups use computers to explore the State of Global Air map (http://www.stateofglobalair.org/air#PM) and then write their observations and possible investigable questions that they are curious about.  
  
**7.2** If any students or groups finish early, they can explore how air pollution levels have changed in different countries over the last couple of decades by following the link to State of Global Air plot view: [http://www.stateofglobalair.org/data/#/air/plot](http://www.stateofglobalair.org/data/#/air/plot)  
  - Go to the “Choose a country” tab  
    - a. In the drop down menu, pick one of the countries you identified from the map view.  
    - b. Click on that country name.  
  - The plot should generate a yellow line representing PM2.5 levels between 1990 and 2015.  
  - To compare the three country PM2.5 in a time series, you can add a country by selecting them in the “+Add countries” drop down menu. | **7.1** Students explore the State of Global Air map, then write observations and investigable questions they are curious about.  
  
**8.2** Students will go to the State of Global Air webpage and explore the map view.  
  
**8.1** Students share with the class interesting observations and investigable questions from their exploration on the State of Global Air webpage. An Exit Ticket could be assigned at this point asking students to summarize what they learned from exploring the State of Global Air webpage.  
  
**8.2** Teacher asks students what we can do with this data and results to improve air quality/pollution in Washington. Teacher asks students to generate ideas in their groups. Students report out and teacher writes ideas on the board. | **8.1** Students share interesting observations and investigable questions they came up with while exploring the State of Global Air website.  
  
**8.2** Students will ask each other questions and discuss their ideas. |
ADAPTATIONS FOR REMOTE INSTRUCTION

This lesson plan has been updated to include adaptations for remote instruction settings. As written, the lesson is intended for in-person, live, classroom-based instruction. Suggestions are summarized in the table below for hybrid and fully remote teaching and learning settings. **Hybrid instruction** assumes several days each week of live, in-person, classroom-based instruction paired with several days of asynchronous, home-based, remote learning. **Asynchronous remote instruction** assumes no in-person, class-based instruction with all learning taking place in students’ own homes. Suggestions focus on asynchronous learning. Teachers who can provide synchronous, live video conference meetings with students may sample from the original lesson plan or the hybrid setting suggestions. The adaptations described below should be considered in addition to the directions in the Instructional Procedure section of the lesson plan.

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<tbody>
<tr>
<td>Teacher Prep for Lesson</td>
<td>• Decide what students will do during in-class days and what they will do from home during remote days.</td>
<td>• Consider recording a video of you presenting the slides (i.e., by using Peardeck for Google Slides or ScreenCast O Matic) for students to view from home.</td>
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<td>• Make digital copies of handout and spreadsheet available to students via your learning management system.</td>
<td>• Make digital copies of handout available to students via your learning management system.</td>
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<tr>
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<td>• Focus in-person time in the classroom on group work, group discussion, and interaction between students.</td>
<td>• Consider using digital bulletin boards (i.e., Padlet, Google Jamboard app, or FlipGrid) as a way for students to communicate, share, and increase interaction, as suggested throughout the procedure below.</td>
</tr>
<tr>
<td>Warm-up Questions and Investigative Question #1 (1.1 – 1.2)</td>
<td>• If you will present the slide deck in class, follow the instructions as written in the Procedure.</td>
<td>• Optional: As an optional way to open the lesson which leverages that students are engaged in learning from home, students could be asked to engage in a self-documentation activity around sources of ambient air pollution in their own community and lives. Students could take photos using a cell phone and/or add text to a collaborative digital space using technology such as Padlet, Google Jamboard app, FlipGrid or Google Slides. This resource provides an overview of how to engage in this kind of culturally-responsive launch to the lesson.</td>
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<td>• If students will review the slide deck on their own during a remote instruction day, follow the instructions in the column to the right. Discussion questions could be reviewed together during the next in-class session.</td>
<td>• (Slides #1-16) Have students review the slide deck and speaker’s notes or view a video of you presenting the slide deck (preferable). See Procedure section as written for more information about the mini-presentations in the slide deck.</td>
</tr>
<tr>
<td>Introduction: Presentation on Air Pollution (2.1)</td>
<td>• If you will present the slide deck in class, follow the instructions as written in the Procedure.</td>
<td>• At the beginning of each mini-presentation, engage students in sensemaking. Students could be asked to respond in writing to the following questions to submit to the teacher. Another option to promote student interaction is to use a digital bulletin board for students to post responses to the prompts and comment on each other’s responses.</td>
</tr>
<tr>
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<td>• If students will review the slide deck on their own during a remote instruction day, follow the instructions in the column to the right. You might consider using a digital bulletin board for capturing students’ responses to the questions posed at the beginning of each mini-presentation.</td>
<td>(continued)</td>
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<td>• Discussion questions could be reviewed together during the next in-class session.</td>
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</table>
| **Introduction:** Presentation on Air Pollution, cont. (2.1) | | • Student questions/prompts:  
  - Intro to Air Pollution (Slides #2-3): What is air pollution? What causes it? Why is it a problem? Where have you seen it or heard about it? Does Seattle (or your own community) have a problem with air pollution? How do you know?  
  - Air Pollution and Human Health (Slide #7): How does air pollution affect human health?  
  - Data Science and Air Pollution in Washington State (Slide #10): What is data science and why is it important?  
  - How Air Pollution is Measured (Slide #13): How is air pollution measured?  
  - Investigative Question #1 (Slide #16): Is there a relationship between the time of year (or season) and the amount of air pollution in Washington? |

| Investigable Questions and Identifying Variables (3.1 – 3.2) | • If students will be able to work in groups on data analysis during an in-classroom day, follow the instructions as written in the Procedure. Divide students into groups of 2 or 3.  
• If students will need to work on data analysis from home during a remote instruction day, follow the instructions in the column to the right. | • Decide if students will be able to work remotely in pairs, or if they will need to work individually on the data analysis project. If working in pairs, consider what technologies are available to your school/district that would allow students to virtually meet-up to complete the assignment together. If this isn’t possible, then adapt the lesson for independent work.  
• **Option A: Working Remotely in Pairs**  
  Follow the directions in the Notes to Teacher for Preparing to Teach This Lesson section of this lesson plan. Assign groups to one of the nine cities.  
• **Option B: Working Remotely as Individuals**  
  Follow the directions in the Notes to Teacher for Preparing to Teach This Lesson section, except do not break students into groups. Instead, assign each individual student to a city and data set. There are 9 cities with datasets. As needed, you may assign multiple students to a dataset.  
• Students will need access to a digital version of Student Handout: Data Science in Global Health. Assign Part I of the handout. |

| Graphing Data to See Patterns (4.1 – 4.7) | • If students will be able to work in groups on data analysis during an in-classroom day, follow the instructions as written in the Procedure. This is encouraged if possible because it allows for collaborative group work and also makes the instructor available for just-in-time troubleshooting assistance.  
• If students will need to work on data analysis from home during a remote instruction day, follow the instructions in the column to the right. | • Students will need access to a digital version of the data from their assigned city from the Excel spreadsheet: "Air Pollution by City_Remote (MS).xlsx"  
• As written in the Procedure, depending on students’ prior experience interpreting and creating graphs, they may need some support. Consider providing an example graph, or a video about how to create line graphs.  
• Assign Part II of the Student Handout. Students should work in their pairs or independently to create a line graph of their city’s air quality data across all years and to answer the data analysis questions.  
• (Slides #17-22) Have students review the slide deck and speaker’s notes or view a video of you presenting the slide deck (preferable).  
• For Slide #18, students will need to share out the months with the highest air pollution and the months with the lowest air pollution for each year for their city (they will have already identified this information in Part II of the Student Handout). If using Google Slides, they can add this information directly into Slide #18. (continued) |
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<tr>
<td><strong>Graphing Data to See Patterns, cont.</strong> (4.1 – 4.7)</td>
<td>• If not, you may create a different digital document in which students can add this information. Alternatively, have them email this information to you so you can create a slide that tallies this information and post it to your digital classroom. Students will need access to this information in order to complete Part III of the Student Handout.</td>
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</tbody>
</table>
| **Making a Claim and Supporting it with Data** (5.1) | • If students will be able to work in groups on data analysis (encouraged) during an in-classroom day, follow the instructions as written in the Procedure.  
• If students will need to work on data analysis from home during a remote instruction day, follow the instructions in the column to the right. | • Assign Part III of the Student Handout. Students will need access to the class data from Slide #18 in order to write their claims and evidence.  
• Determine how students will submit their Claims-Evidence statements. Consider creating a digital assignment with the sentence frames provided in the lesson’s Instructional Procedure. |
| **Generating Basic Statistics to Answer a New Investigative Question** (6.1-6.6) | • If students will be able to work in groups on data analysis (encouraged) during an in-classroom day, follow the instructions as written in the Procedure.  
• If students will need to work on data analysis from home during a remote instruction day, follow the instructions in the column to the right. | • (Slides #23-30) Have students review the slide deck and speaker’s notes or view a video of you presenting the slide deck (preferable).  
• Individual students, from home, will use the dataset for their assigned city to find the mean, median, min, and max in the data for their city. Instructions on the data analysis task are provided in Part IV of the Student Handout. Students may choose to use a calculator or spreadsheet software to help calculate their statistics, or calculate them by hand. Teacher may want to provide an example of how to calculate each statistic with a mock data set. Students will document the findings for each metric on Column 1 of the table in Part IV of the handout.  
• If working in pairs, consider what technologies are available to your school/district that would allow students to virtually meet-up to complete the assignment together and discuss their results.  
• Also consider how students will get help if they encounter problems while engaged in data analysis from home. Consider if drop-in office hours via videoconference are a possibility on the day(s) students are likely to work on Part IV of the Student Handout.  
• In order to complete Part IV, students will also need to share the basic statistics that they calculated for their assigned city. Create a Google Slide version of the slide deck “Data Driven_Part IV_Slides_Remote (MS).pptx” and post it in your learning management system for students to share their statistics with one another. Students should find the slide with their assigned city name on it, and then add their statistics to the table on that slide. Remind students to add their name to the column in which they record their data. That allows an opportunity for the teacher to review the data by city, and determine if there are any inconsistencies due to mathematical error.  
• Students can then choose a comparison city (or you can assign one) and use the data contributed by classmates to complete Column 2 of the table in Part IV of their handout. |
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| Observing and Asking Questions about the State of Global Air Pollution (7.1 – 7.2) | • Part V of the handout should work well for students to complete at home on a remote learning day. If so, follow the instructions in the column to the right.  
• If students will be able to work on Part V during an in-classroom day, follow the instructions as written in the Procedure. | • Assign Part V of the [Student Handout](#).  
• Students will independently explore the State of Global Air online map and record their observations and investigable questions they are curious about. |
| Discussion & Wrap-up (8.1 – 8.2) | • If the discussion will be happening during a live, in-class day, engage the students in a whole class discussion to wrap-up what they have learned about air pollution and human health, both locally, across our region, and globally. Ask students what we can do with this data and results to improve air quality/pollution in the state. Student groups can report out and teacher can write ideas on the board. In addition, ask students to submit their completed Student Handout for grading/credit.  
• If the wrap-up will occur during a remote instruction day, follow the instructions in the column to the right. | • One option for remotely sharing students’ findings from the State of Global Air map is to create a digital document in which they can share their observations (i.e., via [Padlet](#), [Google Jamboard app](#), [FlipGrid](#), etc.). Students can be encouraged to review each other’s posts.  
• A digital Exit Ticket could be assigned at this point asking students to:  
  - Summarize what they have learned about air pollution and human health locally, across our region, and globally.  
  - Summarize what they learned from exploring the State of Global Air website and reviewing other students’ posts. Did they see any patterns or trends?  
• In addition, ask students to submit their completed Student Handout for grading/credit through your classroom learning management system. |
Suggested Lesson Extensions

SELF-DOCUMENTATION
For the Introduction, students could be asked to engage in a self-documentation activity around sources of ambient air pollution in their own community and lives. This resource provides an overview of how to engage in this kind of culturally-responsive launch to the lesson.

STEM Teaching Tools Practice Brief #31: How to Launch STEM Investigations that Build on Student and Community Interests and Expertise.

EXPLORING HEALTH IMPACTS
This lesson could be extended to focus additional time on understanding the health impacts of air pollution on different body systems (pulmonary, cardiac, vascular, and neurological) as well as connections between air pollution, cancer, and other diseases.

MAPPING THE DATA
Students could use the latitude and longitude information provide for each city/region in the dataset to plot the locations using Google Maps.

GLOBAL AIR POLLUTION OVER TIME
Students can also explore how air pollution levels have changed in different countries over the last couple of decades by following the link to State of Global Air plot view: http://www.stateofglobalair.org/data/#/air/plot
1. Go to the “Choose a country” tab
   a. In the drop down menu, pick one of the countries you identified from the map view.
   b. Click on that country name.
2. The plot should generate a yellow line representing PM2.5 levels between 1990 and 2015.
3. To compare the three country PM2.5 in a time series, you can add a country by selecting them in the “+Add countries” drop down menu.

Notes on Adaptations and Inclusivity

INCLUSIVITY FOR ALL LEARNERS
Consider how the lesson activities may need to be adapted to be accessible for all learners. For example, what accommodations may a student with a visual or mobility impairment need to engage in the computational work? How might you elicit, build connections with, and leverage students’ everyday expertise with data practices? How might you group students with diverse expertise and learning needs into teams so that they can support each other?

SCIENTIFIC & COMPUTATIONAL VOCABULARY
Students may need some support in understanding the terminology embedded in this lesson. This may be particularly true for emerging bilingual students and students with lower reading levels. The following list captures some of the scientific, mathematical, and computational terms used in the lesson materials.

- **Mean**: The mean or average that is used to derive the central tendency of the data in question. It is determined by adding all the data points in a population and then dividing the total by the number of points.
- **Median**: A simple measure of central tendency. To find the median, we arrange the observations in order from smallest to largest value. If there is an odd number of observations, the median is the middle value. If there is an even number of observations, the median is the average of the two middle values.
- **Minimum**: The smallest observation (number) in a sample of data.
- **Maximum**: The largest observation (number) in a sample of data.
- **Data assessment**: The process of scientifically and statistically evaluating data in order to determine whether they meet the quality required for projects or business processes and are of the right type and quantity to be able to actually support their intended use.
- **PM2.5**: Refers to atmospheric particulate matter (PM) that have a diameter of less than 2.5 micrometers, which is about 3% the diameter of a human hair.
Teacher Resources

BACKGROUND INFORMATION ON AIR POLLUTION IN GLOBAL HEALTH

Our World in Data: Air Pollution
Hannah Ritchie and Max Roser, October 2017

State of Global Air Report Card
IHME, 2020

Health Impacts of Air Pollution
European Environment Agency, April 2016

Air Pollution, Climate, and Health
Breathe Life; Climate & Clean Air Coalition; WHO, 2016

The Weight of Numbers: Air Pollution and PM2.5
UnDark Magazine & the Pulitzer Center on Crisis Reporting, 2018

CAREER CONNECTIONS

The following careers are related to data sciences and global health:

Biostatistician
https://www.careersinpublichealth.net/careers/biostatisticians/

Data Analyst

Read more about each job by exploring the STEM Global - Pathways to Global Health Careers poster and accompanying fact sheets (see the Information Technology section).

