Food for All - Teacher Materials

Unit 5	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.

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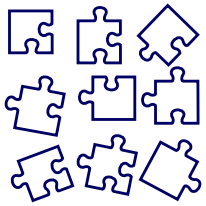
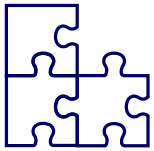
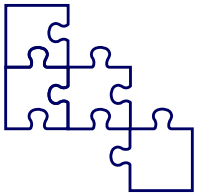
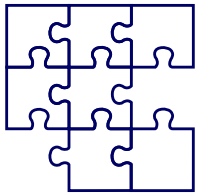
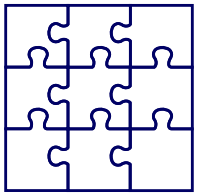
Energy and Matter in Ecosystems

Performance Expectations
HS-LS2-1, HS-LS1-5, HS-LS2-4, HS-LS2-3, HS-LS1-6

Time
26-31 days

What caused an epidemic of pellagra in the early 20th century?

Students learn about the pellagra epidemic in early 20th century southern US, and investigate the causes behind the disease and its disproportionate impact. They figure out that those who were sick primarily ate a corn-based diet, and they use concepts about matter and energy flow to figure out why corn was such an important cereal crop. Then they conduct investigations to figure out that processed food does not decompose as quickly as fresh food, and that tenant farmers relied heavily on processed corn. Through additional investigations and building on their ideas about cellular respiration and photosynthesis, students learn about the importance of niacin, that indigenous people had a process for making the niacin in corn more accessible, and that processing corn reduces the amount of available niacin. This helps them construct an explanation for why people who lacked a diverse diet and primarily ate processed corn suffered from niacin deficiency, the scientific cause of pellagra. They discuss how systemic inequities were the root cause for the disproportionate impact of pellagra on some groups, including Black tenant farmers. Finally they consider the role of processed food in their own communities and health, accessibility to fresh food, and consider innovations that may address this concern.

Unit Opening	Neolithic Revolution 3E	The SuperFood that Changed the World 5E	Infectious Agent or Insufficient Diet 5E	Food for Plants 5E	Unit Closing
Anchor Phenomenon	→	**5E Lessons connect learning to the performance task**	→		**Performance Task**
					
There was a mysterious pandemic spreading across the southern United States in the early 20th century. Why did some groups of people get sick, while others did not?	*Why did human populations increase during the Neolithic Revolution?*	*Why was corn used as a primary source? Was it the cause of the pellagra epidemic?*	*Was pellagra caused by an infectious agent or lack of an adequate diet?*	*What communities were impacted most by the pellagra epidemic?*	*How can we use what we have learned about science and social injustices to explain the causes of the pellagra epidemic and to identify and solve challenges in our own communities today?*

Unit Introduction

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 the causes behind a historical medical mystery, students consider how scientific innovations in farming may provide solutions to the lack of access to healthy foods in many modern communities.

Unit 5 was co-designed with a content expert, Lenora Crabtree, Ph.D. Dr. Crabtree is an instructor at the Department of Middle and Secondary K-12 Education, Cato College of Education, University of North Carolina Charlotte. As an education researcher and teacher educator, Dr. Crabtree uses Design-based Research to study how inquiry, science content, and critical pedagogies of place support teaching and learning for liberation. Dr. Crabtree worked closely with the unit development team providing ideas for investigations, investigative phenomena, writing texts, and identifying sources of original data, particularly around one area of her expertise – the historical Pellagra Epidemic in the SouthEastern United States.

This unit was intentionally designed using a justice-centered approach, drawing from both critical pedagogy and culturally relevant pedagogy, to support students in critically viewing both historical and contemporary systems of oppression. Throughout the unit, students examine the sociopolitical contexts of scientifically informed decision-making. Not only do they develop scientific knowledge and skills, they also develop critical thinking, empathy, and a sense of agency. It encourages students to take action in their local communities and contribute to creating a fairer and more equitable society.

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 5, the overall question about what caused a historical medical mystery 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 5. Each sequence builds towards figuring out something that contributes to explaining the overall unit-level question on what caused the pellagra epidemic, and how similar factors are impacting our food systems and access to healthy food today. The phenomena, the instructional model, and the routines embedded throughout the sequences of lessons are all used in service of coherence across Unit 5.

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 (three in this unit, and one 3E that does not include an Elaborate or Evaluate phase) • 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	There was a mysterious pandemic spreading across the southern United States in the early 20th century. Why did some groups of people get sick, while others did not?	**Performance Expectations**	**Anchor Phenomenon** In the Southeastern United States during the early 20th century, pellagra impacted different groups of people disproportionately.	**Time** 2-3 days

Student Questions	What Students Do	Student Ideas
These questions motivate the unit storyline. • What are the symptoms of pellagra? • Who became ill and who did not? • How can we figure out what caused the illness?	Students read a text in order to gain some background information about the pellagra epidemic and what early researchers thought was causing the disease.. After telling the story of the epidemic, students generate a driving question board, and then record their initial thoughts on the cause behind the pandemic.	*These ideas are revisited throughout the unit storyline.* • Some researchers believed that pellagra was caused by a pathogen; some researchers believed that it was diet related • One common idea was the importance of corn in the diet of people impacted by pellagra • Some groups of people, women and children for example, suffered disproportionately from the epidemic • Indigenous people, that relied on corn, did not get ill from pellagra

Students have been introduced to a historical medical mystery, the Pellagra epidemic. After surfacing their initial ideas and questions, they will begin to investigate the role of corn in the diets of those suffering from the disease, and why corn was such a large proportion of their diet.

Neolithic Revolution 3E	Why did human populations increase during the Neolithic Revolution?	**Performance Expectations** HS-LS2-1	**Investigative Phenomenon** Human populations grew after the Neolithic Revolution	**Time** 3-5 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 3E sequence and the unit storyline. • Why did the human population stay stable for so long? • Why did the human population significantly increase about 10,000 years ago? • How can investigating mice populations help us understand human population dynamics? • How did agriculture change how people lived and contribute to an increase in the global human population?	Students begin by analyzing a graph of the human population over time. They then use a simulation to investigate what factors impact a population of mice in order to surface the idea of carrying capacity and limiting factors. Students then read a text to explain both a mice population graph and a human population graph, using annotations based on the reading. Students share their ideas about how agriculture changed the carrying capacity for humans and generate new questions.	*Students figure out these ideas in this 3E sequence.* • All populations are reliant on resources from their environment • All populations grow through reproduction if nothing limits their growth • Availability of resources limit population growth, factors such as food, water, and predators • Human population stayed relatively stable (dynamic equilibrium) until about 10,000 years ago when its started to increase • The advent of agriculture and resulting Neolithic revolution allowed early human population to grow as it relieved one important limiting factor, food availability • Current human population is increasing

Have students identify which categories/questions they have not addressed yet. Students may have figured out some of the reasons why corn was an important part of the diet, but there should be lingering questions. Additionally, students may still be curious about why indigenous people eating corn did not get sick.

The SuperFood that Changed the World 5E

Why was corn used as a primary source? Was it the cause of the pellagra epidemic?

Performance Expectations
HS-LS1-5, HS-LS2-4

Investigative Phenomenon
In the early 1900s, pellagra was common in the US and Southern Europe, two populations that relied on corn and corn products. Yet, many civilizations and societies have thrived with corn as their primary crop.

