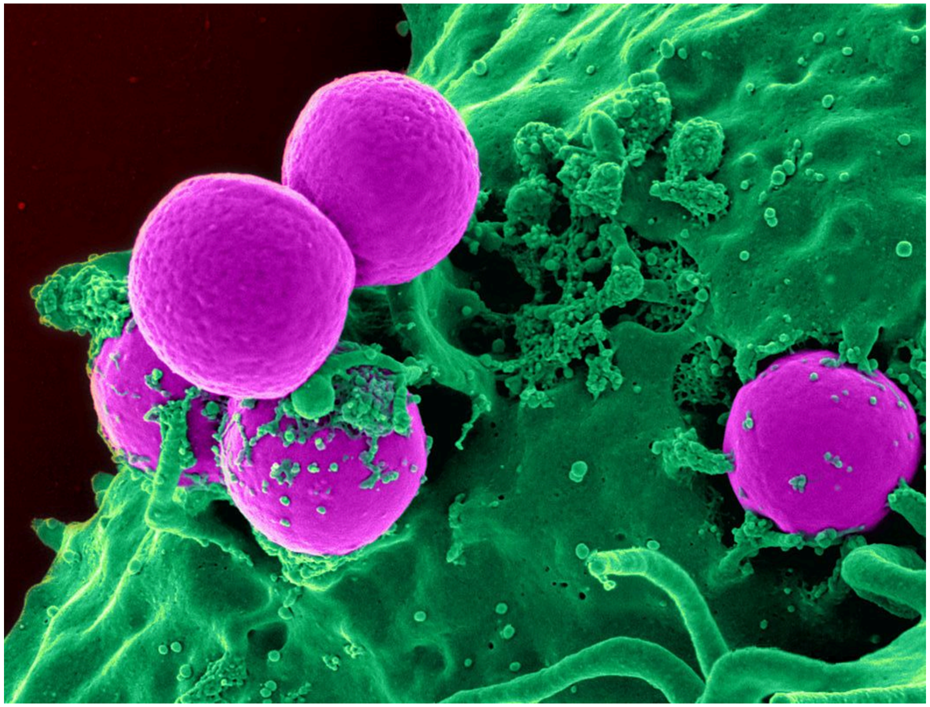
Humans vs. Bacteria - Teacher Materials

Unit 2	Biology



The Curriculum and Instruction Department at New Visions for Public Schools develops free, full-course materials for all areas of high school science, math, ELA, and social studies, for use across our network of 80 New York City schools and beyond.

Unit 2 Humans vs. Bacteria Table of Contents

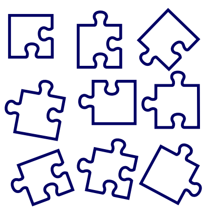
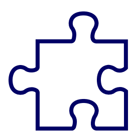
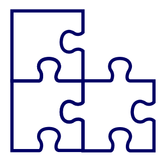
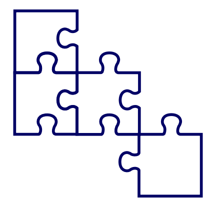
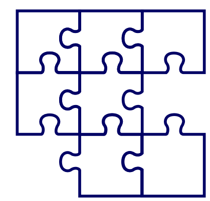
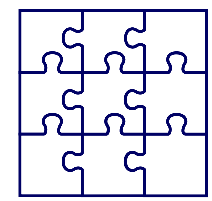
Unit 2 Humans vs. Bacteria
Natural Selection and Evolution

Performance Expectations
HS-LS4-2, HS-LS4-3, HS-LS4-4, HS-LS4-5, HS-LS2-8

Time
33-39 days

How has evolution shaped how humans and bacteria interact? How can we prevent future outbreaks of bacterial infections?

Bacteria are found everywhere: in extreme environments and living in, on, and around us. Some are harmful, some are beneficial, and some barely impact humans at all. Through the forces of natural selection, humans have entered an evolutionary arms race with virulent bacteria that may have lead to a global increase in bacterial infections. At the same time, bacteria have evolved to cooperate both with humans and each other in order to survive and flourish. In this unit, students will consider the factors that impact the rate and scale of evolution and will develop an argument outlining the best strategy to use in preventing a future outbreak. Will human society be able to develop new therapies and technologies in order to fight antibiotic-resistant bacteria and the re-emergence of infectious bacterial diseases?

Unit Opening	The Black Death 5E	Antibiotic Resistance 5E	The Microbiome 5E	Cooperation & Survival 5E	Unit Closing
Anchor Phenomenon	→	**5E Lessons connect learning to the performance task**		→	**Performance Task**
					
Why are bacterial diseases increasing globally? How can we prevent new disease outbreaks?	*What can we learn about infectious disease transmission from past outbreaks like The Black Death? Why were some people able to survive, when so many people did not?*	*Why aren't antibiotics working as well as they used to?*	*How do humans interact with bacteria? How can we fight bacterial infections using other bacteria?*	*How do bacteria interact with each other? How can we leverage those interactions to fight infections?*	*How can we best prevent a future outbreak of cholera?*

Unit Introduction

> This unit is a great way to push your students' thinking above and beyond. Students get super excited to discuss topics that are relevant to today's issues such as antibiotic resistance, and fecal matter transplants. It is a well-designed unit that focuses on the NGSS science practice of engaging in argument from evidence. I was impressed to see how every student was engaged in the end-of-unit Socratic seminar discussing different approaches on how to prevent a future cholera outbreak.
>
> - Andrea Sau, HS teacher in Bronx

How do we make science education meaningful and relevant to our students? High school biology courses are traditionally filled with lectures and cookbook labs, memorizing vocabulary, and an occasional research report. New science education standards (NGSS/NYSSLS) require a more engaging, accessible vision of science teaching and learning to help all students learn about the natural world and become scientifically literate citizens.

The three-dimensional, phenomenon-driven materials in this unit support students in engaging in the authentic practices of science. Students construct meaning about the natural world through modeling, investigations, labs and experiments. As students have opportunities to manipulate the physical tools of science, they also engage in productive struggle that can be resolved through evaluating claims using evidence and engaging in consensus building discussions. The materials support teachers in becoming skillful facilitators of student sense-making and deepen teachers' understanding of how to teach science in an interactive way that is driven by students' questions and ideas.

Problem-solving is also an essential 21st century skill, and through this unit students deepen their understanding of the importance of engaging with problems in science. In addition to figuring out causes for how a future bacteria outbreak can occur, they also learn how to make an argument for the best potential solutions to this relevant and life-threatening global phenomenon.

Unit 2 was co-designed with a content expert, Dr. Sandra Breum Andersen. Dr. Breum Andersen is an evolutionary biologist who researches the relationship between hosts and their microbial communities. She is currently working to understand more about the bacterium *Helicobacter pylori*, which lives in the human stomach. *H. pylori* is thought to have co-evolved with modern humans, and is renowned for causing stomach ulcers and cancer. Infection can, however, also protect against other diseases such as asthma and allergies. Dr. Breum Andersen worked closely with the unit development team providing ideas for investigations, investigative phenomena, writing texts, and identifying sources of original data. The final 5E learning sequence is based on her previous work researching bacterial cooperation in the context of cystic fibrosis patients.

This unit was intentionally designed to build on the first unit of this course, Marathon Runner, in which students generate models based on evidence. In Humans vs. Bacteria, students continue to engage with claims and evidence in order to develop a scientific argument. The common embedded group learning routines and curriculum structures introduced in the first unit are revisited, providing students and teachers multiple opportunities to engage in a culture of collaborative sensemaking around a phenomenon. In this unit, students are encouraged to figure out why infectious diseases are on the rise, and how best to interact with the millions of bacteria that have co-evolved to live in, on, and around us.

The embedded group learning routines and formative assessments found in each of the Biology units support teachers in learning about their students, both academically and personally. Whether students had strong science programs prior to high school, or if three-dimensional teaching and learning is brand new to them (or to the teacher!). This unit is designed to reinforce and further build on students' earlier experiences with three-dimensional learning.

Unit Coherence

In Unit 2, the overall question about humans' interactions with bacteria is intended to motivate student engagement across the unit. It is our intention that from the students' perspective, there is a clear and explicit unit storyline that guides the sequence of activities. Rather than one long continuous unit, we have chosen to use an instructional model to develop four coherent learning sequences within Unit 2. Each sequence builds towards figuring out something that contributes to explaining the overall unit-level question about why infectious diseases continue to increase, even with modern access to antibiotics. The phenomena, the instructional model, and the routines embedded throughout the sequences of lessons are all used in service of coherence across Unit 2.

Phenomenon-Driven Instruction

Phenomena are a key part of instruction in *A Framework for K-12 Science Education* and the NGSS. As in the work of scientists, students should be encouraged to move from observable phenomena to generalizable explanations of the natural world. Too often, traditional science instruction has started with generalizable principles, sidelining the lived experience and intuitions that all young people bring to school. In this unit (and all New Visions units) there are two kinds of phenomena: anchor phenomena and investigative phenomena.

Anchor Phenomenon	Investigative Phenomena
• One per unit; drives the learning of the unit • Attention-grabbing and relevant • Does not have to be phenomenal	• One per 5E sequence (four in this unit) • Presented in the Engage phase of each 5E

Anchor Phenomenon

To support coherence, students are prompted to figure out one overarching, real-world question over the course of the unit. The anchor phenomenon question is revisited across the unit, and this question motivates the investigations conducted in each of the 5E instructional sequences. A good anchor phenomenon should be attention-grabbing and relevant to students but also thought-provoking, comprehensible, and connected to the science learning goals. It needs to be observable to students through firsthand experiences or through someone else's experiences, such as through a video or secondary data. If a teacher feels the anchor phenomenon will not be familiar or accessible to all students, we suggest relating it to similar, more familiar phenomena. It is important to notice that the phenomenon question anchoring the unit is different from the more generalized and abstracted science question for the unit. This difference is part of what helps make the unit more student-centered, rather than teacher-centered.

Investigative Phenomena

Based on the Anchor Phenomenon and three-dimensional learning goals for students for the unit, each 5E instructional sequence has a related investigative phenomenon, typically presented in the Engage phase. This phenomenon brings students together around a shared puzzle or experience that frames the learning for that 5E sequence. Similar to the anchor phenomenon question, the questions about the investigative phenomena are intended to be specific and contextualized, rather than the traditional content questions teachers use as their lesson aims. They present what is being figured out; therefore, the scientific concepts that are in the learning goal cannot be part of the wording of the question!

Solving Problems

One of the major NGSS shifts is integrating engineering into science instruction. Defining problems and developing and optimizing solutions are critical components of engaging in addressing significant global and social problems within an NGSS-designed high school science course. After being presented with the unit anchor phenomena, students are naturally inclined to want to do something about it - and thus students' investigations across a unit are also motivated by the desire to solve the related problem. This engineering thread is intertwined with the anchor phenomenon as the science figured out is useful in arguing for a causal explanation of the phenomenon *and* figuring out a solution.

Storyline and Pacing Guide

Unit Opening	Why are bacterial diseases increasing globally? How can we prevent new disease outbreaks?	**Performance Expectations**	**Anchor Phenomenon** The number of deaths from infectious diseases is increasing globally. Why, after decades of declining deaths from infectious disease, have we seen a resurgence of outbreaks?	**Time** 3-4 days

Student Questions	What Students Do	Student Ideas
These questions motivate the unit storyline: • Could we have a devastating future outbreak of cholera in NYC? • How can we learn about one pandemic to better understand preventing all future pandemics? • Why don't antibiotics always work? • How do we live peacefully with some bacteria while others make us sick? • How can we develop alternative medicines or strategies to fight bacterial infections?	Students read text and data tables in order to tell the story of how infectious diseases are increasing and re-emerging after many decades of success in decreasing infectious disease globally.	*These ideas are revisited throughout the unit storyline.* • There have been many outbreaks of bacterial disease in the past (such as the Black Death) and recently (such as TB). • From our recent experiences with COVID-19, we know that disease outbreaks can cause devastating impacts on our families and communities. • For approximately the past 100 years, the number of deaths from infectious diseases decreased, but recently they have started to increase again. • In the past, we fought virulent bacteria with antibiotics, but those drugs don't always work now. • Some infectious diseases, like cholera, are very contagious.

During the Driving Question Board routine, student questions related to how diseases spread or how we have dealt with outbreaks in the past will come up. Once a category related to these questions has been articulated, let students know that over the next sequences of lessons they will be investigating this question to figure out how disease spreads and how some people were able to survive past pandemics like The Black Death.

The Black Death 5E

What can we learn about infectious disease transmission from past outbreaks like The Black Death? Why were some people able to survive, when so many people did not?

Performance Expectations
HS-LS4-3, HS-LS4-4, HS-LS4-2

Investigative Phenomenon
The black plague killed close to 50% of the population in Europe, but some people survived.

Time
8-9 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • How do bacteria make us sick? • How are infectious diseases passed between people? • Why was the Black Death so deadly? How did some people survive the Black Death? • How do variations between people help them survive? • Why are some variations more beneficial to organisms? • How can learning about immunity and how diseases are transmitted help us prevent a future outbreak of cholera?	Students begin this instructional sequence by reading an historical document about the Black Death in order to generate ideas on how infectious diseases are transmitted between people. They engage in two different simulations to generate observations on how diseases spread and what variables impact how fast a disease can be transmitted to other people. Next, students use a text to evaluate claims about why the Black Death generated such a high death toll. This activity leads to questions about why some people were able to survive this deadly pandemic. Students collect and analyze data on population variation in rock pocket mice in order to surface that due to selection pressures in the environment, certain variations or traits can become beneficial and contribute to survival. Students use sequence charts to make connections between the pocket mice and human variation, including variations in the immune system. Finally, students use evidence collected throughout the 5E sequence to evaluate claims on how to best prevent a future cholera outbreak.	*Students figure out these ideas in this 5E sequence.* • Infectious disease transmission increases with high population density, high population mixing, and poor hygienic conditions. • Some diseases are more contagious and virulent than others. • The Black Death was transmitted through flea bites and through bodily fluids. • Individuals in a population contain variations, some of which are visible (hair/fur color) and some that are not (blood type, lactose tolerance). • Depending on the environmental pressure, a specific variation of a trait may be beneficial; this is called an adaptation. • Possessing beneficial variations of traits may lead to differential survival and differential reproduction. • Differences in human immune systems may have been one contributing factor for those that survived the Black Death.

Have students identify which categories/questions they have not addressed yet. One question category should relate to questions about antibiotics: how they work and why they are not always effective in controlling virulent bacteria. Tell students that in the next sequence of lessons, they will investigate why antibiotics don't always work.

Antibiotic Resistance 5E	Why aren't antibiotics working as well as they used to?	**Performance Expectations** HS-LS4-3, HS-LS4-4, HS-LS4-2, HS-LS4-5	**Investigative Phenomenon** A thousand feet under the New Mexico soil, in the deepest limestone cave in the country, researchers have discovered an ancient bacterium that is resistant to many antibiotics used in human medicine today.	**Time** 7-8 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • Why are there bacteria that are resistant to antibiotics that have never been exposed to modern medicine? • Why does my doctor tell me to finish my entire course of antibiotics, even if I start to feel better? • How do bacteria become resistant to antibiotics? • How do antibiotics work? • Are there alternative ways to fight virulent bacteria, other than antibiotics?	Students begin by questioning why antibiotic resistance would be found in bacteria that live underground and have been isolated from humans and our modern medicine. After surfacing ideas, students engage with an antibiotic resistance simulation to better understand the pattern of how resistance develops. Next, students use cause and effect charts to evaluate the claim that the overuse of antibiotics in agriculture has led to widespread antibiotic resistance. Students make comparisons to their experiences with natural selection in pocket mice to make the connection that the spread of resistance is natural selection in action. Students use this idea to construct a scientific explanation about the cause behind antibiotic resistance in bacteria. Students then explore the idea of phages as an alternative strategy to fight virulent bacteria. Finally, students use the evidence from this 5E learning cycle to evaluate the claim that we should address antibiotic resistance as the primary strategy to prevent a future cholera outbreak.	*Students figure out these ideas in this 5E sequence.* • Bacteria naturally possess variations in traits, including resistance to specific antibiotics. • If the environmental conditions happen to select for that trait (in the presence of the antibiotic) then the bacteria possessing that trait have an advantage -- the presence of this advantageous trait in that environment is considered an adaptation. • Bacteria that possess the beneficial trait have differential survival, reproduce, and pass that trait on to offspring, and over time the population can change to reflect this process. • Resistance can occur in the bacteria in an individual patient, and at a larger scale across a population. • There is a great deal of evidence that the overuse of antibiotics in agriculture may be a contributing factor to the rise in antibiotic-resistant infections. • Phages, or viruses that attack bacteria, may be an alternative strategy that can be explored to replace ineffective antibiotics.

Have students identify which categories/questions they have not addressed yet. One question category should relate to how humans and bacteria interact without making us sick. Tell students that in the next sequence of lessons, they will investigate the human microbiome and how most bacteria interact in a neutral or positive manner with humans.

The Microbiome 5E	How do humans interact with bacteria? How can we fight bacterial infections using other bacteria?	**Performance Expectations** HS-LS4-4, HS-LS4-5	**Investigative Phenomenon** People are being cured of C. diff infections using fecal transplant	**Time** 7-8 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • How can a bacterial infection be treated by different bacteria? • Are there 'good' or helpful bacteria? • Do people have different bacteria that live in/on them? • How are the microbiome and an ecosystem similar to each other? • How do we have so many bacteria on/in us but we are not sick all of the time? • Do some people have 'better' microbiomes than other people?	Connecting to their earlier questions about all of the bacteria we have living in/on us, students share their initial questions about how some doctors treat recurrent bacterial infections with a fecal transplant (transplanting the microbiome of a healthy donor to a patient). They compare the microbiomes of different groups of people to surface the pattern that some groups of people (hunter-gatherers) have many more types of bacteria in the microbiome or a more diverse microbiome. In order to better understand the impacts of this phenomenon, students compare the microbiome to an ecosystem in order to surface the importance of diversity and stability in both contexts. Students use what they discovered about the human microbiome to evaluate a claim on whether or not it would be helpful for everyone to have a fecal transplant so that our microbiome better reflects that of the Hadza (hunter-gatherers in Tanzania). Students use an Evidence Gradient organizer to evaluate the evidence for their claim. Finally, students consider what they have learned about the microbiome to evaluate a claim about how to best prevent a future outbreak of cholera.	*Students figure out these ideas in this 5E sequence.* • Humans in Westernized/industrialized societies (like the USA) have less diverse microbiomes than those living closer to a hunter-gatherer lifestyle. • Diversity, both in terms of an ecosystem and in the microbiome, is beneficial in maintaining health and stability. • Humans rely on symbiotic bacteria for many reasons including breaking down food, releasing beneficial compounds, and out-competing pathogenic bacteria in our gut. • Our microbiome and the existence of specific species are determined by the environment and the food we eat. • Bacteria and humans have, in some cases, co-evolved through the process of natural selection. • Some species of symbiotic bacteria may be going extinct due to human changes in diet and environmental conditions.

Have students identify which categories/questions they have not addressed yet. One question category should relate to questions about alternative strategies to fight bacteria or how bacteria interact with each other. Tell students that in the next sequence of lessons, they will investigate the relationships between bacteria and how those relationships may be leveraged to fight infections.

Cooperation & Survival 5E	How do bacteria interact with each other? How can we leverage those interactions to fight infections?	**Performance Expectations** HS-LS2-8	**Investigative Phenomenon** Bacteria develop biofilms as one way to communicate and cooperate.	**Time** 6-7 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • Why do bacteria form biofilms? • Why do bacteria cooperate with each other? • Why and how do bacteria communicate with each other? • How do other organisms cooperate? • How can we leverage cooperation between bacteria to fight infections?	Students share their initial ideas about why bacteria cooperate to form biofilms. They engage with a simulation about cooperation and analyze a secondary data set on *cooperators* versus *cheaters*. Students use surfaced patterns to construct a scientific explanation of how cooperative behaviors have evolved through natural selection. Then, students brainstorm how we can leverage these cooperative behaviors to fight infections. Students are then asked to consider how cooperative behaviors may have evolved in other organisms, such as the cooperative feeding seen in many marine mammals. Finally, students use their understanding of how bacteria communicate and cooperate to evaluate a claim about the best way to prevent a future outbreak of cholera.	*Students figure out these ideas in this 5E sequence.* • Bacteria, like all organisms, are faced with a set of challenges to their survival. • Bacteria, like many organisms, cooperate and communicate in environments that favor those behaviors. • Cooperative behaviors evolve in organisms through the process of natural selection. • We can leverage what we know about cooperative behaviors in bacteria, such as their use of quorum sensing to communicate with each other, to fight pathogenic infections.

Students work individually to evaluate the claim: “We should leverage cooperative behaviors to fight a future outbreak.”

Unit Closing

How can we best prevent a future outbreak of cholera?

Performance Expectations
HS-LS2-8, HS-LS4-2, HS-LS4-3, HS-LS4-4, HS-LS4-5

Anchor Phenomenon
The number of deaths from infectious diseases is increasing globally. Why, after decades of declining deaths from infectious disease, have we seen a resurgence of outbreaks?

Time
2-3 days

Student Questions	What Students Do	Student Ideas
These questions are addressed in the performance task. • How can we prevent future outbreaks of bacterial diseases? • Why don't antibiotics always work against an infection? • How do humans and bacteria interact? • How is disease transmitted?	Students generate a final scientific argument that proposes the best solution to prevent a future cholera outbreak. To do this, students evaluate each of the claims investigated throughout the unit and decide on the best-supported claim. Students support their claim using evidence and scientific reasoning from the unit. **Extension** Consider organizing a Socratic Seminar for students to share and critique the arguments of others. This activity provides multiple opportunities for students to engage through reading, writing, and discussion.	*These ideas were developed throughout the unit storyline.* • Humans and bacteria have co-evolved over time and are not necessarily enemies. • Bacteria quickly evolve new traits, such as antibiotic resistance, because they have short generation times. • The majority of bacteria surrounding us are neutral to our health, or even beneficial. • The rate of transmission of disease is dependent upon factors such as the population density and contagiousness of the disease. • Humans may be able to use our understanding of how bacteria cooperate and communicate to avoid or reduce the severity of bacterial disease. • Quality evidence for a scientific argument is based on observations and data.

As students' questions about preventing diseases have been answered, and the various claims about solutions have been evaluated, students develop a final argument about disease prevention.

Unit Standards

This unit is designed to meet Next Generation Science Standards Performance Expectations. Since this unit is part of a full-year Biology course, the design includes intentional foregrounding of a limited number of Crosscutting Concepts (CCCs) and Science and Engineering Practices (SEPs). Further, since an aspect of NGSS design is connections to Common Core Math and ELA standards, these connections are highlighted in this section.

Performance Expectations

HS-LS4-2 **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.**
Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.
Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.

HS-LS4-3 **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.**
Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.
Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.

HS-LS4-4 **Construct an explanation based on evidence for how natural selection leads to adaptation of populations.**
Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.
Assessment Boundary: None

HS-LS4-5 **Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.**
Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.
Assessment Boundary: None

In NYS the clarification statement has been edited as follows: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, introduction of invasive species, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.

HS-LS2-8 **Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.**
Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.
Assessment Boundary: None

Unit Standards

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Three-Dimensional Learning Goals in This Unit

Given the breadth of three-dimensional standards for high school biology, Unit 2 focuses primarily on ideas related to evolution, natural selection, and adaptations. These ideas fall mostly within Core Idea LS4 of the NGSS/NYSSLS, Biological Evolution: Unity and Diversity. This unit also introduces students to the SEP of Engaging in Argument from Evidence. That is not to say that students will not engage in other SEPs throughout the lessons; however, it is important to foreground and be explicit about a limited number of practices with enough duration to see how students develop their understanding and ability to use this practice. This is important for both student and teacher learning! Similarly, the foregrounded CCC for this unit is Cause and Effect, which fits well with our selected SEP. As students deepen their understanding of the content to understand how and why infectious diseases spread, they learn how to use multiple lines of evidence to make causal claims and strengthen arguments. Scaffolding across the unit supports students' three-dimensional learning and will help shift classrooms to become more NGSS-aligned spaces.

Three Dimensions in Unit 2

This chart is a high-level summary of the standards for Unit 2. For more detail about specific elements, see the section on Assessment later in this document.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence	LS2.D Social Interactions and Group Behavior	Patterns
Asking Questions and Defining Problems	LS4.B Natural Selection	Cause and Effect
Analyzing and Interpreting Data	LS4.C Adaptation	
Constructing Explanations and Designing Solutions		
Obtaining, Evaluating, and Communicating Information		

Building on Middle School

High school science teaching necessarily builds on student learning from middle school. It is helpful to consider the middle school standards in order to enact a unit that builds on students' prior experiences. As we are in the middle of a multi-year transition, however, it is also critical to keep in mind that not all students will have experienced an NGSS-designed unit when they come to high school, so the process of building on middle school learning may be particularly complex for years to come. The following sections detail the ways in which this unit builds on middle school standards across the three dimensions.

Science and Engineering Practices from Middle School

Analyzing and Interpreting Data

- Students in middle school have previous experience using graphical displays, such as graphs and charts, to identify relationships and to distinguish between causal and correlational relationships. This unit builds on this practice, providing students with multiple opportunities to engage with complex visual representations of data and using concepts of statistics and probability in order to evaluate claims of causal relationships.

Construction Explanations and Designing Solutions

- Students in middle school have previous experience constructing scientific explanations based on evidence; in high school, they expand their use of evidence and focus on revising based on feedback. This unit builds on this practice prompting students to use a variety of valid data sources as evidence, including from simulations, to construct an explanation. Peer feedback is used to engage students in revising and evaluating their explanations.

Engaging in Argument from Evidence

- In middle school, students have previous experience constructing arguments supported by evidence and reasoning, as well as experience comparing and critiquing each others' arguments; in high school, they develop a deeper understanding of how to evaluate the strength of evidence for different claims, and use evidence to critique different arguments. This unit builds on the practice of Engaging in Argument from Evidence through scaffolded speaking and writing experiences.

Disciplinary Core Ideas from Middle School

LS4.B Natural Selection

- In middle school, students learn that natural selection leads to the predominance of certain traits in a population. In high school, they examine the conditions necessary for natural selection to impact the distribution of traits in a population. In this unit, students engage in multiple opportunities to closely examine different examples of natural selection (such as the development of antibiotic resistance and the variation of fur color in mince) and are supported in surfacing the key components of the process such as the variation of traits and how the expression of those traits may lead to differences in performance at the organism and population levels.

LS4.C Adaptation

- Students in middle school learn that adaptation by natural selection over time is an important process that allows organisms to change over time based on environmental conditions. In high school, students greatly expand their understanding of adaptation and its fundamental role in natural selection and change over time. Students also consider the extinction of species that can no longer thrive and reproduce in a changing or altered environment. This unit supports students in developing a more complex understanding of adaptation and natural selection through exploring these phenomena in multiple contexts. For example, students consider the advantageousness of symbiotic relationships between humans and their microbiota; as well as the extinction of some species of these bacteria in response to changing hygienic practices, the use of antibiotics, and changing human diets.

Crosscutting Concepts from Middle School

Cause and Effect

This unit builds on the following aspects of Cause and Effect in middle school.

- Students in middle school learn that relationships may be causal or correlational and that correlation does not always imply causation. This unit builds on this understanding by engaging students in multiple opportunities to evaluate possible causal relationships using empirical evidence. In evaluating claims throughout the unit, students are supported in differentiating between causation and correlation in order to identify the best supported claim.

Patterns

This unit builds on the following aspects of Patterns in middle school.

- Middle school students learn that patterns in data can be identified in graphs and images, and that these patterns can be used to identify cause and effect relationships. Students in middle school also learn that macroscopic patterns observed are related to what is happening at the microscopic level, which will be important in helping them understand and identify causal relationships in this unit.

Assessment

Performance expectations (PEs) in the NGSS describe what students should know and be able to do. Unit 2 targets a bundle of four PEs taken from the fourth core idea in high school life science (HS-LS4), *Biological Evolution: Unity and Diversity*; those standards are HS-LS4-2, HS-LS4-4, HS-LS4-4, and HS-LS4-5. We have also included HS-LS2-8, as it relates to the evolution of group behavior among bacteria. This PE bundle informs the types of three-dimensional tasks in which students engage across the unit. Each sequence of lessons within the unit targets elements from one or more of the performance expectations for the unit, and the teacher has opportunities to collect evidence of student learning around these elements within that learning sequence. The unit-level Performance Task only targets a subset of three-dimensional learnings goals informed by the bundled PEs for the unit. All other evidence of learning related the other dimensions/elements in the PEs can be found within the instructional sequences. It is important to note that for LS4.C(4), Unit 2 addresses all aspects of the element except for the concept of speciation. As written, the course does not include speciation explicitly. However, there are multiple opportunities for teachers to include this concept, especially in Unit 6.

The SEP of Engaging in Argument from Evidence is the primary foregrounded practice for this unit. Providing students with claims to evaluate is a scaffold. Ideally students will generate their own claims for the performance task, but as it's likely the first time they are using this SEP at high school level, teachers need to gauge students' proficiency early on. Based on students' needs, teachers can move forward with all claims provided, can modify them to better align with student-generated claims, or use entirely student-generated claims, keeping in mind the other instructional goals for the unit. Also in service of helping students develop this SEP at the high school level, there is a progression of support in their use of developing claims, identifying and evaluating evidence and using scientific reasoning. It is therefore the implications of these expected progressions that students might be unable to proficiently use this SEP at high school level early in the unit, but that they are by the end of the unit.

The **Teacher Materials** for each 5E instructional sequence includes a matrix that lists which student artifacts can provide evidence of student learning for each of three-dimensional learning goals from that sequence. Each 5E addresses the integration of the three dimensions across the activities. Please keep in mind that Explore/Explain phases in the matrix should be looked at together, as a continuous experience to assess the foregrounded three-dimensional learning goals across the two phases.

This unit was designed to support teachers in tracking student progress across the three dimensions, not for mastery within individual days of instruction. The targeted disciplinary core ideas (DCIs) listed below will be developed throughout the unit. While all of the science and engineering practices (SEPs) may be utilized across the unit, the target SEPs for the unit are listed below. Similarly, many crosscutting concepts (CCCs) may be useful in making sense of the phenomena in this unit, however the foregrounded, targeted CCCs are listed below.

The following Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts are assessed throughout the unit:

	The Black Death 5E	Antibiotic Resistance 5E	The Microbiome 5E	Cooperation & Survival 5E
Engaging in Argument from Evidence	✔	✔	✔	✔
Asking Questions and Defining Problems			✔	
Analyzing and Interpreting Data	✔	✔	✔	✔
Constructing Explanations and Designing Solutions		✔		✔
Obtaining, Evaluating, and Communicating Information			✔	
LS2.D Social Interactions and Group Behavior				✔
LS4.B Natural Selection	✔	✔	✔	✔
LS4.C Adaptation	✔	✔	✔	✔
Patterns	✔	✔	✔	✔
Cause and Effect	✔	✔	✔	✔

At the end of the unit, teachers will have evidence in student work (tasks) related to the elements listed in this table and can therefore make claims at the end of this unit related to student proficiency for all three performance expectations.

To support assessment throughout the unit, rubrics have been included in the **Student Materials** to support the Evaluate phase in every 5E instructional sequence. Teachers should customize these rubrics to support their schools' grading systems. Rubrics address both individual reflection, peer review, and the teacher's feedback. The Unit 2 Performance Task also includes a rubric, and the task can be considered a final summative assessment for the unit - we have not included a traditional "unit test" in our materials. Teachers may opt to create their final exam using their states' previous exam questions, however we believe that the formative assessment tasks embedded in the materials (such as the Looks and Listen For notes, the Explore phase summaries, and the modeling done in the Evaluate phases), along with the Performance Task can serve as sufficient evidence of what students know and can do.