Authorship Credit: This activity was originally developed as a high school-level lesson by the Institute for Health Metrics and Evaluation (IHME), a global health organization located in Seattle, WA and adapted for a STEM Global Teacher Workshop in April 2019. Original authors include: Austin Carter, Doctoral Candidate and Researcher, IHME; Joseph Frostad, Doctoral Candidate and Researcher, IHME; Sean Lassiter, Senior Education Program Manager, IHME. Revisions in July 2020 by Sarah Wozniak and Justin Lo of IHME. This middle school-level adaptation was authored by Janneke Petersen for Laughing Crow Curriculum. Editing and remote learning adaptations by Dr. Kristen Bergsman of Laughing Crow Curriculum.
PART I: INVESTIGABLE QUESTIONS AND IDENTIFYING VARIABLES

Overview: For this lesson, the class will be divided into groups. Each group will be assigned a city in Washington and given some data on air pollution for their city. By graphing the data, you will find out if there is a relationship between the time of year, or season, and the amount of air pollution for your city. Once all groups have determined this for their city, we will see if any trends or patterns can be observed across cities in Washington by compiling our data. You will then write a claim and support it with data to answer the investigative question.

Investigative Question:
Is there a relationship between the time of year/season and the amount of air pollution in Washington?

1. With your group, discuss the following questions before writing your answers.

   a) What is the changed variable in this investigative question? (also known as the independent variable or manipulated variable). In other words, the variable that is affecting the other variable.

   Changed Variable:

   b) What is the measured variable? (also known as the dependent or responding variable). In other words, the variable that is being affected by the changed variable.

   Measured Variable:

   c) What are some things that you think the scientists who measured the air pollution in your city had to control, or keep constant, in order to get data that is a fair test of the time of year’s effect on the amount of air pollution?

   Constants:

2. What is your hypothesis, or prediction? Do you think that the time of year/season affects the amount of air pollution in Washington? Explain your thinking.

   Hypothesis:
PART II: GRAPHING DATA TO SEE PATTERNS

Overview: For this lesson, the class will be divided into groups. Each group will be assigned a city in Washington and given some data on air pollution for their city. By graphing the data, you will find out if there is a relationship between the time of year, or season, and the amount of air pollution for your city. Once all groups have determined this for their city, we will see if any trends or patterns can be observed across cities in Washington by compiling our data. You will then write a claim and support it with data to answer the investigative question.

PLAN IT OUT!

1. The x-axis variable (changed variable):
2. The y-axis variable (measured variable):
3. How I will represent the different years:
4. Graph title:

GRAPHING TIPS:
Things to remember when making your graph

- The changed variable typically goes on the x-axis
- The measured variable typically goes on the y-axis
- Label your x-axis and y-axis
- Use different colors to represent different years
- Include a title for your graph
- Include a legend (or a key) for your graph
- If you have missing data in your data set (labeled N/A) just leave that month blank.
GRAPH ANALYSIS
Discuss each question with your group before writing your response.

1. Which month had the **highest** measured air pollution? (for the years available)
<table>
<thead>
<tr>
<th>Month</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM2.5 value:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In month:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. a) Based on the data from just your city, how confident are you claiming that there is a certain month, or season, in which the air pollution tends to be the **highest** in Washington? Explain why you are confident or not confident.

   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

   b) What would make you more confident that there is a pattern in the time of year and the highest amount of pollution in Washington? (HINT: what kind of additional data might make you more confident?)

   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

3. Which month had the **lowest** measured air pollution? (for the years available)
<table>
<thead>
<tr>
<th>Month</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM2.5 value:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In month:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Based on the data from just your city, how confident are you claiming that there is a certain month, or season, in which the air pollution tends to be the **lowest**? Explain why you are confident or not confident.

   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

PART III: MAKING A CLAIM AND SUPPORTING IT WITH DATA

Overview: You are ready to write a claim that answers the investigative question. A claim is a one sentence answer to the investigative question that you believe to be true based on evidence. Scientists always support their claims with evidence. Support your claim using the table your teacher made (which should be projected) of the compiled class data on the months with the highest and lowest air pollution in cities across Washington.

Investigative Question: Is there a relationship between the time of year/season and the amount of air pollution in Washington?

CLAIM (a claim is a one sentence answer to the investigative question that you believe to be true based on any patterns observed in your data):

EVIDENCE (the evidence should support your claim and should include a discussion of any patterns you observe in your data. Include quantitative details):

Go back and read your hypothesis on page 1. Does the data support or refute your hypothesis? (It doesn’t matter if your hypothesis was correct or not. Scientists base their claims on evidence):
PART IV: GENERATING BASIC STATISTICS TO ANSWER A NEW INVESTIGATIVE QUESTION

Overview: In addition to graphing data, another way that scientists organize and interpret data in order to find meaning is through statistical analysis. You will find some basic statistics for your city’s air pollution and then compare those statistics with another group in order to answer investigative question #2:

Investigative Question #2: How does location (city) affect the amount of air pollution?

In this question, what is the changed variable?  
What is the measured variable?

In order to compare air pollution levels in different cities, you will need to first calculate a few statistics: the minimum, maximum, median and mean for your city. Write your city’s statistics in column 1. Once you’ve calculated your city’s statistics, share your results with a different group and copy their statistics into column 2.

Fill out the table and answer the questions:

<table>
<thead>
<tr>
<th>CITY 1 NAME:</th>
<th>CITY 2 NAME:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>Minimum</td>
</tr>
<tr>
<td>Maximum</td>
<td>Maximum</td>
</tr>
<tr>
<td>Median</td>
<td>Median</td>
</tr>
<tr>
<td>Mean</td>
<td>Mean</td>
</tr>
</tbody>
</table>

1. What interesting differences between cities can you identify?

2. What might be some possible explanations for these differences?

3. Write a claim that answers investigative question #2 and support it with statistics from both of your cities. Discuss with your group which statistics you think might be most relevant to include in your evidence statement.

CLAIM:  
EVIDENCE:  

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V: OBSERVING AND ASKING QUESTIONS ABOUT THE STATE OF GLOBAL AIR POLLUTION

Overview: Air pollution is not just an issue in Washington; it’s a global issue. In this last part, you will explore a map that shows data on global air pollution, make some observations, and write some investigable questions that you’d like to further investigate.

1. Follow this link to State of Global Air map view: http://www.stateofglobalair.org/air#PM
   ▶ Read the information on the webpage
   ▶ Explore the map: move cursor over countries to view levels of PM2.5

2. Study the map and write down two interesting observations you have of global air pollution:

   Observation #1: ________________________________________________
   Observation #2: ________________________________________________
   Observation #3: ________________________________________________
   Observation #4: ________________________________________________

3. What are you curious about? What would you like to find out more about? Write down two investigable questions. Remember, investigable questions have a changed and a measured variable. Scientists’ questions usually come out of observations they find interesting. Your questions might come out of the observations you wrote down above.

   Investigable Question #1: __________________________________________
   Investigable Question #2: __________________________________________
   Investigable Question #3: __________________________________________
   Investigable Question #4: __________________________________________
Physical Sciences/Engineering Design

Drone Drop Challenge
2 50-minute class periods | Grades 6-12

Special Delivery: Design a Vaccine Delivery Solution
1 or more 50-minute class periods | Grades 6-12
Drone Drop Challenge

**PATH**

**Brief Overview:** An authentic global health challenge is the delivery of critical medical supplies (e.g., vaccines, blood products, etc.) to remote communities accessible only by foot, bicycle, or motorbike. In this engineering design challenge—a variation on the classic egg drop challenge—students work in teams to design, prototype, and test a vaccine container that will be delivered via drone technology. Students first explore commercially available delivery technologies and develop a list of requirements for the delivery technology. They then take on the role of a global health non-profit that has received a grant to develop delivery solutions based on drone technology. Students then work in teams to design, build, and test a vaccine container to integrate with the existing drone technology, while considering project criteria and constraints. Before testing their prototype (egg drop), teams present a one-minute pitch for their design solution. This activity represents a partial design cycle, but could be extended to include re-design, re-test, and optimize phases.

**Time:**
- 90-120 minutes or 2 50-minute class periods

**Subject & Grade Level(s):**
- Engineering Design and Physical Science, Grades 6-12. This engineering design challenge can be incorporated into science classes at the middle or high school level. Lesson plan is written at the high school level, with suggestions for adaptations to middle school level.
Student Understandings

DESIGN CHALLENGE SCENARIO
PATH, a global health organization, is working to streamline the “last mile” of cold chain supply systems. The vaccine cold chain is the equipment and systems that maintain vaccines at a safe temperature (usually 2°C to 8°C) from the moment the vaccines are made to the moment they are administered. Vaccine outreach visits to remote villages often require transportation by bike or by foot. After exploring the commercially available delivery technologies and developing a list of requirements for the delivery technology, you have received a grant to develop delivery solutions based on drone technology. Your partner DropShip Inc. manufactures drones for commercial shipping applications. Parcels are picked up by the drone and dropped off at the customer’s doorstep. To adapt this technology, you must design, build, and test a vaccine container to integrate with DropShip’s drones.

DESIGN PROBLEM
A global health organization needs to design a vaccine container that can be used by existing drone technology to quickly and safely deliver vaccines to health care workers located in remote villages. The container needs to be: carried by a drone without decreasing its range below an acceptable level; able to carry a certain number of vaccine vials in a way that is quickly loadable; able to withstand drop/impact without damaging the container, vials, or other objects or people; and reusable for 1,000 delivery cycles.

DRIVING QUESTIONS
► How can a container be designed for the safe delivery of vaccine vials by drone technology that meets the design criteria and constraints?
► How does an understanding of motion and forces help inform our design and testing of the vaccine container?
Next Generation Science Standards

This lesson builds toward the following bundles of middle and high school level Performance Expectations (PEs) from the NRC Framework and Next Generation Science Standards.

The lesson materials are written to support the high school level PEs; therefore adaptations should be made to the lesson to make it appropriate for middle school students (e.g., adapting scientific/engineering vocabulary, complexity of provided materials, inclusion of re-design and optimize phase, etc.).

HIGH SCHOOL BUNDLE OF PERFORMANCE EXPECTATIONS

HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-PS2-3: Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

<table>
<thead>
<tr>
<th></th>
<th>Science and Engineering Practices (SEPs)</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts (CCCs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking Questions and Defining Problems</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
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<td></td>
<td></td>
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<tr>
<td>ETS1.A: Defining and Delimiting Engineering Problems</td>
<td>•</td>
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<td></td>
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<tr>
<td>ETS1.C: Optimizing the Design Solution</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>PS2.A: Forces and Motion</td>
<td>•</td>
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</tr>
<tr>
<td>Influence of Science, Engineering, and Technology on Society and the Natural World</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cause and Effect</td>
<td>•</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### MIDDLE SCHOOL
### BUNDLE OF PERFORMANCE EXPECTATIONS

**MS-ETS1-1**: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

**MS-ETS1-2**: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

**MS-ETS1-4**: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. (With lesson extensions focused on re-design and optimization).

**MS-PS3-5**: Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

<table>
<thead>
<tr>
<th>Science and Engineering Practices (SEPs)</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts (CCCs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking Questions and Defining Problems</td>
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<tr>
<td>Engaging in Argument from Evidence</td>
<td></td>
<td></td>
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<tr>
<td>Developing and Using Models</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connections to Nature of Science:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific Knowledge is Based on Empirical Evidence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ETS1.A: Defining and Delimiting Engineering Problems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ETS1.B: Developing Possible Solutions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ETS1.C: Optimizing the Design Solution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PS3.B: Conservation of Energy and Energy Transfer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Influence of Science, Engineering, and Technology on Society and the Natural World</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy and Matter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Teacher Preparation

MATERIALS:

<table>
<thead>
<tr>
<th>Material</th>
<th>Description/Source</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material Kits</strong></td>
<td>Assemble prototyping materials for kits, including:</td>
<td>1 kit per student team</td>
</tr>
<tr>
<td>- Structural materials</td>
<td>(e.g., PVC pipe &amp; elbow joints, pipe cleaners, popsicle sticks, toothpicks, wire, binder clips, Legos, K’Nex, plastic sheet, cardboard, tape)</td>
<td></td>
</tr>
<tr>
<td>- Soft materials</td>
<td>(e.g., foam, sponge, bubble wrap, newspaper, fabric, plastic produce/grocery bags, balloons)</td>
<td></td>
</tr>
<tr>
<td>- Miscellany</td>
<td>(e.g., rubber bands, springs, string)</td>
<td></td>
</tr>
<tr>
<td><strong>Materials for Exchange (optional)</strong></td>
<td>Assemble leftover extra materials from kits or small volumes of desirable materials not included in kits for Materials Exchange</td>
<td>Optional</td>
</tr>
<tr>
<td><strong>Payload</strong></td>
<td>You may choose to use a raw egg, hard-boiled egg, an acceleration sensor, or other items to represent the payload during the testing phase</td>
<td>1 per student team (disposable) or 1 total (reusable)</td>
</tr>
<tr>
<td><strong>Universal Connector</strong></td>
<td>Choose one material that will function as a universal connector that all teams will need to integrate into their design; their container includes the universal connector which the drone would then use as a handle for picking up/dropping the container. For example, a large binder clip or a hook.</td>
<td>1 per student team</td>
</tr>
<tr>
<td><strong>Testing Tools</strong></td>
<td>Tools for teams to test their products against the specification such as a cardboard box of the correct dimensions, a scale for testing weight, and plastic eggs to fit in their compartments to test size (if performing an egg drop)</td>
<td>1 of each tool</td>
</tr>
<tr>
<td><strong>Ladder or balcony</strong></td>
<td>Ladder, balcony, or other high platform to use for testing the containers (egg drop style)</td>
<td>1</td>
</tr>
<tr>
<td><strong>Landing pad (optional)</strong></td>
<td>A piece of dense foam may be used as a landing pad for the containers during testing</td>
<td>1</td>
</tr>
<tr>
<td><strong>Student Handouts</strong></td>
<td>• Student Handout 1: Team Instructions • Student Handout 2: Design Specifications • Student Handout 3: Prototype Drawing • Student Handout 4: Scoring Sheet</td>
<td>1 set of handouts per student team</td>
</tr>
<tr>
<td><strong>Teacher Resource</strong></td>
<td>Scoring Rubric (spreadsheet to use for assessment purposes)</td>
<td>1</td>
</tr>
<tr>
<td><strong>Computer</strong></td>
<td>Computer with internet access, speakers, and projector. For showing students a video about drone technology for delivery of medical supplies to remote communities</td>
<td>1</td>
</tr>
<tr>
<td><strong>Reward (optional)</strong></td>
<td>Small prize or award certificate for winning team</td>
<td>1</td>
</tr>
</tbody>
</table>
NOTES TO TEACHER FOR PREPARING TO TEACH THIS LESSON:

1. This engineering design challenge could be integrated into a forces and motion unit. This provides an opportunity for making connections to potential energy, kinetic energy, conservation of energy, energy transfer, and force.

2. Determine if you will model this engineering design challenge after the classic egg drop experiment or use a different protocol. See the Resources section.

3. Assemble the Materials Kits, one per team. Ensure that each kit includes the same type and amount of materials. Include structural materials, soft materials, and miscellany.

4. Assemble desired tools for teams to test their products against the specification, such as a cardboard box of the correct dimensions, a scale, and plastic eggs to fit in their compartments (if performing an egg drop).