Time
7 days

Student Questions

These questions motivate this 5E sequence and the unit storyline.

- Why has corn been a primary food source for the US, Europe, and early mesoamerican populations?
- What role, if any, did corn have in the pellagra epidemic?
- Is there something problematic about having a diet primarily based on corn?
- Why did some people and whole societies not get pellagra from having corn as their primary food source?
- Was there something different about the corn in Southern Europe and the US in the early 1900s?
- Could an infectious disease have caused the pellagra epidemic?

What Students Do

Students learn that there have been other societies that also used corn as a primary food source because it provides energy and nutrients. Students investigate why corn is a good source of energy by using a model of photosynthesis to establish how corn is provided with energy and matter to make glucose. Based on student questions about whether there are other plants, animals, or foods in general that are also rich sources of energy, students develop model of the energy pyramid of an ecosystem and learn that food sources that fall in the lowest level of the energy pyramid like corn are more energy efficient than other food sources like meat and dairy. Students then apply their learning to evaluating an innovation for growing energy rich and efficient crops in their community. Finally students revisit the performance task and determine that they do not have sufficient evidence to claim that corn caused the pellagra epidemic.

Student Ideas

Students figure out these ideas in this 5E sequence.

- Carbon dioxide in the air is the source of the carbon in glucose
- Plants transform light energy into chemical energy during the process of photosynthesis
- The energy from the sun is stored in the chemical bonds of glucose, and thus the primary source of matter for new structures including long-chain carbohydrates (starch and cellulose).
- Corn is a more efficient energy source than birds, other animals, or dairy.
- 90% of the energy corn gets from the Sun is not transferred to animals like birds.
- 90% of the energy to animals from producers like corn is passed to consumers like humans and birds of prey.
- If societies eat a lot of birds, other animals, or dairy, they will lose a lot of energy.
- Animals do not eat all of the corn, so some biomass that contains energy is not transferred to the next energy level on the pyramid.
- The processes that take place when an animal is digesting corn require energy, so some energy is lost there too.
- Birds and other animals that eat corn move and do a lot of activities before they are eaten by humans or other predators, so energy is lost by the time a human or another predator eats them.
- Maybe early meso-american societies and other societies have benefited from corn because it's a more efficient source of energy.

Students apply what they have learned to to explain why so many people throughout the course of history, and all over the world, have relied on corn and other cereal crops.

Have students identify which categories/questions they have not addressed yet. One question category should relate to why the US and Southern Europe experienced a pellagra epidemic in the early 1900s and whether corn had anything to do with it. Another question category should relate to whether pellagra could have been caused by infection.

Infectious Agent or Insufficient Diet 5E

Was pellagra caused by an infectious agent or lack of an adequate diet?

Performance Expectations
HS-LS2-3

Investigative Phenomenon
The pellagra epidemic disproportionately spread within institutionalized populations (orphanages and insane asylums) in the south.

Time
7-8 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • What evidence would we need to identify the cause of pellagra? • Why were institutionalized populations (e.g. orphans) experiencing high rates of pellagra, but not their caretakers? • Why would niacin be taken out of the corn? • Why is niacin an important part of the diet? • How does decomposition work in different types of food? • How might agricultural innovations support my community in providing access to fresh, unprocessed food?	Students begin by considering what evidence they would need to identify the cause of pellagra. Then they explore data collected on institutionalized populations in the early 1900's and a text to figure out that pellagra is not infectious, rather it is caused by the lack of niacin in the diet. Next, students explore why niacin is missing by generating observations on the decomposition of different types of food. Students will notice that fresh food decomposes quickly and then use a text to construct a scientific explanation on why corn was processed to remove the germ (the part of the corn that decomposes quickly) so that cornmeal would be cheaper and more shelf-stable, causing pellagra if people ate mostly cornmeal. Finally, students consider the role of processed food in their own communities and health and evaluate an innovation that may address this concern.	*Students figure out these ideas in this 5E sequence.* • Pellagra was caused by a lack of diversity in the diet (and not an infection) • Niacin was the missing nutrient in those that eat mainly processed corn • Niacin is essential for cellular respiration to occur • Without cellular respiration, an individual cannot make ATP, and will not have sufficient energy to complete cellular processes (symptoms of pellagra) • Niacin was removed during the processing of corn to make it more shelf stable (slow down decomposition) • Decomposition is the process that cycles matter between organisms in a system and is done by decomposers • The overconsumption of ultra-processed food is a concern across the US, even today

Have students identify which categories/questions they have not addressed yet. One question category should relate to why only some populations were impacted by pellagra (not everyone in the same region).

Food for Plants 5E

What communities were impacted most by the pellagra epidemic?

Performance Expectations
HS-LS1-6

Investigative Phenomenon
Despite living in agriculturally productive areas, tenant farmers in the Southeastern U.S. experienced extremely high rates of pellagra.

Time
5 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • Why were there some groups of people in the US that were affected more by pellagra? • What communities were impacted most by the pellagra epidemic?	Students look at a map that shows pellagra rates by state and data that compares pellagra cases among different demographics. Students notice that pellagra cases are greatest in the Southeast US and rates are highest in the Black community, especially women. Students wonder what is going on with availability of diverse food sources for the groups that are most affected. Students then look at an image of a typical tenant farm that grows only cotton, prevalence of tenant farming in the Southeastern US, and data that shows a strong positive correlation between cotton farming and incidence of pellagra.	*Students figure out these ideas in this 5E sequence.* • Pellagra cases were common or prevalent in the Southeastern US. • Black females were dying from pellagra at a much higher rate than Black males and white females and males. • Black people were dying from pellagra at a much higher rate than white people. • Nitrogen and carbon that plants use to make niacin and amino acids come from soil. • Soil where only one crop is grown has less nitrogen and carbon then soil where multiple crops are grown and / or rotated and grown with ground cover. • Cash crops are typically grown through monoculture practices. • Sharecroppers and tenant farmers, often Black, were forced to grow cash crops like corn or cotton through a monoculture approach which made the soil unhealthy, with low nitrogen and carbon levels • Food crops did not produce easily on tenant farms and they were unhealthy because of the soil. • Sharecroppers and tenant farmers had to give most of the money they made from farming to the landowner and did not have enough to buy food they needed for a diverse diet. • Lack of access to a diverse diet because of the circumstances was why pellagra cases and deaths were most common among Black people in the Southeast US in the early 1900s.

Have students identify which categories/questions they have not addressed yet or what ideas from the unit they would like to explore further. One question or idea should relate to further exploring the problems in their community that relate to the science and policies that led to inequities in access to healthy and diverse foods.

Unit Closing

How can we use what we have learned about science and social injustices to explain the causes of the pellagra epidemic and to identify and solve challenges in our own communities today?

Performance Expectations
HS-LS1-5, HS-LS2-4, HS-LS2-3

Anchor Phenomenon
In the Southeastern United States during the early 20th century, pellagra impacted different groups of people disproportionately.

Time
2-3 days

Student Questions

These questions are addressed in the performance task.

- How can we use what we have learned about science and social injustices during the pellagra epidemic to identify and solve challenges in our own communities today?

What Students Do

Students review the historical challenges of the pellagra epidemic and why it disproportionately impacted some people more than others, considering both incomplete scientific knowledge and social factors. Students are then asked to make connections between the past and present by considering parallel problems in their own community or neighboring communities. Finally, students explore and use their knowledge of science and their communities to consider potential solutions.