Common Core State Standards (Mathematics)

Standards for Mathematical Practice

MP2 Reason abstractly and quantitatively.	Mathematically proficient students make sense of the quantities and their relationships in problem situations. Students bring two complementary abilities to bear on problems involving quantitative relationships: the ability to decontextualize—to abstract a given situation and represent it symbolically and manipulate the representing symbols as if they have a life of their own, without necessarily attending to their referents—and the ability to contextualize, to pause as needed during the manipulation process in order to probe into the referents for the symbols involved. Quantitative reasoning entails habits of creating a coherent representation of the problem at hand; considering the units involved; attending to the meaning of quantities, not just how to compute them; and knowing and flexibly using different properties of operations and objects.
MP3 Construct viable arguments and critique the reasoning of others.	Mathematically proficient students understand and use stated assumptions, definitions, and previously established results in constructing arguments. They make conjectures and build a logical progression of statements to explore the truth of their conjectures. They are able to analyze situations by breaking them into cases, and can recognize and use counterexamples. They justify their conclusions, communicate them to others, and respond to the arguments of others. They reason inductively about data, making plausible arguments that take into account the context from which the data arose. Mathematically proficient students are also able to compare the effectiveness of two plausible arguments, distinguish correct logic or reasoning from that which is flawed, and—if there is a flaw in an argument—explain what it is. Elementary students can construct arguments using concrete referents such as objects, drawings, diagrams, and actions. Such arguments can make sense and be correct, even though they are not generalized or made formal until later grades. Later, students learn to determine domains to which an argument applies. Students at all grades can listen or read the arguments of others, decide whether they make sense, and ask useful questions to clarify or improve the arguments.
MP4 Model with mathematics.	Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace. In early grades, this might be as simple as writing an addition equation to describe a situation. In middle grades, a student might apply proportional reasoning to plan a school event or analyze a problem in the community. By high school, a student might use geometry to solve a design problem or use a function to describe how one quantity of interest depends on another. Mathematically proficient students who can apply what they know are comfortable making assumptions and approximations to simplify a complicated situation, realizing that these may need revision later. They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions. They routinely interpret their mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose.

MP6 Attend to precision.	Mathematically proficient students try to communicate precisely to others. They try to use clear definitions in discussion with others and in their own reasoning. They state the meaning of the symbols they choose, including using the equal sign consistently and appropriately. They are careful about specifying units of measure, and labeling axes to clarify the correspondence with quantities in a problem. They calculate accurately and efficiently, express numerical answers with a degree of precision appropriate for the problem context. In the elementary grades, students give carefully formulated explanations to each other. By the time they reach high school they have learned to examine claims and make explicit use of definitions.

Standards for Mathematical Content

HSS-ID.C.9 Statistics & Probability	Statisitcs and Probability: Distinguish between correlation and causation

Common Core State Standards (ELA/Literacy)

Speaking and Listening Standards

SL.9-10.1	Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
SL.9-10.4	Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

Reading Standards for Literacy in Science and Technical Subjects

RST.9-10.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects

WHST.9-10.1	Write arguments focused on discipline-specific content.
WHST.9-10.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
WHST.9-10.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.
WHST.9-10.9	Draw evidence from informational texts to support analysis, reflection, and research.

Implementing Unit 2

This unit is designed to be the second unit of the Biology course. We do not recommend spending more than two months on this unit, as our field testing showed that six to eight weeks is the maximum amount of time students can stay engaged with the unit-level anchor phenomenon.

Within the unit, we also suggest spending no more than two weeks on each 5E instructional sequence. It is important to trust that ideas will build over time. Part of learning to teach NGSS-designed curriculum is getting comfortable with moving on, even if not every student “gets it,” with the knowledge that there are additional opportunities to revisit particular standards. See the Assessment section below for guidance on providing multiple opportunities for assessment throughout the unit.

The first time enacting any unit with students may take longer than anticipated, particularly if the pedagogical approach is significantly different from what a teacher is used to. A teacher may want to skip entire lessons or activities, or revert to more traditional approaches when it seems like time is running out. We often ask teachers to think about the best way to modify recipes. Just like when using a recipe for the first time, it’s a good idea to stay as true to the materials as possible before making modifications or substitutions! As teachers become more familiar and comfortable with the instructional model, the embedded routines, and three-dimensional teaching overall, the desire to skip things will dissipate. Teachers using our curriculum over time have noticed that they are able to move a bit quicker through this and other NGSS-designed units every year!

Routines

The table below summarizes the routines embedded in this unit. The number indicates the number of times a given routine appears in a lesson.

	Unit Opening	The Black Death 5E	Antibiotic Resistance 5E	The Microbiome 5E	Cooperation & Survival 5E	Unit Closing
Class Consensus Discussion		2	1	1	1	
Consensus-Building Share		1				
Domino Discover	2	3	3	2	3	
Idea Carousel				1		
Questions Only	1			1		
Read-Generate-Sort-Solve		1	1		1	
Rumors		1	1		1	
Think-Talk-Open Exchange		1			1	

Literacy Strategies

The table below summarizes the literacy strategies embedded in this unit. The number indicates the number of times a given strategy appears in a lesson.

	Unit Opening	The Black Death 5E	Antibiotic Resistance 5E	The Microbiome 5E	Cooperation & Survival 5E	Unit Closing
Cause and Effect Chart			1			
Claim-Evidence-Reasoning (CER)			1			
Concept Mapping				1		
Evidence Gradient				1		
Sequence Chart		1				
Text Annotation	1	1	1	2	1	
Text Graffiti		1				
Three Level Guide				1		

Simulations in this Unit

Lesson	Simulation Title	Source	Technical Notes	Permissions Notes
The Black Death 5E	Annenberg Learner interactive: Disease	https://www.learner.org/wp-content/interactive/envsci/disease/disease.html	NA	NA
Cooperation & Survival 5E	The Evolution of Trust Simulation	https://ncase.me/trust/	NA	NA

Videos in this Unit

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Unit Opening	The Pandemic the World Has Forgotten	https://www.youtube.com/watch?v=hj95IZMlZWw&feature=emb_logo	NA	NA

Lesson	Video Title	Source	Technical Notes	Permissions Notes
The Black Death 5E	What Was the Black Death? (optional video - stop at 4:02)	https://www.youtube.com/watch?v=y7OWLohZ_fs	NA	NA
The Black Death 5E	Plague in the United States	https://www.cdc.gov/plague/maps-statistics/index.html	NA	NA
The Black Death 5E	Ted-Ed Black Death Video	https://www.youtube.com/watch?v=ySClB6-OH-Q&feature=em-subs_digest	NA	NA
The Black Death 5E	The Making of the Fittest: Natural Selection and Adaptation	https://www.biointeractive.org/classroom-resources/making-fittest-natural-selection-and-adaptation	NA	NA
The Black Death 5E	HHMI BioInteractive: Color Variation Over Time in Rock Pocket Mouse Populations Investigation	https://www.biointeractive.org/classroom-resources/color-variation-over-time-rock-pocket-mouse-populations	NA	NA
The Black Death 5E	How your Immune System Works	https://www.youtube.com/watch?v=1KdlU1sQcyc	NA	NA
The Black Death 5E	A Mutation Story	https://ny.pbslearningmedia.org/resource/tdc02.sci.life.gen.mutationstory/a-mutation-story/	NA	NA
Antibiotic Resistance 5E	Caving for Cures: Mining Drugs From Nature (optional)	https://www.amnh.org/explore/videos/humans/caving-for-cures-mining-drugs-from-nature	NA	NA
Antibiotic Resistance 5E	This tutorial: Collecting Lab Data with Google Forms and Sheets	https://www.youtube.com/watch?v=0zaxaGGsSuI	NA	NA

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Antibiotic Resistance 5E	Antibiotic Resistance Data Table	https://docs.google.com/spreadsheets/d/1CK9sqjN-nsdLzpgGiiLLr_oYf-8RN6WfmpN20mCwIPg/edit?gid=1641648070#gid=1641648070	NA	NA
Antibiotic Resistance 5E	Antibiotic Resistance Data Table - Scaffolded Version	https://docs.google.com/spreadsheets/d/1EE6-NAgd7xyyFU6Yv74YAC_fDtTs5bFLOGYAKwzWZs4/edit?gid=1641648070#gid=1641648070	NA	NA
Antibiotic Resistance 5E	Antibiotic Resistance Game Demo	https://drive.google.com/file/d/1hKMxMVRDIzDzkVQIDpQDDFsagWLeOJ0q/view?usp=drive_link	NA	NA
Antibiotic Resistance 5E	Time Lapse Video of Resistance	https://www.youtube.com/watch?v=plVk4NVIUh8	NA	NA
Antibiotic Resistance 5E	Antibiotic Use in Agriculture (can stop at 19:15)	https://www.pbs.org/wgbh/frontline/film/trouble-with-antibiotics/	NA	NA
Antibiotic Resistance 5E	The Deadliest Being on Planet Earth – The Bacteriophage	https://www.youtube.com/watch?v=YI3tsmFsrOg&feature=youtu.be	NA	NA
The Microbiome 5E	Evolution of Diet - The Hadza of Tanzania	https://education.nationalgeographic.org/resource/the-hadza-of-tanzania/	NA	NA
Cooperation & Survival 5E	Time Lapse Video of Biofilm Formation	https://www.youtube.com/watch?v=hAodAX_xjpY	NA	NA

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Cooperation & Survival 5E	Biofilm: A New (Gross) Thing to Worry About Video	https://www.youtube.com/watch?v=twxPyvdc-EE	NA	NA
Cooperation & Survival 5E	The microbial jungles all over the place (and you) Video	https://www.youtube.com/watch?v=pHLP5CZMnL4	NA	NA
Cooperation & Survival 5E	How bacteria 'talk' Video	https://www.ted.com/talks/bonnie_bassler_how_bacteria_talk?language=en	NA	NA
Cooperation & Survival 5E	Fellowship of the Whales: Feeding as a Team Video	https://www.youtube.com/watch?v=Q8iDcLTD9wQ	NA	NA

Lab Materials in this Unit

Lesson	Lab	Materials needed (per group)
The Black Death 5E	Disease Transmission Investigation Lab minutes: 60 minutes	❏ Plastic cup (1 per student) ❏ Dilute sodium hydroxide ❏ Computer access ❏ Phenolphthalein pH indicator solution ❏ Droppers
The Black Death 5E	Color Variation Over Time in Rock Pocket Mouse Populations Lab minutes: 30 minutes	❏ A set of HHMI illustrations (printed in color) for each group
Antibiotic Resistance 5E	Simulating a Bacterial Infection Lab minutes: 45 minutes	❏ Dice ❏ 75 game tokens ❏ Simulating a Bacterial Infection Game Board (printed as big as possible - preferably at least 8.5 x 14)
The Microbiome 5E	Comparing Microbiomes Investigation Lab minutes: 30 minutes	❏ none

Lesson	Lab	Materials needed (per group)
Cooperation & Survival 5E	Cooperation vs. Cheating Investigation Lab minutes: 30 minutes	❑ Cooperation vs. Cheating Foods Scissors Tape Computer access

Other Materials in this Unit

Lesson	Materials needed
Unit Opening	❑ Quarantine image ❑ *Tell the Story Example Student Work* ❑ *Scaffolded Question Set* ❑ post-it notes ❑ Chart paper
The Black Death 5E	❑ *Black Death Quotations* ❑ Post-it notes ❑ Information is Beautiful infographic: The MicrobeScope (optional) ❑ Class wide scientific argument characteristics ❑ Class Consensus Discussion steps ❑ HHMI BioInteractive: Color Variation Over Time in Rock Pocket Mouse Populations Investigation (student handout; illustrations; teacher version) ❑ 5E Plan - Gamete Production - Teacher Plan and Guidelines (optional sexual reproduction resources) ❑ 5E Plan - Molecular Genetics - Teacher Plan and Guidelines (optional mutation resources) ❑ *Rock Pocket Mice Sequence Chart Cards* ❑ NPR article Black Death survivors gave their descendants a genetic advantage — but with a cost (advanced/teacher-level text) ❑ *Immune System Sequence Chart Cards* (optional) ❑ PBS text: A mutation Story ❑ Science Magazine article: Found: genes that sway the course of the coronavirus (optional advanced text) ❑ Class wide scientific argument characteristics ❑ Driving Question Board from the start of the unit should be available ❑ *Claim and Evidence Card Sort - Example Student Work*

Lesson	Materials needed
Antibiotic Resistance 5E	❑ Post-it notes ❑ CIDRAP article: Scientists find ancient, cave-dwelling resistant bacteria (advanced/teacher text) ❑ Scaffolds to support constructing scientific explanations ❑ CNN article: KFC promises to ditch antibiotic-laden chicken (optional) ❑ *Antibiotic Resistance: Evaluating a Claim - Student Work Example* ❑ Chart or poster-sized RGSS organizer (optional) ❑ Class wide scientific argument characteristics ❑ Driving Question Board from the start of the unit should be available ❑ *Antibiotic Resistance - Student Work Example*
The Microbiome 5E	❑ *Color Visual* (laminated or displayed on the smartboard ❑ 1 per group) ❑ National Geographic article: Hadza ❑ Nature article - Gut microbiome of the Hadza hunter-gatherers (advanced/ teacher level text) ❑ NCBI high resolution image: Composition of the Microbiome in Urban Italians and Hunter-gathers ❑ Math is Fun text: Correlation ❑ *Color Visual Edited*(optional) ❑ NPR podcast: Modern Medicine May Not Be Doing Your Microbiome Any Favors (optional resource on the microbiome) ❑ The Guardian article: 'I thought I was going to die': why patients are no longer pooh-poohing faecal transplants (optional resource on fecal transplants) ❑ Strategies for Concept Mapping (optional support) ❑ Class wide scientific argument characteristics ❑ The Coversation article: I spent three days as a hunter-gatherer to see if it would improve my gut health ❑ Class wide scientific argument characteristics ❑ Driving Question Board from the start of the unit should be available ❑ *The Microbiome - Example Student Work*
Cooperation & Survival 5E	❑ Post-it notes ❑ Class wide scientific argument characteristics ❑ Resources on socratic seminar ❑ Driving Question Board from the start of the unit should be available
Unit Closing	❑ Driving Question Board ❑ *Final Argument - Example Student Work* ❑ Socratic Seminar Resources

Teacher Materials for Unit 2

Unit Opening	Why are bacterial diseases increasing globally? How can we prevent new disease outbreaks?	**Performance Expectations**	**Anchor Phenomenon** The number of deaths from infectious diseases is increasing globally. Why, after decades of declining deaths from infectious disease, have we seen a resurgence of outbreaks?	**Time** 3-4 days

Bacteria are found everywhere, in extreme environments and living in, on, and around us. Some are harmful and cause infections, some are beneficial, and some barely impact humans at all. Through the forces of natural selection, humans have entered an evolutionary arms race with virulent bacteria. In this unit, students will consider the factors that impact the rate and scale of evolution. Will human society be able to develop new therapies and technologies in order to fight the resurgence of infectious disease often caused by bacteria?

ANCHOR PHENOMENON	How do infectious diseases spread across the globe?	This is a topic that should incite student curiosity and wonder! All of us have recently experienced a life-altering global pandemic. By working with students to surface their prior knowledge of the recent Coronavirus pandemic, and other infectious diseases that have caused epidemics or pandemics, it will allow them to engage with the unit and increase student buy-in.
DRIVING QUESTION BOARD	What questions do we have?	Based on ideas that have surfaced through student discussion, students create a driving question board.
PERFORMANCE TASK	How can we prevent a future Cholera outbreak?	In the performance task students will develop an argument to support a claim on the best solution we have to deal with *V. cholerae*, a bacterium that infects 2 million people in the world and kills 150,000 of them.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Anchor Phenomenon

How do infectious diseases spread across the globe?

This is a topic that should incite student curiosity and wonder! All of us have recently experienced a life-altering global pandemic. By working with students to surface their prior knowledge of the recent Coronavirus pandemic, and other infectious diseases that have caused epidemics or pandemics, it will allow them to engage with the unit and increase student buy-in.

Preparation

Student Grouping	Routines	Literacy Strategies
None	❏ Domino Discover ❏ Questions Only	❏ Text Annotation

Materials

Handouts	Lab Supplies	Other Resources
❏ Tell the Story	None	❏ Quarantine image ❏ *Tell the Story Example Student Work* ❏ The Pandemic the World Has Forgotten

Observing the Phenomenon

1. Project an image from the recent COVID-19 quarantine, and allow time for students to reflect on their own experiences with quarantine and the pandemic. In pairs, students can share their ideas and experiences.

Quarantine

2. Listen for the idea that pandemics (like COVID-19) spread and can impact large groups of people all over the world.

3. Prompt students to think about other examples of infectious disease that have caused epidemics or pandemics (such as Ebola, flu, HIV/AIDS) in groups. How do each of these diseases spread? How have they impacted your community? How are they both similar to and different from the current COVID-19 pandemic?

4. Surface student thinking by prompting a couple of groups to share their ideas, or use **Domino Discover** to gauge the thinking in the room. Highlight student ideas or questions about the similarities and how we might be able to learn more about all infectious disease outbreaks by examining one example of a pandemic closely.

Routine

This is the first time the routine **Domino Discover** appears in this unit! Please read the Biology Course Guide for detailed steps about this routine.

Look & Listen For

- Some outbreaks are caused by viruses, others by bacteria.
- Like COVID-19, they may start small somewhere else in the world, but may spread and cause severe outbreaks that impact us (in NY) or even globally.
- Transmission can be different, some through contact with bodily fluids, others through the air.
- Like COVID-19, all pandemics can involve misinformation and fear by the public.
- Like with COVID-19, infected individuals may unknowingly transmit some diseases to others (even if they don't feel ill).
- There are differences in how people react to infection, this may be due to variations in the immune system (or other other traits)
- We can learn a lot about all pandemics/disease outbreaks by experiencing or learning about one example.

5. If cholera was not brought up by students, provide students with the example of cholera, a bacterial disease that has caused pandemics and outbreaks throughout history.

6. Show students the video The Pandemic the World Has Forgotten , students use the group learning routine **Questions Only** to surface student ideas and questions about cholera.
7. Chart the higher level questions, or questions that many students are curious about and leave the chart in the room for further discussion.

Access for All Learners

Not all students may be familiar with all of the vocabulary involved with epidemics or pandemics or even the different pathogens such as viruses or bacteria. As students discuss other devastating disease outbreaks they may have heard about in the past (Ebola, Swine flu, etc). Use those examples to help students navigate new vocabulary by generating a class list with examples and student friendly definitions.

Routine

This is the first time the routine **Questions Only** appears in this unit! Please read the Biology Course Guide for detailed steps about this routine.

Telling the Story

1. Highlight that students that they just surfaced a lot of ideas and questions about disease outbreaks in general, and cholera in particular. To generate even more questions and ideas, we will look at some data and read a text about what is happening with infectious disease and the on-going cholera pandemic.

2. Distribute *Tell the Story*.

3. Students read and **annotate** the three texts individually, circling three details that are the most important to the phenomenon being described.

4. Students share their ideas in their group, with every individual identifying the details that they thought were important.

5. As a group, students decide which ideas they think are important, and use those ideas to write out what is happening, or the story of the phenomenon.

6. After students have generated the story of the phenomenon, they identify the problem that is associated with the phenomenon. In this unit, students will develop a scientific argument on the best solution to the problem they have identified (avoiding a future *V. cholera* outbreak.

Access for All Learners

This may be the first time students are exposed to the idea of a surfacing a problem related to a phenomenon. After engaging with the telling the story, prompt students to think about and share ideas on why we might engage with problems in science.

Conferring Prompts

Confer with students as they generate the story:

- Why do you think this detail is important?
- Did your group members and you circle the same details?
- How did you agree, as a group, to the overall story?
- How did you identify the problem? Why is this an important problem to consider?

Driving Question Board

What questions do we have?

Based on ideas that have surfaced through student discussion, students create a driving question board.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	❑ *Scaffolded Question Set* ❑ post-it notes

Generating Questions

1. Prompt students to recall the phenomenon under study, and the associated problem for this unit. Clarify for students that although there are many types of pathogens that can cause a disease (including viruses and fungi), in this unit, we will be looking closely at a bacterial disease as an example pathogen.

2. Highlight that they will be exploring this idea throughout the unit, and will be applying their understanding of the phenomenon to a real life problem; preventing a future cholera outbreak. If students do not have a personal connection to cholera, prompt students to share why it might be important to think about how we could prevent this disease from becoming a problem in our community. It may be helpful to refer back to the video, The Pandemic the World Has Forgotten .

3. At this point, students should have a lot of questions! Let them know that they will be investigating the possibility of a devastating cholera outbreak and how to prevent it. Prompt students to think about what they need to know in order to understand the phenomenon, and the associated problem -- finding a solution to prevent a future outbreak.

4. Individually, students brainstorm as many questions as possible. Post-it notes may be useful, with students writing one question per note. Refer back to the charted questions generated during the initial launch of the phenomenon. Students may have more detailed or relevant questions at this point after discussing and thinking about this problem in more depth. Remind students that although we are focusing specifically on cholera, we are learning about cholera in order to understand more about preventing any future disease outbreak.

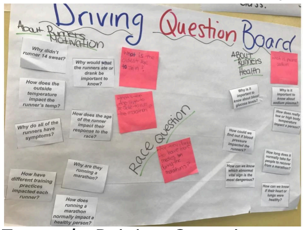
Differentiation Point

Ideally, students should be generating relevant questions based on the unit level phenomenon and problem themselves. If students need more support, provide them with the cut out cards from *Scaffolded Question Set*. Prompt students to generate as many new questions as they can on the empty cards.

Grouping Questions

1. In small groups, prompt students to categorize all of their questions into 3-5 categories. Students should generate a title or an umbrella question that encompasses all of the smaller sub questions they have written (or provided on the cards if using the scaffolded set).

2. As a whole class or in small groups, students share and categorize their questions, as they organize the questions on chart paper.



Example Driving Question Board

Conferring Prompts

Confer with students as they create and categorize questions

- Why do these questions belong together?
- What is the category that connects these?
- Are there other questions within this category?
- Now that you see all of your questions grouped together, do other questions come up?
- For each category, is it possible to develop an umbrella question that encompasses all of the other sub-questions in that category?

Performance Task

How can we prevent a future Cholera outbreak?

In the performance task students will develop an argument to support a claim on the best solution we have to deal with *V. cholerae*, a bacterium that infects 2 million people in the world and kills 150,000 of them.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Initial Argument	None	❑ Chart paper

Launching the Performance Task

1. Prompt students to recall the phenomenon and associated problem under study for this unit.
2. Students individually brainstorm possible solutions to the problem (avoiding a future outbreak of cholera). In pairs or table groups, students share their solutions and categorize their solutions into a few different categories to share out with the class.
3. Chart student ideas that surface on possible solutions. Let students know that as they will develop an argument for the best possible solution, solutions are the claims that we will investigate in the unit.

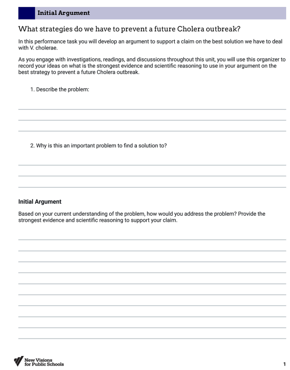
Differentiation Point

Students may generate some appropriate claims, but may struggle with others. Combine ideas across all classes to generate a set of appropriate claims that can be addressed in the unit. Or allow students to vote on one or two claims while providing the remaining claims that students will investigate.

4. Provide students with the *Initial Argument*. Prompt students to read the task, and to respond to the prompts, including their initial claim for the best solution, based on their current knowledge (about preventing a cholera outbreak and on supporting/ evaluating a claim based on evidence and scientific reasoning).

Integrating Three Dimensions

Since this is the first time students are engaging with **SEP#7 Engaging in Argument from Evidence** in this course, they may struggle suggesting appropriate claims. As a scaffold, 5 claims are embedded in the unit: 1) People will be immune to cholera, or will develop immunity 2) We need to disrupt transmission of cholera 3) We need to stop *V. cholerae* from becoming resistant to antibiotics 4) We can leverage a healthy microbiome in order to reduce the chances of infection 5) We can prevent infections/outbreaks by disrupting bacterial cooperation



Initial Argument

What strategies do we have to prevent a future Cholera outbreak?

In this performance task you will develop an argument to support a claim on the best solution we have to deal with V. cholerae.

As you engage with investigations, readings, and discussions throughout this unit, you will use this organizer to record your ideas on what is the strongest evidence and scientific reasoning to use in your argument on the best strategy to prevent a future Cholera outbreak.

1. Describe the problem:

2. Why is this an important problem to find a solution to?

Initial Argument

Based on your current understanding of the problem, how would you address the problem? Provide the strongest evidence and scientific reasoning to support your claim.

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Developing Initial Arguments

1. Remind students that they will be generating a scientific argument; through evaluating claims about the best solution to prevent a future cholera outbreak throughout the unit.
2. In pairs or small groups, prompt students to generate a description of a scientific argument and ask: What is a scientific argument? What are the characteristics of a scientific argument?
3. Use the group learning routine, **Domino Discover**, to surface student ideas and to generate an initial chart of class wide scientific argument characteristics. Hold on to this chart, as it will be used and revisited throughout the unit.

Example student poster

Class Consensus List:
Characteristics of a Scientific Argument

It has two sides

You need proof for each side

once side has more proof

You are trying to change someone's mind or convince someone of your side

Integrating Three Dimensions

Students' early understanding of scientific argument may be simplistic, and that is ok! They will continue to add on the list as they move through the unit, and lean more about **SEP#7 Engaging in Argument from Evidence.** If students are having difficulty generating characteristics of a scientific argument, prompt them to think about an informal argument they have had with others or the characteristics of argumentation in other courses or disciplines.

Standards in Unit Opening

Performance Expectations

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. SEP7(2)	LS4.C Adaptation • Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. LS4.C(2)	

Assessment Matrix

	Anchor Phenomenon	Driving Question Board	Performance Task
Engaging in Argument from Evidence			*Initial Argument*
LS4.C Adaptation	Domino Discover		

Common Core State Standards Connections

	Anchor Phenomenon	Driving Question Board	Performance Task
Mathematics			
ELA/Literacy	RST.9-10.7 WHST.9-10.2 SL.9-10.1 SL 9-10.4		RST.9-10.1 WHST.9-10.1 WHST.9-10.5 WHST.9-10.9 SL.9-10.1 SL 9-10.4

Student Work for Unit Opening

Overall Story of the Phenomenon (Based on Group Discussion)

In the past, there were several cholera pandemics starting in the 1800's. Cholera is a bacterial disease caused by the bacteria, V. cholerae. New York city even had a devastating cholera outbreak in 1832 that killed 1.5% of the population, impacting many immigrants and African Americans. By the 1970's disease experts thought the fight against infectious disease was over. Currently, there is a new concern over infectious diseases including cholera. There is a current cholera pandemic that started in Egypt in the 1960's and has traveled around the world. There was a severe outbreak in Haiti in which over 8,000 people died. In the future, we will worry about a new cholera outbreak because antibiotics and vaccines haven't always been effective.

Based on the phenomenon, what is an important problem we are facing?

The problem is that we could have a future outbreak of cholera because antibiotics are not as effective as they used to be. we need to figure out a solution to this problem so that communities are not negatively impacted by a future outbreak of cholera.

Classroom Resources for Unit Opening
Scaffolded Question Set

Scaffolded Question Set

Cut out these cards.

How do bacteria make us sick?	How do bacteria spread?	Why do bacteria infect us and make us sick?
Why are some people more likely to get infected than others?	Why can some people just fight the cholera/ bacteria off?	Are all bacteria harmful?
What are vaccines? Can they help?	How did some people survive outbreaks of disease in the past?	How did people stop any of the past outbreaks or pandemics?

Why don’t antibiotics work as well as before?	Can we use special technology or new medicines to fight cholera?	What can we do to stop the spread of cholera?
How can we have bacteria on our bodies all the time and we are not sick?		

The Black Death 5E	What can we learn about infectious disease transmission from past outbreaks like The Black Death? Why were some people able to survive, when so many people did not?	**Performance Expectations** HS-LS4-3, HS-LS4-4, HS-LS4-2	**Investigative Phenomenon** The black plague killed close to 50% of the population in Europe, but some people survived.	**Time** 8-9 days

In this 5E instructional sequence, students are investigating the questions about pathogen transmission and how we have dealt with pandemics in the past surfaced during the Driving Question Board launch: *How do bacteria make us sick? What have we learned from historical plagues?* The Black Death was devastating for many people living during that period of time. In many parts of Europe, it killed up to 50% of the population. By investigating the causes behind the Black Death, and the reasons why some people were able to survive, students gain a deeper understanding of the importance of the variation in human immune systems, as well as the role other factors (such as nutrition and hygiene) played in surviving the infection.

ENGAGE	How did some people survive the Black Death?	Connecting to their earlier questions about how bacteria make us sick, and how we have responded to disease outbreaks in the past, students are introduced to the historical events around the The Black Death. Students share their initial ideas about why some people were able to **survive the infection** despite the catastrophic death toll throughout Europe, Asia, and the Middle East.
EXPLORE 1	How do infectious diseases spread between people?	Students interact with simulation-generated data and apply **concepts of probability to investigate** how different **variables increase or impact the rate of disease transmission**.
EXPLAIN 1	Why was the disease that caused The Black Death so deadly?	Students use a text and multimedia to **evaluate claims** on what **caused** such a **high death toll during the Bubonic Plague** (Black Death).
EXPLORE 2	How does natural selection lead to beneficial traits in a population?	Students **collect and analyze population level data** for rock pocket mice in order to surface how **natural variation in traits may confer an advantage in specific environmental conditions**.
EXPLAIN 2	How could natural variations in the immune system of Medieval humans have contributed to their survival during the Black Death?	Students apply their understanding of **natural selection** to **consider the claim** that natural variations in human immune systems may have **affected** chances of survival during the Black Death. Students use sequence charts to represent **causality**.
ELABORATE	What is the evolutionary history of the sickle cell trait?	Students test out their ideas and conceptions about **natural selection by considering how evolution works at different scales and in different population-level systems.**
EVALUATE	How do the characteristics of transmission of disease and immunity connect to identifying the best solution to prevent a future cholera outbreak?	Students **use evidence** generated throughout the unit, and their new understanding of the **causes behind disease transmission and innate immunity**, to **evaluate claims** on the best way to prevent a future cholera outbreak.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

How did some people survive the Black Death?

Connecting to their earlier questions about how bacteria make us sick, and how we have responded to disease outbreaks in the past, students are introduced to the historical events around the The Black Death. Students share their initial ideas about why some people were able to **survive the infection** despite the catastrophic death toll throughout Europe, Asia, and the Middle East.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ Rumors	❑ Text Graffiti

Materials

Handouts	Lab Supplies	Other Resources
❑ Black Death Historical Description	None	❑ *Black Death Quotations* ❑ Post-it notes ❑ What Was the Black Death? (optional video - stop at 4:02) ❑ Plague in the United States

Launch

1. Remind students that during the Driving Question Board launch, one category of questions that emerged was related to how bacteria make us sick and how people have survived infections in the past. Ask students to share about the last time they were ill from an infection and how that impacted others in their family and surroundings. Students may bring up how COVID-19 impacted their lives and community. Prompt students to think about a time when family members were sick (with the flu for example), but they managed to stay healthy. Listen for the observation that illness is often passed from one person to another (especially neighbors and family members), but that not everyone around a sick person also gets sick.

2. Use students' ideas to transition to the question, "Have you ever heard of a situation when a lot of people became sick with the same infection?" Students may have examples such as COVID-19, Swine flu, influenza, etc.

3. Let students know that they are going to consider a historical plague called the Black Death by reading a historical description. Some students may have studied the Black Death in their social studies class; if so, allow students to surface what they already know about the event.

Access for All Learners

All students have some background knowledge on the topic of illness and the transmission of an infection, especially around the recent pandemic Be sure to provide opportunities for students to articulate those ideas at this point, by selecting examples that make sense to them, while being sensitive to the idea that COVID-19 may have negatively touched the lives of your students.