5. Prepare and print student handouts, one set for each student team.
   - Student Handout 1: Team Instructions
   - Student Handout 2: Design Specifications
   - Student Handout 3: Prototype Drawing
   - Student Handout 4: Scoring Sheet

6. Determine how and where you will set up a fair test of each team’s designed container.

7. Decide how you will break students up into design teams.

8. Provide students with any background desired (global health, impact force, etc.). See the Resources section.

PHOTO: Materials kits may include PVC pipe pieces, pipe cleaners, popsicle sticks, toothpicks, wire, binder clips, Legos, K’Nex, plastic sheet, cardboard, tape, foam, sponge, bubble wrap, newspaper, fabric, plastic produce/grocery bags, balloons, rubber bands, springs, string, etc. Photo credit: PATH

STUDENT ASSESSMENT OPPORTUNITIES

- During the design/build phase, teachers may observe the design teams to assess their teamwork and collaboration processes.

- The Scoring Rubric spreadsheet can be used to assess each team’s container design and its performance during testing. However, care should be taken to assess the collaborative design process and not just the final product.

- One or more of the discussion questions may be assigned as an Exit Ticket or homework, providing students an opportunity to reflect on the activity and self-assess their learning processes and contributions to their design team.
**DRONE DROP CHALLENGE — LESSON**

**Instructional Procedure**

**OVERVIEW**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Details</th>
<th>Approx. Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity I: Introduction to the design challenge</td>
<td>Introduce background information and the design challenge, including guidelines and expectations.</td>
<td>10 minutes</td>
</tr>
<tr>
<td>Activity II: Design/Build phase</td>
<td>Teams work collaboratively to design and build a prototype in response to the design challenge.</td>
<td>60 minutes</td>
</tr>
<tr>
<td>Activity III: Test phase</td>
<td>• Teams give a brief presentation and test their designs. • Performance of prototype is scored.</td>
<td>15 minutes</td>
</tr>
<tr>
<td>Activity IV: Discussion</td>
<td>Students reflect on the design process and their proposed solutions.</td>
<td>10 minutes</td>
</tr>
</tbody>
</table>

**ACTIVITY I: INTRODUCTION TO THE DESIGN CHALLENGE (10 MINUTES)**

1. **Open the activity by asking students to think about how important medical supplies, such as vaccines and blood products, are transported to very remote villages.**

   **Ask students:**
   a. What might the challenges be in delivering these materials and accessing remote villages?
   b. What might be some of the methods of delivery used by community health workers?

2. **Show students the “Zipline in Rwanda” video to introduce the design challenge and provide background information about the global health context and drone technology.**

3. **Introduce the design challenge and driving questions (see next page).**
### THE CHALLENGE:

A global health organization is working to streamline the “last mile” of cold chain supply systems. The vaccine cold chain is the equipment and systems that maintain vaccines at a safe temperature (usually 2°C to 8°C) from the moment the vaccines are made to the moment they are administered. Vaccine outreach visits to remote villages often require transportation by bike or by foot, but drone technology could make this process easier and faster.

Your challenge is to design a vaccine container that can be used by existing drone technology to quickly and safely deliver vaccines to health care workers located in remote villages. The container needs to be: carried by a drone without decreasing its range below an acceptable level; able to carry a certain number of vaccine vials in a way that is quickly loadable; able to withstand drop/impact without damaging the container, vials, or other objects or people; and reusable for 1,000 delivery cycles.

### Driving Questions:

a. How can a container be designed for the safe delivery of vaccine vials by drone technology that meets the design criteria and constraints?

b. How does an understanding of motion and forces help inform our design and testing of the vaccine container?

### 4. Discuss the flow of the design process:

a. Teams will design and build a container for dropping from a drone.

b. Students should begin by discussing and drawing a design for their container, and when they have an idea drawn the facilitator will come around and sign off.

c. Once teams have received sign off, they can begin building a prototype of the container.

d. Teams should come up with a “brand” (team name, logo, etc.).

e. After building, all teams will present a 1-minute pitch of their design and brand, then the products will be tested (dropped).

f. Teams will be assessed based on the provided score sheet.

### 5. Distribute materials to each team

*material kits and student handouts*.
ACTIVITY II: DESIGN/BUILD PHASE (45-60 MINUTES)

6. **Design teams can get to work!**
   a. Students should work collaboratively in their groups to design and build a prototype.
   b. Remind students to get sign-off on their design sketch before beginning to build.
   c. If necessary, remind students that their end product does not have to look like their sketch. Iteration is encouraged.

7. **Optional:** Students may trade in some of their kit materials for others available at the Exchange with the permission of the Exchange manager (teacher/facilitator). Students negotiate the trade with the Exchange manager. The Exchange presents an opportunity for teams to personalize their kits and represents the negotiations necessary between partners to achieve common goals.

8. **At 15 minutes,** remind students that they should be getting sign-off and moving on to the build phase.

9. **Optional:** To increase the challenge: At 20 minutes, remove an item from the Material Kits.
   a. For example, “The company we are working with has decided that in an effort to reduce their environmental impact, plastic bags will no longer be allowed on their drop containers.”

10. **Optional:** To increase the challenge: At 25-30 minutes, add an item into the Material Kits that must be incorporated into the final product.
    a. For example, “The company we are working with has decided to standardize the drop container attachment. All containers must use this Universal Connector as a way to attach the container to the drone.”

11. **At 45-60 minutes,** end the Design/Build phase by having students bring their creations to the front of the room (or test area).

ACTIVITY III: TEST PHASE (15 MINUTES)

12. **Bring teams up one at a time** to give their 1-minute pitch/presentation of their design.

13. **Perform a drop** of each team’s container from a ladder (or appropriate platform). Explain how you will be conducting a fair test of each container’s performance.

14. **Assess each container’s drop performance** (e.g., eggshell broken?). Score each team using the Scoring Rubric spreadsheet. Teams can be asked to self-assess the performance of their design using the Student Handout: Scoring Sheet.

15. **Announce the winning team!** **Optional:** Hand out a small reward or award certificate.
ACTIVITY IV: DISCUSSION (10 MINUTES)

16. Employ your classroom discussion strategies to reflect on students’ experience with this design challenge, in design teams and/or as a whole class. This may be done in-class, as an exit ticket, or as homework.

Possible discussion questions include:

a. What went well? What did your team struggle with?

b. Did people take on specific roles and divide up work, or did your team work together on all aspects?

c. Did your end product differ from your initial design?
   • How did your product transform throughout the Design/Build phase?
   • What were some of the major drivers of your iterations?

d. In what ways did you make trade-offs with your design?

e. What was the reasoning behind the design approach that your team took?

f. How did you decide which materials were appropriate to use for your team’s design?
### Suggested Lesson Extensions

#### CRITERIA & CONSTRAINTS
Rather than providing teams with the Design Specification handout, instead work together to develop a list of criteria and constraints for the design challenge.

#### PUGH CHART
In the Design phase, encourage students to initially identify ideas for multiple design solutions. Then, ask each team to use a simple Pugh Chart to help them evaluate the different solutions based on the project’s criteria and constraints. A Pugh Chart is an evaluation tool to aid in selection of a design solution. As the example below shows, list the criteria in the first column and the proposed design solutions in the other columns. Score each solution for each criterion with -1, 1, or +1 points.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Solution #1</th>
<th>Solution #2</th>
<th>Solution #3</th>
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<tbody>
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</table>

#### TOTAL SCORE

#### DESIGN OPTIMIZATION
Extend the activity by adding a re-design, re-test, and optimize phase. This allows students to consider the results of the first drop, and use that performance information to inform a re-design of their prototype. Conduct a second drop test. Then allow time for teams to consider the results of the second drop to optimize their final design solution.

#### BACKGROUND READINGS
Deepen students’ engagement in the activity by having them read news articles about how drone technology is being applied in global health contexts. See the Resources section.

#### MIDDLE SCHOOL
Challenge students to develop a conceptual model that supports the claim that when the kinetic energy of an object changes, energy is transferred to or from the object, using the Drone Drop Challenge as the context for their model. You might consider providing a word bank with terms that should be included in the model.

#### HIGH SCHOOL
Challenge students to develop a conceptual model that explains, using their understanding of forces and motion, how their design minimizes the force on the container during collision with the ground.
Notes on Adaptations and Inclusivity

**ENGINEERING VOCABULARY**
If students are not yet familiar with the language of the engineering design process, they may need some support in understanding the terminology embedded in this lesson. This may be particularly true for middle school students and emerging bilingual students. The following list captures some of the engineering-specific terms used in the lesson materials.

- Constraint
- Criteria
- Design requirements
- Iterate
- Payload
- Prototype
- Prototype/design sketch
- Solution
- Tradeoffs

**COMPLEXITY OF DESIGN CHALLENGE**
The complexity of the design challenge can be increased or decreased, depending on what materials are provided in the Materials Kit and whether or not you decide to add and subtract materials or use the Exchange during the Build phase. You may also choose to adapt the criteria and constraints on the *Design Specification* handout. (If so, be sure to also revise the *Scoring Sheet* and *Scoring Rubric* to be in alignment with those changes).

**INCLUSIVITY FOR ALL LEARNERS**
Consider how the design challenge may need to be adapted to be accessible for all learners. For example, what building materials may work best for a student with a visual or mobility impairment? How might you elicit, build connections with, and leverage students’ everyday expertise with engineering design, tinkering, or drone technology? How might you group students with diverse expertise and learning needs into design teams so that they can support each other?

**VIDEO CAPTIONING**
Subtitles/closed captions can be chosen through YouTube for the Zipline in Rwanda video.

**ARTICLE RESOURCES**
Additional background readings are provided in the *Teacher Resources* section, however most of these have a high school or college reading level. To accommodate readers at different levels, employ your classroom reading strategies such as student grouping and jigsaw structures or create scaffolds or reading guides. In addition, the photographs from these articles could be shared with students to help them understand both the challenges and the innovation of vaccine delivery to remote regions of the world.
Teacher Resources

TEACHER SCORING RUBRIC

EGG DROP EXPERIMENTS

The Egg Drop Experiment is a classic activity in physical science classrooms. The Drone Drop Challenge provides a real world context for the activity by situating it as a global health challenge, as well as focusing on the engineering design process. Adapt your favorite Egg Drop protocol or use this engineering-focused one for inspiration:

**Bombs Away: Egg Drop Experiment**
TeachEngineering, 2 hour egg drop design challenge

BACKGROUND INFORMATION ON VACCINE DELIVERY FOR GLOBAL HEALTH

**Photo Story: How Vaccines Reach the Most Remote Places on Earth**
Unicef photo story, 4/24/17

**Article: Sub-saharan Africa Leads the Way in Medical Drone Delivery**
The Lancelet, Becky McCall, 1/5/19, Reading level: College
Available for free download with registration

**Article: Revolutionary Technology for Vaccine Delivery: Drones in Vanuatu**
Unicef, 6/11/17, Reading level: High School

**Article: Rwanda uses Zipline Drones to Deliver Emergency Blood Supplies**
Rachel Becker, The Verge, 4/13/18, Reading level: Middle to High School

**Article: WakeMed Receives First UPS Drone Delivery of Medicine in U.S.**

**Article: Alaska Tests Drones for Delivery of Medical and Emergency Supplies**
Folake Dosu, BuiltIn, 2/4/19, Reading level: College

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CAREER CONNECTIONS

The following global health careers relate to this activity. Read more about each job from the U.S. Bureau of Labor Statistics or the Pathways to Global Health Careers Fact Sheets.

- Logistics and supply chain manager
  U.S. Bureau of Labor Statistics
- Mechanical engineer
  U.S. Bureau of Labor Statistics
- Aeronautical/aerospace engineer
  U.S. Bureau of Labor Statistics
- Community health advisor
  Human Services, Education, & Training Fact Sheet
- International aid worker
  Human Services, Education, & Training Fact Sheet
- Public health nurse
  Health Sciences Fact Sheet

Read more about each job by exploring the STEM Global - Pathways to Global Health Careers poster and accompanying fact sheets (see the Information Technology section).
Instructions: Read all these instructions before beginning! You have 1 hour for the Design and Build phases. Spend as much time as you would like in the Design phase, but leave yourself enough time to build.

01. DESIGN PHASE

- Your team will be provided with a Design Specification document, Scoring Sheet, paper, and a box of materials.
- Your team must review the Design Specification document and create a prototype sketch (a drawing of your design idea).
- Once your prototype sketch is finished, have a facilitator sign off on the sketch to approve it. Your team may then begin to build your prototype using the materials in your box.
- Note that you can choose not to meet all of the design requirements as it may become necessary to make tradeoffs in your design.
- Your prototype can evolve during construction. The final prototype does not have to match the sketch.
- Come up with a team name and logo and draw it on the supplied paper.

02. BUILD PHASE

- You may construct your prototype with the materials inside and attached to your box. You may not use the box or the lid.
- Limited quantities of additional materials are available from the Exchange. You may request additional materials by negotiating with the supplier.
- A scale is provided at the front of the room. Use it as needed to check weight.
- A box is provided at the front of the room to check that the size of your container does not exceed the size limit.
- Empty payload boxes are available to verify that the payload will fit inside your container.
- Be prepared to give a 1 minute pitch (brief presentation) about your idea to the class. Introduce your team name and logo as part of your pitch.
- You must stop building once the Build phase has ended. Bring your prototype to the table at the front of the room for testing.

03. TEST PHASE

- You will have 1 minute to present your container in a pitch to the class.
- You will then have 30 seconds to load the payload into your container. Exceeding this time will result in points lost.
- Your instructor will perform the drop test and analyze results.
- Final scores will be announced after all drop tests are complete.

Have fun, and remember to work together as a team.
**Overview:** A global health organization is working to streamline the “last mile” of cold chain supply systems. The vaccine cold chain is the equipment and systems that maintain vaccines at a safe temperature (usually 2°C to 8°C) from the moment the vaccines are made to the moment they are administered. Vaccine outreach visits to remote villages often require transportation by bike or by foot, but drone technology could make this process easier and faster. Your challenge is to design a vaccine container that can be used by existing drone technology to quickly and safely deliver vaccines to health care workers located in remote villages. This Design Specification outlines key features and specifications that the container must fulfill.

<table>
<thead>
<tr>
<th>ATTRIBUTE</th>
<th>USER NEED</th>
<th>DESIGN INPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container Size</td>
<td>Container can be carried by drone</td>
<td>Exterior dimensions ≤ 25 cm</td>
</tr>
<tr>
<td></td>
<td>Container must not overly decrease the drone range</td>
<td>Empty container (no payload) weigh less than 800g</td>
</tr>
<tr>
<td>Payload</td>
<td>Must carry enough vaccine vials</td>
<td>Container must accept payload provided to your team</td>
</tr>
<tr>
<td></td>
<td>Must be quickly loadable</td>
<td>Container loading time is under 30 seconds</td>
</tr>
<tr>
<td>Strength</td>
<td>Dropping does not damage container or external objects/people</td>
<td>External forces on impact are minimal</td>
</tr>
<tr>
<td></td>
<td>Vials are not damaged by dropping</td>
<td>Internal compartment forces on impact are minimal</td>
</tr>
<tr>
<td>Reusability</td>
<td>Container is reusable</td>
<td>Design for reuse 1000 cycles (carrier-customer-carrier)</td>
</tr>
<tr>
<td>Identification</td>
<td>Contents of container are easily identifiable by a health care worker</td>
<td>Container has space for removable labels/packing lists</td>
</tr>
<tr>
<td>Storage and Transportation</td>
<td>Containers can be stored with minimal footprint</td>
<td>Containers are stackable</td>
</tr>
<tr>
<td>Instructions for Use</td>
<td>Instructions are easily visible and understandable</td>
<td>Container is printed with graphical instructions for use</td>
</tr>
</tbody>
</table>
Instructions: Draw one or more sketches of your proposed design solution. Add labels. Use extra paper if needed.