Extension
Community-based nonprofits and local organizations where students live may already be doing work to increase access to healthy fresh food. Invite students to engage with these groups that are carrying out the solutions discussed by students in the Performance Task.

Student Ideas

These ideas were developed throughout the unit storyline.

- People got pellagra because their diet was primarily based on corn that was processed.
- People did not understand that processing / degerming the corn so that it does not spoil quickly, takes out the niacin.
- Many people also did not have access to other foods that provide balanced nutrition, including nutrients like niacin.
- Niacin is an essential part of cellular respiration, so people got sick because their bodies could not produce new cells at the rate that is needed to stay healthy.
- Many communities in our city have access to food that is predominantly processed.
- Many communities in our city do not have access to healthy and fresh fruits and vegetables.
- People often have to travel far for diverse foods that are not processed and that's a barrier to eating healthy.
- Even when people can find unprocessed foods like fresh fruits and vegetables, many cannot afford it because they are expensive.
- The overall lack of access to some communities in our city can lead to more people having health problems.

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-LS2-1 **Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales**
Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate, and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.
Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.

In NYS the PE has been edited as follows: Use mathematical and/or computational representations to support explanations of biotic and abiotic factors that affect carrying capacity of ecosystems at different scales.

HS-LS1-5 **Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.**
Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models
Assessment Boundary: Assessment does not include specific biochemical steps.

HS-LS2-4 **Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem**
Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.
Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.

In NYS the clarification statement has been edited as follows: Emphasis is on using a mathematical model such as a pyramid of biomass/energy to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems.

HS-LS2-3 **Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.**
Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.
Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.

In NYS the entire PE has been edited as follows: Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in ecosystems. [Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration and photosynthesis within ecosystems.] [Assessment Boundary: Assessment does not include the specific chemical processes of aerobic respiration, anaerobic respiration, and photosynthesis.]

HS-LS1-6 **Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.**
Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.
Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.

In NYS the entire PE has been edited as follows: Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements such as nitrogen, sulfur, and phosphorus to form amino acids and other carbon-based molecules. [Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations for the synthesis of lipids, starches, proteins, and nucleic acids.] [Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of structural and molecular formulas for macromolecules.]

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.

Three-Dimensional Learning Goals in This Unit

Given the breadth of three-dimensional standards for high school biology, Unit 5 focuses primarily on ideas related to how energy and matter move through ecosystems and carrying capacity. These ideas fall mostly within Core Idea LS2 of the NGSS/NYSSLS, Ecosystems: Interactions, Energy, and Dynamics . This unit also foregrounds the SEP of Constructing Explanations and Designing Solutions. 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 Energy and Matter, which fits well with our selected SEP. As students deepen their understanding of the content to understand how both energy and matter flow through different levels of living systems, they learn how to use evidence to construct and revise a scientific explanation. Furthermore, students are prompted to consider both the durability of scientific knowledge, and how it may change based on new evidence.

Three Dimensions in Unit 5

This chart is a high-level summary of the standards for Unit 5. For more detail about specific elements, see the section on Assessment later in this document.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Using Mathematics and Computational Thinking Constructing Explanations and Designing Solutions	LS1.C Organization for Matter and Energy Flow in Organisms LS2.A Interdependent Relationships in Ecosystems LS2.B Cycles of Matter and Energy Transfer in Ecosystems	Scale, Proportion, and Quantity Energy and Matter

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

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, and incorporating the concept of the durability of science knowledge (that laws and theories that we use to describe the natural world work today as they did in the past). This unit builds on this practice prompting students to use a variety of valid data sources as evidence, and to consider the historical perspective as they construct an explanation. Peer feedback is used to engage students in revising and evaluating their explanations.

Disciplinary Core Ideas from Middle School

LS2.B Cycles of Matter and Energy Transfer in Ecosystems

- In middle school, students learn that food webs model how matter and energy move between organisms and that decomposers play a role in the cycling of nutrients. In this unit, students engage in multiple opportunities to closely examine how energy and matter move through an ecosystem including the inefficiency of transfer as one moves up the food web due to the use of matter and energy by organisms so that it is not available for other organisms further up the food food chain.

LS2.A Interdependent Relationships in Ecosystems

- Students in middle school learn that growth of organisms and population increases are limited by access to resources and other limiting factors such as predators and competition. This unit supports students in developing a more complex understanding of the carrying capacity of ecosystems through exploring this phenomenon in humans pre and post- Neolithic Revolution when humans were able to change the carrying capacity of their environment through agriculture.

Crosscutting Concepts from Middle School

Energy and Matter

This unit builds on the following aspects of Energy and Matter in middle school.

- Students in middle school learn that the transfer of energy can be tracked as energy flows through a designed or natural system. This unit builds on this understanding by engaging students in multiple opportunities to consider how changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

Assessment

Performance expectations (PEs) in the NGSS describe what students should know and be able to do. Unit 5 targets a bundle of three PEs taken from the second core idea in high school life science (HS-LS2), *cosystems: Interactions, Energy, and Dynamics*; those standards are HS-LS2-1, HS-LS2-4, and HS-LS2-3 and two PEs taken from the first core idea in high school life science (HS-LS1) *From Molecules to Organisms: Structures and Processes*; those standards are HS-LS1-5, and HS-LS1-6. 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.

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:

	Neolithic Revolution 3E	The SuperFood that Changed the World 5E	Infectious Agent or Insufficient Diet 5E	Food for Plants 5E
Developing and Using Models		☒	☒	☒
Using Mathematics and Computational Thinking	☒	☒		
Constructing Explanations and Designing Solutions		☒	☒	☒
LS1.C Organization for Matter and Energy Flow in Organisms		☒	☒	☒
LS2.A Interdependent Relationships in Ecosystems	☒	☒		
LS2.B Cycles of Matter and Energy Transfer in Ecosystems		☒	☒	
Scale, Proportion, and Quantity	☒		☒	☒
Energy and Matter		☒	☒	☒

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 5 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

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.

Standards for Mathematical Content

HSS-ID.A.1 Statistics & Probability	Represent data with plots on the real number line (dot plots, histograms, and box plots).

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.9-10.2	Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
RST.9-10.4	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

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

WHST.9-10.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
WHST.9-10.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
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.

Implementing Unit 5

This unit is designed to be the fifth 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	Neolithic Revolution 3E	The SuperFood that Changed the World 5E	Infectious Agent or Insufficient Diet 5E	Food for Plants 5E	Unit Closing
Class Consensus Discussion			2	1	1	
Consensus-Building Share		1		1		
Domino Discover		1	3	3	3	1
Idea Carousel		1				1
Read-Generate-Sort-Solve			1	1		
Rumors				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	Neolithic Revolution 3E	The SuperFood that Changed the World 5E	Infectious Agent or Insufficient Diet 5E	Food for Plants 5E	Unit Closing
C-E-R graphic organizer				1		
Chunking with partner reading				1		
Text Annotation				1		1

Simulations in this Unit

Lesson	Simulation Title	Source	Technical Notes	Permissions Notes
Neolithic Revolution 3E	Population Dynamics of White Footed Mouse Simulation	https://exchange.iseesystems.com/public/jondarkow/population-dynamics-of-white-footed-mouse/index.html#page2	NA	NA