Accessing a Historical Document

1. Use the literacy strategy **text graffiti** to support students in accessing the text.

2. In groups of four, provide each student with a different Black Death Quotation.

3. In 3-5 minutes, students annotate the quote silently, they can:
    a. Circle words they do not know
    b. Rewrite the quote or parts of the quote in their own words
    c. Ask a question
    d. Underline an important phrase and explain its importance

4. Students silently pass each quotation to the person on the right, then take 3-5 minutes to annotate.

5. Once students have had a chance to read and annotate each quote, prompt students to re-read their original quote, with all of the annotations. Prompt students to respond to the following prompts on the back of their paper:
    a. What was the Black Death?
    b. How did it impact people during that time?

6. Provide students with the *Black Death Historical Description* and ask them to read the document then add notes to their responses.

Black Death Historical Description

Michael Platiensis lived in Messina, the first port city in Europe to feel the effects of the plague. The following document is his description of the arrival and progress of the disease in 1347, though the account was written in 1357.

At the beginning of October, in the year of the incarnation of the Son of God 1347, twelve Genoese galleys [trading ships] . . . entered the harbor of Messina. In their bones they bore so virulent a disease that anyone who only spoke to them was seized by a mortal illness and in no manner could evade death. The infection spread to everyone who had any contact with the diseased. Those infected felt themselves penetrated by a pain throughout their whole bodies and, so to say, undermined. Then there developed on the thighs or upper arms a boil about the size of a lentil which the people called "burn boil". This infected the whole body, and penetrated it so that the patient violently vomited blood. This vomiting of blood continued without intermission for three days, there being no means of healing it, and then the patient expired.

Adapted from the New York State Education Department . January 2011. Global History Exam. Internet. Available here; accessed July 16, 2017.

Not only all those who had speech with them died, but also those who had touched or used any of their things. When the inhabitants of Messina discovered that this sudden death emanated from the Genoese ships they hurriedly ordered them out of the harbor and town. But the evil remained and caused a fearful outbreak of death. Soon men hated each other so much that if a son was attacked by the disease his father would not tend him. If, in spite of all, he dared to approach him, he was immediately infected and was bound to die within three days. Nor was this all; all those dwelling in the same house with him, even the cats and other domestic animals, followed him in death. As the number of deaths increased in Messina many desired to confess their sins to the priests and to draw up their last will and testament. But ecclesiastics [clergy who work for the Catholic Church], lawyers and notaries refused to enter the houses of the diseased.

Soon the corpses were lying forsaken in the houses. No ecclesiastic, no son, no father and no relation dared to enter, but they hired servants with high wages to bury the dead. The houses of the deceased remained open with all their valuables, gold and jewels. . . . When the catastrophe had reached its climax the Messinians resolved to emigrate. One portion of them settled in the vineyards and fields, but a larger portion sought refuge in the town of Catania. The disease clung to the fugitives and accompanied them everywhere where they turned in search of help. Many of the fleeing fell down by the roadside and dragged themselves into the fields and bushes to expire. Those who reached Catania breathed their last in the hospitals there. The terrified citizens would not permit the burying of fugitives from Messina within the town, and so they were all thrown into deep trenches outside the walls.

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Classroom Supports

Print each quotation on separate large pieces of paper (11x14 or posters), so that students have adequate space to annotate in the margins.

Differentiation Point

If students are struggling to visualize or understand the impact of the Black Death using only the text, show a brief video clip, What Was the Black Death? stopping the video at 4:02. Additionally, if students struggle to connect to a historical disease, use Plague in the United States to demonstrate that the plague continues to cause illness and death even now in the US.

Surfacing Student Ideas

1. Prompt students to describe the Black Death based on the historical document they read. If students do not have (or have not yet surfaced) background knowledge of the devastation of the Black Death, let them know that the plague killed between one-third and three-fourths of the population of Europe (depending on the region). Point out that not everyone died who came in contact with sick people or was in the area at the time.
2. Prompt students to consider why such a devastating disease did not wipe out all of Europe, and to write out their ideas.
3. Each student reads through their ideas, and decides on their most important idea, writing that one idea on a sticky note. Remember, this should be a response to the question: Why were some people able to survive the Black Death?
4. Use the group learning routine **Rumors** to surface student ideas.
5. After students have shared their ideas through Rumors, categorize student ideas to address during the instructional sequence.
6. End the discussion by asking students how they might investigate how some people survived and others did not.

Routine

The goal of the **Rumors** routine is to have students exchange ideas while listening for similarities and differences in thinking. It's meant to be low stakes, so it is frequently used to surface initial student ideas about phenomena during the Engage phases. This is the first time the routine **Rumors** appears in this unit. Please read the Biology Course Guide for detailed steps of this routine.

Look & Listen For

Students have background knowledge.
They may surface ideas around:

- Some people were lucky or different from the others.
- Some people moved out of the area, stayed inside or were otherwise able to avoid contact.
- Some people were more healthy, ate better food, or had better living conditions.
- Immune to the bacteria or able to fight off the infection (adaptive variations in the immune system).
- Some people were stronger than others (adaptive variations in the immune system).

Explore 1

How do infectious diseases spread between people?

Students interact with simulation-generated data and apply **concepts of probability to investigate** how different **variables increase or impact the rate of disease transmission**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ Consensus-Building Share ❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Disease Transmission Investigation P1 ❑ Making Sense of Disease Transmission Investigation P1 ❑ Disease Transmission Investigation P2 ❑ Making Sense of Disease Transmission Investigation P2 ❑ Disease Transmission Investigation Rubric	❑ Plastic cup (1 per student) ❑ Dilute sodium hydroxide ❑ Computer access ❑ Phenolphthalein pH indicator solution ❑ Droppers	❑ Information is Beautiful infographic: The MicrobeScope (optional) ❑ Annenberg Learner interactive: Disease

Launch

1. Ask students to remind us what we are trying to figure out (why were some people able to survive the Black Death). Remind students that, so far, we have a lot of ideas about immunity and disease transmission; point to Rumors patterns if still visible in the classroom. At this point the class should have some ideas surfaced around why they don't always get sick when other family members do, or why even when a lot of people are getting sick with the flu, not everyone does. Have students recall their earlier discussion about how we might investigate how disease is passed between people (before we can understand why some people don't get sick), and how we may explore how that happens, with emphasis on the fact that we want to investigate this here in the classroom.

2. If a student does not surface the idea, note that it is difficult to study how disease passes between people, because no one wants to get sick! Build off student ideas by reminding them that we used a model organism and simulations in Unit 1, Marathon Runner. Ask students how they might be able to simulate or model disease transmission in the classroom.

Look & Listen For

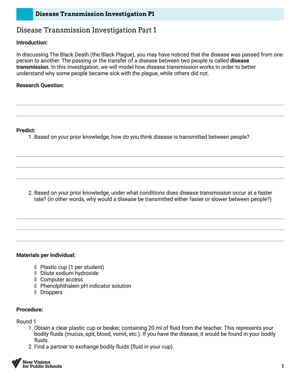
Students may generate ideas such as:
- Passing a secret note between people
- People pretend they are sick and pass it on to others
- Using a computer to model or simulate it
- Look at how this has happened in the past

Investigation: Modeling Disease Transmission Part 1

1. Provide each student with *Disease Transmission Investigation P1*. Each student should receive a small plastic cup or beaker that looks the same, but one will contain a different substance:
    a. 1 student receives dilute sodium hydroxide, or a sodium hydroxide bead dissolved in a small amount of water. (This should be done secretly.)
    b. All of the other students have the same amount of water, so all cups will look approximately the same.

Lab Safety Note: Sodium hydroxide is a strong base that can be harmful to the skin or eyes, even in dilute forms. Be sure to have students wear goggles and lab gloves during this investigation.

2. Prefill the data table in the *Disease Transmission Investigation P1* handout with the class roster; anyone who is absent can be crossed off by the students.
3. In two different rounds, students find a partner to simulate sharing bodily fluids, by pouring a small amount of the liquid in their cup into their partner's cup. Through this process, each student will be a "giver" exactly twice, but the number of times each student is a "receiver" will vary.
4. Add a drop of indicator solution to each student's cup. If the solution remains clear, they are healthy. If the solution turns pink, they are infected.
5. Prompt students to record their data in the data table.
6. As an extension, map out the transmission of the disease and figure out as a class which person was the originator.



Disease Transmission Investigation P1

Disease Transmission Investigation Part 1

Introduction:

In discussing The Black Death (the Black Plague), you may have noticed that the disease was passed from one person to another. The passing or the transfer of a disease between two people is called **disease transmission.** In this investigation, we will model how disease transmission works in order to better understand why some people became sick with the plague, while others did not.

Research Question:

Predict:
1. Based on your prior knowledge, how do you think disease is transmitted between people?
2. Based on your prior knowledge, under what conditions does disease transmission occur at a faster rate? (in other words, why would a disease be transmitted either faster or slower between people?)

Materials per Individual:
- Plastic cup (1 per student)
- Dilute sodium hydroxide
- Computer access
- Phenolphthalein pH indicator solution
- Droppers

Procedure:

Round 1
1. Obtain a clear plastic cup or beaker, containing 20 ml of fluid from the teacher. This represents your bodily fluids (mucus, spit, blood, vomit, etc.). If you have the disease, it would be found in your bodily fluids.
2. Find a partner to exchange bodily fluids (fluid in your cup).

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Differentiation Point

Students may have strong background knowledge on the variables that impact disease transmission. Listen to student ideas during the Engage phase and Explore launch to determine if it is appropriate to skip part 1 of the investigation, and start directly with part 2.

Whole-Class Investigation Summary

1. Provide students with *Making Sense of Disease Transmission Investigation P1*. Ask students to work independently to complete the Data Analysis and Evaluation, then use these completed pages to discuss the findings from part 1 of the investigation.

2. Ask groups to come up with one important idea to share with the whole class, from their analysis or evaluation.

3. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' responses. Plan forward based on the various understandings that students or student groups have articulated. It is appropriate to go onto the next phase once students have had a chance to make sense of the data, and have had the opportunity to clarify what they have figured out about the investigative phenomenon.

Look & Listen For

Possible student ideas:

- Diseases are passed through the exchange of bodily fluids (even though you cannot see the transmission without diagnostic tools).
- Density, crowding, or more physical contact may increase the rate of transmission (but we don't have sufficient data to make this claim).
- The simulation had many limitations, including: a closed/small population; no way to know who was immune; only one trial was conducted.

4. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

Routine

This is the first time **Domino Discover** is being used in this unit. This routine is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Please read the Biology Course Guide for detailed steps of this routine.

Investigation: Modeling Disease Transmission Part 2

1. Provide students with laptops or computer access and the link to the simulation: Annenberg Learner interactive: Disease and the *Disease Transmission Investigation P2* handout.

2. Give students an opportunity to informally engage with the simulation so they can understand the different parts and settings.

3. Before starting the procedure, make sure students have cleared all of the settings.

Conferring Prompts

Confer with students as they work in collaborative groups to collect data

Suggested conferring questions (these should push students' thinking around establishing relationships, observing patterns, identifying variables, and questioning events):

- What are the different examples of bodily fluids that can transmit disease?
- Why does population density impact the transmission of disease?
- Why are some diseases more contagious than others?
- Why does population mixing impact the death toll?
- What does the differences in the slope of the line in the generated graphs tell you about the rate of transmission?
- Why does the number of immune people change over time?

Differentiation Point

If students need more support, or if you would like to extend this concept, provide Information is Beautiful infographic: The MicrobeScope and use it as a discussion tool to surface these ideas further, to compare the transmission and virulence of many different diseases

Whole-Class Investigation Summary

1. Ask students to work independently to complete the Conclusion and Evaluation section of the *Making Sense of Disease Transmission Investigation P2*, then use these completed pages to discuss the findings from the investigation.

2. Ask groups to come up with one important idea to share with the whole class, from their Summary notes.

3. Use the group learning routine **Consensus-Building Share** to surface important trends, inferences, and questions from groups' Summary sections. Take time to facilitate students' building on each others' ideas so that key ideas are surfaced. Plan forward based on the various understandings that students or student groups have articulated. It is appropriate to go onto the next phase once students have had a chance to make sense of the data, and have had the opportunity to clarify what they have figured out about the investigative phenomenon under study in this learning sequence.

Integrating Three Dimensions

This Explore/Explain sequence does not explicitly target the foregrounded DCIs for this unit, but the concepts of immunity and disease transmission are important for the coherence of the unit and support student understanding of the DCIs from **HS-LS1 From Molecules to Organisms: Structures and Processes**, which are addressed in later units.

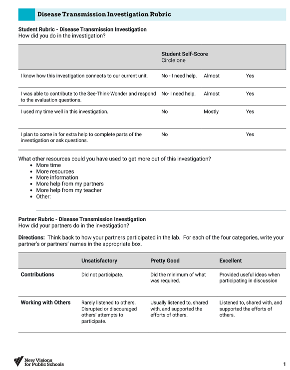
Look & Listen For

Possible student ideas:

- Some diseases are more virulent (deadly) than others, and some are more contagious than others
- As population density increases, the rate of transmission increases (and the death toll)
- As population mixing increases, the rate of transmission increases (and the death toll)
- If people stay contagious for longer, the rate of transmission increases (and the death toll)
- Over time, more people are immune to the disease (as a % of the remaining population)

4. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

5. Provide students with *Disease Transmission Investigation Rubric*. Ask students to use the investigation rubric to self and peer assess their progress on engaging with the investigation individually and as a group.



Disease Transmission Investigation Rubric

Student Rubric - Disease Transmission Investigation
How did you do in the investigation?

	Student Self-Score Circle one		
I know how this investigation connects to our current unit.	No - I need help.	Almost	Yes
I was able to contribute to the See-Think-Wonder and respond to the evaluation questions.	No- I need help.	Almost	Yes
I used my time well in this investigation.	No	Mostly	Yes
I plan to come in for extra help to complete parts of the investigation or ask questions.	No		Yes

What other resources could you have used to get more out of this investigation?
- More time
- More resources
- More information
- More help from my partners
- More help from my teacher
- Other:

Partner Rubric - Disease Transmission Investigation
How did your partners do in the investigation?

Directions: Think back to how your partners participated in the lab. For each of the four categories, write your partner's or partners' names in the appropriate box.

	Unsatisfactory	Pretty Good	Excellent
Contributions	Did not participate.	Did the minimum of what was required.	Provided useful ideas when participating in discussion
Working with Others	Rarely listened to others. Disrupted or discouraged others' attempts to participate.	Usually listened to, shared with, and supported the efforts of others.	Listened to, shared with, and supported the efforts of others.

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Routine

This is the first time the routine **Consensus-Building Share** appears in this unit. This routine is a way to make sensemaking visible and move towards a class-wide consensus around a new idea. Be sure to look at the Biology Course Guide for the action pattern for this routine.

As the whole-class activity for this Explore, it is important to surface as many of the ideas in the Look and Listen For section as possible. For the first time using this routine, it is appropriate to prompt students with questions such as "Did any group find something similar?" or "Can anyone add to that?"

Access for Multilingual Learners

Consensus-Building Share provides receptive language opportunities for students who are **entering and emerging** language learners. For those who are **transitioning and expanding**, this routine provides time to rehearse language with peers, so that students are not responsible for on-the-spot responses before they are ready.

Explain 1

Why was the disease that caused The Black Death so deadly?

Students use a text and multimedia to **evaluate claims** on what **caused** such a **high death toll during the Bubonic Plague** (Black Death).

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs or table groups	❑ Class Consensus Discussion	❑ Text Annotation

Materials

Handouts	Lab Supplies	Other Resources
❑ Black Death Text ❑ Black Death Claims ❑ Summary Task	None	❑ Class wide scientific argument characteristics ❑ Class Consensus Discussion steps ❑ Ted-Ed Black Death Video

Refine Class Consensus on Scientific Argumentation

1. Using the example of the two different simulations and data sets from the Explore 1 (Evaluation question #2 from *Making Sense of Disease Transmission Investigation P2*), prompt students to come up with additions to the class wide list of the characteristics of a scientific argument, focusing on defining what a claim and scientific evidence are.
2. Through class discussion, surface new ideas, as well as ideas students are finding particularly helpful or important, and record those on the class consensus list. At this point, it is fine if students do not have a completely clear or accurate definition of a scientific argument or what constitutes scientific evidence! They will return to this class list throughout the unit.

Classroom Supports

Continue to develop the class consensus list, as this will support student thinking about scientific arguments throughout the unit.

Example student poster

Class Consensus List:
Characteristics of a Scientific Argument

~~It has two sides~~ It compares or considers different claims

~~You need proof for each side~~ You need evidence for each claim that supports it

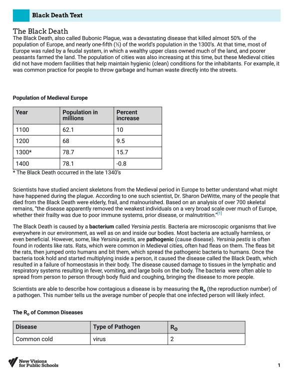
Evidence comes from different places, like experiments and scientists' work

Once side has more ~~proof~~ evidence

You are trying to change someone's mind

Finding Evidence for a Claim

1. Prompt students to work individually to generate evidence for three different claims on why the Black Death was so deadly.
2. Provide students with *Black Death Text* and *Black Death Claims* handouts.
3. Prompt students to read over the three claims and to use the video and the text to gather evidence for each claim.
4. Launch the Ted-Ed Black Death Video , pausing as necessary for students to listen for and write down evidence for each claim if discussed in the video. Provide time for students to read the text, annotating for evidence for each claim. Students should fill in the evidence below each claim
5. After identifying evidence for each claim, prompt students to consider all of the evidence, and respond to the summary prompt: *Which claim has the most evidence?*
6. In pairs or small groups, students share the evidence that they found and their response to the summary prompt.



Black Death Text

The Black Death

The Black Death, also called Bubonic Plague, was a devastating disease that killed almost 50% of the population of Europe, and nearly one-fifth (⅕) of the world's population in the 1300's. At that time, most of Europe was ruled by a feudal system, in which a wealthy upper class owned much of the land, and poorer peasants farmed the land. The population of cities was also increasing at this time, but these Medieval cities did not have modern facilities that help maintain hygienic (clean) conditions for the inhabitants. For example, it was common practice for people to throw garbage and human waste directly into the streets.

Population of Medieval Europe

Year	Population in millions	Percent increase
1100	62.1	10
1200	68	9.5
1300*	78.7	15.7
1400	78.1	-0.8

* The Black Death occurred in the late 1340's

Scientists have studied ancient skeletons from the Medieval period in Europe to better understand what might have happened during the plague. According to one such scientist, Dr. Sharon DeWitte, many of the people that died from the Black Death were elderly, frail, and malnourished. Based on an analysis of over 700 skeletal remains, "the disease apparently removed the weakest individuals on a very broad scale over much of Europe, whether their frailty was due to poor immune systems, prior disease, or malnutrition."[1]

The Black Death is caused by a **bacterium** called *Yersinia pestis.* Bacteria are microscopic organisms that live everywhere in our environment, as well as on and inside our bodies. Most bacteria are actually harmless, or even beneficial. However, some, like *Yersinia pestis,* are **pathogenic** (cause disease). *Yersinia pestis* is often found in rodents like rats. Rats, which were common in Medieval cities, often had fleas on them. The fleas bit the rats, then jumped onto humans and bit them, which spread the pathogenic bacteria to humans. Once the bacteria took hold and started multiplying inside a person, it caused the disease called the Black Death, which resulted in a failure of homeostasis in their body. The disease caused damage to tissues in the lymphatic and respiratory systems resulting in fever, vomiting, and large boils on the body. The bacteria were often able to spread from person to person through body fluid and coughing, bringing the disease to more people.

Scientists are able to describe how contagious a disease is by measuring the R_0 (the reproduction number) of a pathogen. This number tells us the average number of people that one infected person will likely infect.

The R_0 of Common Diseases

Disease	Type of Pathogen	R_0
Common cold	virus	2

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Integrating Three Dimensions

Throughout this Explain phase, students are gathering evidence to support a claim. Keep in mind that students need to go beyond arguing why the Black death was so deadly; this Explain is designed to support them in using a crosscutting concept to do this sensemaking. Be sure to make **CCC #2 - Cause and Effect** explicit for students by elevating and probing for ideas related to the concept that it is challenging to identify causality due to the fact that there may be many factors contributing to a phenomenon.

Differentiation Point

Here are some options for ensuring that all students have access to the information in *Black Death Text*, since there is one version of the text.

1. Shared reading group: support students by having them read the text along with a teacher, in a small group setting.
2. Chunking with Turn and Talk: Break the text up into chunks. In pairs, students read the text and after each chunk, they discuss and try to find relevant evidence for each claim collaboratively.

Class Consensus Discussion

1. Orient the class to the purpose and the format of the group learning routine **Class Consensus Discussion**. You may say something like this:
   - "We have a lot of different ideas circulating in the room right now. It is really important for us to get to some agreement on how we represent what we know about transmission of disease and the Black Death, so that we have a shared understanding to build upon as we move ahead. In order to do this we are going to do something called a **Class Consensus Discussion**. First I will select a few different groups to share their ideas. Then, we will let each group share their response, and discuss what we can agree to as a class."
2. You may decide to walk students through the entire poster, or take them through the steps as you facilitate it.

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

3. Select two or three groups' responses to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of what caused such a high death toll during the plague (Black Death). The decision about which ideas or responses to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.
4. Ask the first group to share their most important ideas. You can do this by:

Routine

Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas.

This is the first time doing such a discussion in this unit, so focus more on the steps and the process. In future parts of this unit, you will use this format to do more in-depth discussions and consensus building. Please read the Biology Course Guide for detailed steps of this routine.

- Projecting using a document camera; OR
- Copying the responses to be shared and passing them out; OR
- Writing key points on the board or on poster paper.

5. Proceed through the steps in the Consensus Discussion Steps. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk; use the guidelines below to ensure the class focuses on ideas that will drive the lesson and unit forward.

Take Time for These Key Points

Pause the discussion and ask for clarification, particularly of the following key points:

- The Black Death was deadly due to a combination of factors including:
  - poor hygiene
  - malnutrition
  - high population density and high population mixing
  - the bacteria that causes it is fairly contagious (and virulent once it reaches the lungs)
  - differences in wealth and resources may have contributed to vulnerability
- Different types of evidence can be used to support a claim, such as: historical records, direct observations, simulations, models, and secondary data sets. (in future lessons we will evaluate evidence).
- It is challenging to identify causality; there may be many contributing factors.

6. Return to student questions from the Engage phase in order to bring up lingering issues not yet resolved, such as:
   - Now that we know why so many people died, why did some people survive?
   - Were some people just different from others? (Immune, lucky, stronger, etc.)
   - How can we apply what we learned about The Black Death to prevent transmission of cholera?

7. Have students complete the *Summary Task* individually.

Classroom Supports

Post the steps to the class consensus discussion in the room, as a reference you can return to in future lessons.

Integrating Three Dimensions

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #2 - Cause and Effect** explicit for students by elevating and probing for ideas related to the concept that it is challenging to identify causality due to the fact that there may be many factors contributing to a phenomenon. This is an important element **CCC #2 - Cause and Effect** at the high school level.

Routine

Class Consensus Discussions are important for the Explain phases across this unit. This is the first time doing such a discussion in this unit, so focus more on the steps and the process (see the Biology Course Guide for more details). In future parts of this unit, you will use this format to do more in-depth discussions and consensus building. For now, it's just about establishing a common understanding of the format.

Integrating Three Dimensions

The summary task prompts here are designed to get students to consider what they know about using the crosscutting concept of Cause and Effect (**CCC #2 - Cause and Effect),** then apply it as a tool for asking more questions that build on prior learning about both DCIs and CCCs. The summary task prompt is modified from STEM Teaching Tools #41, and it gets at the idea of complex causality, which is key for making a strong argument (**SEP #7 - Engaging in Argument from Evidence**).

Explore 2

How does natural selection lead to beneficial traits in a population?

Students **collect and analyze population level data** for rock pocket mice in order to surface how **natural variation in traits may confer an advantage in specific environmental conditions**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Making Sense of Color Variation Over Time in Rock Pocket Mouse Populations Investigation ❑ Color Variation Over Time in Pocket Mice Populations Investigation Rubric	❑ A set of HHMI illustrations (printed in color) for each group	❑ HHMI BioInteractive: Color Variation Over Time in Rock Pocket Mouse Populations Investigation (student handout; illustrations; teacher version) ❑ 5E Plan - Gamete Production - Teacher Plan and Guidelines (optional sexual reproduction resources) ❑ 5E Plan - Molecular Genetics - Teacher Plan and Guidelines (optional mutation resources) ❑ The Making of the Fittest: Natural Selection and Adaptation

Launch

1. Begin by asking students to remind us what we are trying to figure out, (such as: Why did some people survive the Black Death? How can understanding past disease outbreaks help us prevent a new one?). In this investigation, students will begin to figure out answers to their unanswered questions from the previous Explore and Explain phases:
    - Now that we know why so many people died, why did some people survive?
    - Were some people just different than others? (immune, lucky, stronger, etc)

2. Prompt students to think about their earlier discussions on why some people get sick and others do not (even in the same household). Highlight student ideas that surface that there are differences between people, in lots of ways, not just if they get sick easily or not.

3. List on the board ideas around differences (variation) between people. Student may surface ideas such as:
    - Hair color
    - Skin color
    - Height
    - Weight
    - Eye color

4. Ask students to brainstorm ways in which we could investigate how variations in human traits may impact them. Facilitate ideas on investigating other organisms to understand a similar phenomenon that occurs in humans (because humans are so difficult to study!) If no one brings up this idea, remind students about how model organisms were used in Unit 1 Marathon Runner to understand processes going on in humans, and ask students what they learned from that experience. One way we can investigate traits and their impact is to look at the example of pocket mice fur. We are going to investigate color differences in pocket mice fur, to understand how and why people have differences in their traits (and how that might impact them).

Implementation Tip

When returning to the Driving Question Board, these teacher notes are just suggestions! Be sure to allow students' thinking and questions to drive the discussion.

Investigation: Color Variation in Rock Pocket Mice

1. Provide students with the HHMI BioInteractive materials for the HHMI BioInteractive: Color Variation Over Time in Rock Pocket Mouse Populations Investigation . Pass out the student handout, and provide table groups with a set of the illustrations.

2. Students follow steps 1-4 in the student handout, including watching the video when prompted. Stop the video at time 3:16, and provide students time to respond to the prompts (either in their notebooks or on the *Making Sense of Color Variation Over Time in Rock Pocket Mouse Populations Investigation*).

3. Students continue on completing steps 5-6 in the student handout.

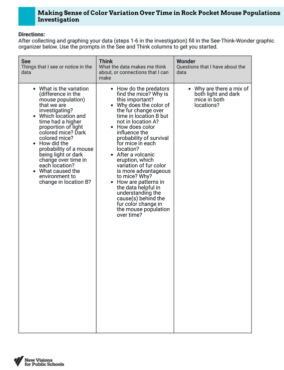
4. Confer with students as they work in groups to collect and analyze the data, using the pocket mice population illustrations.

5. Provide students with the *Making Sense of Color Variation Over Time in Rock Pocket Mouse Populations Investigation* handout (Students respond to these prompts instead of those given in the HHMI student packet.)

6. Students individually fill in the organizer.

Integrating Three Dimensions

The prompts about patterns in the conferring points are in support of students' consideration of **CCC #1 - Patterns**.



Making Sense of Color Variation Over Time in Rock Pocket Mouse Populations Investigation

Directions:
After collecting and graphing your data (steps 1-6 in the investigation) fill in the See-Think-Wonder graphic organizer below. Use the prompts in the See and Think columns to get you started.

See Things that I see or notice in the data	**Think** What the data makes me think about, or connections that I can make	**Wonder** Questions that I have about the data
• What is the variation (difference in the mouse population) that we are investigating? • Which location and time had a higher proportion of light colored mice? Dark colored mice? • How did the probability of a mouse being light or dark change over time in each location? • What caused the environment to change in location B?	• How do the predators find the mice? Why is this important? • Why does the color of the fur change over time in location B but not in location A? • How does color influence the probability of survival for mice in each location? • After a volcanic eruption, which variation of fur color is more advantageous to mice? Why? • How are patterns in the data helpful in understanding the cause(s) behind the fur color change in the mouse population over time?	• Why are there a mix of both light and dark mice in both locations?

Conferring Prompts

Confer with students as they work in pairs to complete the lab activity.

Suggested conferring questions:
(These should push students' thinking around establishing relationships, observing patterns, identifying variables, and questioning events):

- What is the variation (differences) we are exploring in the mice?
- What is the mice's environment like? Why is this important?
- What is eating the mice?
- How do the predators find the mice? Why is this important?
- How did the fur color change in the pocket mice over time?
- What patterns are you noticing in the data?
- How do the patterns you have identified help you understand what is happening with the mice population over time?

Differentiation Point

When engaging with the mice population illustrations, students may struggle with how to predict a sequence, using both locations. Location A is similar to a control, in that it represents the population over time that does not experience a volcanic eruption. Prompt students to focus in on location B, that will demonstrate a pattern (increasing # of black mice) or cut up the visualizations so that location A and B are separated (and students can more easily focus on the changes that occur in location B.)

Whole-Class Investigation Summary

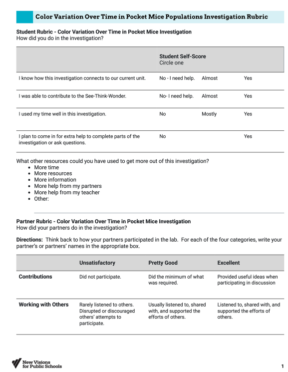
1. Provide students time to share their ideas about the See-Think-Wonder organizer.
2. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' See Think Wonder. Plan forward based on the various understandings that students or student groups have articulated. It is appropriate to go onto the next phase once students have had a chance to make sense of the data, and have had the opportunity to clarify what they have figured out about the investigative phenomenon under study in this learning sequence.

Look & Listen For

During or after the Domino Discover, highlight ideas similar to the following:

- The mice have variation or differences in their fur color due to sexual reproduction and/or mutation.
- The environment changed from light colored soil to dark colored after a volcanic eruption.
- Because predators primarily use sight to catch the mice, the mice that are camouflaged (black on a black environment) have an advantage over those that are not camouflaged.
- Over time, the population changed to include more black mice (because they survived, reproduced, and passed this trait on to offspring).

3. Provide students with *Color Variation Over Time in Pocket Mice Populations Investigation Rubric*. Ask students to use the investigation rubric to self and peer assess their progress on engaging with the investigation individually and as a group.



Color Variation Over Time in Pocket Mice Populations Investigation Rubric

Student Rubric - Color Variation Over Time in Pocket Mice Investigation
How did you do in the investigation?

	Student Self-Score Circle one		
I know how this investigation connects to our current unit.	No - I need help.	Almost	Yes
I was able to contribute to the See-Think-Wonder.	No- I need help.	Almost	Yes
I used my time well in this investigation.	No	Mostly	Yes
I plan to come in for extra help to complete parts of the investigation or ask questions.	No		Yes

What other resources could you have used to get more out of this investigation?
- More time
- More resources
- More information
- More help from my partners
- More help from my teacher
- Other:

Partner Rubric - Color Variation Over Time in Pocket Mice Investigation
How did your partners do in the investigation?

Directions: Think back to how your partners participated in the lab. For each of the four categories, write your partner's or partners' names in the appropriate box.

	Unsatisfactory	Pretty Good	Excellent
Contributions	Did not participate.	Did the minimum of what was required.	Provided useful ideas when participating in discussion
Working with Others	Rarely listened to others. Disrupted or discouraged others' attempts to participate.	Usually listened to, shared with, and supported the efforts of others.	Listened to, shared with, and supported the efforts of others.

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Differentiation Point

In the NGSS, the concept that sexual reproduction along with meiosis and mutation are the sources of novel variation is a middle school DCI. If your students are not ready to incorporate those concepts into the phenomenon under study, use the resources 5E Plan - Gamete Production - Teacher Plan and Guidelines (optional sexual reproduction resources), 5E Plan - Molecular Genetics - Teacher Plan and Guidelines (optional mutation resources) to support your students. Alternatively, be sure to highlight/ review these points using the resources available in the Explain phase.

Routine

This **Domino Discover** routine is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Please read the Biology Course Guide for detailed steps of this routine.

Integrating Three Dimensions

All Explore phases in this unit are designed to surface observations, ideas, and questions related to DCIs, in this case DCIs in **LS4**, but evidence of student understanding of these ideas can be found in the accompanying Explain phase.