What materials will you use?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Teacher’s initials: __________
**Scoring Sheet**

**Directions:** Use this scoring sheet to help you understand how the performance of your design will be scored during the Test Phase. As your teacher performs the drop test, circle each test result to track your prototype’s performance. You can also self-assess your creativity and team name. Add up each points by section, and then the grand total. Your teacher will determine the final scores for each team.

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>Circle One</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container acceptable size and weight?</td>
<td>Yes +10 PTS</td>
</tr>
<tr>
<td></td>
<td>No -10 PTS</td>
</tr>
</tbody>
</table>

| TEST RESULTS                  |
|-------------------------------|------------|
| Performance based on measured drop test data | 1st best +50 PTS |
|                                | 2nd best +40 PTS |
|                                | 3rd best +30 PTS |
|                                | 4th best +15 PTS |
|                                | 5th best +10 PTS |
| Payload remains in container?  | Yes +10 PTS |
|                                | No -5 PTS  |

| CREATIVITY                    |
|-------------------------------|------------|
| Most creative design          | 1st place +15 PTS |
|                                | 2nd place +10 PTS |
|                                | 3rd place +5 PTS |
| Best team name                 | 1st place +5 PTS |
|                                | 2nd place +3 PTS |
|                                | 3rd place +2 PTS |

**GRAND TOTAL =**
Brief Overview: A contemporary global health challenge is the delivery of vaccines to people living in remote villages around the world. Many remote areas struggle to receive necessary vaccines for various reasons, including rough terrain between medical facilities and villages and towns that is impassable to most vehicles. This activity engages students in the engineering design process as they design, build, and test a model of a vehicle capable of traveling rough terrain without damaging the vaccines it is transporting. In this simulated design task, students use K'nex and LEGO building materials to construct a vehicle that can travel along a rough track. This activity could be used to introduce students to the engineering design process. Suggestions are provided for increasing the complexity of the design challenge (e.g., carry more than one container, design a vehicle without wheels, etc.) as well as for incorporating an additional design challenge focused on the cold chain process of vaccine delivery.

pacificsciencecenter.org
**Student Understandings**

**ANCHORING DESIGN PROBLEM**

Many international aid workers struggle to deliver necessary vaccines to remote areas for various reasons, including rough terrain between medical facilities and villages and towns. Your challenge is to design and make a model of a vehicle to transport these vaccines over rough terrain. You will use K’nex and other building materials to construct your model vehicle, which must be capable of safely carrying a container filled with "vaccines" from one end of a track to the other without spilling any contents. To simulate a vehicle driving between two destinations, your model will be pulled at a constant rate by a winch and attached to the winch by way of a small binder clip.

**DRIVING QUESTIONS**

► How can a vehicle be designed so that it can travel rough terrain and safely deliver vaccine vials while meeting specific design criteria and constraints?
► How does an understanding of the engineering design process inform the design work, especially the concepts of tinkering and iteration?

**LEARNING OBJECTIVES**

By the time participants complete this activity, they will be able to:

► Describe the merits and functionality of their design.
► Work with constraints on materials and time.
► Iterate through assorted designs using lessons learned via hands-on tinkering/discovery.

**PERFORMANCE EXPECTATIONS**

**MS-ETS1-4:** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved *(with lesson extensions focused on re-design and optimization)*.

**HS-ETS1-2:** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

**STUDENT ASSESSMENT OPPORTUNITIES**

► During the design/build phase, teachers may observe the design teams to assess their teamwork and collaboration processes.
► One or more of the discussion questions may be assigned as an exit ticket, journal prompt, or homework assignment, providing students an opportunity to reflect on the activity and self-assess their learning processes and contributions to their design team.

**Next Generation Science Standards**

This lesson builds toward the following high school level Performance Expectations (PEs) from the **NRC Framework** and **Next Generation Science Standards**.

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Teacher Preparation

MATERIALS:

Materials needed for building (assumes 20 students):

<table>
<thead>
<tr>
<th>Building Material</th>
<th>Description/Source</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>K’nex building supplies</td>
<td>Provide an assortment of K’nex building materials for each group to be able to construct a vehicle. Be sure to include K’nex wheels and tires if desired. LEGO or other construction materials could be substituted.</td>
<td>Assortment for each group</td>
</tr>
<tr>
<td>Other wheel options</td>
<td>Provide an assortment of alternative wheel options (e.g., masking tape roll, oat canister lid, plastic bottle top).</td>
<td>Assortment</td>
</tr>
<tr>
<td>String</td>
<td></td>
<td>~4’ per group</td>
</tr>
<tr>
<td>Pipe cleaners</td>
<td></td>
<td>~40 total</td>
</tr>
<tr>
<td>Rubber bands</td>
<td></td>
<td>A few handfuls total</td>
</tr>
<tr>
<td>Stir straws</td>
<td></td>
<td>~40 total</td>
</tr>
<tr>
<td>Printer paper or cardstock</td>
<td></td>
<td>~20 sheets total</td>
</tr>
<tr>
<td>Binder clips</td>
<td></td>
<td>~20 total</td>
</tr>
<tr>
<td>Hole punch</td>
<td></td>
<td>~4 total</td>
</tr>
<tr>
<td>Scissors</td>
<td></td>
<td>~12 total</td>
</tr>
</tbody>
</table>

Materials needed for testing/operations:

<table>
<thead>
<tr>
<th>Operations Material</th>
<th>Description/Source</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer and projector</td>
<td>To show Special Delivery Slide Deck.</td>
<td>1</td>
</tr>
<tr>
<td>Student Handout</td>
<td>Student Handout: Design a Vaccine Delivery Solution</td>
<td>1/student</td>
</tr>
<tr>
<td>Printer paper</td>
<td>For sketching designs</td>
<td>~1 sheet/student</td>
</tr>
<tr>
<td>Pencils</td>
<td></td>
<td>1/student</td>
</tr>
<tr>
<td>K’nex winch assemblies</td>
<td>1 K’nex Motor R2a Light/Slow Speed (22 rpm) or similar small motor that is battery-operated and can switch forward/reverse; string; cardstock; K’nex building supplies; AA batteries. See Appendix for assembly information.</td>
<td>At least 2</td>
</tr>
<tr>
<td>Mini binder clips</td>
<td>Used to attach winch/string to vehicle for testing</td>
<td>1/winch</td>
</tr>
<tr>
<td>Spare AA batteries and screwdriver</td>
<td>For K’nex motors</td>
<td>As needed</td>
</tr>
<tr>
<td>LEGO baseplates and bricks</td>
<td>LEGO baseplates and bricks to form terrain (enough to create at least two ‘tracks’ for vehicles). Each track should be at least four baseplates long. See photos in Procedure for examples.</td>
<td>At least 2 tracks</td>
</tr>
</tbody>
</table>

Special Delivery Slide Deck

Download Slide Deck
NOTES TO TEACHER FOR PREPARING TO TEACH THIS LESSON:

1. Decide how you will break students up into 4-6 design teams.
2. Prepare materials
   • Gather materials listed in the “building materials” list and arrange in a central location in the classroom. See photo 1
3. Arrange tables and chairs
   • Arrange 4-5 table pods with enough chairs at each to accommodate students.
4. Adorn tables
   • Set one piece of paper and one pencil at each chair.
   • Set out at least one bin of K’nex with an assortment of K’nex wheels at each table pod.
5. Prepare test station
   • Assemble at least two test tracks.
   • Place at least four LEGO baseplates end-to-end flat on table (per track).
   • Attach LEGO bricks to baseplates to form terrain that becomes progressively “rougher”. See photos 2 & 3
   • Build K’nex winch assembly. See instructions in Appendix.
   • Secure K’nex winch at the “roughest” end of each track. See photos 2 & 3 (see Appendix for more images).
6. Review the Special Delivery Slide Deck and customize, if needed.
7. Provide students with any background desired (global health, vaccine delivery, engineering design process, etc.). See the Resources section.

PHOTO 1: Materials prepared to accommodate approximately eight students at a time.

PHOTOS 2 & 3: Testing station with LEGO terrain and winch assembly at one end of track. Vehicle begins at far end of track and is pulled to near end by winch.
Instructional Procedure

OVERVIEW

<table>
<thead>
<tr>
<th>Activity</th>
<th>Details</th>
<th>Approx. Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity I: Introduce engineering design process</td>
<td><strong>Special Delivery Slide Deck</strong></td>
<td>6 minutes</td>
</tr>
<tr>
<td>Activity II: Introduce design challenge</td>
<td>Use <strong>Student Handout: Design a Vaccine Delivery Solution</strong> to introduce guidelines, expectations, and challenge</td>
<td>3 minutes</td>
</tr>
<tr>
<td>Activity III: Sketching</td>
<td>• Instruct students to sketch invention and write ‘bill of materials’</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Check sketches/plans and direct students to get materials on list</td>
<td>6 minutes</td>
</tr>
<tr>
<td>Activity IV: Build and test prototypes</td>
<td>Set students free to build and test their vehicle designs</td>
<td>25-30 minutes</td>
</tr>
<tr>
<td>Activity V: Showcase inventions</td>
<td>Students share their vehicle designs</td>
<td>5 minutes (Optional)</td>
</tr>
<tr>
<td>Activity VI: Cleanup and discussion</td>
<td>Reflect on the design process</td>
<td>5-10 minutes</td>
</tr>
</tbody>
</table>

ACTIVITY I: INTRODUCTION TO THE ENGINEERING DESIGN PROCESS (6 MIN)

1. Show the Teacher Resource, **Special Delivery Slide Deck** to introduce students to the engineering design process.

2. Discuss the definition of “design process”
   a. Discuss things students used that morning that were designed by an engineer or specific type of designer.
   b. "We like to think of engineers as problem-solvers; what problem does X item address?" (lead by asking students to share what they believe an engineer does).

3. Design process graphic (slide #6)
   a. Note the existence and validity of other representations of the engineering design process; “This is how we choose to represent it in Tinker Tank at Pacific Science Center.”
   b. Discuss each step, referring back to an example provided by students while talking about designed items used earlier in the morning when appropriate (e.g., item is a spoon):
      i. **Identify the problem**: “Somebody or some people decided they wanted a better way to consume liquid foods.”
      ii. **Explore**: “They may have already had knives or something like forks, and likely just drank liquid foods from bowls.”
   c. Allow students to think through process before revealing each step beyond ‘Devise a Plan;’ they will typically reason out that the next step is to create the product/process they designed, then test it, and so on.
ACTIVITY II: INTRODUCE DESIGN CHALLENGE (3 MINUTES)

4. Optional: Students may watch one or more videos from Nature Video or PBS Rx for Survival. See Slide #8 and the Extension section below. (Note that this will extend the estimated lesson time).

5. Introduce the challenge and kick off the design phase. Provide each student with Student Handout: Design a Vaccine Delivery Solution.

6. Discuss guidelines and expectations.
   a. Upon receiving the challenge, students will be tasked with sketching a design and writing a ‘bill of materials.’ They must talk with an instructor or chaperone about their plan to get checked off before collecting any construction materials.
   b. Students may test their vehicle as many times as time allows; early and frequent testing is encouraged.
   c. You may wish to facilitate a whole class discussion in which students define ‘success’ prior to designing the vehicle. How will they know if they had a successful test of their vehicle design?

7. Assign teams (2-4 students per team).

ACTIVITY III: SKETCH TIME (6 MINUTES)

8. Instruct students to sketch their design and write a ‘bill of materials’ on a piece of paper.

9. Check sketches/plans and direct students to gather materials on list.

Prompt students with questions about their design and design process, such as:
   a. Tell me about your design!
   b. Why did you choose X type/amount of wheel/ski/sledge?
   c. How will your vehicle prevent the vials from spilling?

THE CHALLENGE:

Many international aid workers struggle to deliver necessary vaccines to remote areas for various reasons, including rough terrain between distribution facilities and villages and towns. Logistics and supply chain managers can only plan with the tools and technology available to them. This is where people such as mechanical engineers, vehicle operators, and automotive mechanics play a significant role. In this scenario, this is the expertise called upon to deliver critical healthcare.

Your challenge is to design and make a model of a vehicle to transport these vaccines from this end of the track to the other without spilling any contents. The vehicle will be pulled at a constant rate and attached to the winch by way of a small binder clip.
ACTIVITY IV: CREATE AND TEST VEHICLES (25-30 MINUTES)

10. As students get their sketches approved, direct them to begin building and testing their vehicles.

11. Facilitator should demonstrate testing procedure to at least the first couple groups ready to test and check in when possible beyond that.

12. Testing procedure:
   a. Turn on motor in reverse and gently pull binder clip on string to the lower-terrain end of the test track. Turn off motor.
   b. Direct student to load half-full film canister (e.g., load with lentils, ¼” stir straw segments, beans) in their vehicle. Do not put the lid on the canister. You may wish to offer a ‘dry run’ without filling the canister first.
   c. Direct another student to attach a mini-binder clip to their vehicle in the place they believe will allow for the best performance and position their vehicle at the track.
   d. Direct another student to turn on the motor (forward) to pull the vehicle.
   e. Typically, a test is considered successful when the vehicle reaches the winch and the contents of the film canister have remained in the canister. What criteria did the students develop for determining a successful test?

13. Extend the design challenge as appropriate by issuing additional challenges. These may include modifying the vehicle to:
   a. Work without any wheels,
   b. Use X number of pieces/materials,
   c. Transport multiple canisters, or
   d. Traverse rougher terrain.

ACTIVITY V: SHOWCASE INVENTIONS (5 MINUTES, OPTIONAL)

14. Teams volunteer to share their vehicles with the class, highlighting their design’s key features and explaining any obstacles they encountered in the design process and how they iterated to solve those challenges. Students should complete section 3 “Invention Showcase” on the Student Handout: Design a Vaccine Delivery Solution.
ACTIVITY VI: CLEAN-UP AND DISCUSSION (5-10 MINUTES)

15. Employ your classroom discussion strategies to reflect on these discussions, in design teams and/or as a whole class. This may be done in-class, as an exit ticket, or as homework.

Possible discussion questions include:

a. What element of your vehicle design worked particularly well?

b. What were the weaknesses of your design? What would you change about your vehicle if you had more time or different materials?

c. Which criteria and constraints did you find most challenging?

d. Describe a challenge you encountered and how you iterated on your design to navigate the obstacle.

e. What sort of terrain or obstacles might one encounter when delivering vaccines to remote destinations?

f. What are some other ways vaccines could be delivered to remote villages?

g. Think about the people who might be involved in transporting vaccines or other medical supplies to remote destinations. What type of jobs might be involved in this work?
Suggested Lesson Extensions

GLOBAL HEALTH CONTEXT – BACKGROUND READINGS & VIDEOS
Deepen students’ engagement in the activity by having them read news articles or watch videos about how vaccines and medical supplies are delivered to remote destinations. These materials could be used when the design challenge is issued to help contextualize the problem and/or during the discussion to share one approach to solving the problem. See the Teacher Resources section.