Videos in this Unit

Lesson	Video Title	Source	Technical Notes	Permissions Notes
The SuperFood that Changed the World 5E	The Story of All of Us - Corn	https://www.youtube.com/watch?v=9QhX0D23R5I	NA	NA
The SuperFood that Changed the World 5E	Origin of Corn (optional)	https://www.biointeractive.org/classroom-resources/popped-secret-mysterious-origin-corn	NA	NA
The SuperFood that Changed the World 5E	Corn Cob Sprouting in Water	https://thewonderofscience.com/phenomenon/2018/7/9/corn-cob-sprouting-in-water	NA	NA
Infectious Agent or Insufficient Diet 5E	Pellagra - A Medical Mystery	https://www.youtube.com/watch?v=reYKBgdrZsM	NA	NA

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Infectious Agent or Insufficient Diet 5E	Time Lapsed Fruit and Vegetable Decomposition Video	https://www.youtube.com/watch?v=c0En-_BVbGc	NA	NA
Infectious Agent or Insufficient Diet 5E	The Decomposition Of McDonald's Burgers And Fries	https://www.youtube.com/watch?v=8uHxRwQqWFo	NA	NA
Infectious Agent or Insufficient Diet 5E	What is Nixtamalization?	https://www.youtube.com/watch?v=TIs3gjOPevw	NA	NA
Food for Plants 5E	Life in the South After the Civil War	https://study.com/academy/lesson/life-in-the-south-after-the-civil-war.html	NA	NA
Food for Plants 5E	Mill Mother's Lament	https://www.youtube.com/watch?v=jlaO0AsteD4	NA	NA
Unit Closing	NYC's Biggest Outdoor Aquaponic Farm	https://www.youtube.com/watch?v=8_sp6V03emQ	NA	NA
Unit Closing	AQUAPONICS Animated Introduction	https://www.youtube.com/watch?v=5094hoUSM4w	NA	NA
Unit Closing	Brooklyn Grange and the Farm at the Javits Center	https://www.brooklyngrangefarm.com/javits	NA	NA
Unit Closing	Rooftop farm at Bronx healthcare center supports wellness focus	https://www.food-management.com/healthcare/rooftop-farm-bronx-healthcare-center-supports-wellness-focus	NA	NA

Lab Materials in this Unit

Lesson	Lab	Materials needed (per group)
Neolithic Revolution 3E	Mouse Population Investigation Lab minutes: 30 minutes	laptop with wifi connection 1 laptop with wifi connection
The SuperFood that Changed the World 5E	How did it grow? Investigation Lab minutes: 45 minutes	3 test tubes light source 1 elodea plant (note: in New York State Brazilian elodea Egeria densa is an invasive plant but American waterweeds (E. canadensis E. nuttallii) are both native) aluminum foil plastic wrap 75 ml of water 25 ml of bromothymol blue 1 straw 1 250 ml beaker splint and match for the demonstration
The SuperFood that Changed the World 5E	Discovering Patterns in Pyramids Investigation Lab minutes: 45 minutes	
Infectious Agent or Insufficient Diet 5E	Goldberger's Investigation Part 1, Goldberger's Investigation Part 2 Lab minutes: 45 minutes	
Infectious Agent or Insufficient Diet 5E	Decomposition Investigation Lab minutes: 30 minutes	
Food for Plants 5E	Agricultural Practices in the SE US Investigation Lab minutes: 45 minutes	

Other Materials in this Unit

Lesson	Materials needed
The SuperFood that Changed the World 5E	ORIGINS AND PRIMARY REGIONS OF DIVERSITY OF AGRICULTURAL CROPS *Human Population Graph*

Lesson	Materials needed
Infectious Agent or Insufficient Diet 5E	Post-it notes Malnourished: Cultural ignorance paved the way for pellagra
Unit Closing	*How Vertical Farming Works*

Teacher Materials for Unit 5

Unit Opening

There was a mysterious pandemic spreading across the southern United States in the early 20th century. Why did some groups of people get sick, while others did not?

Performance Expectations

Anchor Phenomenon
In the Southeastern United States during the early 20th century, pellagra impacted different groups of people disproportionately.

Time
2-3 days

Students are introduced to the pellagra epidemic that was occurring in the southern United States in the early 20th century. Although there is evidence that earlier groups of people in Europe had also suffered from pellagra, other people did not seem to become ill. This leads to questions about the cause behind the disease and why some people became ill, while others did not.

ANCHOR PHENOMENA	Why did an epidemic of pellagra occur in the United States in the first four decades of the 20th Century and why did only some people fall ill?	Students learn about a novel disease and **ask questions** about whether **geography, income, microbes, and diet** might be factors in **causing** the outbreak.
DRIVING QUESTION BOARD	What questions do we have?	Based on **ideas** that have surfaced through student discussion, students **generate questions** and create a driving question board that will be used throughout the unit.
PERFORMANCE TASK	Why did some people become sick with pellagra?	Students construct **an initial explanation** of the **cause** behind the **pellagra epidemic**.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Anchor Phenomena

Why did an epidemic of pellagra occur in the United States in the first four decades of the 20th Century and why did only some people fall ill?

Students learn about a novel disease and **ask questions** about whether **geography, income, microbes, and diet** might be factors in **causing** the outbreak.

Preparation

Student Grouping	Routines	Literacy Strategies
▯ Table groups	None	None

Materials

Handouts	Lab Supplies	Other Resources
▯ Tell the Story	None	

Surfacing Student Ideas

1. Prompt students to discuss in pairs factors that cause disease.
2. Surface ideas that highlight the role microbes, including those carried by insects and other vectors, and environmental conditions, including food availability, play in human disease.
3. Encourage students to think about how researchers might uncover the cause of a new disease when it appears and how long that process may take. (In light of the ongoing pandemic, students may focus primarily on diseases caused by microbes including viruses. If they do, the tendency to focus on that which we are most familiar with and miss other explanations could become a good talking point later in the Unit.)
4. Tell students that during this unit they will be exploring a historic epidemic whose cause eluded researchers for almost four decades.

Telling the Story

1. Provide students with *Tell the Story*
2. Have students read and annotate the three texts, circling or highlighting three details that are the most important to the phenomenon being described.
3. Students share their ideas in their group, with every individual identifying the details that they thought were important.

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

Driving Question Board

What questions do we have?

Based on **ideas** that have surfaced through student discussion, students **generate questions** and create a driving question board that will be used throughout the unit.

Preparation

Student Grouping	Routines	Literacy Strategies
Table groups	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	

Developing Questions

1. At this point, students should have a lot of questions! Let them know that they will be investigating the cause behind pellagra throughout the unit
2. Individually, students come up with questions they would need to answer in order to figure out the phenomenon. Each question goes on a separate sticky note.
3. As a whole class or in small groups, students share and categorize their questions, as they organize the questions on chart paper.

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

Why did some people become sick with pellagra?

Students construct **an initial explanation** of the **cause** behind the **pellagra epidemic**.

Preparation

Student Grouping	Routines	Literacy Strategies
☒ Pairs	None	None

Materials

Handouts	Lab Supplies	Other Resources
☒ Initial Explanation	None	

Introducing the Performance Task

1. Distribute the *Initial Explanation*
2. Prompt students to work in pairs to develop an initial explanation, based on evidence and reasoning, on the cause behind the pellagra epidemic.

Integrating Three Dimensions

In this task, students are constructing their initial explanation, using a middle school element of **SEP#6 Constructing Explanations and Designing Solutions.** Subsequent revisions of their explanation, later in the unit, will provide evidence of student use of this SEP at the high school level.