Explain 2

How could natural variations in the immune system of Medieval humans have contributed to their survival during the Black Death?

Students apply their understanding of **natural selection** to **consider the claim** that natural variations in human immune systems may have **affected** chances of survival during the Black Death. Students use sequence charts to represent **causality**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Triads	❑ Think-Talk-Open Exchange ❑ Class Consensus Discussion	❑ Sequence Chart

Materials

Handouts	Lab Supplies	Other Resources
❑ Pocket Mice Sequence Chart ❑ Natural Selection Text + Sequence Chart ❑ Think-Talk-Open Exchange + Buzzwords ❑ Summary Task ❑ The Immune System (NYSSLS extension)	None	❑ *Rock Pocket Mice Sequence Chart Cards* ❑ NPR article Black Death survivors gave their descendants a genetic advantage — but with a cost (advanced/teacher-level text) ❑ *Immune System Sequence Chart Cards* (optional) ❑ HHMI BioInteractive: Color Variation Over Time in Rock Pocket Mouse Populations Investigation ❑ How your Immune System Works

Launch

1. Introduce the guiding question for this Explain phase activity, connecting to one or more questions from the end of the Explore phase: How could natural variations in the immune system of Medieval humans have contributed to their survival during the Black Death?

Integrating Three Dimensions

Keep in mind that students need to go beyond explaining why some people survived the Black Death and some people didn't; this Explain is designed to support them in using a crosscutting concept to do this sensemaking. Be sure to make **CCC#1 - Patterns** explicit for students by elevating and probing for ideas related to the concept that identifying patterns at the genetic, individual, and population levels can help us understand how natural selection works.

Pocket Mice Sequence Charts

1. Provide student groups with the cards (precut) for the *Rock Pocket Mice Sequence Chart Cards* activity, and *Pocket Mice Sequence Chart*. Make sure the cards are not in the correct order.
2. Students use their knowledge of the rock pocket mice to put the cards in the correct order, prompt students to pay close attention to the bolded words. Confer with students as they work, asking them to revise as necessary.
3. Re-watch the HHMI BioInteractive: Color Variation Over Time in Rock Pocket Mouse Populations Investigation , this time watching the entire video (no need to stop at 3:16). Students can revise their sequence based on any new information in the video.
4. Students should document their sequence using the sequence chart.
5. Groups should display their sequence on their table (with the cards or their written sequence), so they can continue to reflect on it through the remaining steps.
6. Provide students with *Natural Selection Text + Sequence Chart* handout. Students read the text, looking for information that responds to the guiding question: How could natural variations in the immune system of Medieval humans have contributed to their survival during the Black Death?
7. Using the first sequence chart as an example, students individually fill in the sequence chart, responding to the guiding prompt.

Access for All Learners

Prompting students to sequence or reorganize information provides access to learners who need additional time to process and make sense of the learning.

Routine

This is the first time students are using **Think-Talk-Open Exchange**. Notice the addition of the variation **Buzzwords** with this routine. For more support, see the Biology Course Guide.

Differentiation Point

The rock pocket mice card sort is designed to be a scaffold to support students generating a sequence chart on human immune system variation. If additional support is needed, the teacher can use the matching card set, *Immune System Sequence Chart Cards*. Alternatively, students that have met or exceeded the standard, can use the advanced text, NPR article Black Death survivors gave their descendants a genetic advantage — but with a cost that includes a brief recording summarizing the main ideas, to develop their sequence chart.

8. Provide students with the *Think-Talk-Open Exchange + Buzzwords* note-catcher. Students individually respond to the prompt, using the buzzwords: adaptation, variation, differential survival, heritable, and therefore. The prompt is: How might natural variations in humans have contributed to their ability to survive diseases such as the Black Death?

9. Students use the group learning routine **Think-Talk-Open Exchange + Buzzwords** to share their ideas with their peers, using *Think-Talk-Open Exchange + Buzzwords* note-catcher to record their ideas.

10. After everyone in the group has exchanged ideas, students should write down any new ideas they learned from their partners.

Access for Multilingual Learners

By providing time for students to think through the reasoning of their argument (in the card sort), **transitioning** language learners get time to work with the requisite language in preparation for writing and speaking. The routine **Think-Talk-Open Exchange** provides comprehensible input for **emerging** language learners, and rehearsal time for **transitioning** learners.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:

   - “We are going to use a **Class Consensus Discussion**, just like we did a few days ago, to learn about all the thinking in the room and come to some decisions about how natural selection may have changed some immune system traits in humans because of the Black Death.”

2. You may decide to walk students through the entire poster again, or take them through the steps as you facilitate it.

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

Routine

Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Please read the Biology Course Guide for detailed steps of this routine.

3. Select two or three groups' or individuals' sequence charts or written responses to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of natural selection. The decision about which responses to share with the class should be based on both the ideas circulating in the classroom *and* the goals of this part of the 5E sequence.

4. Ask the first group to share their response. You can do this by:
   - Projecting using a document camera; OR
   - Copying the responses to be shared and passing them out to the class; OR
   - Taking a picture of each and projecting them as slides.

5. Proceed through the steps in the Consensus Discussion Steps. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk, so be sure to facilitate the conversation so that key ideas emerge.

Take Time for These Key Points

Pause the discussion and ask for clarification, particularly of the following key points:

- *Natural selection* is a process by which populations change over time.
- Populations possess *variation* in *heritable* traits (fur color in mice, immune systems in humans, etc.).
- Based on environmental conditions and selective pressure, specific variations can be beneficial to the organism; these are called *adaptations*. -- these variations were present in the population before they were necessarily beneficial in a particular environment.
- Organisms that possess a beneficial trait may benefit from *differential survival*, and pass on that trait to their offspring.
- Over time, the population can change based on environmental pressure and differential reproduction.
- Some humans in Medieval times may have possessed specific traits in their immune systems that provided some immunity to the Black Death, contributing to their survival.
- Identifying patterns can help us understand how natural selection works at the genetic, individual, and population levels.

Implementation Tip

Evolution by natural selection is only introduced in this 5E. Students have many more opportunities to make sense of this process in every 5E sequence in the unit. Therefore, students should be able to discuss the "Take Time for These Key Points" concepts, but they will also have many more opportunities to master them.

6. Return to student questions that bring up lingering issues not yet resolved, such as:
   - Are there other diseases that humans have evolved immunity to?
   - Are genetic variations in human systems impact COVID-19 susceptibility?
   - Are some people immune to cholera?
   - What strategies could be used to boost immunity to different diseases like cholera?

Integrating Three Dimensions

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #1 - Patterns** explicit for students by elevating and probing for ideas related to the concept that identifying patterns at the genetic, individual, and population levels can help us understand how natural selection works. This is an important element **CCC #1 - Patterns** at the high school level.

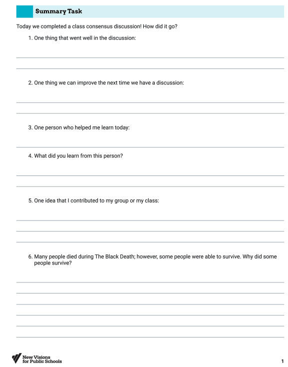
Access for Multilingual Learners

Rather than assigning a list of vocabulary words—a technique that rarely works for learning new vocabulary—this activity allows language learners to learn vocabulary from context. This approach is particularly helpful for **transitioning** multilingual learners, and it is a key part of the instructional model for all learners!

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.

2. The results of this task can be used to make determinations about which students need more time to engage in sensemaking about natural selection and human variation.



Summary Task

Today we completed a class consensus discussion! How did it go?

1. One thing that went well in the discussion:
2. One thing we can improve the next time we have a discussion:
3. One person who helped me learn today:
4. What did you learn from this person?
5. One idea that I contributed to my group or my class:
6. Many people died during The Black Death; however, some people were able to survive. Why did some people survive?

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Integrating Three Dimensions

This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas:

1) understanding how they are using the three dimensions, including the concept of natural selection, to make sense of a phenomenon, surviving a disease outbreak (the Black Plague); 2) ideas about how they and their peers are building knowledge together; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

The final prompt in the summary task assesses students' use of **CCC #1 - Patterns**. The prompt is modified from STEM Teaching Tools.

NYSSLS Extension

1. For teachers implementing the NYSSLS, a deeper investigation of the immune system is required.
2. Introduce the guiding question for the Explain 2 activity, connecting to the question: how might the ERAP2 gene variant help people be naturally more immune to infection?
3. Provide students with *The Immune System*. This activity can be done individually or in groups; the handout can be printed on larger paper or made into posters for students to work collaboratively.
4. Students read the introductory paragraph and analyze the images, predicting the roles of structures, cells, and molecules in the immune system. Pause to confer with students after they determine which parts of the immune system are barriers (e.g. skin) versus which parts of the immune system are involved in fighting pathogens once they enter the body (e.g. lymph nodes, bone marrow). Then, guide students in zooming into the body (particularly the blood) to consider the role of immune cells and molecules such as antibodies in the immune response.
5. When students are done with their initial predictions, provide time for students to engage in the text, and video on the immune system. In pairs or small groups, students revise the role of each cell or molecule, using the appropriate vocabulary for each image.
6. Depending on available instructional time and student interest, prompt students to generate a model of how the immune system may have responded in different individuals to the bubonic plague (the disease that caused the black death) both with and without the protective version of ERAP2.

Integrating Three Dimensions

Disease as a disruption of homeostasis is touched upon in many parts of the unit, including the Black Death 5E. For those that are implementing the NYSSLS, use the extension activity to bring the NYSED-specific DCI related to immunity to the forefront, emphasizing the structure and function aspect of antibody-antigen specificity, using the ERAP2 gene as an example.

Elaborate

What is the evolutionary history of the sickle cell trait?

Students test out their ideas and conceptions about **natural selection** **by considering how evolution works at different scales and in different population-level systems.**

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Table groups	❏ Read-Generate-Sort-Solve	None

Materials

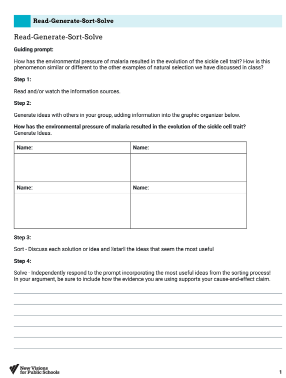
Handouts	Lab Supplies	Other Resources
❏ Read-Generate-Sort-Solve	None	❏ PBS text: A mutation Story ❏ Science Magazine article: Found: genes that sway the course of the coronavirus (optional advanced text) ❏ A Mutation Story

Text-Based Task

1. Organize students into table groups. Highlight for students that in the previous Explore & Explain, they figured out how the Black Plague served as a selective pressure on the human immune system. Students may wonder if there are other diseases that have exerted selective pressure, or other diseases that some people have evolved immunity for.

2. Provide students with the *Read-Generate-Sort-Solve* handout, and the PBS text: A mutation Story . As a class, watch A Mutation Story and allow students to first individually respond to the guiding prompt on their handout, using the information found in the video and on-line text.

3. Facilitate the group learning routine **Read-Generate-Sort-Solve**, as a way for students to synthesize and extend their thinking.



Read-Generate-Sort-Solve

Read-Generate-Sort-Solve

Guiding prompt:

How has the environmental pressure of malaria resulted in the evolution of the sickle cell trait? How is this phenomenon similar or different to the other examples of natural selection we have discussed in class?

Step 1:

Read and/or watch the information sources.

Step 2:

Generate ideas with others in your group, adding information into the graphic organizer below.

How has the environmental pressure of malaria resulted in the evolution of the sickle cell trait?
Generate Ideas.

Name:	**Name:**
Name:	**Name:**

Step 3:

Sort - Discuss each solution or idea and star the ideas that seem the most useful

Step 4:

Solve - Independently respond to the prompt incorporating the most useful ideas from the sorting process! In your argument, be sure to include how the evidence you are using supports your cause-and-effect claim.

New Visions for Public Schools 1

Routine

The **Read-Generate-Sort-Solve** routine promotes collaborative engagement in problem-solving and supports students in articulating their thinking and making it transparent, before considering solutions. This is the first time the class has engaged in this routine during this unit, so be sure to refer to the Biology Course Guide for planning support.

Differentiation Point

Students may be curious about if variations in the immune system may protect against COVID-19. If so, provide students with the advanced text, Science Magazine article: Found: genes that sway the course of the coronavirus as an extension or alternative to exploring malaria and sickle cell anemia.

Evaluate

How do the characteristics of transmission of disease and immunity connect to identifying the best solution to prevent a future cholera outbreak?

Students **use evidence** generated throughout the unit, and their new understanding of the **causes behind disease transmission and innate immunity**, to **evaluate claims** on the best way to prevent a future cholera outbreak.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Table groups	❏ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Claim and Evidence Card Sort ❏ The Black Death Argument ❏ Cholera - Immunity & Transmission Text ❏ Black Death Mini-Rubric ❏ Cholera Outbreaks Surge Worldwide as Vaccine Supply Drains (optional)	None	❏ Class wide scientific argument characteristics ❏ Driving Question Board from the start of the unit should be available ❏ *Claim and Evidence Card Sort - Example Student Work*

Revisit the Performance Task

1. Prompt students to consider where they currently stand on the question category from the Driving Question Board that they have been investigating throughout the Black Death instructional sequence (for example: What can we learn from past disease outbreaks such as The Black Plague?).

Implementation Tip

When returning to the Driving Question Board, be sure to change these suggested teacher notes so that they match your class's actual questions!

2. Listen to student ideas, and probe students about their understanding of claims, evidence, and reasoning in developing scientific arguments. Revisit the class wide scientific argument characteristics as needed.

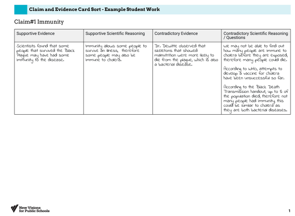
3. Provide table groups with *Claim and Evidence Card Sort* (pre-cut) for the card sort.
    - Students identify which claim each idea is related to. This 5E has two associated claims: Immunity and Disrupting Transmission.

Access for All Learners

The card sort activity provides an opportunity for students to discuss in groups and surface their initial ideas about how to differentiate claims, evidence, and reasoning in scientific argumentation. The cards are not the only possible examples of evidence or reasoning, students should be encouraged to add additional ideas!

- For each claim, students sort the cards to represent evidence or concepts for the claim (scientific reasoning) and evidence or concepts that refute the claim.

4. Provide students with *The Black Death Argument*. Students work individually to make sense of how the learning from this 5E sequence contributes to the overall task.



Claim and Evidence Card Sort - Example Student Work

Claim#1 Immunity

Supportive Evidence	Supportive Scientific Reasoning	Contradictory Evidence	Contradictory Scientific Reasoning / Questions
Scientists found that some people that survived the Black Plague may have had some immunity to the disease.	Immunity allows some people to survive an illness, therefore some people may also be immune to cholera.	Dr. Dewitte observed that skeletons that showed malnutrition were more likely to die from the plague, which is also a bacterial disease.	We may not be able to find out how many people are immune to cholera before they are exposed, therefore many people could die. According to WHO, attempts to develop a vaccine for cholera have been unsuccessful so far. According to the Black Death Transmission handout, up to 1/3 of the population died, therefore not many people had immunity, this could be similar to cholera as they are both bacterial diseases.

New Visions for Public Schools 1

Integrating Three Dimensions

This is an opportunity for students to synthesize their learning related to **SEP #7 - Engaging in Argument from Evidence**. This task supports students in building a deeper understanding of what constitutes good evidence. This is an idea they will return to throughout the unit.

Differentiation Point

Students that meet or exceed the PEs addressed in this 5E can investigate and incorporate additional details about cholera into their Performance Task. Provide them with, *Cholera - Immunity & Transmission Text*. Additionally, students may be curious about cholera vaccines. Provide students with the optional reading Cholera Outbreaks Surge Worldwide as Vaccine Supply Drains .

5. Confer with students while they are working.

6. Students should note their final ideas in the *The Black Death Argument* and use all of the evidence, reasoning, (as well as ideas that refute the claim) to respond to the prompt: At this point in the unit how do you think we can prevent another Cholera outbreak? Support your answer using evidence and scientific reasoning from your previous responses.

7. After completing their response, use the *Black Death Mini-Rubric* as self, peer, or teacher feedback on their argument.

Conferring Prompts

Confer with students as they work to sort the cards. Prompt students to return to the class wide scientific argument characteristics, posted in the room.
Suggested conferring questions:

- How does this piece of evidence connect to a specific claim?
- Can you think of other evidence that supports each claim?
- Is some evidence more trustworthy? Why or why not?
- Can you think of other evidence or ideas that refute this claim?

Document Class Thinking

1. Prompt students to discuss, in table groups, each claim from this 5E sequence (immunity and disrupting transmission). Students can use the notes in their *The Black Death Argument* for these discussions.

2. Each group comes to a consensus answer on each claim (Is this the strongest claim, is this the best solution to stopping a future outbreak?) Students decide—Yes, No, or Maybe—and should be able to articulate their reasoning.

3. Conduct a **Domino Discover** to hear from each group, and tally the responses on chart paper. It is not necessary to discuss all the positions or get to class consensus at this point. Listen for students' ability to use evidence and reasoning to back up or refute a claim.

Revisit the Driving Question Board

1. Use the **Driving Question Board** routine to discuss which of their questions have been answered.

2. Have students identify which categories/questions they have *not* figured out yet. Students should share out these questions and document new questions that arise based on what they have been learning, which can be added to the Driving Question Board.

3. One question category still unanswered should relate to questions about why antibiotics are not working as well as they used to, or if we can develop new antibiotics. Tell students that in the next sequence of lessons, they will investigate this phenomenon and the related claim(s) on the best solution to avoid a future outbreak of *V. cholerae*.

Standards in The Black Death 5E

Performance Expectations

HS-LS4-2	**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.** Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning. Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.
HS-LS4-3	**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.** Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations. Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.
HS-LS4-4	**Construct an explanation based on evidence for how natural selection leads to adaptation of populations.** Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations. Assessment Boundary: None

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. SEP4(2) Engaging in Argument from Evidence • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. SEP7(2)	LS1.A Structure and Function • Disease is a failure of homesotasis. Organisms have a variety of mechanisms to prevent and combat disease. Technological advances including vaccinations and antibiotics have contributed to the prevention and treatment of disease LS1.A(6)NYS LS4.B Natural Selection • Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. LS4.B(1) • The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. LS4.B(2) LS4.C Adaptation • Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. LS4.C(1) • Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. LS4.C(2)	Patterns • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. CCC1(1) Cause and Effect • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CCC2(1)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
	• Adaptation also means that the distribution of traits in a population can change when conditions change. LS4.C(3)	

Assessment Matrix

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Analyzing and Interpreting Data		*Making Sense of Disease Transmission Investigation P1* *Making Sense of Disease Transmission Investigation P2*	*Making Sense of Color Variation Over Time in Rock Pocket Mouse Populations Investigation* *Pocket Mice Sequence Chart* *Natural Selection Text + Sequence Chart Summary Task*		
Engaging in Argument from Evidence		*Making Sense of Disease Transmission Investigation P1* *Making Sense of Disease Transmission Investigation P2* *Black Death Claims Summary Task*		*Read-Generate-Sort-Solve*	*Claim and Evidence Card Sort* *The Black Death Argument* *Black Death Mini-Rubric*
LS1.A Structure and Function		*Black Death Claims Summary Task*			
LS4.B Natural Selection	Rumors post-it notes		*Making Sense of Color Variation Over Time in Rock Pocket Mouse Populations Investigation* *Pocket Mice Sequence Chart* *Natural Selection Text + Sequence Chart* *Think-Talk-Open Exchange + Buzzwords Summary Task* HHMI Rock Pocket Mice Variation Student Handout *Making Sense of Color Variation Over Time in Rock Pocket Mouse Populations Investigation*	*Read-Generate-Sort-Solve*	*The Black Death Argument* *Black Death Mini-Rubric*

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
LS4.C Adaptation			*Pocket Mice Sequence Chart* *Natural Selection Text + Sequence Chart* *Think-Talk-Open Exchange + Buzzwords Summary Task* HHMI Rock Pocket Mice Variation Student Handout *Making Sense of Color Variation Over Time in Rock Pocket Mouse Populations Investigation Summary Task*	*Read-Generate-Sort-Solve*	*The Black Death Argument* *Black Death Mini-Rubric*
Patterns			*Making Sense of Color Variation Over Time in Rock Pocket Mouse Populations Investigation Summary Task*		*The Black Death Argument* *Black Death Mini-Rubric*
Cause and Effect		*Black Death Claims Summary Task*	HHMI Rock Pocket Mice Variation Student Handout *Pocket Mice Sequence Chart*	*Read-Generate-Sort-Solve*	*The Black Death Argument* *Black Death Mini-Rubric*

Common Core State Standards Connections

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Mathematics		MP2 MP3 MP4 MP6	MP2 MP3 MP4 MP6		
ELA/Literacy		WHST.9-10.9	WHST.9-10.9	WHST.9-10.1 WHST.9-10.5 SL.9-10.4	WHST.9-10.1 WHST.9-10.9

Student Work for The Black Death 5E

Claim#1 Immunity

Supportive Evidence	Supportive Scientific Reasoning	Contradictory Evidence	Contradictory Scientific Reasoning / Questions
Scientists found that some people that survived the Black Plague may have had some immunity to the disease.	Immunity allows some people to survive an illness, therefore some people may also be immune to cholera.	Dr. Dewitte observed that skeletons that showed malnutrition were more likely to die from the plague, which is also a bacterial disease.	We may not be able to find out how many people are immune to cholera before they are exposed, therefore many people could die. According to WHO, attempts to develop a vaccine for cholera have been unsuccessful so far. According to the Black Death Transmission handout, up to ½ of the population died, therefore not many people had immunity, this could be similar to cholera as they are both bacterial diseases.

Claim#2 Transmission

Supportive Evidence	Supportive Scientific Reasoning	Contradictory Evidence	Contradictory Scientific Reasoning / Questions
From the simulation, we observed that high population densities increase transmission rates. From the simulation, we observed that high population mixing increases transmission rates.	From the Black Death Transmission handout, we learned that Cholera has a high Ro (is very contagious). According to the world Health organization (WHO), cholera is typically spread through poor sanitary conditions such as infected food and water.		According to WHO, people from past cholera outbreaks were able to avoid infection if they were wealthy and able to leave the area. This was similar to what we observed with the Black Plague. It may not be practical to ask people to leave crowded areas, as they may not have money to move. It may not be practical to ask people to leave an area of infection, because people may not want them to enter their town, as we saw with the Black Plague historical document. It may be impossible to stop people from interacting or mixing with other people during an outbreak, as people need to get food, go to work, go to funerals, or do other necessary activities.

Classroom Resources for The Black Death 5E

Immune System Sequence Chart Cards
Rock Pocket Mice Sequence Chart Cards
Black Death Quotations
Claim and Evidence Card Sort

Immune System Sequence Chart Cards

Use this master to create cards for the card sequence activity.

Before the Black Death, the bacteria Y. *pestis* was not commonly found in most humans' **environments.**	Most humans did not possess the protective variant of the *ERAP2* gene. However, there was always some **variation** in the population due to **sexual reproduction** and **mutations**, so some people had this variant.	The spread of Y. *pestis* bacteria through fleas and the global movements of people changed the **environment**, so that many people came into contact with the bacteria
People that just happened to have inherited the protective variant of the immune system gene, *ERAP2* were better able to fight off the Y. *pestis* bacteria and not get sick or die from the plague. Having the protective variant at that time could be considered an **adaptation**.	Having immunity (even partial immunity) to the Y. *pestis* bacteria was an **advantage** during the Black Death, because these people were less likely to get sick and die.	During the Black death more people without the protective variant of the gene died. This is called **differential survival**. People that survived were more likely to reproduce and pass the protective variant on to their offspring. Over time, the number of people in the population with the protective variant of the gene increased.

Rock Pocket Mice Sequence Chart Cards

Use this master to create cards for the card sequence activity.

A long time ago, all the soils in the pocket mice's **environment** were composed of light colored sand.	Most of the pocket mice had light colored fur. However, there was always some **variation** in the population due to **sexual reproduction** and **mutations**, so some mice had dark fur.	A volcanic eruption changed the **environment**, so that instead of light colored soils, the lava flow made black soil.
On black soils, darker colored mice are able to better camouflage with their surroundings. This is called an **adaptation**.	Predators tend to use sight to capture the mice, so those that had the darker colored fur had an **advantage**, in that predators did not see them as easily and were caught and eaten less.	On the black soils, more dark colored mice survived and reproduced. This is called **differential survival** because those that had the dark fur survived and those without it did not. Therefore, over time, the whole population of pocket mice living on lava flows changed so that there are more dark colored mice than light colored mice.

4 quotes meant to be printed on 11x17 paper, for students to use with Text Graffiti

"At the beginning of October, in the year of the incarnation of the Son of God 1347, twelve Genoese galleys [trading ships] . . . entered the harbor of Messina. In their bones they bore so virulent a disease that anyone who only spoke to them was seized by a mortal illness and in no manner could evade death."

"When the inhabitants of Messina discovered that this sudden death emanated from the Genoese ships they hurriedly ordered them out of the harbor and town. But the evil remained and caused a fearful outbreak of death."
"When the catastrophe had reached its climax the Messinians resolved to emigrate. One portion of them settled in the vineyards and fields, but a larger portion sought refuge in the town of Catania. The disease clung to the fugitives and accompanied them everywhere where they turned in search of help."

“Soon the boils grew to the size of a walnut, then to that of a hen's egg or a goose's egg, and they were exceedingly painful, and irritated the body, causing the sufferer to vomit blood. The sickness lasted three days, and on the fourth, at the latest, the patient succumbed.”

Succumbed - gave in; died

Claim and Evidence Card Sort

Use this master to create cards for the card sort activity.

From the simulation, we observed that high population densities increase transmission rates.	From the simulation, we observed that high population mixing increases transmission rates.	From the Black Death Transmission handout, we learned that Cholera has a high R0 (is very contagious).
According to the World Health Organization (WHO), cholera is typically spread through poor sanitary conditions such as infected food and water.	Dr. Dewitte observed that skeletons that showed malnutrition were more likely to die from the plague, which is also a bacterial disease.	According to WHO, people from past cholera outbreaks were able to avoid infection if they were wealthy and able to leave the area. This was similar to what we observed with the Black Plague.

It may not be practical to ask people to leave crowded areas, as they may not have money to move.	It may not be practical to ask people to leave an area of infection, because people may not want them to enter their town, as we saw with the Black Plague historical document.	It may be impossible to stop people from interacting or mixing with other people during an outbreak, as people need to get food, go to work, go to funerals, or do other necessary activities.
According to WHO, cholera outbreaks often occur after a natural disaster, and in developing areas, so it may be difficult to ensure proper hygienic conditions.	Scientists found that some people that survived the Black Plague may have had some immunity to the disease, therefore some people may also be immune to cholera.	We may not be able to find out how many people are immune to cholera before they are exposed, therefore many people could die.
According to WHO, attempts to develop a vaccine for cholera have been unsuccessful so far.	According to the Black Death Transmission handout, up to ½ of the population died, therefore not many people had immunity, this could be similar to cholera as they are both bacterial diseases.	

Antibiotic Resistance 5E

Why aren't antibiotics working as well as they used to?	**Performance Expectations** HS-LS4-3, HS-LS4-4, HS-LS4-2, HS-LS4-5	**Investigative Phenomenon** A thousand feet under the New Mexico soil, in the deepest limestone cave in the country, researchers have discovered an ancient bacterium that is resistant to many antibiotics used in human medicine today.	**Time** 7-8 days

Scientists recently discovered that bacteria living in isolated environments, and not exposed to modern medicine like antibiotics, have resistance to many commonly used antibiotics. In this 5E instructional sequence, students explore how and why this may have occurred. They consider why antibiotic resistance is increasing globally, and what threat this phenomenon may pose to human health and well-being. One important cause behind the increase in antibiotic resistance is the overuse of antibiotics in agriculture. Students explore how humans have modified the environment to speed up or facilitate the evolution of resistance.

ENGAGE	Why would bacteria never exposed to people be able to resist antibiotics that we use?	Connecting to their earlier questions about why antibiotics do not work against all bacterial infections, students share their initial ideas about why bacteria would develop resistance even without exposure to human medicine. This leads students to express a need to investigate **the evolution of antibiotic resistance** further.
EXPLORE	How do bacteria become resistant to antibiotics?	Students **collect data from a simulation** in order to investigate how antibiotics affect the **distribution of traits in a population** of bacteria, surfacing **patterns** related to antibiotic resistance.
EXPLAIN	How do bacteria become resistant to antibiotics?	Students use a **cause and effect** graphic organizer to **construct an explanation** on how **antibiotic resistance in bacteria** develops at different scales.
ELABORATE	How can we leverage phages to fight antibiotic resistant infections?	Students test out their ideas and conceptions about fighting bacterial infections by applying their thinking to a new tool to fight infections, phages. Using a text, and their understanding of **the causes** behind **bacterial infections and antibiotic resistance,** students provide an **explanation of** how phages can be leveraged to fight infections.
EVALUATE	How does antibiotic resistance occur and how does this impact our ability to fight bacterial infections such as cholera?	Students **evaluate a claim** using their understanding of the **causes behind antibiotic resistance and how natural selection works** in evolving populations.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

Why would bacteria never exposed to people be able to resist antibiotics that we use?

Connecting to their earlier questions about why antibiotics do not work against all bacterial infections, students share their initial ideas about why bacteria would develop resistance even without exposure to human medicine. This leads students to express a need to investigate **the evolution of antibiotic resistance** further.

Preparation

Student Grouping	Routines	Literacy Strategies
None	❏ Rumors	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Microbes in Caves Text	None	❏ Post-it notes ❏ CIDRAP article: Scientists find ancient, cave-dwelling resistant bacteria (advanced/teacher text) ❏ Caving for Cures: Mining Drugs From Nature (optional)

Launch and Surfacing Student Ideas

1. Remind students that, during the Driving Question Board launch, one category of questions that emerged was related to why antibiotics were not working against bacterial infections, and how we might find new antibiotics to fight infections. Ask students to share more about why they asked those questions, and listen for the observation that we have relied on antibiotics in medicine for a long time (everyone in the room has taken at least one course of antibiotics in their lifetime … what if they stop working?!).
2. Use students' questions and observations to transition to the guiding question: Why would bacteria have antibiotic resistance if they've never been around human medicine?

Differentiation Point

If students are unfamiliar with the term *resistant*, pause and surface students ideas on what that word might mean, and develop a class definition.

Access for All Learners

In the field test for this unit, we saw that it can be tricky to introduce this phenomenon in a way that sparks student thinking. You may want to start by asking, What do you think it's like in a cave? What would you expect to see in a cave?

3. Provide students with the handout *Microbes in Caves Text*, and show the optional video Caving for Cures: Mining Drugs From Nature . If using the video clip, be sure to stop it at 0:35, as it gives away many of the answers to this question.
4. Use the group learning routine **Rumors** to surface and categorize student ideas about the following question: How are there antibiotic resistant bacteria in these caves?

Look & Listen For

- Bacteria fight off other bacteria by creating their own antibiotics (competition).
- It's an accident (or random)
- Bacteria are preparing for encountering possible antibiotics (this misconception should be addressed later in the 5E sequence!).
- They limit their own population for more resources.
- Antibiotics are naturally in the environment, so they developed defenses.

Differentiation Point

The investigative phenomenon in this 5E is based on the work of Hazel A. Barton, PhD, from the University of Akron. Interested students can learn more at her site: http://www.cavescience.com/.

Routine

The goal of the **Rumors** routine is to have students exchange ideas while listening for similarities and differences in thinking. It's meant to be low stakes, so it is frequently used to surface initial student ideas about phenomena during the Engage phases. Please read the Biology Course Guide for detailed steps about this routine.

Explore

How do bacteria become resistant to antibiotics?