DEFINING CRITERIA & CONSTRAINTS
As part of issuing the design challenge, have students identify and consider the criteria and constraints involved in the design problem, including time, materials, costs, scientific issues, users’ needs, safety, cultural considerations, and environmental impacts (builds toward MS-ETS1-1, MS-ETS1-2, HS-ETS1-1 and HS-ETS1-3).

COLD CHAIN DESIGN CHALLENGE
In a longer or multi-period session, students can be challenged to produce a more detailed model of the delivery container for the vaccines that would be on a transport vehicle. Provide a range of insulator options (e.g., foam, felt of various colors, bubble wrap) for students to use in their design. Place an ice cube in the model container and place the container under a stage light, heat lamp, or similar. Assess the success of designs based on the time it takes for the ice to melt. Students should define criteria and constraints if possible. Some may include:

- Minimum melt time,
- Maximum container weight, or
- Minimum container capacity.

Notes on Adaptations and Inclusivity

ENGINEERING VOCABULARY
If students are not yet familiar with the language of the engineering design process, they may need some support in understanding the terminology embedded in this lesson. This may be particularly true for middle school students and emerging bilingual students. The following list captures some of the engineering-specific terms used in the lesson materials.

- Criterion(a)
- Iterate
- Constraint
- Winch
- Design sketch

COMPLEXITY OF DESIGN CHALLENGE
The complexity of the design challenge can be increased or decreased, depending on materials provided and additional design challenges you may choose to issue.

INCLUSIVITY FOR ALL LEARNERS
Consider how the design challenge may need to be adapted to be accessible for all learners. For example, what building materials may work best for a student with a visual or mobility impairment? How might you elicit, build connections with, and leverage students’ everyday expertise with engineering design, tinkering, and building? How might you group students with diverse expertise and learning needs into design teams so that they can support each other?
BACKGROUND INFORMATION ON VACCINE DELIVERY FOR GLOBAL HEALTH

The Bill & Melinda Gates Foundation recognizes the delivery of vaccines as a high priority for increasing health—especially children’s health—around the world. This is the challenge that they recognize:

Vaccines save millions of lives each year and are among the most cost-effective health interventions ever developed. Immunization has led to the eradication of smallpox, a 74 percent reduction in childhood deaths from measles over the past decade, and the near-eradication of polio.

Despite these great strides, there remains an urgent need to reach all children with life-saving vaccines. One in five children worldwide are not fully protected with even the most basic vaccines. As a result, an estimated 1.5 million children die each year—one every 20 seconds—from vaccine-preventable diseases such as diarrhea and pneumonia. Tens of thousands of other children suffer from severe or permanently disabling illnesses.

Vaccines are often expensive for the world’s poorest countries, and supply shortages and a lack of trained health workers are challenges as well. Unreliable transportation systems and storage facilities also make it difficult to preserve high-quality vaccines that require refrigeration.

Source: Vaccine Delivery Strategy Overview

CAREER CONNECTIONS

The following global health careers relate to this activity. Read more about each job from the U.S. Bureau of Labor Statistics or by exploring the STEM Global - Pathways to Global Health Careers poster and accompanying fact sheets.

- Logistics and supply chain manager
  Transportation, Distribution & Logistics Fact Sheet

- Mechanical engineer
  U.S. Bureau of Labor Statistics

- Automotive mechanic
  U.S. Bureau of Labor Statistics

- Community health advisor
  Human Services, Education, & Training Fact Sheet

- International aid worker
  Human Services, Education, & Training Fact Sheet

- Public health nurse
  Health Sciences Fact Sheet
VIDEOS ON VACCINE DELIVERY VIA MOTORCYCLES

Rx for Survival and Riders for Health: The Rx for Survival videos document global health challenges in the field and can be used to develop and ground the design challenge scenario. The episode “Delivering the Goods” (55:26 minutes) shows the difficulty in bringing life-saving technologies and pharmaceuticals to people in geographically challenging rural areas lacking transportation infrastructure. It features the organization Riders for Health that transforms a motorcycle sidecar into an ambulance, which makes for a relevant and inspiring engineering story.

- A clip of the video could be shown starting at 4:15 minutes and ending at 7:25 minutes.
- Option: Continue viewing video through 12:04 minutes to include a feature on an infant/child field nurse.
- Option: Continue viewing video through 14:04 minutes to show the motorcycle ambulance in action.

Nature video: The video, “Vaccine Delivery: The Last Mile” (4:58 minutes) features Riders for Health and their use of motorcycles to transport vaccines to rural areas. This video nicely sets up the barriers to vaccine delivery that present design/logistical challenges.

PBS Rx for Survival website.

Authorship Credit: This activity was originally developed by Pacific Science Center for use in their Tinker Tank program and adapted for a STEM Global Teacher Workshop in April 2019. Pacific Science Center is an independent, not-for-profit institution located in Seattle, WA that ignites curiosity and fuels a passion for discovery, experimentation, and critical thinking. This activity was authored by Brittany Strachota, PSC Tinker Tank Program Lead. Lesson plan adaptations supported by Kristen Bergsman of Laughing Crow Curriculum.
K’NEX WINCH ASSEMBLY:

1. The winch shown here is made from K’nex, cardstock, string, and a small binder clip. You may use any means of pulling a load at a consistent rate that suits your needs and resources.

2. A triangular stand holds a K’nex motor in position. On one end of the axle, a cardstock circle (~5” diameter) is slid to the motor before a length of string (at least 1.5x the length of the test track) is tied in place; a congruent circle sandwiches the string. You may use a dab of hot glue to secure the end of the string and the discs to the axle.

3. Turn on the motor to wind the string around the axle and feed the end through a K’nex guide. Attach a small binder clip – or other material you plan to use to attach vehicles to the winch for testing.

4. This is a good baseline design; you will likely make some tweaks. Once you are confident in your design, you may wish to make more robust discs (e.g., using chipboard).

PHOTO 1: Straight-on view of the winch to be assembled from K’next motor and parts, including a spool built from paper.

PHOTO 2: Side-view of the winch assembly, including the small binder clip that will be attached to each vehicle during testing.
ADDITIONAL EXAMPLE VEHICLE DESIGNS

PHOTO 3: A gallery of different vehicle designs

PHOTO 4: A vehicle navigating its way down the rough LEGO track
Design a Vaccine Delivery Solution

Name: ____________________________ Date: ____________ Period: ______

DESIGN PROCESS

The procedure engineers and designers follow to create something useful

- Identify the problem
- Devise a plan
- Create it
- Test it out
- Explore
- Assess test results

DESIGN PROBLEM

Many international aid workers struggle to deliver necessary vaccines to remote areas for various reasons, including rough terrain between medical facilities and villages and towns.

The design challenge: How can a vehicle be designed so that it can travel rough terrain and safely deliver vaccine vials while meeting specific design criteria and constraints?

You will use K’nex and other building materials to construct your model vehicle, which must be capable of safely carrying a container filled with “vaccines” from one end of a track to the other without spilling any contents.

INVENTION SHOWCASE

1. What are the main features of your design?

2. What changes did you make as you iterated on your design?

3. How did it perform?

4. What changes would you make if you had more time?

► Individually: Sketch out your ideas. What materials do you need?
► As a group: Discuss your ideas. Combine them! Make a new sketch together.
► Start building: Test often and iterate on your design.
  • Your vehicle must be able to carry a film canister.
  • Bartering for materials between groups is allowed.
  • Test on the track using an empty film canister.
Global Health Careers

Exploring Pathways to Global Health Careers

1 Lesson | Grades 6-12

Pathways to Global Health Careers Poster & Fact Sheets

2 Resources | Grades 6-12
Exploring Pathways to Global Health Careers

**STEM GLOBAL**

**Brief Overview:** This lesson engages students in exploring careers in the global health sector. The goal is to broaden students’ awareness of the types of careers available within the field and to develop an understanding of the educational pathways required for these types of careers. Students begin by reading about careers in global health. They then work in groups to explore the website of a global health organization and share their findings with the class. Next, students explore a careers pathway poster and choose a career to research, using a set of provided fact sheets and additional online resources. They share their findings in small groups and then summarize what they learned about these careers in an Exit Ticket. This lesson can easily be adapted for both synchronous and asynchronous remote instruction settings.

[link to website](wghalliance.org/initiative/stem-global/)
Student Understandings

DRIVING QUESTIONS

► What types of careers are available within the field of global health?
► What educational pathways are required for these careers?

Next Generation Science Standards

This lesson builds toward the following bundle of high school level Performance Expectations (PEs). Hyperlinks direct to relevant sections of the Next Generation Science Standards and A Framework for K-12 Science Education.

Remote Learning Adaptations

This lesson plan would work well for remote instruction settings. As written, the lesson is intended for in-person, live, classroom-based instruction. However, all lesson materials can be accessed online and activities would work well in a remote learning environment. Activities could be accomplished during synchronous class meetings via video conferencing, using breakout rooms to have students meet in small groups. Alternatively, activities could be completed asynchronously by students working independently from home and submitting work to the teacher for credit/grading.
Teacher Preparation

MATERIALS:

<table>
<thead>
<tr>
<th>Material</th>
<th>Description/Source</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Handouts</td>
<td>• Student Handout: Careers in Global Health&lt;br&gt;• Pathways to Global Health Careers Poster (also available on pg 320)&lt;br&gt;• Global Health Careers Fact Sheets (also available starting on pg 321)</td>
<td>1 per student group</td>
</tr>
<tr>
<td>Computer</td>
<td>Computer with internet access so that students can access online resources.</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTES TO TEACHER FOR PREPARING TO TEACH THIS LESSON

1. Students need internet access in order to access online resources for this lesson.
2. The following resources could be uploaded to your classroom learning management system:
   • Student Handout: Global Health Careers
   • Pathways to Global Health Careers Poster
   • Global Health Careers Fact Sheets

STUDENT ASSESSMENT OPPORTUNITIES

► Student groups’ informal presentations on global health organizations can be assessed for student participation and engagement.
► Small group discussions can be assessed for student participation and engagement.
► Exit Tickets can be collected and scored for credit as a way to assess what students learned about the career they researched.
Instructional Procedure

OVERVIEW

<table>
<thead>
<tr>
<th>Day</th>
<th>Activity</th>
<th>Details</th>
<th>Approx. Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day One</td>
<td>Activity I: Introduction to the Field of Global Health</td>
<td>Students brainstorm a list of global health organizations and related careers and then read background information.</td>
<td>20 minutes</td>
</tr>
<tr>
<td></td>
<td>Activity II: Exploring Global Health Organizations</td>
<td>Students work in groups to explore the website of a global health organization and share their findings with the class.</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Day Two</td>
<td>Activity III: Exploring the Global Health Pathways Poster</td>
<td>Students explore a career pathways poster and choose a career to research.</td>
<td>15 minutes</td>
</tr>
<tr>
<td></td>
<td>Activity IV: Researching a Global Health Career</td>
<td>Students use the provided fact sheets to learn about a career. They share their findings in small groups.</td>
<td>30 minutes</td>
</tr>
<tr>
<td></td>
<td>Activity V: Exit Ticket</td>
<td>Students respond to prompts to summarize what they learned about one career.</td>
<td>5 minutes</td>
</tr>
</tbody>
</table>

1 DAY ONE

ACTIVITY I: INTRODUCTION TO THE FIELD OF GLOBAL HEALTH (20 MINUTES)

1. Introduce students to the idea that the field of global health includes a wide variety of organizations located all around the world working toward different purposes and goals. These organizations employ people with diverse backgrounds, career paths, and areas of expertise. Explain that today students will be exploring careers in the global health sector.

2. As a whole class, or in small groups, ask students if they know of any organizations that work in the global health sector. Using the whiteboard or chart paper, record students’ responses, and then organize them by category.

3. Next, ask students if they can think of some types of jobs that might be needed by these organizations. Encourage students to think broadly of all of the kinds of jobs that are needed to carry out the organization’s mission and to function as an organization. Record their responses next to each organization, or create a separate list.

Potential categories include:
- a. International agencies
- b. Government agencies
- c. Non-governmental organizations (NGOs)
- d. Biomedical research institutes
- e. Health care/hospitals
- f. Universities/colleges
- g. Philanthropic organizations
- h. Faith-based organizations
- i. Lending/finance agencies
- j. Other organizations
4. **Use the Student Handout: Careers in Global Health and any of the following readings**, which are available online, to help orient students to careers in the global health sector. Students could all be assigned the Student Handout, or different readings could be assigned to each group as a jigsaw activity in which small groups meet to share what they read.

   ![Student Handout: Global Health Careers](image1)

   ![Global Health Careers: How Can I Make a Difference?](image2)

   ![Profiles of People Working in Global Health](image3)

   ![Global Health Careers](image4)

   ![Careers in Global Health](image5)

   ![Degrees in Global Health](image6)

5. **ACTIVITY II: EXPLORING GLOBAL HEALTH ORGANIZATIONS (30 MINUTES)**

   5. **Next**, challenge students to work in pairs or small groups to spend some time getting to know a global health organization. They may choose a global (e.g., WHO), national (e.g., CDC, USAID), or local organization. For organizations local to Washington State, a great starting point is the member listing for the Washington Global Health Alliance, which has clickable logos for all member organizations.

   6. **Students should attempt to answer the questions (see box to the right) about their chosen organization** and be prepared to share it out with the class. For the last question, students need to find the Careers, Job Openings, or Join Us section of the organization’s website to find current job openings. You might consider creating a slide deck so that each group has an assigned slide on which they can add the information they found about their organization.

   7. **Allow time for groups to explore their chosen organization’s website**, prepare their slide, and then provide time for each group to make a brief presentation to the class.

   **Students should prepare to share:**
   a. Organization’s name
   b. Type of organization (see list of categories in Activity 1 above)
   c. Organization’s mission or vision (copied or in your own words)
   d. A few examples of their areas of focus
   e. Where they do their work (countries, regions)
   f. 1-2 examples of current job openings that interest you (job title, education requirements)
   g. Anything you found particularly interesting

   ![Global Health Careers: How Can I Make a Difference?](image2)
   ![Profiles of People Working in Global Health](image3)
   ![Global Health Careers](image4)
   ![Careers in Global Health](image5)
   ![Degrees in Global Health](image6)
ACTIVITY III: EXPLORING THE GLOBAL HEALTH PATHWAYS POSTER (15 MINUTES)

8. Explain to students that now that they have some understanding of the types of organizations that make up the global health sector, and some examples of jobs in global health, they will use several tools to explore global health careers that might match up to their own career interests. Whether or not a career in global health is in their future, students may be able to find a match between their own existing interests and job opportunities in global health. The goal is to help expand students’ ideas of what it means to work in global health, including who does this work, what organizations they work for, and what they do.

9. Provide access to the Pathways to Global Health Careers Poster and Global Health Careers Fact Sheets from the STEM Global program. Students may easily access the poster and fact sheets online or they may be saved as PDFs and uploaded to your classroom learning management system.

10. Spend a few minutes orienting students to the poster and fact sheets.
   a. Point out the eight career clusters across the bottom of the infographic, and note that they are color coded. Emphasize that global health is a truly interdisciplinary career, as demonstrated by the diversity of the career clusters.
   b. Career titles within each of the career clusters are each provided a color-coded pathway. Each pathway can be traced to find out information about a career’s median salary and the required entry level degree.
   c. Note that the poster highlights a few example careers within each career cluster, but this is not inclusive of the hundreds of careers within the global health sector.