Standards in Unit Opening

Performance Expectations

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts

Assessment Matrix

	Anchor Phenomenon	Driving Question Board	Performance Task

Common Core State Standards Connections

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

Neolithic Revolution 3E

Why did human populations increase during the Neolithic Revolution?

Performance Expectations
HS-LS2-1

Investigative Phenomenon
Human populations grew after the Neolithic Revolution

Time
3-5 days

For most of human history, the human population maintained a dynamic equilibrium around a set point, or the carrying capacity of the environment. Early human populations were limited by finite resources such as food availability. Around 10,000 years ago, some humans started engaging in agriculture. As this practice spread, human populations increased.

ENGAGE	How can we analyze a graph of the human population over time?	Students **analyze a graph** to better understand how the human **population has changed** over time.
EXPLORE	How do limiting factors impact a population?	Students **use a simulation to generate mathematical representations** of mice populations **under different environmental factors** to **surface the idea of carrying capacity.**
EXPLAIN	How did the Neolithic Revolution impact human populations?	Students **use mathematical representations of carrying capacity** to explain changes in the human population overtime and **at different scales**.
ELABORATE	This 3E has no Elaborate	
EVALUATE	This 3E has no Evaluate	

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

How can we analyze a graph of the human population over time?

Students **analyze a graph** to better understand how the human **population has changed** over time.

Preparation

Student Grouping	Routines	Literacy Strategies
☒ Pairs	☒ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
☒ Human Population Graph	None	

Launch

1. Remind students that during the Driving Question Board launch, one category of questions that emerged was related to corn: *What role, if any, did corn have in the pellagra epidemic? Why were their diets based on corn? Have there been other societies that have a diet primarily based on corn? Did they suffer a pellagra epidemic?*
2. Let students know that we are going to zoom out and think about human populations over time, what their diets were, and how people lived to be able to start to answer some of these questions. Provide students with *Human Population Graph*.
3. In pairs or table groups, students use the See-Think-Wonder graphic organizer to make sense of the human population graph.

Surfacing Student Ideas

1. Use the group learning routine, **Domino Discover** to facilitate students sharing their ideas and questions as a class.

Look & Listen For

- Early history (approximately before 12-10,000 years ago) human population was relatively stable
- Starting around 12-10,000 years ago, the population started to increase
- Approximately around 3-2,000 years ago the population started to increase dramatically
- The population continues to increase to the present
- Why was the human population stable until about 10,000 years ago?
- What caused it to start increasing?
- What caused the next dramatic increase (about 2,000 years ago?)

Routine

The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. In the Engage phase, it is often used to surface student ideas that can be used to transition the class to the investigation.

Explore

How do limiting factors impact a population?

Students **use a simulation to generate mathematical representations** of mice populations **under different environmental factors** to **surface the idea of carrying capacity.**

Preparation

Student Grouping	Routines	Literacy Strategies
☐ Table groups	☐ Consensus-Building Share	None

Materials

Handouts	Lab Supplies	Other Resources
☐ Mouse Population Investigation ☐ Making Sense of the Mouse Population Simulation ☐ Mouse Population Investigation Rubric	☐ laptop with wifi connection	☐ Population Dynamics of White Footed Mouse Simulation

Launch

1. Emphasize student questions about why the human population stayed relatively constant until about 10,000 years ago. Before starting the investigation, prompt students to think about how humans lived in our prehistoric past. If needed, remind students that in Unit 3, we investigated the lifestyle of extant hunter-gatherers (the Hadza of Tanzania). Allow students time to describe what they know or remember about prehistoric humans or hunter-gatherers that in many cases, live similar lives to our predecessors.

Look & Listen For

- Reliant on resources that they or their families could hunt or gather themselves
- Ate gathered plants and hunted animals from their environment
- Lived in settings based off of natural materials (e.g. grass/ wood structures, caves)
- No modern healthcare, electricity, or transportation
- Reliant on water from rain, rivers, ponds
- Susceptible to predators and other dangers including infections, etc.

Using a Simulation to Investigate Populations

1. Prompt students to consider how we could investigate how the factors they surfaced (resources, predators, etc) impacted early human populations. In pairs, students brainstorm and share their ideas with the class.

Look & Listen For

- Archeological evidence
- Simulations
- Use a model population to understand more about how these factors impact other organisms

2. Let students know that they will use a simulation about mouse populations to investigate population dynamics and how environmental variables impact population growth, so that we can start to understand human population changes. Provide students with *Mouse Population Investigation* and access to laptops so they can use Population Dynamics of White Footed Mouse Simulation .

3. Provide students time to explore the simulation and ask clarifying questions. In pairs, students should choose at least 2 variables to manipulate. Encourage pairs at tables to investigate different variables, or connect students after completing the simulation that investigated different variables.

Implementation Tip

Once students are investigating specific variables, encourage them to keep it simple! The relationships are easier to view when the simulation is kept at the Mouse Population (N) setting, and when the 'Explorable' button is not pushed.

Making Sense of the Investigation

1. Provide students with *Making Sense of the Mouse Population Simulation*. After students have had the opportunity to make sense of the data, use the group learning routine **Consensus Building Share** to facilitate a sharing of ideas and questions about the data.

Look & Listen For

- Increasing/decreasing the variables resulted in a increase/decrease of the population (e.g. increasing predators decreased the population/ decreasing predators increased the population)
- The population generally demonstrated a dynamic equilibrium at a set point regardless of the overall increase or decrease of the population
- The set point changed based on environmental variables
- The population generally demonstrated logistic growth (s-shaped curve)
- In comparing the human population and the mouse population dynamics the graphs are similar for pre-10,000 years ago humans but after about 10,000 years ago, human population growth is different

2. 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.

3. Provide students with *Mouse Population 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

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. 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?" Be sure to look at the Biology Course Guide for the action pattern for this routine.

Explain

How did the Neolithic Revolution impact human populations?

Students **use mathematical representations of** **carrying capacity** to explain changes in the human population overtime and **at different scales**.

Preparation

Student Grouping	Routines	Literacy Strategies
▯ Table groups	▯ Idea Carousel	None

Materials

Handouts	Lab Supplies	Other Resources
▯ Population Graphs ▯ Population Graphs Text ▯ Summary Task	▯ 1 laptop with wifi connection	

Accessing a Complex Text

1. Highlight student observations and questions from the Explore phase, emphasizing the need to figure out why the mouse population and the human population was stable around a set point until about 10,000 years ago.
2. Provide students with *Population Graphs* and *Population Graphs Text*. As students read the text, ask them to annotate the graphs, using the information from the text.
3. In table groups, students generate a poster to represent the phenomenon under study. Students respond to the prompt: Explain the human population graph from about 20,000 years ago to about 4,000 years ago. Predict what you think is occurring with the human population for the remaining time up to today.
4. Using the group learning routine, **Idea Carousel,** table groups share out their ideas.

type	3D

Routine

This is the first time the routine **Idea Carousel** appears in this unit! This routine supports groups of students in thinking through a set of related problems, tasks, or visuals, in order to develop a larger insight or discovery. Therefore, it's great for developing complex understandings of a phenomenon in science. For the first implementation, focus on having students learn the steps. Please read the Biology Course Guide for detailed steps about this routine.

text	Keep in mind that students need to go beyond explaining how the Neolithic Revolution impacted human populations; this Explain is designed to support them in using a crosscutting concept to do this sensemaking. Be sure to make **CCC #3 - Scale, Proportion, & Quantity** explicit for students by elevating and probing for ideas related to the concept of the significance of a phenomenon being dependent on the scale, proportion, and quantity at which it occurs.