Students **collect data from a simulation** in order to investigate how antibiotics affect the **distribution of traits in a population** of bacteria, surfacing **patterns** related to antibiotic resistance.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Simulating a Bacterial Infection Investigation ❑ Simulating a Bacterial Infection Investigation (Scaffolded Version) ❑ Making Sense of Simulating a Bacterial Infection Investigation ❑ Simulating a Bacterial Infection Investigation Rubric	❑ Dice ❑ 75 game tokens ❑ Simulating a Bacterial Infection Game Board (printed as big as possible - preferably at least 8.5 x 14)	❑ This tutorial: Collecting Lab Data with Google Forms and Sheets ❑ Antibiotic Resistance Data Table ❑ Antibiotic Resistance Data Table - Scaffolded Version ❑ Antibiotic Resistance Game Demo

Launch

1. Ask students to remind us what we are trying to figure out (how bacteria have developed resistance to antibiotics).

2. Have students recall their earlier discussion about how we might investigate phenomena that are difficult to see with our eyes, or that work at a population level. Ask students to suggest ideas on how we could investigate this phenomenon. Listen for student ideas that emphasize that we want to investigate antibiotic resistance here in the classroom, but we need to do this through a simulation.

3. Prompt students to review the idea of simulation from their work in the Black Death 5E investigation.

Implementation Tip

Even before this unit, students have had opportunities to make sense of a phenomenon without collecting data that is directly related to the phenomenon. In Unit 1, they did this through the use of model organisms (yeast). This is a good opportunity to make connections to any relevant past experiences in the classroom community.

Investigation: Antibiotic Resistance Simulation

1. Provide each student with the *Simulating a Bacterial Infection Investigation* handout, and each pair with 50-75 game tokens (beads, chips, or any other small item), the *Simulating a Bacterial Infection Game Board*, and dice.

2. Have groups carry out the simulation for populations of bacteria not exposed to antibiotics and then exposed to multiple rounds of antibiotics.

3. When students enact the simulation, they will first simulate what happens when the bacteria reproduce. Help students understand how to perform this reproduction so that only the existing tokens reproduce, and the new ones mutate.

Differentiation Point

When bacterial populations reproduce and mutate, it can be challenging to keep track of the "parents," who are reproducing, and the "offspring," who have the potential to mutate. The first few times that students are simulating this process, recommend that they slide the tokens that are already on their game board to the bottom of each box that they are in. Then, pick up each token, one at a time, when it is that one's turn to reproduce. Slide that token towards the top of the box that it is in, and pick up a new token to be its offspring. Before placing the new token on the board, roll the die and follow the rules in the game to decide if the token stays with its "parent" or moves to a different box. If it stays with its parent, place the token down on top of its parent at the top of the box it is in. If it moves to a different box, place it in the top half of that new box, keeping it separate from the "parents" in the new box. Work through all of the "parent" tokens across the board, until each one has "reproduced" and none of the "offspring" have.

Only tokens that were present during the last round reproduce. Any new tokens that enter the game during the reproduction phase do not. After the reproduction and mutation phase, there should be twice as many tokens as there were at the beginning.

4. After groups have practiced bacterial reproduction and mutation with no antibiotics, have them move on to simulating what happens when bacteria are exposed to multiple antibiotics. In this phase, students determine how many of each population in each box will survive based on their resistance. For example, the population in the "No antibiotic resistance box" will lose 75% of its population when exposed to Antibiotic A, but bacteria in the boxes "Resistant to A," "Resistant to A and B," "Resistant to A and C" and "Resistant to A, B, and C" will not experience any losses.

Note: there is no simulated antibiotic that will actually be handed out to students or bacteria. They simply simulate what would happen to each population if an antibiotic existed by removing tokens from the game board according to the rules.

5. Decide either as a class or in groups how the antibiotics should be "administered." In the simulation, each antibiotic A, B, and C should be administered three times, but the order in which they are given can vary:
    - Alternating A, B, and C
    - Three rounds of A, then three of B, then three of C
    - In a random order, using something like a random name generator

It may be that the entire class chooses to administer antibiotics in the same order, or that different groups make different decisions, or that the teacher assigns how students should administer them. The order of antibiotic administration should be noted in student data tables.

Differentiation Point

If students are struggling to determine the order to administer the antibiotics in, groups may need the scaffolded version. Provide *Simulating a Bacterial Infection Investigation (Scaffolded Version)* for those individuals or groups. Additionally, all students may need support using Google apps for data analysis, This tutorial: Collecting Lab Data with Google Forms and Sheets can provide some assistance in getting started.

6. In table groups, provide students time to review the procedure, engage in the simulation, collect and analyze the data in the Google sheet. Encourage students to use Google forms, Google Sheets, Excel, or other electronic technologies to assist in generating graphs and further analysis.

7. Use conferring questions to push students' thinking about the investigation while they are collecting data.

Conferring Prompts

Confer with students during and after the lab. Encourage students to use new terminology and science vocabulary from this unit to discuss what they are doing.
Suggested during-lab conferring questions:
- What are the variables we are testing?
- What was your prediction when we started?
- What does each component represent in this simulation? (boxes on the game board, tokens, dice)
- How did you make decisions in terms of data collection and analysis?

Suggested post-lab conferring questions:
- What is the trend you observed?
- What do you predict is going on to create this trend?

Investigation: Whole-Class Investigation Summary

1. Provide students with *Making Sense of Simulating a Bacterial Infection Investigation* so that they can independently graph, or insert a graph generated in a spreadsheet, and make sense of the data collected during the simulation.

2. Ask students to work independently to complete the Summary section, then use these completed pages to discuss the findings from the investigation.

3. Ask groups to come up with one important idea to share with the whole class, from their Summary notes.

4. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' Summary sections. Plan forward based on the various understandings that students or student groups have articulated. It is appropriate to go onto the next phase once students have had a chance to make sense of the data, and have had the opportunity to clarify what they have figured out about the investigative phenomenon under study in this learning sequence.

Look & Listen For

Possible student ideas from the Summary page:

- At the beginning of the investigation, none of the bacteria had antibiotic resistance
- Over the course of the investigation, the population shifted towards having more individuals with more antibiotic resistance
- By the end of the investigation, most of the bacteria were resistant to multiple antibiotics
- At first the numbers of bacteria decreased when antibiotics were given, but they increased again at the end
- Giving multiple rounds of antibiotics may help treat infections by killing off populations quickly, but any remaining bacteria that survive have a possibility of gaining a mutation that confers resistance
- Over time, resistant bacteria take over, and antibiotics no longer work to control their populations
- One important limitation is the small number of trials done.
- An important limitation is the small number of tokens we used for the population
- An important limitation is the small number of antibiotics we used

5. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

6. Provide students with *Simulating a Bacterial Infection Investigation Rubric*. Ask students to use the investigation rubric to self and peer assess their progress on engaging with the investigation individually and as a group.

Routine

The **Domino Discover** routine is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Unit 1 Teacher Guide for support with this routine.

Access for Multilingual Learners

Using **Domino Discover** at this stage provides support for multilingual learners who are **emerging** and **transitioning**. Providing different types of unique comprehensible input, all from peers in the classroom, supports students' language development. Refer to the Biology Course Guide for more information on this routine.

Simulating a Bacterial Infection Investigation Rubric

Student Rubric - Simulating Repeated Exposures to Antibiotics Investigation
How did you do in the investigation?

	Student Self-Score Circle one		
I know how this investigation connects to our current unit.	No - I need help.	Almost	Yes
I was able to contribute to the Data Analysis and respond to the Summary questions.	No- I need help.	Almost	Yes
I used my time well in this investigation.	No	Mostly	Yes
I plan to come in for extra help to complete parts of the investigation or ask questions.	No		Yes

What other resources could you have used to get more out of this investigation?

- More time
- More resources
- More information
- More help from my partners
- More help from my teacher
- Other:

Partner Rubric - Simulating a Bacterial Infection Investigation
How did your partners do in the investigation?

Directions: Think back to how your partners participated in the lab. For each of the four categories, write your partner's or partners' names in the appropriate box.

	Unsatisfactory	**Pretty Good**	**Excellent**
Contributions	Did not participate.	Did the minimum of what was required.	Provided useful ideas when participating in discussion
Working with Others	Rarely listened to others. Disrupted or discouraged others' attempts to participate.	Usually listened to, shared with, and supported the efforts of others.	Listened to, shared with, and supported the efforts of others.

Explain

How do bacteria become resistant to antibiotics?

Students use a **cause and effect** graphic organizer to **construct an explanation** on how **antibiotic resistance in bacteria** develops at different scales.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs or table groups	❑ Domino Discover ❑ Class Consensus Discussion	❑ Cause and Effect Chart ❑ Text Annotation ❑ Claim-Evidence-Reasoning (CER)

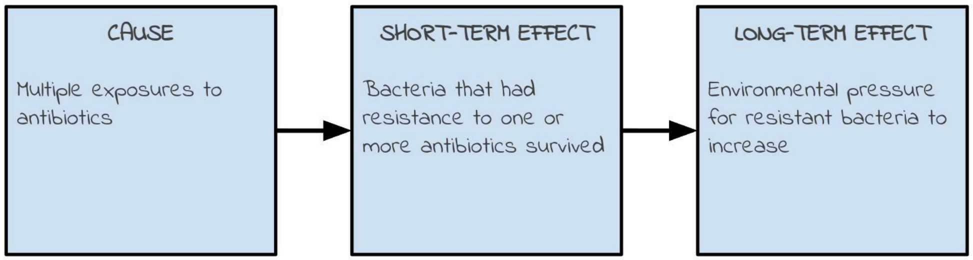
Materials

Handouts	Lab Supplies	Other Resources
❑ Antibiotic Resistance: Evaluating a Claim ❑ Antibiotic Resistance Text ❑ Natural Selection Comparison Chart ❑ C-E-R Graphic Organizer ❑ C-E-R Rubric ❑ Summary Task	None	❑ Scaffolds to support constructing scientific explanations ❑ CNN article: KFC promises to ditch antibiotic-laden chicken (optional) ❑ *Antibiotic Resistance: Evaluating a Claim - Student Work Example* ❑ Time Lapse Video of Resistance ❑ Antibiotic Use in Agriculture (can stop at 19:15)

Evaluating Evidence for a Claim

1. In the Explore phase, students have surfaced that populations experiencing repeated doses of antibiotics may encourage antibiotic resistance. Review this phenomenon with the class, using a cause and effect chart on poster paper or on the board.

Development of Antibiotic Resistance in an Individual

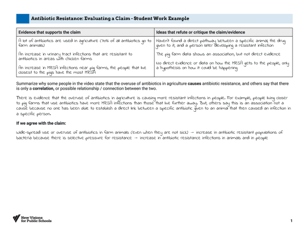


Example student response

2. Prompt students to reflect on their unanswered questions from the Explore phase. They may still wonder how or why this is happening at the population level (in caves or in the infectious bacteria impacting humans). Point to or highlight relevant student artifacts from the Explore phase, or facilitate student thinking on why it might be important to investigate this investigative phenomenon.

3. In order to transition to thinking about the evolution of antibiotic resistance at the population level, show students the Time Lapse Video of Resistance . Prompt a few students to share their observations or questions, and facilitate the surfacing of the guiding prompt (or something similar): How do bacteria become resistant to antibiotics at the population level?

4. Let students know that some people claim that the overuse of antibiotics in agriculture has caused this phenomenon of wide-scale resistance at the population level. Tell students they will watch a video to evaluate this claim, and start the PBS video Antibiotic Use in Agriculture . Provide students with the *Antibiotic Resistance: Evaluating a Claim*. Students will note evidence discussed in the video, as well as critiques of the claim and evidence. Pause the video as evidence is brought up so that students have an opportunity to write down their ideas in the handout. The entire video is a great resource, but if instructional time is limited, stop the video at about 19:15.



5. Allow students to discuss their cause and effect chart and summary question #2 from the *Antibiotic Resistance: Evaluating a Claim* in pairs or table groups. Use **Domino Discover** to surface high level ideas.

Integrating Three Dimensions

In this unit students are developing proficiency with the **CCC#2 Cause and Effect**, differentiating between cause and correlation. This is the first opportunity students have to experience and discuss this concept, which will be further explored in the next 5E sequence. Use this opportunity to clarify the meaning of both correlational and causal relationships.

Access for All Learners

Students may struggle to connect to this content (large scale agriculture) Provide the optional on-line article, CNN article: KFC promises to ditch antibiotic-laden chicken as an extension or homework assignment, so that students may be able to understand how this phenomenon connects to their food supply or life.

Look & Listen For

- Overuse of antibiotics in agriculture may cause a short term effect of increased resistance at the individual and population level (in animals).
- This may lead to a long term effect of increased antibiotic resistant infections in humans.
- There is a correlation between antibiotic use in agriculture and increased human infections, but more evidence maybe needed to identify causality.

Constructing a Scientific Explanation

1. Remind students of their earlier questions about how bacteria develop antibiotic resistance (both in caves and in the bacteria that infect humans) and that we looked at a claim around what might be causing antibiotic resistance on a larger scale. Prompt students to consider how the process of natural selection may help us understand this phenomenon better. Provide students with *Antibiotic Resistance Text*. Students read and annotate for information that helps us make sense of antibiotic resistance at the population level.

2. Confer with students as they develop a scientific explanation in response to the following prompt: How does antibiotic resistance develop in a bacteria population? Develop a claim in response to this question, and support your claim with evidence from the lab or video and sufficient scientific reasoning.

Integrating Three Dimensions

The use of constructing explanations (CER) in this Explain phase is to support the development of students' use of reasoning, in service of the foregrounded element in **SEP #7 - Engaging in Argument from Evidence**.

Differentiation Point

If students are having difficulty in making the connections between how natural selection may confer antibiotic resistance at the population level in both agricultural settings and extreme environments like caves, provide students with *Natural Selection Comparison Chart* to work through in pairs or as a whole class.

3. Provide students with the *C-E-R Graphic Organizer* to generate their initial draft

4. Students switch papers with a partner, and use the *C-E-R Rubric* to provide peer review and feedback.

Differentiation Point

This is the first time students have constructed a scientific explanation in this unit. Use this opportunity to surface where students are struggling with scientific explanations or scientific reasoning and provide the appropriate scaffold (see this guide).

5. Provide time for students to use peer feedback to draft their final explanation.

Differentiation Point

□↔○ ○↔□ □↔○ Understanding that bacteria exchange genes (conjugation) is not essential to understand natural selection, but could be a great concept to introduce here based on student interest and readiness (and may be especially helpful in understanding antibiotic resistance in caves).

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:
    - "We are going to use a **class consensus discussion**, just like we did in the last 5E, to learn about all the thinking in the room and come to some decisions about how natural selection can lead to antibiotic resistance in bacterial populations in range of environments such as caves, large scale agricultural systems or human populations."

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

Routine

Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Please read the Biology Course Guide for detailed steps of this routine.

2. Select two or three student explanations to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of natural selection. The decision about which explanations to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.

3. Ask the first student or group to share their explanation. You can do this by:
    - Projecting using a document camera; OR
    - Copying the written explanation to be shared and passing them out to the class; OR
    - Taking a picture of each explanation and projecting them as slides.

4. Proceed through the steps in the Consensus Discussion Steps.

5. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk.

Take Time for These Key Points

Pause the discussion and ask for clarification, particularly of the following key points:

- *Mutations* (both for generating antibiotics and for antibiotic resistance) happen *randomly* -- which results in *variation* (some have the gene(s) some do not).
- Competition for resources and the struggle for survival results in differential reproduction and survival (and can lead to a virtual arms race between organisms).
- The presence of antibiotics becomes a *selective pressure* in the environment.
- Once antibiotics are introduced into the environment, possessing the resistance gene(s) becomes an *adaptation* for survival.
- Humans may have sped up this process by:
    - Overuse of antibiotics in people, and people not completing their course of antibiotics.
    - Overuse of antibiotics in agriculture, with antibiotic resistant bacteria spreading to people through various means.
- Those with resistance survive (are not killed by the antibiotic) and reproduce more than those without resistance.
- Over time, the population of resistant bacteria increases because they are better suited for an environment rich in antibiotics (similarly, those that produce antibiotics in caves can increase).

Integrating Three Dimensions

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #2 - Cause and Effect** explicit for students by elevating and probing for ideas related to the concept that empirical evidence is required to differentiate between causation and correlation, an important element of cause and effect at the high school level. The prompts about patterns in the Class Consensus Discussion are in support of students' consideration of **CCC #2 - Cause and Effect**.

6. Return to student questions that bring up lingering issues not yet resolved, such as:
    - How do antibiotics kill bacteria?
    - Are there other ways to kill bacteria without using antibiotics?
    - How quickly does resistance develop?

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.

2. The results of this task can be used to make determinations about which students need more time to engage in sense-making about how antibiotic resistance develops.

Implementation Tip

This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas: 1) understanding how they are using the three dimensions, including the concept of natural selection, to make sense of a phenomenon 2) ideas about how they and their peers are building knowledge together; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

Elaborate

How can we leverage phages to fight antibiotic resistant infections?

Students test out their ideas and conceptions about fighting bacterial infections by applying their thinking to a new tool to fight infections, phages. Using a text, and their understanding of **the causes** behind **bacterial infections and antibiotic resistance,** students provide an **explanation of** how phages can be leveraged to fight infections.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Triads	❑ Read-Generate-Sort-Solve	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Antibiotics Text ❑ Bacteriophage Text ❑ RGSS Graphic Organizer	None	❑ Chart or poster-sized RGSS organizer (optional) ❑ The Deadliest Being on Planet Earth – The Bacteriophage

Text-Based Task

1. Organize students into groups of three. Prompt students to review what they figured out in the previous Explore and Explain. Facilitate students' figuring out the idea that bacteria develop antibiotic resistance through natural selection -- resulting in antibiotic resistance in both pristine environments like caves and in human agricultural and medical systems.

2. Return to questions from the beginning of this 5E cycle or in the Driving Question board highlight students' questions that consider what other strategies we can use to fight virulent bacteria. Ask students to list reasons why this might be helpful to figure out.

3. Let students know that some scientists are working on something called phages, that might serve as a good alternative to antibiotics. Other scientists continue to work on finding new antibiotics to fight infections. Jigsaw students to investigate these two solutions. Provide the first student with *Antibiotics Text*, the second with *Bacteriophage Text*, and the third with a laptop to watch the video The Deadliest Being on Planet Earth – The Bacteriophage . Provide each group with *RGSS Graphic Organizer* or a poster-sized version.

4. Facilitate the group learning routine **Read-Generate-Sort-Solve**, as a way for students to synthesize and extend their thinking.

Routine

The **Read-Generate-Sort-Solve** routine promotes collaborative engagement in problem-solving and supports students in articulating their thinking and making it transparent, before considering solutions. Please read the Biology Course Guide for detailed steps of this routine.

Access for All Learners

Read-Generate-Sort-Solve is an important routine because it builds in individual think time and opportunities for all students to contribute to the group answer. Students who need additional processing time, or a chance to adjust their thinking after hearing from peers, get that opportunity. This additional time for language input is especially helpful for **emerging language learners**.

Evaluate

How does antibiotic resistance occur and how does this impact our ability to fight bacterial infections such as cholera?

Students **evaluate a claim** using their understanding of the **causes behind antibiotic resistance and how natural selection works** in evolving populations.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Antibiotic Resistance Argument ❑ Antibiotic Resistance & Cholera Text ❑ Antibiotic Resistance Mini-Rubric	None	❑ Class wide scientific argument characteristics ❑ Driving Question Board from the start of the unit should be available ❑ *Antibiotic Resistance - Student Work Example*

Revisit the Performance Task

1. Prompt students to consider where they currently stand on the question category from the Driving Question Board that they have been investigating throughout this 5E instructional sequence. This will be something like: Why don't antibiotics work as well as they used to? A few students can share their thoughts, use examples of student work from the Explain phase to review or clarify any remaining questions.

Implementation Tip

When returning to the Driving Question Board, be sure to change these suggested teacher notes so that they match your class' actual questions!

2. Remind students that they are generating an argument about our unit level performance task, and we need to consider as a class how our ideas are developing about what a scientific argument is and what constitutes a strong claim / evidence. Prompt students to return to the Class wide scientific argument characteristics chart and revise their ideas.

Class Consensus List:
Characteristics of a Scientific Argument

~~It has two sides~~ It compares or considers different claims

~~You need proof for each side~~ You need evidence for each claim that supports it

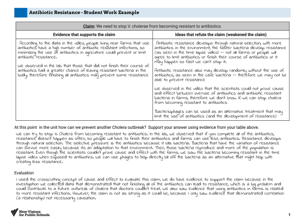
Evidence comes from different places, like experiments, observations, and the experiments and observations of others (scientists)

Evidence should be questioned

One ~~side~~ claim has more ~~proof~~ evidence

You are trying to ~~change someone's mind~~ support the strongest claim

3. Provide students with *Antibiotic Resistance Argument*. Students work individually to make sense of how the learning from this 5E sequence contributes to the overall task. They should think through the investigation and resources provided in this 5E plan to evaluate the claim: We need to stop *V. cholerae* from becoming resistant to antibiotics.



Antibiotic Resistance - Student Work Example

Claim: We need to stop V. cholerae from becoming resistant to antibiotics.	
Evidence that supports the claim	**Ideas that refute the claim (weakened the claim)**
According to the data in the video, people living near farms that use antibiotics have a high number of antibiotic resistant infections, so minimizing the use of antibiotics in agriculture could prevent or limit antibiotic resistance. we observed in the lab that those that did not finish their course of antibiotics had a greater chance of leaving resistant bacteria in the body, therefore finishing all antibiotics may prevent some resistance	Antibiotic resistance develops through natural selection, with more antibiotics in the environment, the faster bacteria develop resistance (as seen in the time lapse video) -- not all farms or people will agree to limit antibiotics or finish their course of antibiotics or it may happen so fast we can't stop it. Antibiotic resistance also may develop randomly without the use of antibiotics, as seen in the cave bacteria -- therefore we may not be able to prevent resistance we observed in the video that the scientists could not prove cause and effect between overuse of antibiotics and antibiotic resistant bacteria in farms, therefore we don't know if we can stop cholera from becoming resistant to antibiotics Bacteriophages can be used as an alternative treatment that may limit the use of antibiotics (and the development of resistance)

At this point in the unit how can we prevent another Cholera outbreak? Support your answer using evidence from your table above.

we can try to stop V. Cholera from becoming resistant to antibiotics. In the lab, we observed that if you complete all of the antibiotics, resistance doesn't happen as often, so people will have to finish their antibiotics and farms can use less antibiotics. Resistance develops through natural selection. The selective pressure is the antibiotics because it kills bacteria. Bacteria that have the variation of resistance can survive more easily because its an adaptation to that environment. Then, those bacteria reproduce and more of the population is resistant. Even though the scientists couldn't prove cause and effect with the farms, we saw the bacteria becoming resistant in the time lapse video when exposed to antibiotics. we can use phages to help directly kill off the bacteria as an alternative that might help with creating less resistance.

Evaluation

I used the crosscutting concept of cause and effect to evaluate this claim. we do have evidence to support the claim because in the investigation we collected data that demonstrated that not finishing all of the antibiotics can lead to resistance, which is a big problem and could contribute to a future outbreak of cholera that doctors couldn't treat. we also saw evidence that using antibiotics in farms is related to more resistant infections. However, the claim is not as strong as it could be, because I only saw evidence that demonstrated correlation (a relationship) not necessarily causation.

New Visions for Public Schools 1

Differentiation Point

Students that meet or exceed the PEs addressed in this 5E can investigate and incorporate additional details about cholera into their Performance Task. Provide them with, *Antibiotic Resistance & Cholera Text*.

4. Confer with students while they are working.

5. After completing their response, use the *Antibiotic Resistance Mini-Rubric* as self, peer, or teacher feedback on their argument.

Conferring Prompts

Confer with students as they work to develop their arguments. Prompt students to return to the class wide scientific argument characteristics, posted in the room.
Suggested conferring questions:

- What evidence did you generate in this 5E sequence?
- Where did the evidence come from?
- How well does that evidence support the claim?
- What ideas or contradictory evidence weaken the claim?

Document Class Thinking

1. Prompt students to discuss with their groups their decision regarding the claim: We need to stop *V. cholerae* from becoming resistant to antibiotics. Students can use the notes in their performance task organizers in these discussions.

2. Each group comes to a consensus answer to the question—*Yes, No, or Maybe*—and articulates their reasoning.

3. Conduct a **Domino Discover** to hear from each group, and tally the responses on chart paper. It is not necessary to discuss all the positions or get to class consensus at this point.

Revisit the Driving Question Board

1. Use the **Driving Question Board Routine** to discuss which of the class's questions have been answered.

2. Have students identify which categories or questions they have not figured out yet. Prompt students to share out these questions, and document new questions that arise based on what they have been learning.

3. Add new questions to the Driving Question Board.

4. One question category still unanswered relates to questions about whether or not all bacteria are harmful. Tell students that, in the next sequence of lessons, they will investigate the relationship between us and the billions of bacteria that live in and on us, and how better understanding this relationship will allow us to evaluate claims on the best solution to preventing a future outbreak of *V. cholerae*.

Performance Expectations

HS-LS4-2	**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.** Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning. Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.
HS-LS4-3	**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.** Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations. Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.
HS-LS4-4	**Construct an explanation based on evidence for how natural selection leads to adaptation of populations.** Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations. Assessment Boundary: None
HS-LS4-5	**Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.** Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species. Assessment Boundary: None

In NYS the clarification statement has been edited as follows: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, introduction of invasive species, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.

Aspects of Three-Dimensional Learning

Science and Engineering Practices

Analyzing and Interpreting Data

- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. SEP4(2)

Constructing Explanations and Designing Solutions

- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. SEP6(2)

Engaging in Argument from Evidence

- Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. SEP7(2)

Disciplinary Core Ideas

LS4.B Natural Selection

- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. LS4.B(2)

LS4.C Adaptation

- Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. LS4.C(1)
- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. LS4.C(2)
- Adaptation also means that the distribution of traits in a population can change when conditions change. LS4.C(3)
- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. LS4.C(4)

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. CCC1(1)

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CCC2(1)

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Analyzing and Interpreting Data		*Simulating a Bacterial Infection Investigation (Scaffolded Version)* *Making Sense of Simulating a Bacterial Infection Investigation*			
Constructing Explanations and Designing Solutions			*C-E-R Graphic Organizer*		*Antibiotic Resistance Argument* *Antibiotic Resistance Mini-Rubric*
Engaging in Argument from Evidence			*Antibiotic Resistance: Evaluating a Claim* *Summary Task*	*RGSS Graphic Organizer*	*Antibiotic Resistance Argument* *Antibiotic Resistance Mini-Rubric*
LS4.B Natural Selection		*Making Sense of Simulating a Bacterial Infection Investigation*	*Antibiotic Resistance: Evaluating a Claim* *C-E-R Graphic Organizer* *Summary Task*	*RGSS Graphic Organizer*	*Antibiotic Resistance Argument* *Antibiotic Resistance Mini-Rubric*
LS4.C Adaptation	Rumors routine	*Making Sense of Simulating a Bacterial Infection Investigation*	*Antibiotic Resistance: Evaluating a Claim* *C-E-R Graphic Organizer* *Summary Task*	*RGSS Graphic Organizer*	*Antibiotic Resistance Argument* *Antibiotic Resistance Mini-Rubric*
Patterns		*Making Sense of Simulating a Bacterial Infection Investigation*	*Natural Selection Comparison Chart* *Summary Task*		*Antibiotic Resistance Argument* *Antibiotic Resistance Mini-Rubric*
Cause and Effect			*Antibiotic Resistance: Evaluating a Claim* *C-E-R Graphic Organizer* *Summary Task*		*Antibiotic Resistance Argument* *Antibiotic Resistance Mini-Rubric*

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics		MP2	MP2 MP3		
ELA/Literacy			RST.9-10.1	RST.9-10.1 RST 9-10.8	WHST.9-10.1 WHST.9-10.5

Student Work for Antibiotic Resistance 5E

Claim: We need to stop V. cholerae from becoming resistant to antibiotics.	
Evidence that supports the claim	**Ideas that refute the claim (weakened the claim)**
According to the data in the video, people living near farms that use antibiotics have a high number of antibiotic resistant infections, so minimizing the use of antibiotics in agriculture could prevent or limit antibiotic resistance. we observed in the lab that those that did not finish their course of antibiotics had a greater chance of leaving resistant bacteria in the body, therefore finishing all antibiotics may prevent some resistance	Antibiotic resistance develops through natural selection, with more antibiotics in the environment, the faster bacteria develop resistance (as seen in the time lapse video) -- not all farms or people will agree to limit antibiotics or finish their course of antibiotics or it may happen so fast we can't stop it. Antibiotic resistance also may develop randomly without the use of antibiotics, as seen in the cave bacteria -- therefore we may not be able to prevent resistance we observed in the video that the scientists could not prove cause and effect between overuse of antibiotics and antibiotic resistant bacteria in farms, therefore we don't know if we can stop cholera from becoming resistant to antibiotics Bacteriophages can be used as an alternative treatment that may limit the use of antibiotics (and the development of resistance)

At this point in the unit how can we prevent another Cholera outbreak? Support your answer using evidence from your table above.

we can try to stop V. Cholera from becoming resistant to antibiotics. In the lab, we observed that if you complete all of the antibiotics, resistance doesn't happen as often, so people will have to finish their antibiotics and farms can use less antibiotics. Resistance develops through natural selection. The selective pressure is the antibiotics because it kills bacteria. Bacteria that have the variation of resistance can survive more easily because its an adaptation to that environment. Then, those bacteria reproduce and more of the population is resistant. Even though the scientists couldn't prove cause and effect with the farms, we saw the bacteria becoming resistant in the time lapse video when exposed to antibiotics. we can use phages to help directly kill off the bacteria as an alternative that might help with creating less resistance.

Evaluation

I used the crosscutting concept of cause and effect to evaluate this claim. we do have evidence to support the claim because in the investigation we collected data that demonstrated that not finishing all of the antibiotics can lead to resistance, which is a big problem and could contribute to a future outbreak of cholera that doctors couldn't treat. we also saw evidence that using antibiotics in farms is related to more resistant infections. However, the claim is not as strong as it could be, because I only saw evidence that demonstrated correlation (a relationship) not necessarily causation.

Antibiotic Resistance: Evaluating a Claim - Student Work Example

Evidence that supports the claim	Ideas that refute or critique the claim/evidence
A lot of antibiotics are used in agriculture (70% of all antibiotics go to farm animals) An increase in urinary tract infections that are resistant to antibiotics in areas with chicken farms An increase in MRSA infections near pig farms, the people that live closest to the pigs have the most MRSA	Haven't found a direct pathway between a specific animal, the drug given to it, and a person later developing a resistant infection The pig farm data shows an association, but not direct evidence No direct evidence or data on how the MRSA gets to the people, only a hypothesis on how it could be happening

Summarize why some people in the video state that the overuse of antibiotics in agriculture **causes** antibiotic resistance, and others say that there is only a **correlation,** or possible relationship / connection between the two.

There is evidence that the overuse of antibiotics in agriculture is causing more resistant infections in people. For example, people living closer to pig farms that use antibiotics have more MRSA infections than those that live further away. But, others say this is an association not a cause because no one has been able to establish a direct link between a specific antibiotic given to an animal that then caused an infection in a specific person.

If we agree with the claim:

wide-spread use or overuse of antibiotics in farm animals (even when they are not sick) → increase in antibiotic resistant populations of bacteria because there is selective pressure for resistance → increase in antibiotic resistance infections in animals and in people

Classroom Resources for Antibiotic Resistance 5E

Simulating a Bacterial Infection Game Board

No Resistance	Resistant to A	Resistant to B	Resistant to C
Resistant to A and B	Resistant to A and C	Resistant to B and C	Resistant to A, B, and C

Antibiotic Resistance Game Board

The Microbiome 5E	How do humans interact with bacteria? How can we fight bacterial infections using other bacteria?	**Performance Expectations** HS-LS4-4, HS-LS4-5	**Investigative Phenomenon** People are being cured of C. diff infections using fecal transplant	**Time** 7-8 days

Students are presented with the puzzling situation that sometimes patients with a persistent bacterial infection, called *Clostridium difficile* (*C. diff*), are treated through a fecal transplant. This investigative phenomenon will generate questions about the relationship humans have with the billions of bacteria that live in and on us. The microbiome of many Americans is much less diverse than people living a traditional or hunter-gatherer lifestyle due to diet changes, the overuse of antibiotics, and hygiene practices. This lack of diversity may be contributing to chronic health conditions many of us face, including *C. diff.* In this 5E instructional sequence, students will explore the microbiome and how maintaining a diverse set of microbiota contributes to our health; it may even be able to help us prevent bacterial infections such as cholera.