11. Allow time for students to explore the poster in small groups. Then ask for any questions or observations that they would like to share with the class.
ACTIVITY IV: RESEARCHING A GLOBAL HEALTH CAREER (30 MINUTES)

12. Challenge each student to select one career that best matches their own career interests or that they are simply interested in learning more about. Once all students have chosen a career, ask them to find the information about that career in the Global Health Careers Fact Sheets. The Fact Sheets are organized by career clusters. If a student wants to research a job not featured on the poster and fact sheets, they can seek outside sources of information. See the Global Health Career Connections table in the Resources section for information on careers that align to each lesson/unit within the STEM Global curriculum collection.

13. Optional: If you have additional time, encourage students to also seek out other sources of information to learn about their chosen career. A good starting place is the online Occupational Outlook Handbook (use the Search Handbook feature) from the U.S. Bureau of Labor Statistics.

14. After students have had time to read the Fact Sheet for their career (or conduct online research about it), have students meet in small groups to share with each other what they learned about global health careers.

15. Bring the class back together. Ask students to share observations, things that interested them, or questions that they might have.

ACTIVITY V: EXIT TICKET (5 MINUTES)

16. Assign an Exit Ticket with the following prompts (could be assigned as homework).

Global Health Careers - Exit Ticket/Homework Questions:

a. What career did you choose to learn about?

b. Did you use any sources of information other than the poster/fact sheet? If so, name them.

c. What education/degrees/training are required for this career?

d. What about this career did you like or would make it a good fit for you?

e. What about this career did not interest you?

f. Describe 2 things you learned about the other careers that your group mates shared.
# Career Connections & Resources

This table displays connections between global health careers and the lessons/units that make up this STEM Global curriculum collection. Links are provided to resources to learn more about each career.

<table>
<thead>
<tr>
<th>Career</th>
<th>COVID Testing</th>
<th>Diagnostic Detective</th>
<th>Code Coding</th>
<th>Data Driven (HS)</th>
<th>Data Driven (MS)</th>
<th>Drone Drop Challenge</th>
<th>Special Delivery</th>
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<tr>
<td>Aeronautical/ Aerospace Engineer</td>
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<table>
<thead>
<tr>
<th>STEM Global Lesson/Unit</th>
<th>Career Connections &amp; Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Fred Hutch)</td>
<td>• Biomedical Lab Technician (<a href="https://www.stem.org/">STEM Fact Sheet</a>)</td>
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Suggested Lesson Extensions

SPEAKERS BUREAU
Invite a global health professional into your classroom (virtually or in-person) to talk about their job and their educational pathway. Contact the Research Ambassadors (Northwest Association for Biomedical Research), the Washington Global Health Alliance, Skype a Scientist, a university global health department, or global health organizations.

PREPARING FOR A GLOBAL HEALTH CAREER
Challenge students to find a university or college that offers degrees in Global Health or Public Health. What degrees are offered? What prerequisites and coursework are required? For example in Washington State, see:

- Department of Global Health at the University of Washington
- Paul G. Allen School for Global Animal Health at Washington State University
- Public Health at Eastern Washington University
- Public Health at Western Washington University

GLOBAL HEALTH SECTOR IN YOUR STATE
Challenge students to learn about the global health sector in their own state. For example, Washington State has a large, active global health sector. Explore these resources to learn more:

- Washington Governor: Life Sciences and Global Health
- Washington Global Health Alliance

Notes on Adaptations and Inclusivity

INCLUSIVITY FOR ALL LEARNERS
Consider how the lesson activities may need to be adapted to be accessible for all learners. For example, what accommodations may a student with a visual or mobility impairment need to engage in the work? How might you elicit, build connections with, and leverage students’ everyday expertise and knowledge of global health organizations and careers? How might you group students with diverse expertise and learning needs into teams so that they can support each other?

Teacher Resources

- Women in Global Health Seattle
- WGHA: Field Notes Live
- WGHA: Job Search Resources
- NWABR: Science Careers

Authorship Credit: This activity was developed by Kristen Bergsman, PhD of Laughing Crow Curriculum for the STEM Global program of Washington Global Health Alliance.
Another major scope of global health involves non-communicable diseases, which are among the leading causes of disability worldwide, such as:

- Diabetes
- Obesity
- Substance abuse
- Tobacco use
- Mental illness

**GLOBAL PUBLIC HEALTH**

Infectious and non-communicable diseases and epidemics are a major concern, and one of the greatest challenges to the health of major populations:

- **AIDS** has claimed the lives of more than 35 million people since its discovery.
- **Tobacco**-related deaths are expected to account for nearly 10 percent of all deaths globally by 2030.
- **Chronic diseases** that result from high blood pressure account for 13 percent of all deaths globally.
- **Cancers** figure among the leading causes of death worldwide, accounting for 9.6 million deaths in 2018.

Infectious diseases and other health threats have prompted the United States to enhance its capability to respond to infectious diseases globally by developing a real-time infectious disease surveillance system.

**WHAT IS GLOBAL HEALTH?**

As the world becomes more globalized, and as international travel and commerce becomes more extensive, public health must be considered in a global context. A complex international distribution chain has also resulted in potential international outbreaks from contaminated consumer goods, poor-quality pharmaceuticals, and foodborne illnesses, just to name a few.

**MAJOR PLAYERS IN GLOBAL HEALTH PROGRAMS AND INITIATIVES**

The goal of global health is to improve public health and strengthen U.S. national security through global disease detection, response, prevention, and control strategies. The work of public health professionals in global health is vital for researching and containing diseases and working toward eradication. They also craft policies that help prepare for disease outbreaks and oversee programs that educate communities about effective treatment for diseases.
For example, public health professionals actively work to fight HIV/AIDS in developing countries by educating populations about HIV prevention and transmission, distributing condoms, increasing access to antiretroviral medications, and encouraging healthy behaviors that help prevent the spread of the virus.

Public health professionals work for U.S. government agencies, public health agencies, nonprofit organizations, advocacy groups, academic institutions, and private businesses. These public health employers may provide education, funding, resources, and technical support for global health initiatives, and many of these organizations combine their efforts and provide assistance to international organizations.

For example, the U.S.-based Global Initiative invested more than $63 billion in 2010 to help partner countries improve health outcomes through strengthened health systems.

**JOBS IN GLOBAL HEALTH**

Global health affects everyone. Therefore, professionals in global health are directly responsible for the study and practice of population-level health interventions in communities around the world.

These specialists are focused on health within all countries, across borders, across boundaries, and across all socio-economic statuses. In other words, global health professionals are focused on health issues that transcend boundaries and that are important both domestically and internationally.

Global health professionals may study large-scale epidemics, vaccines, treatments, and other methods of mitigating the spread of these diseases. They may also collaborate with community leaders, governmental agencies, relief organizations, and other groups to promote global health and medical awareness.

**Some jobs in global health include:**

**HIV/AIDS Research Associates**

HIV/AIDS research associates work with other researchers and study participants to implement an organized HIV/AIDS research agenda. Their work includes managing research grant portfolios, monitoring and evaluating grantee progress, and working with senior-level directors and researchers to design and implement modifications to grant programs.

Other job responsibilities of HIV/AIDS research associates include:

► Assisting in the development of strategic plans that support research
► Assisting with communications and fundraising endeavors
► Helping design plans that raise the profile of a company or organization’s research efforts
► Monitoring and analyzing research issues in a swiftly changing environment

Some of the largest supporters of global health in the U.S. include:

- Centers for Disease Control (CDC)
- World Health Organization (WHO)
- Global Health Council
- Task Force for Global Health
- Bill & Melinda Gates Foundation
- Care International
- American Red Cross
- Save the Children
- William J. Clinton Foundation
- World Vision
- National Institutes of Health
International NGO Aid Workers

International aid workers in non-governmental aid organizations (NGO) serve as first responders during times of crisis. They are the frontline workers who bring relief to places devastated by war, disease, famine, or natural disasters. They must adhere to safety and health regulations and create programs to respond to emergencies that require budgetary constraints and the work of local staff and volunteers.

Job responsibilities of international NGO aid workers in director/manager positions include:

► Managing, monitoring, and evaluating projects
► Conducting needs assessments
► Organizing fundraising efforts
► Researching and writing grant proposals and reports
► Engaging in strategic planning for long-term development and/or disaster management to reduce the need for crisis intervention
► Managing budgets and allocating resources
► Recruiting, managing, and training staff and volunteers
► Developing relationships with partner organizations
► Implementing security procedures to ensure the safety of workers in unstable areas

Global Infectious Disease Analysts

Global infectious disease analysts are responsible for collecting, interpreting, and analyzing epidemiological data and research regarding global infectious diseases. The epidemiology of infectious diseases involves studying risk factors of infectious diseases, as well as their prevalence and incidence.

Global infectious disease analysts implement and evaluate interventions at both the individual and community levels to prevent primary infection, prevent disease-associated deaths and disabilities, and prevent diseases from developing further.

These professionals are called upon to answer a number of questions, such as:

► How can treatment best be delivered and health systems strengthened?
► How can treatment regimens be optimized and the quality of care improved?
► How can resistance and transmission be prevented?
► How does poverty and disease impact global policy?

Global infectious disease analysts use the results of their research to improve healthcare delivery and to guide the design and implementation of health policies.
DEGREE OPTIONS FOR A CAREER IN GLOBAL HEALTH

Those interested in working in the global health field often pursue undergraduate degrees in the social sciences, public health, or in the allied health fields. One of the most widely held graduate degrees among global health professionals is the Master of Public Health (MPH) with a concentration in global health. Similar program concentrations include global health communications, global health program design, global health policy, and global environmental health.

An MPH in Global Health provides study in the social, economic, and political determinants of health, as well as the history of global responses to health problems. Graduates of MPH in Global Health programs possess the skills necessary to pursue careers in academia, industry, government, foundations, and non-governmental organizations.

Courses in an MPH degree that are focused on global health include:

- Issues in global health
- Global health policy and delivery
- Program evaluation in public health

Some of the areas frequently explored in global health graduate programs include:

- Biomedical research
- Chronic diseases
- Climate change
- Global medicines safety
- Global trauma and violence
- Health metrics and evaluation
- Implementation science
- Infectious diseases
- Mental health
- Women, children, and adolescent health
- Workforce development

Text sourced from: [https://www.publichealthcareeredu.org/global-health](https://www.publichealthcareeredu.org/global-health) and [https://www.who.int/cancer/about/facts/en](https://www.who.int/cancer/about/facts/en)
Brief Overview: Global health organizations currently employ more than 14,000 people just in Washington State. The global health workforce—in the U.S. and worldwide—attracts people with diverse backgrounds, as it takes an interdisciplinary approach to solve some of the world’s most complex problems. This Pathways to Global Health Careers poster features a beautiful infographic that maps the broad variety of careers that make up the global health sector and the education required to land them. A set of Global Health Careers Fact Sheets accompany the poster, providing information on featured jobs across eight different career and technical education career clusters. Featured information on each job includes median salary, job description, minimum education requirements, certification/licensure, and internships/apprenticeships/volunteer opportunities.

wghalliance.org/initiative/stem-global/
Pathways to Global Health Careers Poster

https://www.wghalliance.org/resource/global-health-career-poster/
**Pathways to Global Health Careers Fact Sheets**

[Link to Fact Sheets](https://www.wghalliance.org/resource/global-health-career-fact-sheets/)

### Global Health Careers in Transportation, Distribution, & Logistics

**Logistics/Supply Chain Manager**

- **Median Salary:** $74,600 Annually
- **Job Description:** A logistics/supply chain manager is responsible for coordinating and managing an organization's supply chain, which is the flow of a product (material, finished, and decommissioned) from raw materials to the customer, including warehousing and distribution. They are knowledgeable about inventory management, scheduling, and coordinating with suppliers, manufacturers, and customers.

### Human Services, Education, & Training

**Community Health Advisor**

- **Median Salary:** $46,000 Annually
- **Job Description:** community health advisors (CHAs) help people overcome their health and their faith. They educate people about how to prevent disease and to improve their access to health and human services. CHAs are trained to handle issues related to healthcare and social services, including challenges such as HIV/AIDS and substance abuse.

### Internships, Apprenticeships, Volunteer Opportunities

WGU has a variety of opportunities that could help strengthen your job skills, including the STEM Career program. Look for internship opportunities related to supply chain management, contract negotiations, transportation, and distribution.

### Distribution, Field Operations, and Quality Management

**Industrial Plant/Lab Manager**

- **Minimum Education:** Associate’s degree in health, business, or science-related fields and/or sociology; coursework in business and technology.
- **Internships, Apprenticeships, Volunteer Opportunities:** Look for internship opportunities related to supply chain management, transportation, and distribution.

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**GLOBAL HEALTH CAREERS IN STEM**

**Biomedical Laboratory Technician**

*Median Salary: $46,100 Annually*

**Job Description:** Laboratory technicians contribute to research on global health issues. Most medical laboratory technicians work in hospital laboratories, public health laboratories, biotechnology companies, pharmaceutical companies, chemical analysis laboratories, and the medical industry. Medical laboratory technicians carry out laboratory procedures on body fluids and other bodily fluids using laboratory equipment such as microscopes, chemicals, and computers. Technicians usually perform their duties in a laboratory setting under the supervision of a medical laboratory scientist or pathologist. Other laboratory technicians work in a variety of fields related to the biological sciences, such as medicine, engineering, and health.

**Minimum Education:** Associates degree or Bachelor's degree. Knowledge and technical skills provide specific introduction to medical laboratory technology.

- **High School Coursework:** Coursework to meet college entrance requirements, including courses in biology, chemistry, physics, mathematics, English, and health.
- **Post-High School Study:** Two-year Associate's degree program in medical laboratory technology that includes clinical training.

**Bioscientist**

*Median Salary: $42,100 Annually*

**Job Description:** Biologists study the characteristics, properties, and behavior of living organisms. They conduct research that explores a variety of topics, including genetics, environmental issues, and conservation. Biologists work in a variety of fields, such as agriculture, forestry, government, and research.

**Salary:** Biologists earn an average of $42,100 per year. The highest-paying states for biologists are California, Massachusetts, and New York.

**Education:** Typically requires a Bachelor's degree, although some research positions may require a Master's degree.

**Science, Technology, Engineering, & Mathematics**

**GOVERNMENT & PUBLIC ADMINISTRATION**

**Legislative Assistant/Aide**

*Median Salary: $45,520 Annually*

**Job Description:** Legislative assistants work in political campaigns and can be a political aide in the U.S. government. They may work in the legislative office of a U.S. representative or senator in Washington, D.C., or in a state or federal office. Legislative assistants are responsible for tasks such as research, outreach, communications, and constituent services. They may also be responsible for tracking key legislation, developing public outreach materials, and coordinating events.

**Minimum Education:** Bachelor's degree in a relevant field is generally required, although some may accept candidates with a Master's degree.

**Post-High School Study:** Most jobs will require a Bachelor's degree in a relevant field.

- **High School Coursework:** Coursework to meet college entrance requirements. In particular, take courses in communications, social studies, government, and economics. Consider joining FFA or student government.

**Internship, Apprenticeship:** Voluntary Opportunity. Viewed favorably by graduate admissions. Consider applying to the Congressional Page Program for high school students or the Career Technical Education program at your school.

**Foreign Service Officer/Diplomat**

*Median Salary: $45,520 Annually*

**Job Description:** Foreign Service Officers and Diplomats are specialists who represent the interests of the U.S. government and its allies in protecting and promoting American citizens and democracy around the world. They are stationed in embassies, consulates, and diplomatic missions overseas.