Take Time for These Key Points

- Prior to the neolithic revolution human populations were subject to a lower carrying capacity
- Carrying capacity is the number of individuals that can be supported in a specific environment. It can change (increase or decrease) based on resource availability
- The factors that limit any population are factors such as: food, water, space, predators, and disease
- The advent of agriculture increase the amount of food available to humans, so the population increased
- As humans began to form civilization, improvements in farming, reduction of predators, etc – continued the increase in the population
- Students may wonder if there is a current carrying capacity for humans or why there was an exponential increase starting around 2,000 years ago

Elaborate

This 3E has no Elaborate

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	

Evaluate

This 3E has no Evaluate

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	

Standards in Neolithic Revolution 3E

Performance Expectations

HS-LS2-1 **Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales**
Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate, and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.
Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.

In NYS the PE has been edited as follows: Use mathematical and/or computational representations to support explanations of biotic and abiotic factors that affect carrying capacity of ecosystems at different scales.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. SEP5(2)	LS2.A Interdependent Relationships in Ecosystems • Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. LS2.A(1) • Carrying capacity results from the availability of biotic and abiotic factors and from challenges such as predation, competition, and disease. LS2.A(2)NYS	Scale, Proportion, and Quantity • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. CCC3(1)

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Using Mathematics and Computational Thinking	Domino Discover	*Mouse Population Investigation* *Making Sense of the Mouse Population Simulation*	*Population Graphs Text* Idea Carousel *Summary Task*		
LS2.A Interdependent Relationships in Ecosystems	Domino Discover	*Mouse Population Investigation* *Making Sense of the Mouse Population Simulation*	*Population Graphs Text* Idea Carousel *Summary Task* *Summary Task*		
Scale, Proportion, and Quantity		*Mouse Population Investigation* *Making Sense of the Mouse Population Simulation*	*Population Graphs Text* Idea Carousel *Summary Task*		

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics					
ELA/Literacy	SL.9-10.1				

The SuperFood that Changed the World 5E

Why was corn used as a primary source? Was it the cause of the pellagra epidemic?

Performance Expectations
HS-LS1-5, HS-LS2-4

Investigative Phenomenon
In the early 1900s, pellagra was common in the US and Southern Europe, two populations that relied on corn and corn products. Yet, many civilizations and societies have thrived with corn as their primary crop.

Time
7 days

In this 5E instructional sequence, students investigate why societies have used corn and other cereal crops as a primary food source and consider if what they learn provides evidence that supports or refutes that corn caused the pellagra epidemic. Finally, students reflect about how what they learned about cereal crops relates to their community.

ENGAGE	Why did human populations increase exponentially as they developed the technology to grow crops like corn?	Connecting to their earlier questions about why humans have cultivated corn and other grains, and how these foods provide energy to humans, students **develop initial claims** about what may have led humans to cultivate corn and other grains as **primary food sources**.
EXPLORE 1	How do plants, like corn, transform energy from sunlight into stored chemical energy?	Students **use a model** to **illustrate** how **photosynthesis transforms light energy into stored chemical energy**.
EXPLAIN 1	Where does corn get the carbon, oxygen, and energy that is contained in glucose?	Students **revise their models** of **photosynthesis** to include **carbon dioxide as the source of carbon in glucose**, and thus the primary **source of matter and energy** for new structures including long-chain carbohydrates (starch and cellulose).
EXPLORE 2	Why was corn so useful to the early meso-americans and other societies? Why did corn allow civilizations to emerge and grow? How much energy does corn provide compared to other foods like meats and dairy?	Students **develop a mathematical model** of **energy flow through the food chain system** to **gather evidence** regarding whether corn provides more energy than other foods like meat and dairy.
EXPLAIN 2	Why was corn so useful to the early meso-american societies and other societies?	Students use their **mathematical model** of **energy flow through the food chain system** to **develop an explanation** regarding whether corn provides more energy than other foods like meat and dairy.
ELABORATE	What staple crops do people eat around the world?	Students consider staple crops around the world and in their own communities. They then use their **energy pyramid models to develop a claim** about why these crops are also efficient **energy sources** like corn.
EVALUATE	What have we figured out about whether corn played a role in the US pellagra epidemic that occurred in the early 1900s?	Students **use their models** of how corn **plants transfer energy efficiently** to develop an **initial explanation** of the role corn may have played in the pellagra epidemic.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

Why did human populations increase exponentially as they developed the technology to grow crops like corn?

Connecting to their earlier questions about why humans have cultivated corn and other grains, and how these foods provide energy to humans, students **develop initial claims** about what may have led humans to cultivate corn and other grains as **primary food sources**.

Preparation

Student Grouping	Routines	Literacy Strategies
☒ Whole Class	☒ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
☒ Story of All of Us: Corn - See-Think-Wonder	None	☒ The Story of All of Us - Corn ☒ Origin of Corn (optional)

Launch

1. Remind students that during the last investigation they learned that the carrying capacity of early human populations (hunters and gatherers) was limited by the availability of energy in their ecosystems, but that they still have not fully answered the question whether the invention of farming and its advancement over time is associated with exponential growth in human populations.

2. Revisit the carrying capacity graph for human populations after the neolithic revolution and the graph of exponential growth in human populations. Ask students to think about what they have learned so far and brainstorm all their ideas about why the invention of farming may have led to an increase in carrying capacity for humans and exponential population growth.

3. Tell students that the video, The Story of All of Us - Corn , will discuss the role of corn in different societies in human history. Share the guiding prompts: *How has corn played a role in human societies and population size?*

4. Show the video and ask students to complete a See-Think-Wonder with the guiding prompts in mind.

Note: As an alternative if time allows, or as background information for teachers, use the video, Origin of Corn , which discusses the origins of corn and builds on what students have learned in Unit 4.

Surfacing Student Ideas

1. Ask students to share their ideas from their See-Think-Wonders and agree on one important observation, inference, and question they want to share with the whole class.

2. Use the group learning routine **Domino Discover** to surface important observations, inferences, and questions from groups' See-Think-Wonders.

Look & Listen For

Students may generate questions such as:

- Corn (or maize) is a very productive crop and provides energy and vitamins.
- Civilizations in the early Americans would not exist if it was not for corn.
- Today, corn plays an extremely important part in America.
- Why is corn so productive?
- How much energy does corn provide compared to other foods like meats and dairy?
- Are there other super crops like corn?
- Why was corn so useful to the early meso-americans and other societies, but associated with an epidemic in the US and Southern Europe in the early 1900's?
- Why did corn allow civilizations to emerge and grow?
- Was there something different about the corn in Southern Europe and the US in the early 1900's?
- Did they do something to the corn in the US and Southern Europe in the Early 1900's that made it bad for you?
- Or was it an infectious disease that was spreading in the US and Southern Europe in the early 1900's?

Routine

The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. In the Engage phase, it is often used to surface student ideas that can be used to transition the class to the investigation.

Explore 1

How do plants, like corn, transform energy from sunlight into stored chemical energy?

Students **use a model** to **illustrate** how **photosynthesis transforms light energy into stored chemical energy**.