ENGAGE	Why would we be able to treat a bacterial infection by introducing more bacteria?	Connecting to their earlier questions about if all bacteria are virulent or harmful, students share their initial ideas and questions about why doctors would treat a bacterial infection with a fecal transplant. This leads students to express a need to investigate **the co-evolution of bacteria and humans** further.
EXPLORE	How are microbiomes different across different populations of people?	Students **engage with secondary data sets** on **the microbiomes of different populations of people** in order to surface **patterns on causes of** **health problems in unhealthy gut microbiomes**.
EXPLAIN	How can we understand the differences between human microbiomes and the impact these differences may have on our health?	Students engage with complex visuals and a text to better understand **variations in microbiomes** across different populations of people. Students consider **common patterns across** human microbiomes and ecosystems to **construct an explanation** on how **diversity supports ecosystem/microbiome health.**
ELABORATE	Should we preemptively get a fecal transplant from people like the Hadza? What does the evidence say?	Students use evidence and **scientific reasoning** from investigations and a text to **evaluate a claim** on if **the use of fecal transplants can cause positive health outcomes.**
EVALUATE	How does a healthy microbiome impact our ability to fight bacterial infections such as cholera?	Students **evaluate a claim** using their understanding of how an **unhealthy or deficient microbiome** **can cause** a more severe cholera infection.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

Why would we be able to treat a bacterial infection by introducing more bacteria?

Connecting to their earlier questions about if all bacteria are virulent or harmful, students share their initial ideas and questions about why doctors would treat a bacterial infection with a fecal transplant. This leads students to express a need to investigate **the co-evolution of bacteria and humans** further.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Pairs or triads	❏ Questions Only	❏ Text Annotation

Materials

Handouts	Lab Supplies	Other Resources
❏ New Treatment	❏ None	

Launch and Surfacing Student Ideas

1. Remind students that, during the Driving Question Board launch, one category of questions that emerged was related to understanding if all bacteria were virulent (or bad). Ask students to share more about why they asked questions and listen for the observation that many of us have heard about good bacteria or that eating probiotics (like yogurt) is good for us. Students may wonder why in some cases we want bacteria, and in other cases we want to get rid of them.

2. Use students' questions and observations to transition to the guiding question: *Why and how are some doctors treating bacterial infections by introducing more bacteria?*

3. Provide students with the *New Treatment* text and ask students to **annotate** the text by:
    - Putting * next to interesting/surprising ideas
    - Circling ideas that they want to know more about
    - Adding ideas/new thoughts/connections in the margins

4. Use the group learning routine **Questions Only** to surface and categorize student questions
    - Students individually list 5-10 questions they have about the phenomenon being described in the text.
    - Students star or circle their top 3 questions.
    - Students share their top 3 questions in pairs or triads.
    - Students agree on top questions for their group and share out to the class.
    - Chart questions, so that the class can circle back to them later in the 5E sequence.

Routine

The **Questions Only** routine offers students an opportunity to generate questions that can guide their investigations about a phenomenon. Please read the Biology Course Guide for detailed steps for this routine.

Explore

How are microbiomes different across different populations of people?

Students **engage with secondary data sets** on **the microbiomes of different populations of people** in order to surface **patterns on causes of health problems in unhealthy gut microbiomes**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ Domino Discover	❑ Three Level Guide

Materials

Handouts	Lab Supplies	Other Resources
❑ Comparing Microbiomes Investigation ❑ Comparing Microbiomes Image Three Level Guide ❑ Making Sense of Comparing Microbiomes Investigation ❑ Comparing Microbiomes Investigation Rubric	❑ none	❑ *Color Visual* (laminated or displayed on the smartboard ❑ 1 per group) ❑ National Geographic article: Hadza ❑ Nature article - Gut microbiome of the Hadza hunter-gatherers (advanced/ teacher level text) ❑ NCBI high resolution image: Composition of the Microbiome in Urban Italians and Hunter-gathers ❑ Math is Fun text: Correlation ❑ *Color Visual Edited*(optional) ❑ Evolution of Diet - The Hadza of Tanzania

Launch

1. Ask students to remind us what we are trying to figure out - why fecal transplants (symbiotic bacterial communities) may be able to treat *C. diff* infections. Remind students that feces contain a lot of bacteria that live in our gut (between 25-50% of our stool is made up of both living and dead bacteria).

2. Prompt students to think about all the different things people do that might impact the bacteria that live in and on them. For example, students may have heard that they shouldn't use a lot of hand sanitizer. Ask students how we might understand what our microbiome was like before we had things like antibacterial soap and antibiotics. Highlight ideas around comparing our microbiomes to people that have not used those things (people not living in industrialized communities).

3. Ask students to predict how bacteria that live in and on us may be different between three different communities:

1.) Hunter-gatherers or people that live in isolated indigenous communities (e.g. the Hadza, or native peoples living in the Amazon rainforest)
2.) People that live on farms in rural areas
3.) People that live in a city

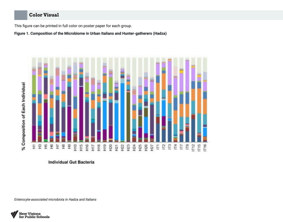
Use example images of these three human environments or communities to prompt what students already know about the different environments. Let students know that we have microbiome data from example populations from each of these types of communities: the Hadza of Tanzania, rural east Africans, and urban Italians

Access for All Learners

Students may be unfamiliar with hunter-gathers or those living in isolated indigenous communities. If so, project the brief video, Evolution of Diet - The Hadza of Tanzania or the National Geographic article: Hadza to provide more context. As students transition into the investigation, prompt students to think about what people living in an industrialized society (i.e. modern day USA) may be able to learn from those living in non-industrialized societies, like the Hadza. Return to this idea after completing the investigation, highlighting the importance of celebrating human diversity and the exchange of ideas between different cultures.

Investigation Part 1: Comparing Microbiomes

1. Provide each student with the *Comparing Microbiomes Investigation* handout, the *Comparing Microbiomes Image Three Level Guide*, and at least one large *Color Visual* per group so that students can clearly see the visual they are interacting with. It may also be helpful to project the NCBI high resolution image: Composition of the Microbiome in Urban Italians and Hunter-gathers .



Differentiation Point

The *Comparing Microbiomes Image Three Level Guide* is a scaffold designed to support students in accessing a complex visual. This may be a challenging data set for students with visual impairments. Plan accordingly by grouping students and allowing for estimation (rather than exact counts of species types). Alternatively, provide students with the edited version of the visual that includes less data: *Color Visual Edited*

2. In the *Comparing Microbiomes Investigation* students analyze three different data sources (a complex visual, a graph, and a data table) to make comparisons between different populations and their microbiomes. Students note their inferences and questions about each data set in the See-Think-Wonder graphic organizer.

3. Use conferring questions to push students' thinking about the investigation while they are analyzing the data.

Conferring Prompts

Confer with students during and after the lab. Encourage students to use new terminology and science vocabulary from this unit to discuss what they are doing.

Suggested during-lab conferring questions:
- What do you notice about the total number of bacteria across all three groups?
- What do you notice about the total number of different kinds of bacteria across all three groups?
- Why do you think these trends are important?

Suggested post-lab conferring questions:
- What is the trend you observed?
- What do you think is going on to create this trend?
- What impact do you think this trend has on each group of people?
- How did calculating the correlation coefficient help you differentiate between correlation and causality?

4. Students choose one variable from the Table. 1 Lifestyle Comparison, to investigate its relationship with the data found in Figure 2. Microbiome diversity in different populations of people by generating a scatter plot and calculating the correlation coefficient. Possible variables include % plant food in the diet, % animal food in the diet, % processed food in the diet, and the Defined Daily Doses (DDD) of antibiotics per population. DDD is a universal measurement used to quantify the prescription rate of antibiotics per 1000 people in a country.

When students construct their graphs, the Y axis should be "microbiome diversity," with 40 as the highest number (from Figure 2). The X axis should be the variable the students chose (from Table 1). One option is to assign different data sets to each group.

5. Prompt students to share the results from the variable they choose, ensuring that the correlation coefficient is surfaced from each variable across the entire classroom.

Differentiation Point

If students need further support with generating a scatter plot, calculating the correlation coefficient, or determining the line of best fit, provide them with the on-line resource, Math is Fun text: Correlation

Whole-Class Investigation Summary

1. Ask students to work independently to complete the *Making Sense of Comparing Microbiomes Investigation*. Then use these completed pages to discuss the findings from the investigation.

2. Ask groups to come up with one important idea to share with the whole class, from their notes.

3. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' Summary sections. Plan forward based on the various understandings that students or student groups have articulated. It is appropriate to go onto the next phase once students have had a chance to make sense of the data, and have had the opportunity to clarify what they have figured out about the investigative phenomenon under study in this lesson sequence.

Look & Listen For

Possible student ideas:

- Hadza had the most diverse bacteria across all groups, followed by (agricultural/rural society), followed by Westerner (Italian).
- Hadza and Italians have some bacteria in common, but in different proportions.
- Hadza and Italians have some unique bacteria that they do not share with the other group.
- Hadza had a larger number of unknown bacteria.
- Depending on the variable investigated, there are correlations (of varying strength) between lifestyle and microbiome diversity.
- These trends may have to do with the environment (lack of hygiene, more contact with soil and animals, no antibiotics) and diet.
- We need more information before identifying causality.
- Students may wonder which type of microbiome is 'better' or more 'healthy,' or if having a diverse microbiome is an advantageous adaptation.

4. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

5. Provide students with *Comparing Microbiomes Investigation Rubric*. Ask students to use the investigation rubric to self and peer assess their progress on engaging with the investigation individually and as a group.

Routine

The **Domino Discover** routine is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Please read the Biology Course Guide for detailed steps of this routine.

Integrating Three Dimensions

In this investigation, students calculate a correlation coefficient and generate a line of best fit in service of **SEP#4 Analyzing and Interpreting Data,** and in building their fluency in using **CCC#2 Cause and Effect.** Pause at this point and assess student understanding of how to differentiate between correlation and causation.

Comparing Microbiomes Investigation Rubric

Student Rubric - Comparing Microbiomes Investigation
How did you do in the investigation?

	Student Self-Score Circle one		
I know how this investigation connects to our current unit.	No - I need help.	Almost	Yes
I was able to contribute to the See-Think-Wonder and respond to the Investigation Summary questions.	No- I need help.	Almost	Yes
I used my time well in this investigation.	No	Mostly	Yes
I plan to come in for extra help to complete parts of the investigation or ask questions.	No		Yes

What other resources could you have used to get more out of this investigation?
- More time
- More resources
- More information
- More help from my partners
- More help from my teacher
- Other:

Partner Rubric - Comparing Microbiomes Investigation
How did your partners do in the investigation?

Directions: Think back to how your partners participated in the lab. For each of the four categories, write your partner's or partners' names in the appropriate box.

	Unsatisfactory	**Pretty Good**	**Excellent**
Contributions	Did not participate.	Did the minimum of what was required.	Provided useful ideas when participating in discussion
Working with Others	Rarely listened to others. Disrupted or discouraged others' attempts to participate.	Usually listened to, shared with, and supported the efforts of others.	Listened to, shared with, and supported the efforts of others.

Explain

How can we understand the differences between human microbiomes and the impact these differences may have on our health?

Students engage with complex visuals and a text to better understand **variations in microbiomes** across different populations of people. Students consider **common patterns across** human microbiomes and ecosystems to **construct an explanation** on how **diversity supports ecosystem/microbiome health.**

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ Idea Carousel ❑ Class Consensus Discussion	❑ Text Annotation ❑ Concept Mapping

Materials

Handouts	Lab Supplies	Other Resources
❑ The Microbiome as an Ecosystem ❑ Summary Task	None	❑ NPR podcast: Modern Medicine May Not Be Doing Your Microbiome Any Favors (optional resource on the microbiome) ❑ The Guardian article: 'I thought I was going to die': why patients are no longer pooh-poohing faecal transplants (optional resource on fecal transplants) ❑ Strategies for Concept Mapping (optional support)

Comparing the Human Microbiome to an Ecosystem

1. Prompt students to reflect on unanswered questions from the Explore phase, pointing out student generated questions from the See-Think-Wonder or investigation summary discussion. For example, students may have surfaced that different human microbiomes have different amounts of diversity, but they are not sure why or how this might be important for health/ dealing with bacterial infections such as *C. difficile*.

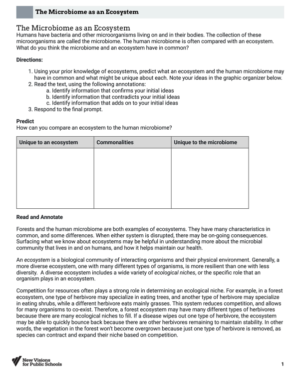
2. Remind students that it can sometimes be helpful to better understand one system (the microbiome) by comparing it to a system that we know more about (a forest ecosystem). Provide students with the *The Microbiome as an Ecosystem* handout. Prompt students to first use their prior knowledge to predict or brainstorm ideas on how to compare ecosystems with the human microbiome, noting their ideas in the provided graphic organizer.

Access for All Learners

Students should have a background in ecology from middle school. If students are struggling, you may want to review a few ideas about diversity and food webs. Students will explore extinction, ecosystem diversity, and resiliency in more depth in Unit 6: Woolly Mammoth Extinction.

3. Then, individually or in pairs, students read the text, looking for information that confirms, modifies or contradicts their predictions. Students then individually respond to the final prompt: Based on your understanding of evolution by natural selection, ecosystem dynamics, and extinction; Why are fecal transplants used to treat infections such as *C. difficile*?

4. In table groups, students generate a visual or concept map on a chart paper that represents their most important ideas on the prompt: Based on your understanding of evolution by natural selection, ecosystem dynamics, and extinction; Why are fecal transplants used to treat infections such as *C. difficile?*



The Microbiome as an Ecosystem

The Microbiome as an Ecosystem

Humans have bacteria and other microorganisms living on and in their bodies. The collection of these microorganisms are called the microbiome. The human microbiome is often compared with an ecosystem. What do you think the microbiome and an ecosystem have in common?

Directions:

1. Using your prior knowledge of ecosystems, predict what an ecosystem and the human microbiome may have in common and what might be unique about each. Note your ideas in the graphic organizer below.
2. Read the text, using the following annotations:
   a. Identify information that confirms your initial ideas
   b. Identify information that contradicts your initial ideas
   c. Identify information that adds on to your initial ideas
3. Respond to the final prompt.

Predict

How can you compare an ecosystem to the human microbiome?

Unique to an ecosystem	Commonalities	Unique to the microbiome

Read and Annotate

Forests and the human microbiome are both examples of ecosystems. They have many characteristics in common, and some differences. When either system is disrupted, there may be on-going consequences. Surfacing what we know about ecosystems may be helpful in understanding more about the microbial community that lives in and on humans, and how it helps maintain our health.

An *ecosystem* is a biological community of interacting organisms and their physical environment. Generally, a more diverse ecosystem, one with many different types of organisms, is more resilient than one with less diversity. A diverse ecosystem includes a wide variety of *ecological niches*, or the specific role that an organism plays in an ecosystem.

Competition for resources often plays a strong role in determining an ecological niche. For example, in a forest ecosystem, one type of herbivore may specialize in eating trees, and another type of herbivore may specialize in eating shrubs, while a different herbivore eats mainly grasses. This system reduces competition, and allows for many organisms to co-exist. Therefore, a forest ecosystem may have many different types of herbivores because there are many ecological niches to fill. If a disease wipes out one type of herbivore, the ecosystem may be able to quickly bounce back because there are other herbivores remaining to maintain stability. In other words, the vegetation in the forest won't become overgrown because just one type of herbivore is removed, as species can contract and expand their niche based on competition.

New Visions for Public Schools 1

Differentiation Point

Students may have a strong interest in understanding more about the human microbiome and/or fecal transplants. Students with the interest and readiness can explore these topics further, listening to the optional NPR podcast: Modern Medicine May Not Be Doing Your Microbiome Any Favors or reading the optional on-line article, The Guardian article: 'I thought I was going to die': why patients are no longer pooh-poohing faecal transplants and sharing their new insights with the class.

Differentiation Point

If students struggle with generating a concept map for their poster, provide an optional scaffold for this task, Strategies for Concept Mapping

Surfacing Student Ideas

1. Confer with students as they create their chart paper in small groups.
2. Use the group learning routine **Idea Carousel** to surface student thinking.
3. When students return to their original poster, prompt students to discuss in their group how they will revise their ideas and written response to incorporate the new ideas from others.
4. Students should collaboratively develop a response to the guiding question that they can share out with their peers.

Routine

This is the first time students are using the group learning routine **Idea Carousel** in this unit. Refer to the Biology Course Guide for support in implementing this routine.

Integrating Three Dimensions

The work students are doing in this Explain phase support their development and use of two related crosscutting concepts: **CCC #1 - Patterns** and **CCC #2 - Cause and Effect**. The time students have in their groups to make sense of different kinds of ecosystems, from the micro to the macro, supports their development of these lenses.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:
    - “We are going to use a **class consensus discussion**, just like we did in the last 5E, to learn about all the thinking in the room and come to some decisions about how a diverse microbiome contributes to our health. *C. difficile* infections are one example, but we also read about the many things symbiotic bacteria may contribute to our health.”
2. Select two or three group responses from the Idea Carousel posters to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of diversity and loss of diversity through extinction, coevolution, and the microbiome. The decision about which explanations to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.
3. Ask the first students to share their explanation. You can do this by:
    - Projecting using a document camera; OR
    - Copying the written explanation to be shared and passing them out to the class; OR
    - Taking a picture of each explanation and projecting them as slides.

Routine

Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Please refer to the Biology Course Guide for detailed steps of this routine.

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

4. Proceed through the steps in the Consensus Discussion Steps. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get "buried" in student talk.

Take Time for These Key Points

Pause the discussion and ask for clarification, particularly of the following key points:

- *Diversity* in both ecosystems and in the microbiome means having a high number of different species (types of organisms).
- Diversity and competition facilitate *stability* in an ecosystem or Microbiome.
- Different species play different roles, or *niches* in the ecosystem/microbiome; each organism is important in playing a role and maintaining stability.
- Humans and bacteria have both evolved over time through natural selection to co-exist because it is advantageous for both organisms.
- A healthy/diverse microbiome means that bacteria are living *symbiotically* with humans and completing many beneficial tasks (food digestion, releasing beneficial molecules, training the immune system, outcompeting virulent bacteria).
- Species of bacteria are going *extinct* because of changing lifestyles and environments and they cannot adapt in time -- this may be detrimental to human microbiome health.
- In fecal transplants, a patient usually has a deficient microbiome (that is leading to instability/ not resilient/ dominance by 1-2 types of bacteria). They receive an infusion of diverse microbes from a healthy donor, to restore a healthy community.

5. Return to student questions that bring up lingering issues not yet resolved, such as:
   - How do we know if we have a healthy microbiome?
   - Can we do things to improve our microbiome?
   - How does the diverse microbiome of the Hadza impact their health? (are they really healthier than us because of their microbiome?)
   - How can we use what we know about the microbiome to help prevent cholera infections?

Integrating Three Dimensions

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #1 - Patterns** and **CCC #2 - Cause and Effect** explicit for students by elevating and probing for ideas related to the concept that patterns at different levels of a system can provide evidence for causality in explanations of phenomena and empirical evidence is required to differentiate between causation and correlation.

6. Chart or acknowledge student questions, as many of them will be explored in the Elaborate phase and beyond.

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.
2. The results of this task can be used to make determinations about which students need more time to engage in sense-making about diversity and the microbiome

Integrating Three Dimensions

The summary task supports student reflection around **CCC #2 - Cause and Effect**. It's also an opportunity for the teacher to assess weather individual students are developing proficiency around the an opportunity for the teacher to assess weather The prompt is modified from STEM Teaching Tools #41 (http://stemteachingtools.org/brief/41), and it gets at the idea of distinguishing between correlation and causation, which in turn is key for making a strong argument (**SEP #7 - Engaging in Argument from Evidence**). development of these lenses.

Elaborate

Should we preemptively get a fecal transplant from people like the Hadza? What does the evidence say?

Students use evidence and **scientific reasoning** from investigations and a text to **evaluate a claim** on if **the use of fecal transplants can cause positive health outcomes.**

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs or triads	None	❑ Evidence Gradient

Materials

Handouts	Lab Supplies	Other Resources
❑ Hadza Microbiome Text ❑ Evidence Gradient Graphic Organizer	None	❑ Class wide scientific argument characteristics ❑ The Coversation article: I spent three days as a hunter-gatherer to see if it would improve my gut health

Text-Based Task

1. Organize students into pairs or triads. Prompt students to review what they figured out about the microbiome in the previous Explore & Explain phases, and what questions remained unanswered at the end of the Explain phase. Students may surface that a diverse microbiome might be important to human health. An example is using fecal transplants to treat *C. diff* infections. They may also discuss that the typical American / Westerner has a much less diverse microbiome that those of hunter-gatherers.

2. If this question has not surfaced yet, prompt students to consider why we have less diversity in our microbiota, and would it be helpful for us to have a microbiome that is closer to a hunter-gather (like the Hadza? Ask students to list reasons why this might be helpful to figure out.

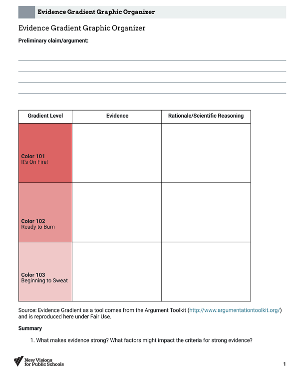
3. Provide the guiding prompt for working through the *Hadza Microbiome Text* handout.
    - Should we all have a fecal transplant from the Hadza? What does the evidence say?

4. Students decide on/ or predict if they agree or disagree with the claim (yes, we should, or no we should not). Provide students with *Hadza Microbiome Text*. In order to evaluate the claim, students should review and note down appropriate evidence and scientific reasoning from their previous work in the learning cycle (investigations, discussions, texts).

Access for All Learners

The literacy strategy **evidence gradient** is a student-centered approach to promote agency allowing all students to grapple with how to evaluate evidence and develop their reasoning skills.

5. Students then read the provided text, and identify additional evidence and reasoning that supports or refutes their claim.


Evidence Gradient Graphic Organizer

Evidence Gradient Graphic Organizer

Preliminary claim/argument:

Gradient Level	Evidence	Rationale/Scientific Reasoning
Color 101 It's On Fire!		
Color 102 Ready to Burn		
Color 103 Beginning to Sweat		

Source: Evidence Gradient as a tool comes from the Argument Toolkit (http://www.argumentationtoolkit.org/) and is reproduced here under Fair Use.

Summary

1. What makes evidence strong? What factors might impact the criteria for strong evidence?

6. In order to consider the strengths and weaknesses and evidence for/against the claim, provide students with *Evidence Gradient Graphic Organizer*. Students use the graphic organizer to record their evidence along a gradient from strongest to weakest. This may be done individually or in pairs or groups of three.

7. Share out student ideas on how they determined the strength of evidence, decide as a class, how to define quality evidence, and add these ideas to your class list on scientific argumentation.

Example poster

Class Consensus List:
Characteristics of a Scientific Argument

~~It has two sides~~ It compares or considers different claims

~~You need proof for each side~~ You need evidence for each claim that supports it

Empirical evidence comes from ~~different places~~, data collected during experiments, observations, and the experiments and observations of others (scientists)

we have to consider where evidence comes from: direct measurement, observations, controlled experiments, simulations, etc and its' strength or weakness depending on the source of the evidence

Evidence should be questioned and evaluated. In evaluating evidence, be careful to distinguish between correlation and causation

Concepts, ideas, and logical conclusions are not evidence, but can be used to link the evidence to the claim or to refute a claim

one ~~side~~ claim has more ~~proof~~ evidence

You are trying to ~~change someone's mind~~ support the strongest claim, using evidence and scientific reasoning

Evaluate

How does a healthy microbiome impact our ability to fight bacterial infections such as cholera?

Students **evaluate a claim** using their understanding of how an **unhealthy or deficient microbiome can cause** a more severe cholera infection.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Table groups	❏ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❏ The Microbiome Argument ❏ Cholera & The Microbiome Text ❏ The Microbiome Mini-Rubric	None	❏ Class wide scientific argument characteristics ❏ Driving Question Board from the start of the unit should be available ❏ *The Microbiome - Example Student Work*

Revisit the Performance Task

1. Prompt students to consider where they currently stand on the question category from the Driving Question Board that they have been investigating throughout this 5E instructional sequence. This will be something like: How do humans and bacteria interact? Or Are all bacteria bad/pathogenic?

Implementation Tip

When returning to the Driving Question Board, be sure to change these suggested teacher notes so that they match your class' actual questions!

2. Remind students that they are generating an argument for our unit level performance task, and we need to consider as a class how our ideas are developing about what a scientific argument is and how to evaluate a strong claim / evidence. Prompt students to return to the class characteristics list and revise their ideas.

Example poster

Class Consensus List:
Characteristics of a Scientific Argument

~~It has two sides~~ It compares or considers different claims

~~You need proof for each side~~ You need evidence for each claim that supports it

Empirical evidence comes from ~~different places~~, data collected during experiments, observations, and the experiments and observations of others (scientists)

we have to consider where evidence comes from: direct measurement, observations, controlled experiments, simulations, etc and its strength or weakness depending on the source of the evidence. It can be evaluated by the quality of the evidence. For example, direct observations of a phenomena (data collected) is high quality.

A science fact is not evidence, but can help us link the evidence to a claim, or provide more context on causality

In evaluating evidence, be careful to distinguish between correlation and causation

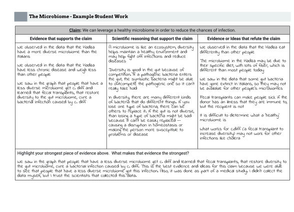
Concepts, ideas, and logical conclusions are not evidence, but can be used to link the evidence to the claim or to refute a claim

one ~~side~~ claim has more ~~proof~~ evidence

one ~~side~~ claim has more ~~proof~~ evidence or higher quality evidence

You are trying to ~~change someone's mind~~ encourage scientific discourse and evaluate all possible claims

3. Provide students with *The Microbiome Argument*. Students work individually to make sense of how the learning from this 5E sequence contributes to the overall task. They should think through the investigation and resources provided in this 5E plan to evaluate the claim: We can leverage a healthy microbiome in order to reduce the chances of infection/severity of a cholera infection.



Differentiation Point

Students that meet or exceed the PEs addressed in this 5E can investigate and incorporate additional details about cholera into their Performance Task. Provide them with, *Cholera & The Microbiome Text*.

4. Confer with students while they are working.

Conferring Prompts

Confer with students as they work to develop their arguments. Prompt students to return to the class wide scientific argument characteristics, posted in the room. Suggested conferring questions:

- What evidence did you generate in this 5E sequence?
- Where did the evidence come from?
- How well does that evidence support the claim?
- What ideas or contradictory evidence weaken the claim?

5. After completing their argument individually, provide students with *The Microbiome Mini-Rubric* to provide self, peer, or teacher feedback.

Document Class Thinking

1. Prompt students to discuss with their groups their decision regarding the claim, We can leverage a healthy microbiome in order to reduce the chances of infection. Students can use the notes in their performance task organizers in these discussions.
2. Each group comes to a consensus answer to the question—*Yes, No, or Maybe*—and articulates their reasoning.
3. Conduct a **Domino Discover** to hear from each group, and tally the responses on chart paper. It is not necessary to discuss all the positions or get to class consensus at this point.

Revisit the Driving Question Board

1. Use the **Driving Question Board** routine to discuss which of the class's questions have been answered.
2. Have students identify which categories or questions they have not figured out yet. Prompt students to share out these questions, and document new questions that arise based on what they have been learning.
3. Add new questions to the Driving Question Board.
4. One question category still unanswered relates to questions about if we can find alternative ways to fight pathogenic bacteria. Tell students that, in the next sequence of lessons, they will investigate how

bacteria interact with each other, and how we may be able to leverage those interactions in order to evaluate claims about developing novel therapies against *V. cholerae* infections.

Performance Expectations

HS-LS4-4 **Construct an explanation based on evidence for how natural selection leads to adaptation of populations.**
Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.
Assessment Boundary: None

HS-LS4-5 **Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.**
Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.
Assessment Boundary: None

In NYS the clarification statement has been edited as follows: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, introduction of invasive species, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. SEP4(2) Constructing Explanations and Designing Solutions • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. SEP6(2) Engaging in Argument from Evidence • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. SEP7(2)	LS4.B Natural Selection • The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. LS4.B(2) LS4.C Adaptation • Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. LS4.C(1) • Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. LS4.C(2) • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. LS4.C(4) • Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. LS4.C(5)	Patterns • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. CCC1(1) Cause and Effect • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CCC2(1)

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Analyzing and Interpreting Data		*Comparing Microbiomes Investigation* *Making Sense of Comparing Microbiomes Investigation*			
Constructing Explanations and Designing Solutions			*The Microbiome as an Ecosystem Summary Task*		
Engaging in Argument from Evidence				*Evidence Gradient Graphic Organizer*	*The Microbiome Argument* *The Microbiome Mini-Rubric*
LS4.B Natural Selection	*New Treatment*	*Making Sense of Comparing Microbiomes Investigation*	*The Microbiome as an Ecosystem Summary Task*		
LS4.C Adaptation		*Making Sense of Comparing Microbiomes Investigation*	*Summary Task* *The Microbiome as an Ecosystem Summary Task*	*Evidence Gradient Graphic Organizer*	*The Microbiome Argument* *The Microbiome Mini-Rubric*
Patterns					*The Microbiome Argument* *The Microbiome Mini-Rubric*
Cause and Effect		*Comparing Microbiomes Investigation* *Making Sense of Comparing Microbiomes Investigation*	*The Microbiome as an Ecosystem Summary Task*	*Evidence Gradient Graphic Organizer*	*The Microbiome Argument* *The Microbiome Mini-Rubric*

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics		MP2 MP4 HSS-ID.C.9	MP 3 HSS-ID.C.9		
ELA/Literacy		RST.9-10.1	RST.9-10.1	WHST.9-10.9	WHST.9-10.1 WHST.9-10.9

Student Work for The Microbiome 5E

Claim: We can leverage a healthy microbiome in order to reduce the chances of infection.		
Evidence that supports the claim	**Scientific reasoning that support the claim**	**Evidence or Ideas that refute the claim**
we observed in the data that the Hadza have a more diverse microbiome than the Italians we observed in the data that the Hadza have less chronic disease and weigh less than other people we saw in the graph that people that have a less diverse microbiome get c. diff and learned that fecal transplants, that restore diversity to the gut microbiome, cure a bacterial infection caused by c. diff	A microbiome is like an ecosystem, diversity helps maintain a healthy environment and may help fight off infections and reduce diseases Diversity is good in the gut because of competition. If a pathogenic bacteria enters the gut, the symbiotic bacteria might be able to outcompete the pathogenic one so it can't really take hold In diversity, there are many different kinds of bacteria that do different things. If you lose one type of bacteria, there can be others to replace it. If the gut is not diverse, than losing a type of bacteria might be bad because it can't be easily replaced -- causing a disruption in homeostasis or making the person more susceptible to problems or disease	we observed in the data that the Hadza eat differently than other people The microbiome in the Hadza may be due to their specific diet, with lots of fiber, which is different than most people today we saw in the data that some gut bacteria have gone extinct in Italians, so they may not be available for other people's microbiomes Fecal transplants can make people sick if the donor has an illness that they are immune to, but the recipient is not It is difficult to determine what a 'healthy' microbiome is what works for c.diff (a fecal transplant to increase diversity) may not work for other infections like cholera
Highlight your strongest piece of evidence above. What makes that evidence the strongest? we saw in the graph that people that have a less diverse microbiome get c. diff and learned that fecal transplants, that restore diversity to the gut microbiome, cure a bacterial infection caused by c. diff. This is the best evidence and ideas for this claim because we were able to see that people that have a less diverse microbiome got this infection. Also, it was done as part of a medical study. I didn't collect the data myself, but I trust the scientists that collected this data.		