**Salary:** Foreign Service Officers and Diplomats earn an average of $45,520 per year. The highest-paying states for Foreign Service Officers and Diplomats are California, Massachusetts, and New York.

**Education:** Typically requires a Bachelor's degree, although some diplomatic positions may require a Master's degree.

**Post-High School Study:** Most jobs will require a Bachelor's degree in a relevant field, such as international studies, political science, or foreign languages.

- **High School Coursework:** Coursework to meet college entrance requirements. In particular, take courses in social studies, government, and economics. Consider joining FFA or student government.

**Internship, Apprenticeship:** Voluntary Opportunity. Viewed favorably by graduate admissions. Consider applying to the Foreign Service Officer Test (FSOT) program.

- **Salary:** Diplomats earn an average of $45,520 per year. The highest-paying states for Diplomats are California, Massachusetts, and New York.

**Government & Public Administration**

**Lawmaker, Politician, Legislative Assistant/Aide, Patient Lawyer, Human Rights Lawyer, Paralegal, Legal Secretary, County Director, Global Health Policy Analyst, Diplomat, Philanthropist, Peace Corps Volunteer, Foreign Service Officer/Diplomat, FTA Consumer Safety Officer, District Director of Health, Medical Director for Global Issues and Projects**

**Salary:** Typically earns an average of $45,520 per year. The highest-paying states for legislative assistants are California, Massachusetts, and New York.

**Education:** Typically requires a Bachelor's degree, although some positions may require a Master's degree.

**Post-High School Study:** Most jobs will require a Bachelor's degree in a relevant field, such as international studies, political science, or foreign languages.
HEALTH SCIENCES
Healthcare In Clinical & Community Settings

GLOBAL HEALTH CAREERS IN
Health Sciences

Doctor, Field Doctor, Infectious Disease Doctor, Family Medicine Doctor, Pediatrician, Farm Worker's Clinic (PhARMacist's Assistant), Nurse, Epidemiologist, Nurse Aide, Pediatric Nurse, Pharmacist, Pharmacist, Public Health Practitioner, Medical Records and Health Information Technician, Medical Technologist, Medical Transcriptionist, Medical Assistant, Nurse Midwife, Registered Nurse, Genetic Counselor, Family Advocate, Health, Health Practitioner, Outreach Worker, Patient Navigator, Health Interpreter, Public Health Aide, Nurse Practitioner, Public Health Nurse

Epidemiologist
Median Salary: $75,000 Annually
Job Description: Epidemiologists study the spread of diseases and disease outbreaks and devise ways to prevent or control them. There are two focuses for Epidemiological research or clinical trials. In the area of research, they design and test possible treatments. In clinical trials, they design and oversee studies that can establish being a consultant in a hospital, informing medical staff of infectious outbreaks, and providing ways to control the spread of diseases. Epidemiologists typically work in labs testing out new research, but they may also work with patients to study the effects of certain diseases within the community. Some Epidemiologists work with international groups who are trying to stop how diseases spread. Often work at: private, corporate, international organizations, and global, state, and federal health agencies.

Minimum Education: Masters degrees from a school of Public Health. Some positions may require a Doctoral degree.

- High School Equivalents: Knowledge in research with an emphasis on advanced courses in Health, Life, Physics, Biology, and Math.
- Post-High School Study: Bachelor’s degree in Public Health is a typical study and want in course that focus on math, biology, health sciences, demography, and research methods. Master’s degree in epidemiology. You may want to pursue a Master’s degree in a related area.
- Licenses/Exams: Certification in Epidemiology is required.

Internships: Applicants to this career are expected to gain experience in Public Health agencies or related fields.

Veterinarian Technician
Median Salary: $35,000 Annually
Job Description: Veterinarian Technicians play working with animals. They perform basic procedures on animals. They also assist in the care and supervision of a licensed veterinarian. Veterinary Technicians work in veterinary clinics, feedlots, feedlots, animal shelters, and research facilities. They may also assist in the care and supervision of a licensed veterinarian. They may also assist in the care and supervision of a licensed veterinarian.

Minimum Education: Associates degree from an American Veterinary Medical Association (AVMA) accredited community/hospital veterinary technician program.

- High School Equivalents: A strong high school academic record in biology, zoology, and/or mathematics is recommended.
- Post-High School Study: A two-year Associate's degree in a four-year accredited community college program in veterinary technology, with coursework in clinical and veterinary studies. Graduates generally begin work in a technician under a licensed Veterinarian.

Internships: Students are encouraged to work in a veterinary clinic or hospital under the supervision of a licensed veterinarian. Internships are not required but may be helpful.

Agriculture, Food, & Natural Resources
Farming, Ranching, & Natural Resource Management


Veterinarian Technician
Median Salary: $35,000 Annually
Job Description: Veterinarian Technicians play working with animals. They perform basic procedures on animals. They also assist in the care and supervision of a licensed veterinarian. Veterinary Technicians work in veterinary clinics, feedlots, feedlots, animal shelters, and research facilities. They may also assist in the care and supervision of a licensed veterinarian. They may also assist in the care and supervision of a licensed veterinarian.

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Internships: Students are encouraged to work in a veterinary clinic or hospital under the supervision of a licensed veterinarian. Internships are not required but may be helpful.

Hydrologist
Median Salary: $70,000 Annually
Job Description: Hydrologists are specialists in surface and underground water. They work with water resources, as well as monitoring the change of impact on global water cycles. Hydrologists help develop water resources and assist in land use development around the globe.

Minimum Education: Bachelor's degree in Hydrology.

- High School Equivalents: Knowledge in research with an emphasis on advanced courses in mathematics and science, and math courses is recommended.
- Post-High School Study: A four-year degree in earth, environmental, or geosciences with a focus in geology, chemistry, and/or biology. Master's degree in Hydrology.

Internships: A number of states require practice in earth sciences and offer internships directly to the public. It is also possible to obtain a bachelor's degree in Hydrology.

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BUSINESS & FINANCE

Business Management, Administration, & Finance

Bookkeeper

Minimum Salary: $39,200 Annually
Job Description: Bookkeepers work on the financial side of an organization, keeping track of income, expenses, and inventory. They may manage employee time cards, process payroll, and keep accounts receivable and payable records. They may also track accounts and make bank deposits.

Minimum Education: A high school diploma or equivalent is required.

Internships, Apprenticeships, Volunteer Opportunities: Consider volunteering in a bookkeeping or accounting role. You may also participate in internships that provide hands-on experience in bookkeeping.

Administrative Assistant

Minimum Salary: $37,800 Annually
Job Description: Administrative Assistants are the backbone of any office. They assist with tasks such as scheduling appointments, handling correspondence, and organizing files. They may also help with filing, faxing, and other office procedures.

Minimum Education: A high school diploma or equivalent is required. Experience may also be helpful.

Software Developer

Minimum Salary: $106,000 Annually
Job Description: Software Developers develop applications that run on computers and mobile devices. They may work on the design, development, testing, debugging, and launch of computer software. In a global health context, these systems and devices, which permit people to access health services, change drug formulas, or provide data for decision making, may be critical to improving health outcomes.

Minimum Education: A Bachelor’s degree in computer science, programming, or software engineering, with a background in coding, is required. A Master’s degree or equivalent experience is helpful.

Web Designer

Minimum Salary: $39,200 Annually
Job Description: Web Designers use software and tools to design websites. They may work on the design, development, testing, debugging, and launch of websites. In a global health context, websites may provide information, resources, and tools to improve health outcomes.

Minimum Education: A Bachelor’s degree in graphic design, computer science, or a related field is required.

Informatics

Minimum Salary: $65,000 Annually
Job Description: Informaticists analyze and interpret data to help improve healthcare delivery. They may work on the design, development, testing, debugging, and launch of computer software and systems. In a global health context, these systems and devices, which help improve healthcare delivery, may be critical to improving health outcomes.

Minimum Education: A Bachelor’s degree in computer science, programming, or software engineering, with a background in coding, is required. A Master’s degree or equivalent experience is helpful.

GLOBAL HEALTH CAREERS IN

Business & Finance

BOOKKEEPER & FACT SHEETS

Developed by Laughing Crow Curriculum LLC   |   Designed by Clayton DeFrate

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INFORMATION TECHNOLOGY

Communications, Design, & Information Technology

Graphic Designer

Minimum Salary: $48,700 Annually
Job Description: Graphic Designers use creative tools to help businesses communicate through illustrations, graphics, logos, and text. They may design brochures, reports, advertisements, books, websites, or patient education materials produced by a global health organization. They may design these assets within budgets, by using design software for digital images, or by editing images by hand or through the use of computer software for digital images. Graphic Designers may also be self-employed or work within the graphics, communications, or design departments of a larger organization.

Minimum Education: A Bachelor’s degree is required.

Internships, Apprenticeships, Volunteer Opportunities: Consider an internship that provides hands-on experience in graphic design.

Software Developer

Minimum Salary: $98,300 Annually
Job Description: Software Developers develop applications that run on computers and mobile devices. They may work on the design, development, testing, debugging, and launch of computer software. In a global health context, these systems and devices, which permit people to access health services, change drug formulas, or provide data for decision making, may be critical to improving health outcomes.

Minimum Education: A Bachelor’s degree in computer science, programming, or software engineering, with a background in coding, is required. A Master’s degree or equivalent experience is helpful.

GLOBAL HEALTH CAREERS IN

Information Technology

Video Producer, Film Maker, Web Designer, Graphic Designer, Technical Writer, Database Administrator, Software Developer, Network Administrator, Computer Programmer, App Architect, Data Analyst

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Teaching About COVID-19: Resource List

STEM GLOBAL | AUGUST 2020

Compiled by Kristen Bergsman, Laughing Crow Curriculum LLC for Washington Global Health Alliance's STEM Global Program

In the midst of a global health pandemic, SARS-CoV-2 (the novel coronavirus identified in 2019 that originated in Wuhan, China) and COVID-19 (the disease it causes) is on everyone's mind. This presents serendipitous teaching opportunities for engaging students in increasing their understanding of multiple aspects related to the virus, disease, pandemics, public health policies, and societal impacts.

Particularly for science teachers, this presents an opportunity to incorporate contemporary scientific phenomena into the classroom curriculum. Microbiology, infectious diseases, antigen and antibody testing, vaccine development, global health, and bioethics are all particularly relevant areas.

Math teachers will also find connections, whether it is studying exponential growth, statistics, computational modelling, or data visualization. In particular, an understanding of statistics will help students become more data literate and able to critically analyze information presented in the media.

For social studies teachers, relevant topics include: the ways that different countries are differently dealing with and experiencing outbreaks, health disparities and inequities, regional and global economic impacts, changing governmental policies, coordination between local/state/national/global agencies, racial bias, and impacts on personal freedom for the greater good. In addition, students could investigate other epidemics and pandemics throughout history, such as avian influenza, swine flu, Zika virus, Ebola, cholera, tuberculosis, bubonic plague, and more.

For all educators, caregivers, and parents, we need to think about social stigma, racialized fear, and xenophobia in how we act and talk to the young people in our lives, and to think about what they are seeing online and through social media.
Teaching About COVID-19: Resource List
The following list from the STEM Global program provides descriptions and links to teaching resources related to coronavirus, COVID-19, and global health epidemics and pandemics.

Educator Workshop

STEM GLOBAL EDUCATOR WORKSHOP JAN. 30, 2021 RECORDING
A recording of WGHA’s STEM Global Educator Workshop (01/30/21). This workshop is designed to share free activities and curriculum resources centered around COVID-19 to integrate into virtual classrooms. English and Spanish captions. 3 hrs 15 minutes.

COVID-19 & Inequities Curricula

CURRICULUM UNIT
COVID-19 Testing and Inequities is a curriculum unit developed by the Science Education Partnership at Fred Hutchinson Cancer Research Center. The unit was developed for high school biology and biotech courses. It includes six lessons that provide an overview of COVID-19 testing procedures (molecular testing and antibody testing), bioethics, health inequities, and Nextstrain (a data visualization tool that tracks genomic data of viral evolution). These lessons are available as Google docs and slides. It is important that you first download them (as Word and PPT files) to save to your personal folders prior to making changes. The lessons are licensed under a Creative Commons Attribution 4.0 License. If you do use the unit, SEP (sep@fredhutch.org) would welcome feedback about any changes you made and how the lessons went with students.

CURRICULUM UNITS
OpenSciEd has released free, NGSS-aligned curriculum materials for Elementary, Middle School, and High School focused on COVID-19 and health inequities. The high school unit storyline focuses on the driving question, How can we slow the spread of the COVID-19 virus to protect our communities? Lesson

One and Lesson Six in particular focus on how people from different communities experience COVID-19 differently. These lessons focus on data from six different communities in Chicago and Northwest Indiana, including examining the impacts of systemic inequities. Other lessons are more focused on the science behind the pandemic, including the coronavirus and transmission, strategies to slow the spread of the disease, vaccine development, COVID-19 treatments, and more.

VIRTUAL FIELD TRIP
Beginning in October 2020, the Bill & Melinda Gates Discovery Center began offering free virtual programs focused on COVID-19 science and health inequities. Join their mailing list for updates and schedule a free program through their website.

CURRICULUM UNITS
Houghton Mifflin Harcourt’s COVID-19 teaching modules are online science activities related to COVID-19. Start here and then scroll down to bottom for a list of related activities. Elementary, middle, and high school activities are available. There are three activities for Grades 9-12:

• Modeling SARS-CoV-2 to Communicate Information (use a model to learn about the virus)
• The SARS-CoV-2 Genome (analyze models of segments of genome)
• Testing for the COVID-19 Virus (PCR-based testing)

Data Visualization

DATA VISUALIZATION PLATFORM
Nextstrain is an open-source platform that allows for real-time tracking of disease outbreaks and pathogen evolution. Scientists worldwide are currently using this platform to track the spread of the novel coronavirus (hCoV-19) through the use of genomic epidemiology. Biology teachers in particular may be interested in sharing with their students the latest data, analysis, visualization, and situation reports. Click on the “about” option to learn about Nextstrain, learn how to interpret...
the phylogentic tree that forms the basis of the Nextstrain visualization, and learn how to interact with the phylogeographic visualizations. There is also background on coronavirus and FAQs with links out to further reading.

In addition, the Fred Hutch COVID-19 Testing & Inequities curriculum unit, described above, can be used to help students understand Nextstrain (see Lesson 6).

Fred Hutch’s Tracking a Pandemic site shows how scientists worked in collaboration to investigate the novel coronavirus, from its early spread to expansion and global exposure. This site explains the critical role of Nextstrain in this process.

DATA VISUALIZATION TOOL
IHME’s COVID-19 Projections tool provides visualizations of COVID statistics, organized by country and U.S. state. Students can explore these projections as a scientific or mathematical exercise, and use them to create their own recommendations related to social distancing, opening schools, vaccine distribution, and allocating hospital resources. For background information and FAQs about the projection tool, visit the IHME COVID-19 Resources page.

DATA VISUALIZATION TOOL
The COVID-19 Interactive Map, from the Johns Hopkins University Coronavirus Resource Center, tracks COVID-19 cases across the globe using maps, graphs, and case counts (confirmed, deaths, recovered).

MUSEUM EXHIBIT
The interactive exhibit Uncovering Reality, from Pacific Science Center and University of Washington’s Center for an Informed Public, is focused on helping young people learn how data visualizations can be distorted and manipulated and how to be data literate.