Preparation

Student Grouping	Routines	Literacy Strategies
Table groups	Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
Cob Sprouting in Water: See-Think-Wonder How did it grow? Investigation Making Sense of the How did it grow? Investigation How did it grow? Investigation Rubric	3 test tubes light source 1 elodea plant (note: in New York State Brazilian elodea Egeria densa is an invasive plant but American waterweeds (E. canadensis E. nuttallii) are both native) aluminum foil plastic wrap 75 ml of water 25 ml of bromothymol blue 1 straw 1 250 ml beaker splint and match for the demonstration	Corn Cob Sprouting in Water

Launch

1. Remind students that a category of questions that emerged during the Engage phase was: *How does corn provide energy to humans and other animals that eat it? Where does corn get its energy and nutrients? What types of nutrients are in corn?*

2. Ask students to think about what they have learned about the source of energy we get from foods in general. Listen for students to say we get our energy from foods from glucose, which we convert into energy (ATP).

3. Show an image of a glucose molecule and ask students to notice what they see. Students are likely to say they see many carbons and oxygens and bonds that store energy.

4. Ask students whether they think corn has glucose and where they think corn could get the carbon, oxygen, and energy that is contained in glucose. Students may have a range of ideas, including the idea that corn gets energy, carbon, and oxygen from the soil.

5. Tell them that to think about these questions further and develop an explanation, the class will be watching a video that shows corn growing and then develop an initial model of how it grows.

6. Provide students with the handout, *Cob Sprouting in Water: See-Think-Wonder*. Prompt students to complete the See-Think-Wonder based on what they are observing the video.

7. After the video, prompt students to share their See-Think-Wonder table with a partner.

8. Ask groups to come up with one important idea from their See-Think-Wonder to share with the whole class.

9. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' See-Think-Wonders.

Look & Listen For

Students may generate ideas and questions such as:

- The corn was sitting in water.
- There was no soil.
- There was light present.
- The corn grew little by little over time – it did not stop growing.
- I think photosynthesis is somehow taking place.
- How can it grow without soil?
- Does it get its mass from the water?
- Does it get its mass from the air?
- Where is the corn getting glucose from?
- Glucose is made out of carbon, where is that coming from?
- I think it might have something to do with CO_2 in the air or water.
- How is photosynthesis connected to cellular respiration (because CO2 is released)?

Investigation

1. Use questions about where the mass came from, whether it came from water, whether it came from the air, and where the glucose comes from to transition to the investigation. Tell students that they will now have an opportunity to further investigate where the corn plant gets its mass by testing for different substances such as CO_2 and O_2. Provide the handout, *How did it grow? Investigation*, and have students work in table groups to complete the investigation.

Lab Safety Note: To avoid harmful irritation from bromothymol blue, ensure that everyone is wearing goggles and gloves during this lab. Do not allow students to handle broken glass at any time. An adult should use forceps, tongs, scoops, or other mechanical devices for removing broken glass from the work area. Additionally, an adult should complete the splint test for each group, demonstrating for students the results of the test.

Conferring Prompts

Confer with students as they work in collaborative groups to collect data and complete the See-Think-Wonder chart.

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

- What change occurred when you blew air into a sample of water with BTB. What do you think that change means?
- What happened to the blue water you did not blow into? What do you think that tells you?
- What happened to the control that you did blow carbon dioxide into? What do you think that tells you?
- What happened to the yellowish-green sample (with carbon dioxide) that we left the elodea plant in for 24 hours? Why?

Whole-Class Investigation Summary

1. Provide students with *Making Sense of the How did it grow? Investigation*. Have them work independently to complete it, then use these completed pages to discuss the findings from the investigation with their group.

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

3. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups. 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 phenomenon.

Look & Listen For

While students work on the investigation summary, listen for the following ideas:

- When we blew air into a sample of water with BTB, it turned green
- Because we breathe out carbon dioxide (from cellular respiration) and BTB turns yellowish-green when carbon dioxide is present.
- The water stayed blue in the sample we did not blow carbon dioxide into, meaning it still had no carbon dioxide.
- Carbon dioxide is not naturally present in the water
- In Test Tube 2 (no light exposure) - the solution turned green (positive for CO_2) but negative for O_2
- In test tube 3 (light exposure) - the solution was blue (negative for CO_2) but positive for O_2.
- Photosynthesis (test tube 3) is $H_2O + CO_2$ (in the presence of light) $\rightarrow O_2$ + glucose
- The plant does both photosynthesis and cellular respiration (releasing CO_2) but if it is actively photosynthesizing, less CO_2 is available in the solution (as it is being used for photosynthesis)

Routine

The **Domino Discover** 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 Biology Course Guide for support with this routine.

Implementation Tip

Digital dissolved oxygen and carbon dioxide probes (if available) will generate more accurate data.

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 *How did it grow? 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.

Explain 1

Where does corn get the carbon, oxygen, and energy that is contained in glucose?

Students **revise their models** of **photosynthesis** to include **carbon dioxide as the source of carbon in glucose**, and thus the primary **source of matter and energy** for new structures including long-chain carbohydrates (starch and cellulose).

Preparation

Student Grouping	Routines	Literacy Strategies
☒ Table Groups	☒ Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
☒ How did it grow? Explanatory Model ☒ Summary Task	None	

Developing an Explanatory Model

1. Return to student questions from the end of the Explore phase. Chart them on the board or on poster paper.
2. Tell students that they will now use what they learned from the *How did it grow?* activity and from previous investigations to develop a model that explains the following:
    a. How the corn grew and where it gets its energy and nutrients from.
    b. Where the glucose in corn comes from.
3. Provide students with the handout, *How did it grow? Explanatory Model*. Tell them to independently or in pairs draw a model.
4. Put students in groups of 3-4, and tell them to take turns sharing ideas from their models and develop a group model on poster paper.

Integrating Three Dimensions

Keep in mind that students need to go beyond explaining where corn gets the carbon, oxygen, and energy that is contained in glucose it contains; this Explain is designed to support them in using a crosscutting concept to do this sensemaking. Be sure to make **CCC #5 - Energy and Matter** explicit for students by elevating and probing for ideas related to how energy drives the flow of matter and how energy and matter are flowing within and between systems.

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 how the corn grew and where it gets its energy and nutrients from, 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 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 how the corn grew and where it gets its energy and nutrients from. 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:
    - 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. Refer to the Biology Course Guide for support with 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.

Take Time for These Key Points

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

- Carbon dioxide in the air is the source of the carbon in glucose
- Plants transform light energy into chemical energy during the process of photosynthesis
- The energy from the sun is stored in the chemical bonds of glucose, and thus the primary source of matter for new structures including long-chain carbohydrates (starch and cellulose).

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 #5 - Energy and Matter** explicit for students by elevating and probing for ideas related to how energy drives the flow of matter and how energy and matter are flowing within and between systems. This is an important element **CCC #5 - Energy and Matter** at the high school level.

Summary

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

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** to make sense of a phenomenon, 2) ideas about how they and their peers are building knowledge together, and 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.

Explore 2

Why was corn so useful to the early meso-americans and other societies? Why did corn allow civilizations to emerge and grow? How much energy does corn provide compared to other foods like meats and dairy?

Students **develop a mathematical model** of **energy flow through the food chain system** to **gather evidence** regarding whether corn provides more energy than other foods like meat and dairy.