Use all of the evidence, and relevant scientific reasoning to evaluate the claim: We can leverage a healthy microbiome in order to reduce the chances of infection/severity of a cholera infection.

C. diff is a bacteria, just like V. cholera, so having a healthy and diverse microbiome may help prevent people from getting cholera in the first place. However, it may be difficult to maintain a diverse microbiome because people would have to change their diet to be more like the Hadza. In the investigation, we looked at data that showed the Hadza have a more diverse microbiome and less disease than other people like urban Italians and Americans. We also saw that people that get C. diff infections have a less diverse microbiome, and many can be treated through a fecal transplant (that has gut bacteria) from a more diverse donor. A diverse microbiome may help with fighting infections because of competition. If there are a lot of bacteria, and many types of bacteria in the gut, there is more competition for resources. Therefore, pathogenic bacteria, like cholera, may have a more difficult time infecting (or severely infecting) a person with a diverse microbial population. The gut is like an ecosystem, with all the different types of bacteria doing different things to maintain homeostasis. Additionally, humans and bacteria have co-evolved to exist together through natural selection. It was advantageous for both humans and bacteria to live together, called symbiosis. When people use antibiotics, they lose species of bacteria, which normally do a specific job, resulting in a loss of homeostasis for the human, maybe making them more susceptible to disease like cholera.

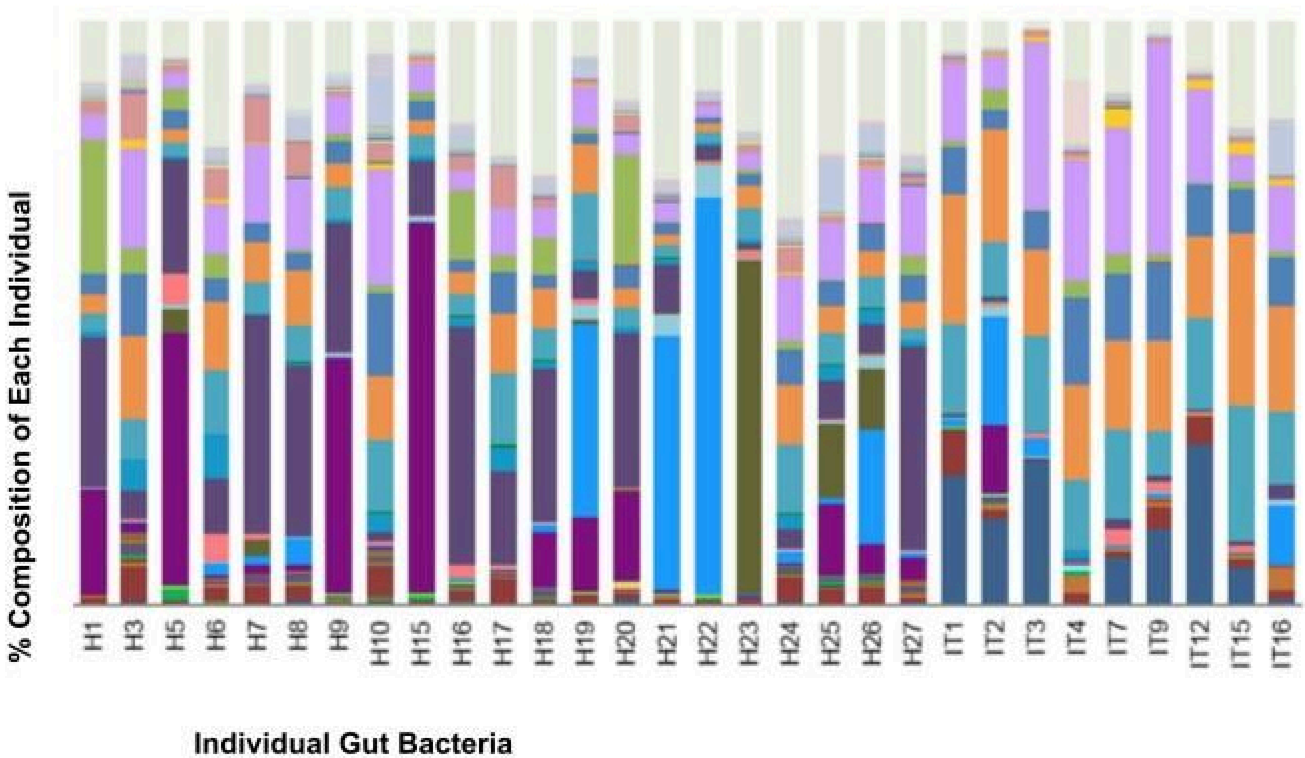
Classroom Resources for The Microbiome 5E

Color Visual
Color Visual Edited

Color Visual

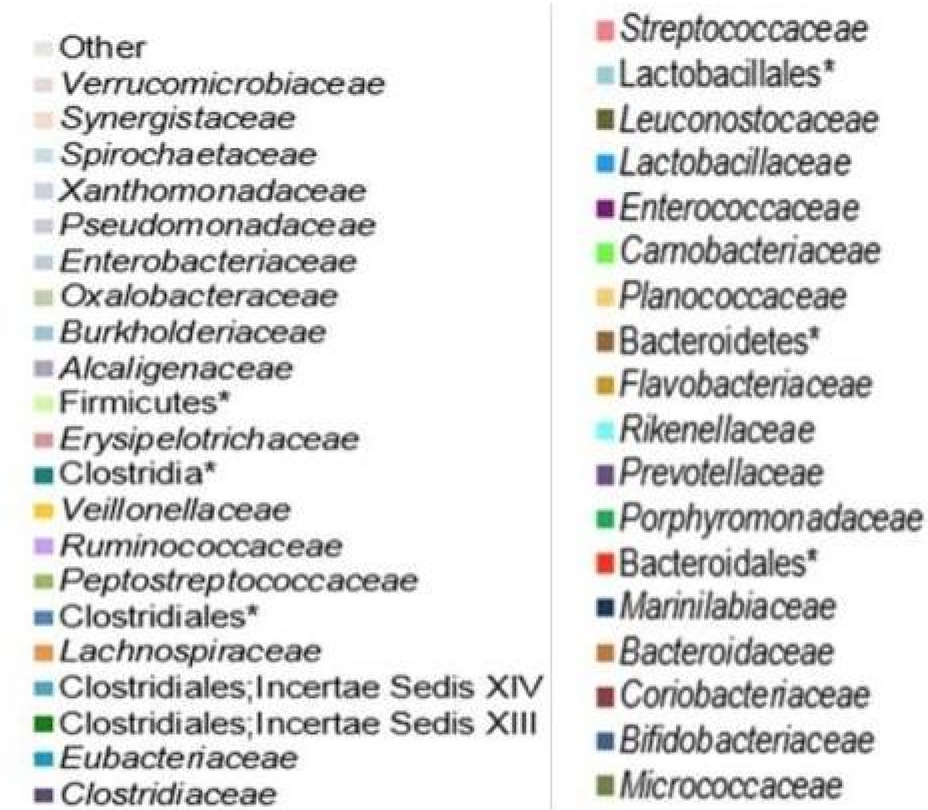
This figure can be printed in full color on poster paper for each group.

Figure 1. Composition of the Microbiome in Urban Italians and Hunter-gatherers (Hadza)



Enterocyte-associated microbiota in Hadza and Italians

Types of Bacteria

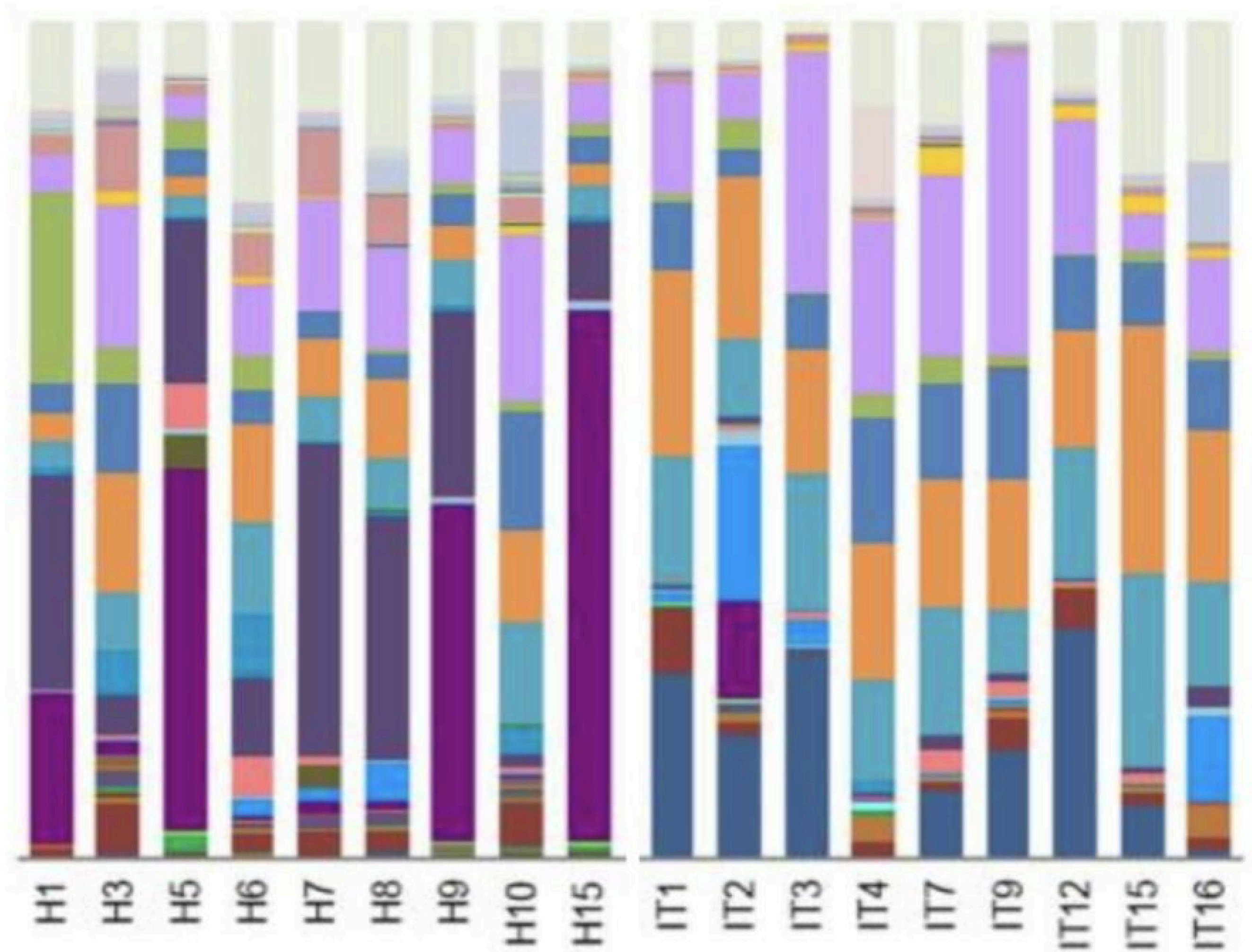


Enterocyte-associated microbiota in Hadza and Italians (Key)

Color Visual Edited

This figure can be printed in full color on poster paper for each group.

Figure 1. Composition of the Microbiome in Urban Italians and Hunter-gatherers (Hadza)



Color Visual Edited

Types of Bacteria

Enterocyte-associated microbiota in Hadza and Italians (Key)

Cooperation & Survival 5E

How do bacteria interact with each other? How can we leverage those interactions to fight infections?

Performance Expectations
HS-LS2-8

Investigative Phenomenon
Bacteria develop biofilms as one way to communicate and cooperate.

Time
6-7 days

In this 5E instructional sequence, students are investigating the questions about how bacteria interact with each other and how we can develop alternative strategies to fight bacterial infections surfaced during the Driving Question Board launch. Bacteria are faced with the same struggles for survival that all organisms face: finding sufficient nutrients, energy, and space and evading predators (or the immune system!). Bacteria have evolved cooperative behaviors, including developing biofilms and communication systems, in order to increase their chances of survival in challenging circumstances. Students will consider the evolution of these behaviors, and how to best leverage them to prevent future disease outbreaks.

ENGAGE	Why do bacteria cooperate and generate biofilms?	Connecting to their earlier questions about how bacteria interact, students are introduced to the phenomenon that bacteria band together and generate cooperative biofilms, and share their initial ideas about **why bacteria would cooperate.**
EXPLORE	Why is it advantageous for bacteria to cooperate? Do bacteria cheat when cooperating?	Students **analyze and interpret data from a simulation** in order to **surface pattern**s on **cooperative behaviors in bacteria.**
EXPLAIN	How did cooperation evolve, and how might we disrupt it in bacteria to fight infections?	Students **construct an explanation** on the **evolution of cooperation** in bacteria. Then, students consider how humans might introduce changes to the environment that **cause changes in the effectiveness** of **cooperative behaviors** in order to fight bacterial infections.
ELABORATE	Do other organisms demonstrate cooperative behaviors?	Students test out their ideas and conceptions about **the evolution of cooperative behaviors** by **identifying evidence** for the **causality behind** the cooperative feeding behavior in whales.
EVALUATE	How do the cooperative behaviors of bacteria connect to identifying the best solution to prevent a future cholera outbreak?	Students **use evidence** generated throughout the unit, and their new understanding of the **causes behind collaborative behaviors** in order to **evaluate claims** on how to best prevent a future cholera outbreak.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

Why do bacteria cooperate and generate biofilms?

Connecting to their earlier questions about how bacteria interact, students are introduced to the phenomenon that bacteria band together and generate cooperative biofilms, and share their initial ideas about **why bacteria would cooperate.**

Preparation

Student Grouping	Routines	Literacy Strategies
None	❏ Rumors	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Biofilm See-Think-Wonder	None	❏ Post-it notes ❏ Time Lapse Video of Biofilm Formation

Launch

1. Remind students that during the Driving Question Board launch, one category of questions that emerged was related to how bacteria interact with each other or what are alternative ways to fight infections (rather than antibiotics). If students do not surface ideas or questions about bacterial cooperation, prompt them to think about our comparison between the microbiome and an ecosystem. Highlight a student idea from that discussion that connects to cooperation or communication between bacteria (or organisms in an ecosystem). Let students know that we are going to think about alternative ways to ward off infections by investigating cooperation between bacteria.
2. Ask students to share more the last time they worked in a group, and why it was both beneficial and challenging. Listen for the observation that cooperation makes the work easier or faster.
3. Use students' ideas to transition to the question, "Why would bacteria evolve to cooperate with each other?"
4. Let students know that they are going to consider an example of bacteria cooperating to generate something called a biofilm, which is just one example of cooperation in bacteria and other species.

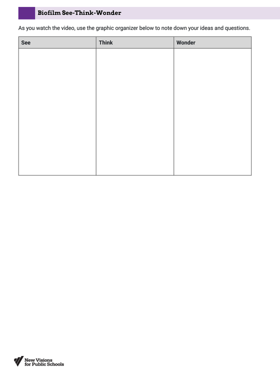
Access for All Learners

All students have some background knowledge on the topic of cooperation. Be sure to provide opportunities for students to articulate those ideas at this point, by selecting examples that make sense to them.

See-Think-Wonder

1. Start the Time Lapse Video of Biofilm Formation for students to watch as a class.

2. Provide students with the *Biofilm See-Think-Wonder*, students should fill in the graphic organizer individually.
3. Prompt students to identify their most important idea or question from the graphic organizer.



Biofilm See-Think-Wonder

As you watch the video, use the graphic organizer below to note down your ideas and questions.

See	Think	Wonder

New Visions for Public Schools 1

Surfacing Student Ideas

1. Students write their most important idea or question on a post-it note.
2. Students share their ideas using the group learning routine **Rumors.**
3. Categorize student ideas.

Routine

The goal of the **Rumors** routine is to have students exchange ideas while listening for similarities and differences in thinking. It's meant to be low stakes, so it is frequently used to surface initial student ideas about phenomena during the Engage phases. Please read the Biology Course Guide for detailed steps about this routine.

Explore

Why is it advantageous for bacteria to cooperate? Do bacteria cheat when cooperating?

Students **analyze and interpret data from a simulation** in order to **surface patterns** on **cooperative behaviors in bacteria.**

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Cooperation vs. Cheating Investigation ❑ Cooperation vs. Cheating Investigation (Scaffolded Version) ❑ Making Sense of the Cooperation vs. Cheating Investigation ❑ Cooperation vs. Cheating Investigation Rubric	❑ Cooperation vs. Cheating Foods Scissors Tape Computer access	❑ The Evolution of Trust Simulation

Launch

1. Ask students to remind us what we are trying to figure out (why some bacteria cooperate or work together to make biofilms).

2. Introduce the idea that it is difficult to study cooperation in bacteria, using the materials we have in the lab. Ask students how they might be able to simulate or model this idea.

Investigation: Cooperation vs. Cheating

Part 1:

1. In preparation for the lab, print out several copies of *Cooperation vs. Cheating Foods*. Each student will need a page with the ten dollars printed.

2. Set up a grocery store for students to buy food using the printed money. It may be easiest to tape food items around the room for students to take in exchange for their dollars, so that one teacher is not overwhelmed with trying to make sales with a large group of students.

3. Provide each student with *Cooperation vs. Cheating Investigation*. Also provide each student with the page of dollars from the handout *Cooperation vs. Cheating Foods*. Give students scissors to cut apart each dollar.

4. Explain to students that their goal is to get as nutritious a meal as possible using the foods available in the store. Students will visit the store and use their dollars to purchase food items. They will tally up their nutrition scores using the information at the top of each food item page. If a student has more than two servings of the same food, they can only count the nutrition scores for two. In other words, a student cannot get 24 nutrition points from eating a whole pizza; they can get 6 points for 2 slices, and the rest do not count.

5. Give students a few minutes to strategize how they will acquire the most nutritious meal possible. Then, open the "store" to allow students to begin shopping.

Implementation Tip

Hopefully students will employ a range of strategies to assemble nutritious meals. The goal is for some students to choose to work cooperatively and pool their resources, for other students to work independently, and for a few students to try to cheat by taking food they didn't pay for. If different strategies aren't emerging, assign two students to be cheaters by telling them privately to do so; and nudge students towards cooperating by asking a student with a full pizza what they should do with their extra slices.

6. When students are done assembling their meals, have them work through Part 1 of the handout *Cooperation vs. Cheating Investigation*.

7. Give students an opportunity to discuss the strategies employed by different students, and to weigh the costs and benefits of each one. Tell students that they will now explore a computer simulation in which they observe how different strategies like cooperation and cheating play out in large groups over long periods of time.

Part 2:

1. Provide each student with computer access.

2. Students use the The Evolution of Trust Simulation to run different strategies (which combination of cooperating and cheating is most advantageous) and record their work in Part 2 of the student handout.

Access for All Learners

Prompt students to consider their own experiences collaborating in groups. Ask, "What are those experiences like, and what happens to the group when someone cheats or doesn't do their part of the work?"

Part 3:

1. Students discuss in small groups how to best analyze the provided data on bacteria in a CF patient over time. Confer with students and provide support as needed to develop a data analysis plan.

Differentiation Point

If students need support with data analysis, provide the scaffolded version of the investigation, *Cooperation vs. Cheating Investigation (Scaffolded Version)*.

2. Students generate observations based on the data in the investigation handout.

Conferring Prompts

Confer with students as they work in collaborative groups

Suggested conferring questions (these should push students' thinking around establishing relationships, observing patterns, identifying variables, and questioning events):

- What happens when you only cooperate?
- What happens when you only cheat?
- Which strategy combination of cooperation and cheating is the most beneficial?
- How do you think the bacteria 'know' when to cooperate or cheat?
- How might you best represent this data? Why?
- How might you further analyze this data set? What other information might be helpful in understanding the relationships demonstrated in the data?

Whole-Class Investigation Summary

1. Ask students to work independently to complete the *Making Sense of the Cooperation vs. Cheating Investigation* , then use these completed pages to discuss the findings from the investigation.

2. Ask groups to come up with one important idea to share with the whole class, from their Summary notes.

3. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' Summary sections. Plan forward based on the various understandings that students or student groups have articulated. It is appropriate to go onto the next phase once students have had a chance to make sense of the data, and have had the opportunity to clarify what they have figured out about the investigative phenomenon under study in this lesson sequence.

Routine

The **Domino Discover** routine is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Please refer to the Biology Course Guide for detailed steps of this routine.

Look & Listen For

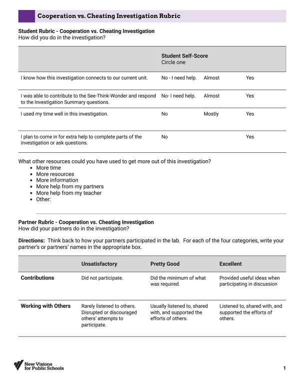
- If everyone/all organisms cooperate, everyone/all organisms benefit.
- In a population of cooperators, a mutation can arise that leads to non-cooperators (cheaters) -- in the game, this was represented by the ‘mistake.’
- If individuals cheat (non-cooperators) they win only if the majority of the remaining population cooperate, but at the expense of those cooperating.
- If we have too many cheaters, no one benefits (as seen in the CF patients).
- Human cooperation behavior is complex, but has the same basic principles as cooperation in other organisms such as bacteria.
- How do bacteria ‘know’ how to collaborate (i.e. How have bacteria evolved the ability to cooperate)?

Access for Multilingual Learners

Domino Discover provides receptive language opportunities for students who are **entering** and **emerging** language learners. For those who are **transitioning** and **expanding**, this routine provides time to rehearse language with peers, so that students are not responsible for on-the-spot responses before they are ready.

4. If students don’t surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

5. Provide students with *Cooperation vs. Cheating Investigation Rubric*. Ask students to use the investigation rubric to self and peer assess their progress on engaging with the investigation individually and as a group.



Cooperation vs. Cheating Investigation Rubric

Student Rubric - Cooperation vs. Cheating Investigation
How did you do in the investigation?

	Student Self-Score Circle one		
I know how this investigation connects to our current unit.	No - I need help.	Almost	Yes
I was able to contribute to the See-Think-Wonder and respond to the Investigation Summary questions.	No- I need help.	Almost	Yes
I used my time well in this investigation.	No	Mostly	Yes
I plan to come in for extra help to complete parts of the investigation or ask questions.	No		Yes

What other resources could you have used to get more out of this investigation?
- More time
- More resources
- More information
- More help from my partners
- More help from my teacher
- Other:

Partner Rubric - Cooperation vs. Cheating Investigation
How did your partners do in the investigation?

Directions: Think back to how your partners participated in the lab. For each of the four categories, write your partner’s or partners’ names in the appropriate box.

	Unsatisfactory	Pretty Good	Excellent
Contributions	Did not participate.	Did the minimum of what was required.	Provided useful ideas when participating in discussion
Working with Others	Rarely listened to others. Disrupted or discouraged others’ attempts to participate.	Usually listened to, shared with, and supported the efforts of others.	Listened to, shared with, and supported the efforts of others.

New Visions for Public Schools 1

Explain

How did cooperation evolve, and how might we disrupt it in bacteria to fight infections?

Students **construct an explanation** on the **evolution of cooperation** in bacteria. Then, students consider how humans might introduce changes to the environment that **cause changes in the effectiveness** of **cooperative behaviors** in order to fight bacterial infections.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Triads	❑ Think-Talk-Open Exchange ❑ Class Consensus Discussion ❑ Domino Discover	❑ Text Annotation

Materials

Handouts	Lab Supplies	Other Resources
❑ Evolution of Cooperation Notetaker ❑ Cooperative Behavior of Bacteria in CF Patients ❑ C-E-R Graphic Organizer ❑ C-E-R Rubric ❑ Leveraging Cooperative Behaviors Brainstorm	None	❑ Biofilm: A New (Gross) Thing to Worry About Video ❑ The microbial jungles all over the place (and you) Video ❑ How bacteria 'talk' Video

Part 1: Understanding the Evolution of Cooperative Behavior

1. In the Engage and Explore phases students surfaced that cooperative behaviors have advantages and disadvantages, and under what conditions social bacteria may cooperate or ‘cheat.’ Facilitate students in reviewing the remaining questions they still have from their See-Think-Wonder organizer or from the investigation summary questions. Highlight that we don’t understand yet how bacteria ‘know’ how to collaborate or how they may have evolved to exhibit this complex behavior. So, we need to look further into these concepts.

2. Provide each student with *Evolution of Cooperation Notetaker* and jigsaw each of the following 3 resources:
   a. Biofilm: A New (Gross) Thing to Worry About Video , The microbial jungles all over the place (and you) Video (2 videos about 5 minutes each)
   b. How bacteria 'talk' Video (about 18 minutes long)
   c. *Cooperative Behavior of Bacteria in CF Patients*

Differentiation Point

The biofilm videos are the most accessible, and can be assigned to students that need more time to make sense of the concepts, or may need to watch the videos more than once. The Quorum sensing video is a little longer and may be assigned to students who are ready to watch a longer and more in-depth video. The text is complex, and should be assigned purposefully to students ready to engage in a complex text. It can also be assigned to pairs for partner reading.

3. In jigsawed groups, students watch or read their assigned resources and fill in their graphic organizer. Prompt students to use **text annotation** for the reading.

Differentiation Point

Here are some options for ensuring that all students have access to the information in the *Cooperative Behavior of Bacteria in CF Patients* , since there is one version of the text, and it uses some advanced scientific vocabulary.

1. Shared reading group: support students by having them read the text long with a teacher, in a small group setting.
2. Chunking with Turn and Talk: Break the text up into chunks. In pairs, students read the text and after each chunk, they discuss and try to find relevant evidence for each claim collaboratively

4. Back in home groups (of 3), each student shares their ideas and peers write down notes in *Evolution of Cooperation Notetaker*.

Constructing a Scientific Explanation

1. Provide students with, *C-E-R Graphic Organizer*. Individually, students use the ideas from the group share out, the investigation, and their understanding of evolution by natural selection to construct a scientific explanation to the guiding question, "How do cooperative behaviors evolve over time through natural selection?"

2. After completing the initial draft of the explanation, provide students with the *C-E-R Rubric*, so that students may self or peer assess with the rubric. Provide time for students to revise based on self, teacher, and/or peer feedback.

Class Consensus Discussion

1. Orient the class to the purpose and the format of the group learning routine **Class Consensus Discussion**. You may say something like this:
    - "We have a lot of different ideas circulating in the room right now. It is really important for us to get to some agreement on how we represent what we know about the evolution of cooperative behaviors, so that we have a shared understanding to build upon as we move ahead. In order to do this we are going to use a **Class Consensus Discussion** to help narrow down and clarify our ideas.. First I will select a few different groups to share their ideas. Then, we will let each group share their response, and discuss what we can agree to as a class."
2. You may decide to walk students through the entire poster, or take them through the steps as you facilitate it.

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

3. Select two or three individual explanations to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of why and how cooperative behaviors have evolved through natural selection. The decision about which responses to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.
4. Ask the first group to share their most important ideas. You can do this by:
    - Projecting using a document camera; OR
    - Copying the responses to be shared and passing them out; OR
    - Writing key points on the board or on poster paper.
5. Proceed through the steps in the Consensus Discussion Steps. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk; use the guidelines below to ensure the class focuses on ideas that will drive the lesson and unit forward.

Routine

Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Please refer to the Biology Course Guide for detailed steps of this routine.

Classroom Supports

Post the steps to the class consensus discussion in the room, as a reference you can return to in future lessons.

Access for Multilingual Learners

Rather than assigning a list of vocabulary words—a technique that rarely works for learning new vocabulary—this activity allows language learners to learn vocabulary from context, which may be particularly helpful for **transitioning** language learners, who already have some mastery of language.

Take Time for These Key Points

Pause the discussion and ask for clarification, particularly of the following key points:

- *Cooperative behaviors* evolve through natural selection
- Bacteria have to *compete* for resources and to avoid predation and attack by the immune system
- If cooperation is beneficial, bacteria possessing that trait will be selected for in that environment -- an *adaptation*
- Cheating can arise through a *mutation* (variation in the population); if cheating is beneficial in an environment, the cheating behavior will increase until there are only cheaters because that is the trait that is being passed on to the next generation more frequently. The converse is true for cooperation.
- Cooperative behaviors may increase in the population if it is beneficial for that specific environment because those with the trait enjoy *differential survival* and *reproduction*.
- Group behavior, like cooperating to obtain resources, is often seen in closely related (genetically) individuals. For example, bacteria in groups are often clones of each other

Part 2: Identifying Ways to Leverage Cooperative Behaviors

1. Remind students of earlier questions about what types of alternative therapies we can develop to fight bacterial infections (other than antibiotics).
2. Provide students the *Leveraging Cooperative Behaviors Brainstorm* handout.
3. Individually, students brainstorm how we can use our understanding of cooperative behaviors to fight bacterial infections using the behavior that they focused on in Part 1.
4. Using the group learning routine **Think-Talk-Open Exchange**, each student shares their ideas with their peers. During the open exchange portion, encourage students to discuss which cooperative behavior scientists should target in terms of preventing a cholera outbreak. In other words, how can we leverage what we know about a specific cooperative behavior in bacteria to better prevent or fight off cholera?
5. Prompt student groups to share ideas with the class.

Look & Listen For

- We can develop drugs/molecules that target biofilms, so that antibiotics become more effective.
- We can develop drugs/molecules that disrupt the communication systems of bacteria so that they do not 'talk' to each other or send the wrong message.
- We can infuse sick patients with 'cheaters' of the same type of bacteria.
- We can develop drugs/molecules that disrupt how the bacteria are cooperating to obtain specific nutrients such as iron.

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.
2. The results of this task can be used to make determinations about which students need more time to engage in sense-making about bacteria cooperation.

Integrating Three Dimensions

The summary task supports student reflection around **CCC #2 - Cause and Effect**. The prompt is modified from STEM Teaching Tools #41 (http://stemteachingtools.org/brief/41), and it gets at the idea of distinguishing between correlation and causation, which in turn is key for making a strong argument (**SEP #7 - Engaging in Argument from Evidence**). development of these lenses.

Elaborate

Do other organisms demonstrate cooperative behaviors?

Students test out their ideas and conceptions about **the evolution of cooperative behaviors** by **identifying evidence** for the **causality behind** the cooperative feeding behavior in whales.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Table groups	❏ Read-Generate-Sort-Solve	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Whales Bubble Feeding Text ❏ RGSS Organizer	None	❏ Fellowship of the Whales: Feeding as a Team Video

Text-Based Task

1. Organize students into triads. Highlight for students that in the previous Explore & Explain, they figured out how bacteria cooperate in order to survive and reproduce. Students may wonder if there are other organisms demonstrating cooperative behaviors (other than humans), and what types of behaviors are seen.

2. As needed, watch Fellowship of the Whales: Feeding as a Team Video to get students interested in cooperative feeding behaviors, surfacing ideas and further questions about the phenomenon.

3. Provide the *Whales Bubble Feeding Text* so that students can look closely at the example of whale cooperative feeding.

4. Facilitate the group learning routine **Read-Generate-Sort-Solve** as a way for students to synthesize and extend their thinking. Students use the *RGSS Organizer* to respond to the prompts: Why do these whales cooperate in this way? How can we understand the cause or causes behind the evolution of this cooperative behavior? What evidence would we need to demonstrate that this behavior is beneficial to the survival and reproduction of the whales?

Access for All Learners

Prompt students to think about other examples of cooperative feeding or hunting that they know about (lions for example) or any time they have noticed groups of organisms working together (flocks of birds, fish swimming together, lions or hyenas hunting as a pack, etc).

Routine

The **Read-Generate-Sort-Solve** routine promotes collaborative engagement in problem-solving and supports students in articulating their thinking and making it transparent, before considering solutions. Please refer to the Biology Course Guide for detailed steps of this routine.

Evaluate

How do the cooperative behaviors of bacteria connect to identifying the best solution to prevent a future cholera outbreak?