NEWSPAPER ARTICLE
This New York Times article shows different ways to explore the math of the coronavirus using different graphs and data visualization tools. In addition, these articles provide visualizations/graphics on COVID-19 structure and spread for engaging students in sensemaking practices.

• Bad News Wrapped in Protein
• How Coronavirus Mutates
• How the Coronavirus Got Out

Vaccines, Research, and More

FRED HUTCH INFO PAGE
Fred Hutch’s Coronavirus (Covid-19) page provides excellent background information on the virus, testing process, and vaccine trials, as well as stories about the scientists behind the research. These would make good background readings for students, or could be used as a site for uncovering information for a student’s research project. Also see Fred Hutch’s COVID-19 Testing and Inequities curriculum unit developed by the Science Education Partnership, mentioned above, which focuses on the science behind COVID-19 testing.

PATH INFO PAGE
PATH Responds to COVID-19 is a webpage that collects information that shows how a Seattle-based global health organization is responding to the pandemic across multiple fronts, from research to printing face shields. This page could be used as a site for uncovering information for a student’s research project.

ONLINE GAME
Foldit is a gamified, crowdsourced, citizen science project from the University of Washington focused on protein folding. Their new module focuses on finding antiviral drugs that might stop coronavirus.
Keeping Up to Date on COVID Research News

**BLOG**
Science educator Michael DiSpezio's blog, *Understanding COVID-19: The Science, Spread, and Therapies* is focused on helping teachers understand and teach about COVID-19. Also check out his COVID-focused twitter handle @mdispezio.

Various Teaching Resources on Coronavirus/COVID-19

**MUSEUM EXHIBIT**
Pacific Science Center's *Understanding Covid-19* offers virtual interactive exhibits for students to explore online. These exhibits include:

- Facts in the Time of COVID-19
- Vaccines and Immunity: It Takes a Village
- COVID-19 Interactive Glossary of Terms
- Behind the News: Coronavirus
- Uncovering Reality (data literacy)

**LESSON PLANS**
Ed Week offers three teacher-authored lessons for science, math, and media literacy on coronavirus COVID-19.

**CASE STUDIES**
The National Center for Case Study Teaching in Science offers a variety of case studies focused on coronavirus and COVID-19.

**TEACHING RESOURCES**
For helping students understand the laboratory processes for COVID-19 testing, check out Bio-Rad Laboratories' *COVID-19 Teaching Resources*:

- ELISA antibody test animation
- ELISA antigen test animation
- PCR animation
- ELISA paper model activity
- PPT: Biology of SARS-CoV-2 Coronavirus
- PPT: Detection Methods for SARS-CoV-2

Microbes

**CURRICULUM UNITS**
*Edcurrious* offers a two-week long middle school level, project-based learning units that were produced in partnership with *National Geographic*. These are available as open-access educational materials with no charge.

- **Misunderstood Microbes**: Students learn to make connections between the systems of the human body and common microbes that live in and on humans.
- **Menacing Microbes**: Students learn about how communities prevent and contain outbreaks of infectious diseases.

Handwashing

**ARTICLE**
This article for students focuses on the "Chemistry of Hand Washing & Covid-19", and was adapted by Jeanne Norris, WUSTL Institute for School Partnership from a Twitter thread by Palli Thordarson, Professor of Chemistry.

**TEACHING PROP**
School nurses, parents, and others are focusing a lot of energy on teaching kids proper handwashing techniques. *GloGerm Gel or Powder* along with a UV-light is a great way to teach kids how to wash their hands (and shows them if they haven’t been doing a good enough job). There are some great lesson plans available that visually demonstrate disease transmission too. A quick Google search will turn up classroom activities using this fun product.
Bioethics

CURRICULUM MATERIALS
The Northwest Association for Biomedical Research offers a collection of bioethics curriculum units for high school science teachers. These include a unit focused on the ethics of research with humans, which is applicable to COVID-19 vaccine trials.

CURRICULUM UNIT
Also see the COVID-19 Testing and Inequities curriculum unit developed by the Science Education Partnership at Fred Hutchinson Cancer Research Center, mentioned above (See Lessons 4 and 5).

Global Health Topics & Careers

CURRICULUM UNIT
Washington Global Health Alliance’s STEM Global program offers this 10th grade Global Health curriculum which includes lesson plans for U.S. History, General Chemistry, and Advanced Algebra focused on the global health topics of influenza, cholera, malaria, and tuberculosis. Students might be interested in engaging with data and cases from other relevant examples like these, and teachers might consider ways to adapt these materials (or inspire new lessons) to the COVID-19 pandemic.

STEM CAREER RESOURCES
STEM Global also provides career resources. What types of careers work in the global health sector? Share this careers poster and these accompanying fact sheets with secondary students to help them understand the many kinds of expertise that come together to make up this interdisciplinary field.
**BMGF Discovery Center Field Trips**

**Brief Overview:** The Bill & Melinda Gates Foundation Discovery Center—located near Seattle Center—provides free field trip (in-person and virtual) opportunities for students to engage with contemporary global health challenges and innovative solutions in a museum-like setting. At the Discovery Center, students will encounter powerful stories about the impact of the Bill & Melinda Gates Foundation and its partners toward improving the quality of life for billions of people. The interactive exhibits let students explore first-hand bold, innovative solutions to the most pressing challenges facing communities around the globe. Bring your curiosity and leave inspired to take action for a cause you care about!

**Permanent exhibits include four galleries and a theater:**

- Welcome (welcome video and digital narratives of BMGF founders and partners)
- Our Work (reducing inequities in poverty, health, and education)
- Global Challenges (interactive display of data-driven approaches)
- Fighting Disease (vaccines, maternal/child health, drugs, and diagnostics)
- Get Involved (inspiration and ideas for changing the world)
- Make a Difference Now (action projects and ideas for immediate impact)

**Virtual Exhibition: Enduring COVID-19: Stories from Our Transforming World**

Explore our new virtual exhibit Enduring COVID-19: Stories from Our Transforming World to hear powerful stories of communities coming together. This Exhibition will open at the Discovery Center Spring 2022.

Learn more about booking an in-person or virtual field trip at discovergates.org
ALIGNMENT TO THE NEXT GENERATION SCIENCE STANDARDS

A field trip to the Discovery Center will be customized based on your group (student ages, size of group, interests) and what you do to prepare for and reflect on students’ experiences while visiting the Center. However, there are opportunities in the galleries, films, special exhibits, and interpreter-led activities for your students to engage in concepts and practices that relate to science and engineering education as outlined in the Next Generation Science Standards. These potential NGSS alignments are identified on the table to the right, with a focus on the ones most salient to students’ likely interactions in the Discovery Center. Field trip experiences will also likely relate to humanities standards.

<table>
<thead>
<tr>
<th>Science and Engineering Practices (SEPs)</th>
<th>Disciplinary Core Ideas (DCIs)</th>
<th>Crosscutting Concepts (CCCs)</th>
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<tbody>
<tr>
<td>Asking questions and defining problems</td>
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<td>Analyzing and interpreting data</td>
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<td>Constructing explanations and designing solutions</td>
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<td>MS-ESS3: Earth and Human Activity</td>
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<td>HS-ESS3: Earth and Human Activity</td>
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<td>MS-ETS1: Engineering Design</td>
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<td>HS-ETS1: Engineering Design</td>
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<td>Systems and system models</td>
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<td>Structure and function</td>
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<td>Stability and change</td>
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<tr>
<td>Understandings about the Nature of Science</td>
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<tr>
<td>• Science is a human endeavor</td>
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<tr>
<td>• Science addresses questions about the natural and material world</td>
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**CONNECTING TO STEM GLOBAL CURRICULUM RESOURCES**

The following table shows some explicit connections between the activities featured in the STEM Global curriculum collection and exhibits and resources at the Discovery Center.

<table>
<thead>
<tr>
<th>Connecting to STEM Global Curriculum Resources</th>
<th>COVID Testing</th>
<th>Diagnostic Detective</th>
<th>Code Cracking</th>
<th>Data Driven (HS)</th>
<th>Data Driven (MS)</th>
<th>Drone Drop Challenge</th>
<th>Special Delivery</th>
</tr>
</thead>
</table>

**IN THE GALLERIES—ENGINEERING DESIGN:**
Examples of engineering design and design thinking can be found throughout all the galleries. Ask students to look for examples of engineering problems, criteria/constraints, ideation, understanding user needs and preferences, prototypes, testing methods, and dissemination strategies. In the permanent exhibits, look for innovative and low-cost solutions to toilets, mosquito nets, vaccine coolers, and more.

Design thinking strategies are featured in the Get Involved gallery. Encourage students to invent a solution using computer-based prompts or try out the hands-on prototyping station.

**IN THE GALLERIES—VACCINES:**
The Fighting Disease gallery showcases how vaccines help fight deadly diseases. Students can check out a vaccine vial transport cooler, and examine color-changing vaccine vial stickers that tell if the vaccine has been heat-damaged. Learn more about how PATH’s freeze-preventive vaccine carrier is being used in India and Nepal.

**Learn more:**
- [https://path.org/vaccines/](https://path.org/vaccines/)
- [https://www.path.org/articles/vaccine-vial-monitor-worlds-smartest-sticker/](https://www.path.org/articles/vaccine-vial-monitor-worlds-smartest-sticker/)

**IN THE GALLERIES—COVID-19:**
In the virtual exhibit *Enduring COVID-19: Stories from Our Transforming World*, students can hear powerful stories of communities coming together in the face of a global pandemic.

**IN THE GALLERIES—MATERNAL/INFANT/CHILD HEALTH:**
The Fighting Disease gallery features some of PATH’s other innovations, focusing on those protecting maternal/infant health. Encourage students to try feeding, weighing, resuscitating, and wearing (Kangaroo wrap style) the newborn infant dolls. Along the wall, students can investigate other PATH innovations, including a low-cost safe delivery kit for childbirth.

**Learn more:**
- [https://path.azureedge.net/media/documents/TS_update_delivery_kit.pdf](https://path.azureedge.net/media/documents/TS_update_delivery_kit.pdf)
CONNECTING TO STEM GLOBAL CURRICULUM RESOURCES, CONT.

IN THE GALLERIES—HIV TESTING AND LOW-COST DISEASE DIAGNOSTICS:
Learn how free HIV at-home test kits are being used in South Africa. Other innovations include low-cost diagnostic tests using paper-based fluidics.
Learn more:
  (HIV Test Kit, see page 63 and other diagnostic tests, see pages 43-46)
• https://www.gatesfoundation.org/What-We-Do/Global-Health/HIV

IN THE GALLERIES—DATA-DRIVEN SOLUTIONS TO GLOBAL CHALLENGES:
In the Global Challenges gallery, students can see how the BMGF uses data to drive their work toward some of the toughest global challenges. Gather around a giant digital map and discover global trends related to key issues of poverty and health, across time and region. Pick up one of the “pucks” to dive deeper into topics, stories and facts. Share what you have discovered to the big screen. Elsewhere in the Global Challenges and Fighting Disease galleries, encourage students to consider the ways that data is used and represented throughout the exhibit to explore topics related to child mortality rates, global immunization rates, poverty rates, and more. Encourage students to notice the types of data representations (i.e., line graphs, bubble charts, concept maps, and more).

FIELD TRIP EXPERIENCES:
When booking your field trip (in-person or virtual), consider mentioning a specific focus on engineering design, vaccines, or whatever your particular area of interest. Interpreters have several activities to choose from, including a Design a Milk Jug challenge, and activities focused on vaccine transport and delivery, menstrual products, global health data, malaria parasites, intestinal parasites, COVID-19, and more!
Brief Overview: This free virtual field trip experience is offered by the Gates Foundation Discovery Center. The focus of this program allows for its integration into courses across disciplines, including science. However, rather than focusing on the science behind the virus or disease, this program provides students with an opportunity to create their own COVID-19 story through interactive and creative activities designed to help students reflect on the impact of the pandemic on their lives since March 2020.

Writing and drawing are pathways for consciousness-raising of context matters as we navigate the human experience, especially during the COVID-19 pandemic. This program invites students to curate their personal stories in writing, illustration, or other formats. Students will share their personal stories and “pandemic perspectives” with their peers. Students will also walk away with reflective prompts to share their stories with others, in both the present and post pandemic future.

Resources for extension activities are available on the program website. Live captioning is available through the Microsoft TEAMS meeting platform. An ASL interpreter can be arranged with a minimum advance notice of two weeks.

Student Understandings

ANCHORING PHENOMENON:
The COVID-19 global pandemic has impacted people across the world. However, the effects of the pandemic disproportionately affect people based on their community, access to healthcare, income level, employment type, understandings of scientific and medical discoveries, and other factors. Media portrayals capture some of the similarities and differences of people’s individual and collective experiences during this challenging time. As students learn about and personally experience the disparities surfaced and exacerbated by the pandemic, it is important to give both space and structure to allow them to process these feelings and experiences.
DRIVING QUESTIONS:
► How can we reflect on and respond to our individual and collective experiences within the context of the COVID-19 pandemic?
► How can we think critically and reflect honestly on the impact of the pandemic and its effect on our lives?
► How can we document through writing and illustration our COVID-19 experience?

Alignment to Science and Social Emotional Learning Standards

NEXT GENERATION SCIENCE STANDARDS
This lesson builds toward the following high school level Nature of Science Standards from the Next Generation Science Standards.

Nature of Science: Science Addresses Questions about the Natural and Materials World
► Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.
► Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.
► Many decisions are not made using science alone but rely on social and cultural contexts to resolve issues.

WASHINGTON STATE SOCIAL EMOTIONAL LEARNING STANDARDS
This lesson builds toward the following high school level Social Emotional Learning Standards developed for the Washington Office of Superintendent of Public Instruction by the SEL Workgroup.

Standard 1: Self-Awareness - Individual has the ability to identify their emotions, personal assets, area for growth, and potential external resources and supports.
• Benchmark 1A: Demonstrates awareness and understanding of one’s own emotions and emotion’s influence on behavior.
• Benchmark 1C: Demonstrates self-awareness and understanding of external influences e.g., culture, family, school, and community resources and supports.

Standard 4: Social Awareness - Individual has the ability to take the perspective of and empathize with others from diverse backgrounds and cultures.
• Benchmark 4A: Demonstrates awareness of other people’s emotions, perspectives, cultures, languages, histories, identities, and abilities.

Credit: COVID-19: Your Story program and associated materials were developed by members of the Triangle Associates, a consulting firm located in Seattle, WA for use by the Gates Foundation Discovery Center in Seattle, WA. This virtual field trip program is offered by the Gates Foundation Discovery Center. The program’s pilot, COVID-19: In Context, was presented at a STEM Global Educator Workshop in January 2021.
Additional Global Health Education Resources

Through the STEM Global program, the Washington Global Health Alliance and its member organizations are inspiring and preparing the next generation of global health researchers, practitioners and champions. Students can experience global health in action and learn how STEM skills solve the world’s most complex problems and increase health equity. Teachers can explore new ways to integrate global health into their classrooms and champion global health opportunities for their students.

The STEM Global website hosts a list of resources for educators and students interested in learning more about the field of global health.

Resources for Educators:
- Curricula on COVID-19
- Curricula on Global Health Topics
- Tools for Further Exploration

Resources for High School Students:
- Tools for Further Exploration
- Global Health Careers and Job Search Resources
If you have any questions, comments or feedback regarding this collection of STEM Global curriculum, please contact us at admin@wghalliance.org