Students **use evidence** generated throughout the unit, and their new understanding of the **causes behind collaborative behaviors** in order to **evaluate claims** on how to best prevent a future cholera outbreak.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Cooperation & Survival Argument ❑ Cholera & Bacterial Cooperation Text ❑ Cooperation & Survival Mini-Rubric	None	❑ Class wide scientific argument characteristics ❑ Resources on socratic seminar ❑ Driving Question Board from the start of the unit should be available

Revisit the Performance Task

1. Prompt students to consider where they currently stand on the question category from the Driving Question Board that they have been investigating throughout this 5E instructional sequence. This will be something like: How do bacteria cooperate with each other? What are some alternative ways to fight bacterial infections?

Implementation Tip

When returning to the Driving Question Board, be sure to change these suggested teacher notes so that they match your class' actual questions!

2. Remind students that they are generating an argument for our unit level performance task, and we need to consider as a class how our ideas are developing about what a scientific argument is and how to evaluate a strong claim or evidence. Prompt students to return to the class characteristics list and revise their ideas.

Example poster

Class Consensus List:
Characteristics of a Scientific Argument

~~It has two sides~~ It compares or considers different claims

~~You need proof for each side~~ You need evidence for each claim that supports it

Evidence comes from different places, like experiments, observations, and the experiments and observations of others (scientists)

Evidence should be ~~questioned~~ evaluated. It can be evaluated by the quality of the evidence. For example, direct observations of a phenomena (data collected) is high quality.

we have to consider where evidence comes from: direct measurement, observations, controlled experiments, simulations, etc and its strength or weakness depending on the source of the evidence

Cross-cutting concepts can help us evaluate evidence and claims, and in understanding how scientific reasoning connects the claim and evidence. For example, understanding the difference between correlation and causation is important in evaluating a claim.

A science fact is not evidence, but can help us link the evidence to a claim. The relevant science concepts make up our scientific reasoning.

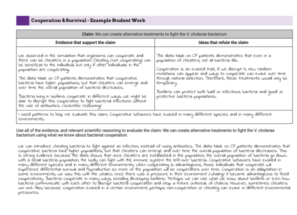
Concepts, ideas, and logical conclusions are not evidence, but can be used to link the evidence to the claim or to refute a claim

one ~~side~~ claim has more ~~proof~~ evidence or higher quality evidence

Discussing a counterclaim can strengthen the argument

You are trying to ~~change someone's mind~~ encourage scientific discourse and evaluate all possible claims. Thinking through counter-claims helps us evaluate each side.

3. Provide students with *Cooperation & Survival Argument*. Students work individually to make sense of how the learning from this 5E sequence contributes to the overall task. They should think through the investigation and resources provided in this 5E plan to evaluate the claim: We can prevent infections/outbreaks by disrupting bacterial cooperation


Cooperation & Survival - Example Student Work

Differentiation Point

Students that meet or exceed the PEs addressed in this 5E can investigate and incorporate additional details about cholera into their Performance Task. Provide them with, *Cholera & Bacterial Cooperation Text*.

4. Confer with students while they are working.

Conferring Prompts

Confer with students as they work to sort the cards. Prompt students to return to the class wide scientific argument characteristics, posted in the room.

Suggested conferring questions:

- How does this piece of evidence connect to a specific claim?
- Can you think of other evidence that supports each claim?
- Is some evidence more trustworthy? Why or why not?
- Can you think of other evidence or ideas that refute this claim?

5. After completing their argument individually, provide students with *Cooperation & Survival Mini-Rubric* to provide self, peer, or teacher feedback.

Document Class Thinking

1. Prompt students to discuss, with their groups, each claim from this 5E sequence (cooperation & survival). Students can use the notes in their Performance Task Organizers in these discussions.
2. Each group comes to a consensus answer on each claim (Is this the strongest claim, is this the best solution to stopping a future outbreak?) Students decide—Yes, No, or Maybe—and should be able to articulate their reasoning.
3. Conduct a **Domino Discover** to hear from each group, and tally the responses on chart paper. It is not necessary to discuss all the positions or get to class consensus at this point. Listen for students' ability to use evidence to back up a claim, and reasoning in how they refute a claim.

Standards in Cooperation & Survival 5E

Performance Expectations

HS-LS2-8	**Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.** Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming. Assessment Boundary: None

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. SEP4(2) Constructing Explanations and Designing Solutions • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. SEP6(2) Engaging in Argument from Evidence • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. SEP7(2)	LS2.B Cycles of Matter and Energy Transfer in Ecosystems • Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. LS2.B(2) LS2.D Social Interactions and Group Behavior • Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. LS2.D(1) LS4.B Natural Selection • Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. LS4.B(1) • The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. LS4.B(2) LS4.C Adaptation • Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction,	Patterns • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. CCC1(1) Cause and Effect • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CCC2(1)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
	(3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. LS4.C(1) • Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. LS4.C(2) • Adaptation also means that the distribution of traits in a population can change when conditions change. LS4.C(3)	

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Analyzing and Interpreting Data		*Cooperation vs. Cheating Investigation* *Making Sense of the Cooperation vs. Cheating Investigation*		*RGSS Organizer*	
Constructing Explanations and Designing Solutions			*C-E-R Graphic Organizer* *Summary Task*		
Engaging in Argument from Evidence					*Cooperation & Survival Argument* *Cooperation & Survival Mini-Rubric*
LS2.B Cycles of Matter and Energy Transfer in Ecosystems		*Making Sense of the Cooperation vs. Cheating Investigation*			
LS2.D Social Interactions and Group Behavior	*Biofilm See-Think-Wonder*	*Cooperation vs. Cheating Investigation (Scaffolded Version)* *Making Sense of the Cooperation vs. Cheating Investigation*	*C-E-R Graphic Organizer* *Summary Task*	*RGSS Organizer*	*Cooperation & Survival Argument* *Cooperation & Survival Mini-Rubric*
LS4.B Natural Selection			*C-E-R Graphic Organizer* *Summary Task*		
LS4.C Adaptation			*C-E-R Graphic Organizer* *Summary Task*		*Cooperation & Survival Argument* *Cooperation & Survival Mini-Rubric*
Patterns		*Cooperation vs. Cheating Investigation (Scaffolded Version)* *Making Sense of the Cooperation vs. Cheating Investigation*			*Cooperation & Survival Argument* *Cooperation & Survival Mini-Rubric*
Cause and Effect			*Summary Task*	*RGSS Organizer*	*Cooperation & Survival Argument* *Cooperation & Survival Mini-Rubric*

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics					
ELA/Literacy		RST.9-10.1	RST.9-10.1	WHST.9-10.9	WHST.9-10.1 WHST.9-10.5

Student Work for Cooperation & Survival 5E

Claim: We can create alternative treatments to fight the V. cholerae bacterium	
Evidence that support the claim	**Ideas that refute the claim**
We observed in the simulation that organisms can cooperate and there can be cheaters in a population. Cheating (not cooperating) can be beneficial to the individual, but only if other individuals in the population are cooperating. The data table on CF patients demonstrates that cooperative bacteria have higher populations, but that cheaters can emerge and over time the overall population of bacteria decreases. Bacteria living in biofilms cooperate in different ways. We might be able to disrupt this cooperation to fight bacterial infections without the use of antibiotics. (scientific reasoning)	The data table on CF patients demonstrates that even in a population of cheaters, not all bacteria die. Cooperation is an evolved trait, if we disrupt it, new random mutations can appear and ways to cooperate can evolve over time through natural selection. Therefore, these treatments would only be temporary. Biofilms can protect both 'bad' or infectious bacteria and 'good' or protective bacteria populations.
I used patterns to help me evaluate this claim. Cooperative behaviors have evolved in many different species and in many different environments.	

Use all of the evidence, and relevant scientific reasoning to evaluate the claim: We can create alternative treatments to fight the V. cholerae bacterium using what we know about bacterial cooperation.

We can introduce cheating bacteria to fight against an infection, instead of using antibiotics. The data table on CF patients demonstrates that cooperative bacteria have higher populations, but that cheaters can emerge and over time the overall population of bacteria decreases. This is strong evidence because the data shows that once cheaters are established in the population, the overall population of bacteria go down. With a small bacteria population, the body can fight with the immune system the left-over bacteria. Cooperative behaviors have evolved in many different species and in many different environments. When cooperating is advantageous, those individuals that cooperate will experience differential survival and reproduction so more of the population will be cooperators over time. Cooperation is an adaptation in some environments, we saw this with the whales. Once there was a pressure in their environment (whaling) it became advantageous to feed cooperatively. Bacteria cooperate in many ways, including developing biofilms. Perhaps we can use what we know about biofilms or even how bacteria communicate with each other to disrupt bacteria cooperation and stop a future outbreak of cholera. However, sometimes cheaters win out. Also, because cooperation evolved in a certain environment, perhaps non-cooperation or cheating can evolve in different environmental pressures.

Classroom Resources for Cooperation & Survival 5E

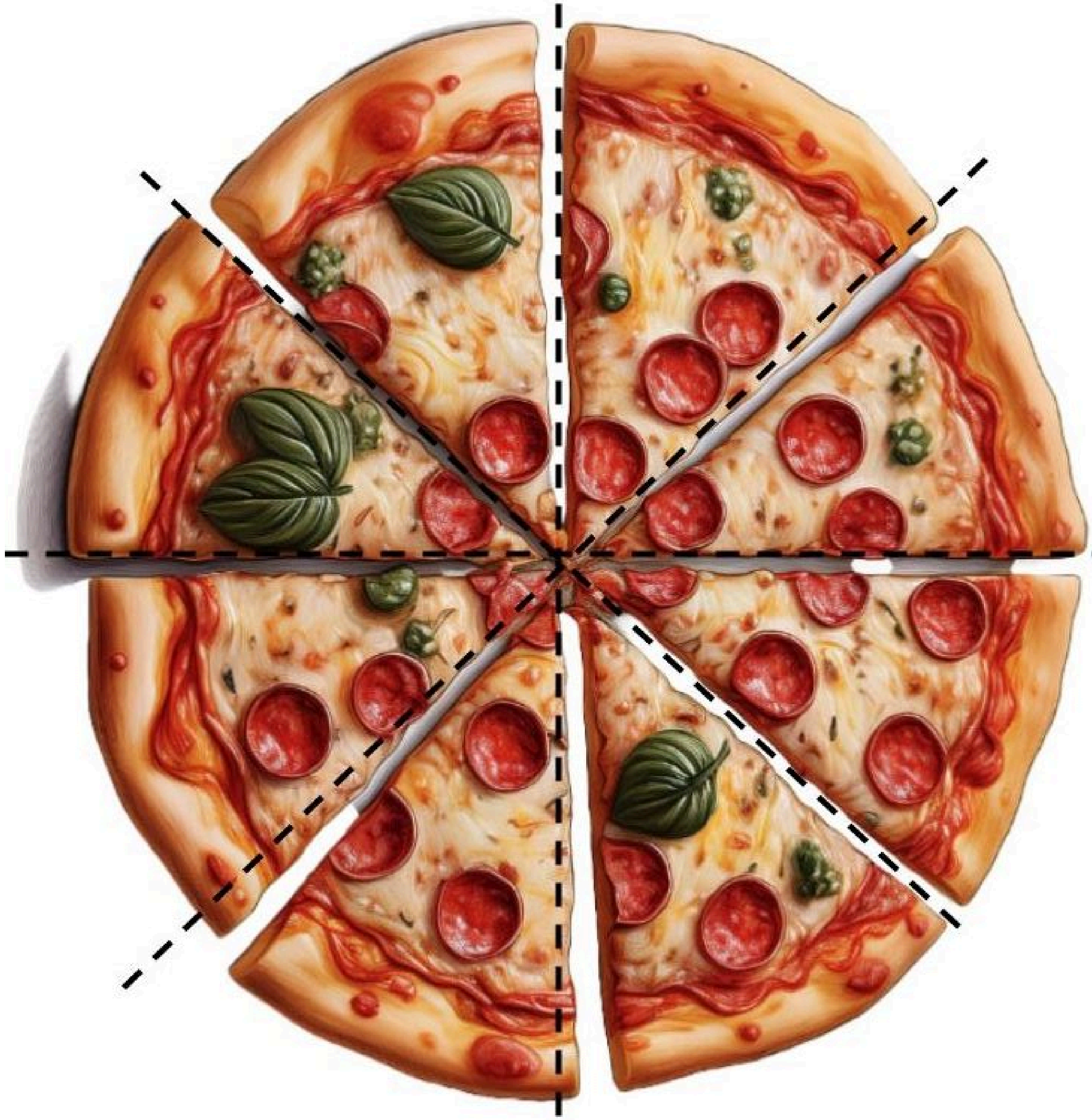
Cooperation vs. Cheating Foods









1 pizza = $10
Contains 8 Servings
Each serving gives 3 nutrition points

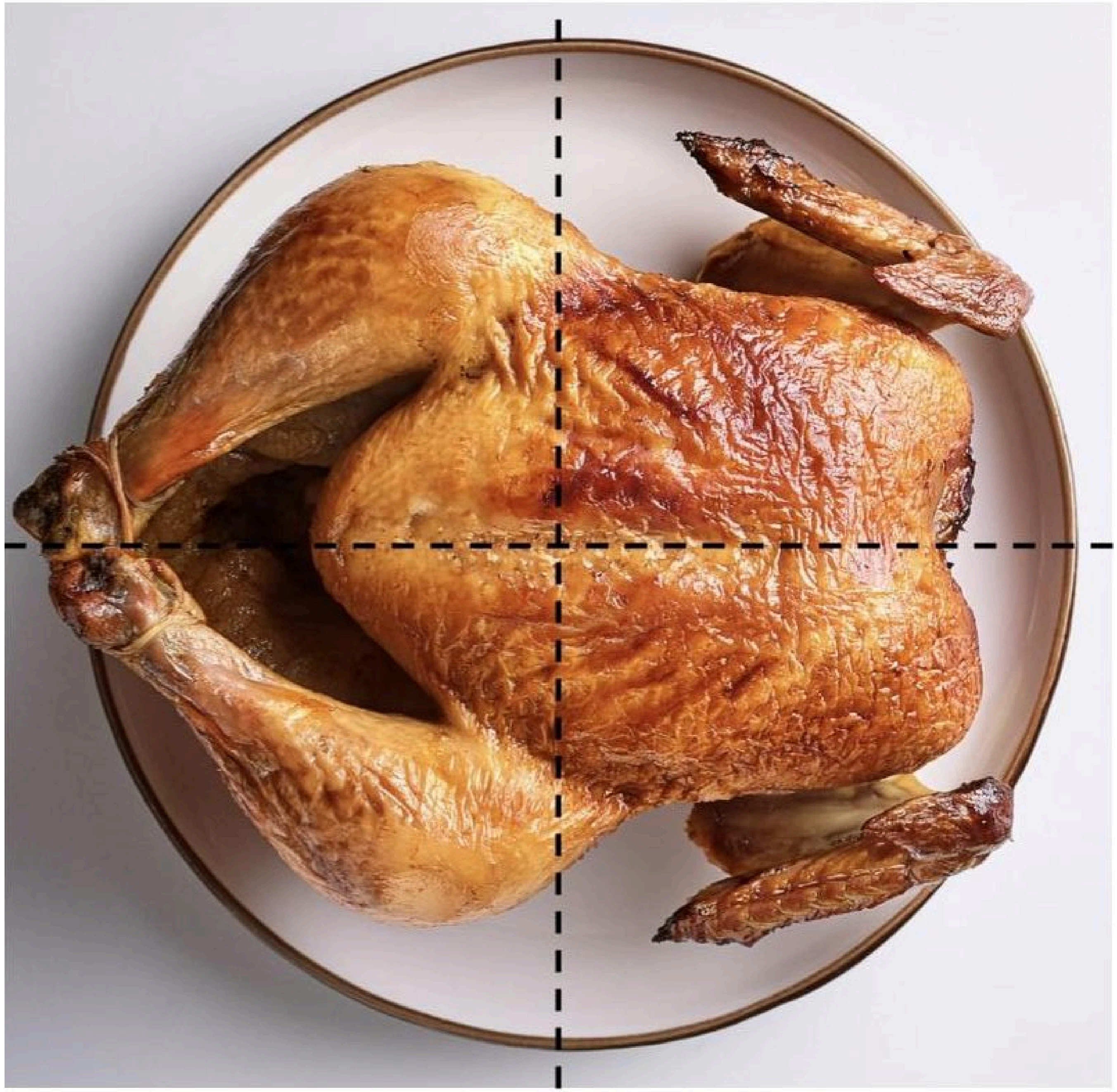
1 salad = $10
Contains 4 Servings
Each serving gives 4 nutrition points

1 apple = $2
Contains 1 serving
Each apple gives 3 nutrition points

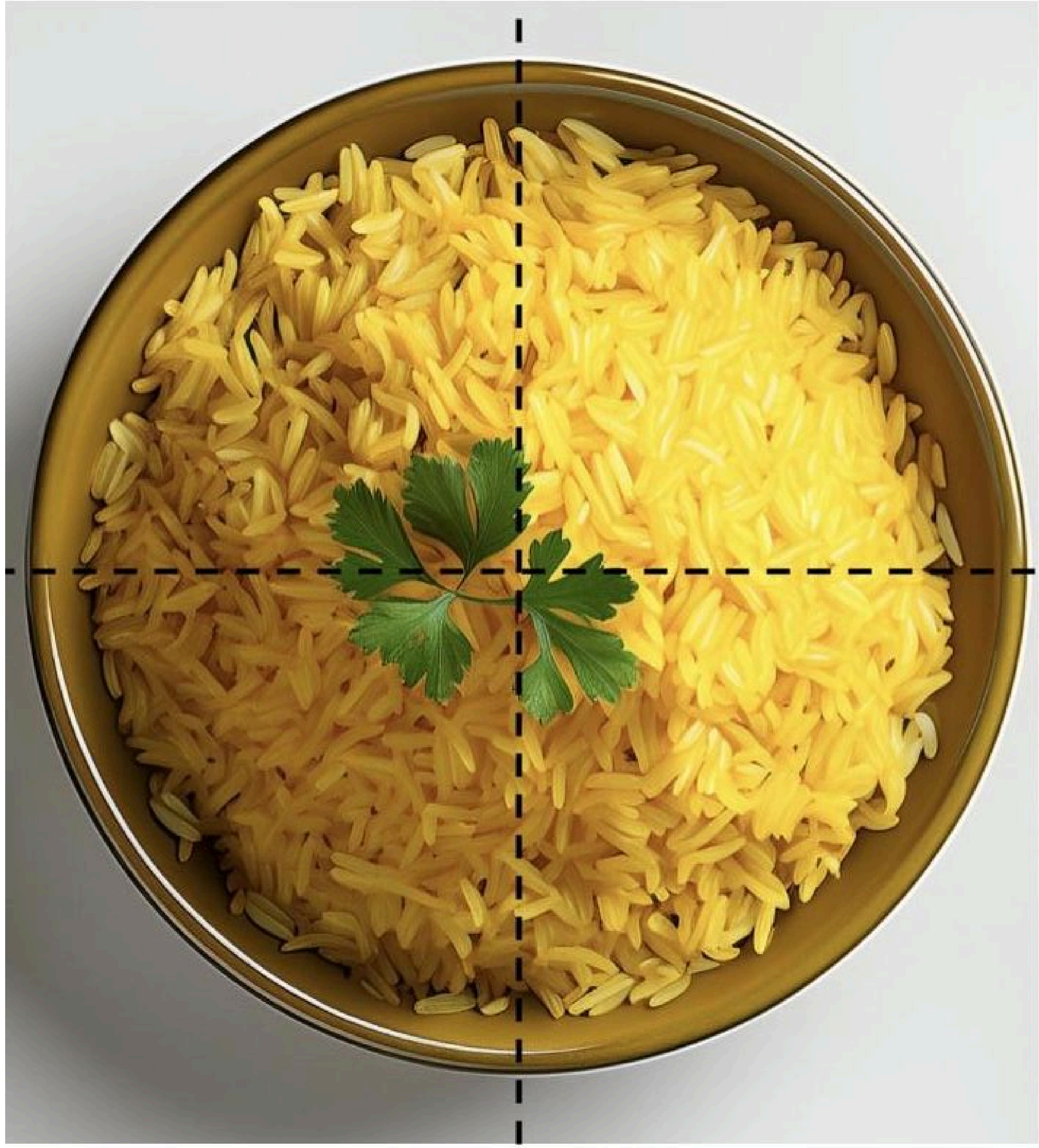
7 apples = $10
Contains 7 servings
Each apple gives 3 nutrition points

Bowl of Beans = $5
Contains 6 servings
Each serving gives 4 nutrition points

1 bagel = $2
Contains 1 serving
Each bagel gives 2 nutrition points

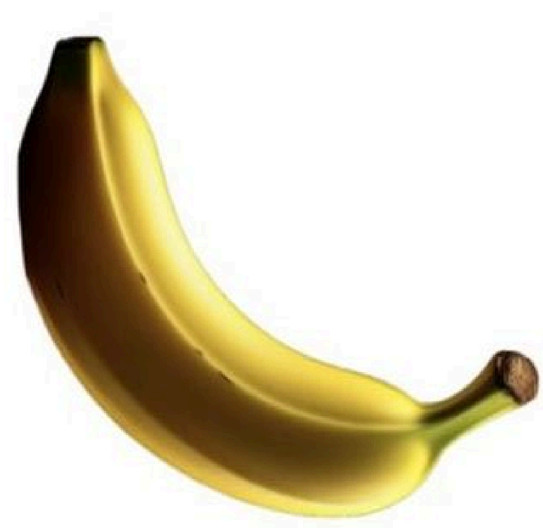


1 chicken = $10
Contains 4 servings
Each serving gives 3 nutrition points



Bowl of rice = $6
Contains 4 servings
Each serving gives 3 nutrition points

1 banana = $1
Contains 1 servings
Each banana gives 3 nutrition points



1 bag of chips = $1
Contains 1 servings
Each bag of chips gives 1 nutrition point

Unit Closing

How can we best prevent a future outbreak of cholera?

Performance Expectations
HS-LS2-8, HS-LS4-2, HS-LS4-3, HS-LS4-4, HS-LS4-5

Anchor Phenomenon
The number of deaths from infectious diseases is increasing globally. Why, after decades of declining deaths from infectious disease, have we seen a resurgence of outbreaks?

Time
2-3 days

Based on the investigations and learning throughout the unit, students generate a final scientific argument outlining the best possible solution to a future cholera outbreak.

ANCHOR PHENOMENON	Why are infectious diseases increasing globally?	Based on the investigations and learning throughout the unit, students review their ideas on why infectious diseases are increasing globally.
DRIVING QUESTION BOARD	What questions have been answered? What have we not answered yet?	Based on the investigations and learning throughout the unit, students return to the Driving Question Board to reflect on questions generated throughout the unit.
PERFORMANCE TASK	How can we prevent a future outbreak of infectious diseases such as cholera?	Based on the investigations and learning throughout the unit, students generate a final scientific argument outlining the best solution for preventing a future cholera outbreak.
UNIT REFLECTION	How can we evaluate our progress on the scientific practice of arguing from evidence?	Students reflect on their learning and use of scientific argumentation throughout the unit.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Anchor Phenomenon

Why are infectious diseases increasing globally?

Based on the investigations and learning throughout the unit, students review their ideas on why infectious diseases are increasing globally.

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	

Generating Ideas about Anchor Phenomenon

1. Students return to the anchor phenomenon and review their ideas on why infectious diseases are increasing globally, and why this might be a problem we need to address.

Driving Question Board

What questions have been answered? What have we not answered yet?

Based on the investigations and learning throughout the unit, students return to the Driving Question Board to reflect on questions generated throughout the unit.

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	❏ Driving Question Board

Driving Question Board

1. Students return to the questions generated throughout the unit and reflect. What questions have been answered? Are there questions that we still need to investigate?

2. Note that not all of the students' questions will be answered at the end of the unit, and students may have generated entirely new questions. Depending on student interest and instructional time, prompt students to explore some of the unanswered questions independently.

Differentiation Point

In terms of the unit phenomenon, we only investigated the increase in bacterial disease. In reality, other types of infectious disease are also increasing such as zoonotic diseases (COVID-19 is a great example) and vector-borne disease increases due to climate change. Encourage students who have already demonstrated proficiency regarding the bundled standards to investigate these topics independently or in small groups.

Performance Task

How can we prevent a future outbreak of infectious diseases such as cholera?

Based on the investigations and learning throughout the unit, students generate a final scientific argument outlining the best solution for preventing a future cholera outbreak.

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Final Argument ❑ Final Argument Rubric	None	❑ *Final Argument - Example Student Work* ❑ Socratic Seminar Resources

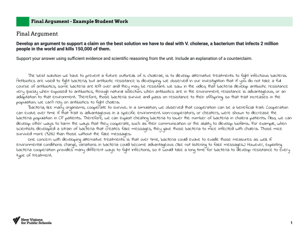
Develop a Scientific Argument

1. Prompt students to review all of the claims that they have investigated and evaluated throughout the unit. Students will decide on which claim is the best supported, using evidence and scientific reasoning from the unit and any outside research or sources they have found. To encourage students to identify the best supported claim, frame the decision point around the idea of limited financial resources. You can say something like,

"The World Health Organization has only a limited amount of money and would like to use their resources to fund the most effective solution. Keeping that in mind, and all of the evidence we have generated throughout the unit, which solution would you propose?"

2. Provide students with the *Final Argument*, and *Final Argument Rubric*, and the opportunity to review all of the initial arguments and associated feedback from throughout the unit.

3. Students individually develop their scientific argument.



Final Argument - Example Student Work

Final Argument

Develop an argument to support a claim on the best solution we have to deal with V. cholerae, a bacterium that infects 2 million people in the world and kills 150,000 of them.

Support your answer using sufficient evidence and scientific reasoning from the unit. Include an explanation of a counterclaim.

The best solution we have to prevent a future outbreak of V. cholerae, is to develop alternative treatments to fight infectious bacteria. Antibiotics are used to fight bacteria, but antibiotic resistance is developing. We observed in our investigation that if you do not take a full course of antibiotics, some bacteria are left over and they may be resistant. We saw in the video, that bacteria develop antibiotic resistance very quickly when exposed to antibiotics, through natural selection. When antibiotics are in the environment, resistance is advantageous, or an adaptation to that environment. Therefore, those bacteria survive and pass on resistance to their offspring so that trait increases in the population. We can't rely on antibiotics to fight cholera.

Bacteria, like many organisms, cooperate to survive. In a simulation, we observed that cooperation can be a beneficial trait. Cooperation can evolve over time if that trait is advantageous in a specific environment. Non-cooperators, or cheaters, were shown to decrease the bacteria population in CF patients. Therefore, we can exploit cheating bacteria to lower the number of bacteria in cholera patients. Also, we can develop other ways to harm the ways that they cooperate, such as their communication or the ability to develop biofilms. For example, when scientists developed a strain of bacteria that creates fake messages, they gave those bacteria to mice infected with cholera. Those mice survived more (92%) than those without the fake messages.

One concern with developing alternative treatments is that over time, bacteria could evolve to evade those measures as well. If environmental conditions change, variations in bacteria could become advantageous (like not listening to fake messages.) However, exploiting bacteria cooperation provides many different ways to fight infections, so it would take a long time for bacteria to develop resistance to every type of treatment.

New Visions for Public Schools 1

Integrating Three Dimensions

The final argument task and evaluation provide the opportunity to assess student progress in many of the **DCIs** found in **LS4** and **LS2**. However, based on which claim students choose to discuss, evidence for all of those DCIs may not be found in their argument, but can be found in previous 5E sequences. Additionally, students may choose to discuss either **CCC#1 Patterns** OR **CCC#2 Cause and Effect**, but not necessarily both. Tailor assessment and feedback to address the DCIs and the CCC that are appropriate to their specific claim.

Access for All Learners

Consider organizing a Socratic Seminar for students to share and critique the arguments of others. This activity provides multiple opportunities for students to engage through reading, writing, and discussion. Resources for Socratic Seminars in science classrooms can be found here.

Unit Reflection

How can we evaluate our progress on the scientific practice of arguing from evidence?

Students reflect on their learning and use of scientific argumentation throughout the unit.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Individual	None	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Argument Evaluation ❏ Final Argument Rubric	None	

Self-Evaluation in the Practice of Arguing from Evidence

1. Remind students that they started the unit out generating an initial set of characteristics of scientific argumentation, and generated an initial argument based on their background knowledge.

2. Prompt students to identify how their thinking has changed on what a scientific argument is and why the practice is important to engage in. Support the generation of student ideas by showing the initial and final class wide scientific argument characteristics chart, and/or asking students to compare their initial argument with their final argument.

3. Provide students with the *Argument Evaluation* to complete individually.

4. Use the *Final Argument Rubric* to provide feedback as students are working.

Standards in Unit Closing

Performance Expectations

HS-LS2-8	**Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.** Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming. Assessment Boundary: None
HS-LS4-2	**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.** Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning. Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.
HS-LS4-3	**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.** Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations. Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.
HS-LS4-4	**Construct an explanation based on evidence for how natural selection leads to adaptation of populations.** Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations. Assessment Boundary: None
HS-LS4-5	**Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.** Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species. Assessment Boundary: None

In NYS the clarification statement has been edited as follows: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, introduction of invasive species, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. SEP6(2) Engaging in Argument from Evidence • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. SEP7(2)	LS2.D Social Interactions and Group Behavior • Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. LS2.D(1) LS4.C Adaptation • Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. LS4.C(1) • Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. LS4.C(2) • Adaptation also means that the distribution of traits in a population can change when conditions change. LS4.C(3) • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. LS4.C(4)	Patterns • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. CCC1(1) Cause and Effect • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CCC2(1)

Assessment Matrix

	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Constructing Explanations and Designing Solutions			*Final Argument*	
Engaging in Argument from Evidence			*Final Argument*	*Argument Evaluation*
LS2.D Social Interactions and Group Behavior			*Final Argument*	
LS4.C Adaptation			*Final Argument*	
Patterns			*Final Argument*	*Argument Evaluation*
Cause and Effect			*Final Argument*	*Argument Evaluation*

Common Core State Standards Connections

	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Mathematics				
ELA/Literacy			WHST.9-10.1 WHST.9-10.2 WHST.9-10.5 SL.9-10.4	WHST.9-10.1 WHST.9-10.2 WHST.9-10.5 SL.9-10.4

Student Work for Unit Closing

Final Argument

Develop an argument to support a claim on the best solution we have to deal with V. cholerae, a bacterium that infects 2 million people in the world and kills 150,000 of them.

Support your answer using sufficient evidence and scientific reasoning from the unit. Include an explanation of a counterclaim.

The best solution we have to prevent a future outbreak of V. cholerae, is to develop alternative treatments to fight infectious bacteria. Antibiotics are used to fight bacteria, but antibiotic resistance is developing. We observed in our investigation that if you do not take a full course of antibiotics, some bacteria are left over and they may be resistant. We saw in the video, that bacteria develop antibiotic resistance very quickly when exposed to antibiotics, through natural selection. When antibiotics are in the environment, resistance is advantageous, or an adaptation to that environment. Therefore, those bacteria survive and pass on resistance to their offspring, so that trait increases in the population. We can't rely on antibiotics to fight cholera.

Bacteria, like many organisms, cooperate to survive. In a simulation, we observed that cooperation can be a beneficial trait. Cooperation can evolve over time if that trait is advantageous in a specific environment. Non-cooperators, or cheaters, were shown to decrease the bacteria population in CF patients. Therefore, we can exploit cheating bacteria to lower the number of bacteria in cholera patients. Also, we can develop other ways to harm the ways that they cooperate, such as their communication or the ability to develop biofilms. For example, when scientists developed a strain of bacteria that creates fake messages, they gave those bacteria to mice infected with cholera. Those mice survived more (92%) than those without the fake messages.

One concern with developing alternative treatments is that over time, bacteria could evolve to evade those measures as well. If environmental conditions change, variations in bacteria could become advantageous (like not listening to fake messages.) However, exploiting bacteria cooperation provides many different ways to fight infections, so it would take a long time for bacteria to develop resistance to every type of treatment.