Preparation

Student Grouping	Routines	Literacy Strategies
☒ Pairs	☒ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
☒ Discovering Patterns in Pyramids Investigation ☒ Making Sense of the Discovering Patterns in Pyramids Investigation ☒ Discovering Patterns in Pyramids Investigation Rubric	None	

Launch

1. Tell students that they will now have an opportunity to investigate their questions and test their initial ideas about: *Why was corn so useful to the early meso-americans and other societies. Why did corn allow civilizations to emerge and grow? How do corn and other grains provide energy for humans?* How much energy does corn provide compared to other foods like meats and dairy?

2. Share with students that humans are not the only species who have used corn as a source of energy. Mice, raccoons, and deer like to eat corn, too. Ask students: Given what we know about the use of corn and the food chains it is a part of, how can we track the amount of energy corn provides to the food chain compared to other foods like milk and dairy? Listen for students to say that they can calculate how much energy corn can provide compared to other foods.

3. Provide students with the handout, *Discovering Patterns in Pyramids Investigation*, and ask them to work in pairs to complete the investigation.

Conferring Prompts

Confer with students as they work in collaborative groups to collect data and complete the investigation.

- What do you notice about the number of organisms as you move up the food chain?
- What happens to the amount of energy as you move up the pyramid? Why do you think that happens?
- Do you see a pattern in the amount of energy lost from one level to the next?
- Which level of the pyramid includes the most energy efficient food sources?

Whole-Class Investigation Summary

6. After students have completed the investigation, provide them with *Making Sense of the Discovering Patterns in Pyramids Investigation.* Have them work independently to complete it, then use these completed pages to discuss the findings from the investigation with their group.

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

8. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups. 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 phenomenon.

Look & Listen For

Students may generate ideas and questions such as:

- As you move up a food chain / energy pyramid, the number of organisms decreases.
- There are more than one species on each of the levels of an energy pyramid.
- There is less biomass and less energy as you move up an energy pyramid.
- Only about one percent of the energy from the Sun is used by corn (plants).
- About 10% of energy from one species in each level of the energy pyramid is used by species in the next level.
- 90% of the energy corn gets from the Sun is not transferred to animals like birds.
- 90% of the energy to animals from producers like corn is passed to consumers like humans and birds of prey.
- Corn seems to be a more efficient source of energy.
- Where does all the energy go? Why is energy lost from one energy level of the pyramid to the next?
- What makes corn a more efficient source of energy?
- How does corn transform energy from sunlight into chemical energy?

9. 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

The **Domino Discover** 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 Biology Course Guide for support with this routine.

10. Provide students with *Discovering Patterns in Pyramids 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.

Explain 2

Why was corn so useful to the early meso-american societies and other societies?

Students use their **mathematical model** of **energy flow through the food chain system** to **develop an explanation** regarding whether corn provides more energy than other foods like meat and dairy.

Preparation

Student Grouping	Routines	Literacy Strategies
☒ Table groups	☒ Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
☒ Where did the energy go? ☒ Summary Task	None	

Using a Mathematical Model to Develop an Claim

1. Ask students which of their questions can be answered with the data they collected from their mathematical models of energy pyramids. Listen for students to say they can respond to questions about whether corn provides more energy than birds, other animals, or dairy and that they now know corn does provide more energy because only a fraction of it is transferred to birds and other animals that eat it, so humans and birds of prey will not have all that energy available them from those animals.

2. Use these questions to introduce the task, *Where did the energy go?*. Tell students that they will be engaging in a group discussion and using what they learn from that discussion to answer the question and develop an explanation.

3. Distribute the handout, *Where did the energy go?*. Have students work individually or in pairs to respond to the questions.

4. After students have had a chance to respond to the questions on the *Where did the energy go?* handout, have students work in groups of 3-4 to develop a model that illustrates the ideas they have in response to the questions.

type	3D

text	Keep in mind that students need to go beyond explaining why was corn so useful to the early meso-american societies and other societies; this Explain is designed to support them in using a crosscutting concept to do this sensemaking. Be sure to make **CCC #5 - Energy and Matter** explicit for students by elevating and probing for ideas related to how energy cannot be created or destroyed and how energy and matter are flowing within and between systems.

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 whether corn is a more efficient energy source than animals or dairy, 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 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 why corn is a more efficient energy source than animals or dairy. 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:
    - Projecting using a document camera; OR

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. Refer to the Biology Course Guide for support with 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.

- 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:

- Corn is a more efficient energy source than birds, other animals, or dairy.
- 90% of the energy corn gets from the Sun is not transferred to animals like birds.
- 90% of the energy to animals from producers like corn is passed to consumers like humans and birds of prey.
- If societies eat a lot of birds, other animals, or dairy, they will lose a lot of energy.
- Animals do not eat all of the corn, so some biomass that contains energy is not transferred to the next energy level on the pyramid.
- The processes that take place when an animal is digesting corn require energy, so some energy is lost there too.
- Birds and other animals that eat corn move and do a lot of activities before they are eaten by humans or other predators, so energy is lost by the time a human or another predator eats them.
- Maybe early meso-american societies and other societies have benefited from corn because it's a more efficient source of energy.

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 #5 - Energy and Matter** explicit for students by elevating and probing for ideas related to how energy cannot be created or destroyed and how energy and matter are flowing within and between systems. This is an important element **CCC #5 - Energy and Matter** at the high school level.

Summary

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

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** to make sense of a phenomenon, 2) ideas about how they and their peers are building knowledge together, and 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

What staple crops do people eat around the world?

Students consider staple crops around the world and in their own communities. They then use their **energy pyramid models to develop a claim** about why these crops are also efficient **energy sources** like corn.

Preparation

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

Materials

Handouts	Lab Supplies	Other Resources
Staple Crops Around the World R-G-S-S	None	ORIGINS AND PRIMARY REGIONS OF DIVERSITY OF AGRICULTURAL CROPS

Making Connections to Today

1. Invite students to think about whether there are other crops that are efficient like corn and whether other cultures, including their own, have a different staple crop. Have students turn and talk to a partner about what are some staple crops from their own community and from other cultures around the world.
2. Use the group learning routine **Domino Discover** to surface ideas from the partner discussion.
3. Distribute the map, ORIGINS AND PRIMARY REGIONS OF DIVERSITY OF AGRICULTURAL CROPS and the handout, *Staple Crops Around the World R-G-S-S*. Ask students to consider the foods from the map and the foods they named and use their energy pyramids and other knowledge about photosynthesis to answer the questions: What are some examples of other foods that you think are efficient sources of energy like corn? How do you know? Why are these foods different in different places? Facilitate student discussion around these prompts using the group learning routine, **Read-Generate-Sort-Solve**.

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. Refer to the Biology Course Guide for planning support.

Evaluate

What have we figured out about whether corn played a role in the US pellagra epidemic that occurred in the early 1900s?

Students **use their models** of how corn **plants** **transfer energy efficiently** to develop an **initial explanation** of the role corn may have played in the pellagra epidemic.

Preparation

Student Grouping	Routines	Literacy Strategies
☒ Pairs	None	None

Materials

Handouts	Lab Supplies	Other Resources
☒ Scientific Explanation ☒ Scientific Explanation Mini Rubric	None	☒ *Human Population Graph*

Revisit the Performance Task

1. Prompt students to return to the human population graph introduced in the beginning of the first learning sequence, found in *Human Population Graph*. In pairs, students consider how agriculture changed the carrying capacity of human populations, and what is happening with the human population today (why it is increasing, and if it will continue to increase in the future).

Look & Listen For

- Agriculture, focusing on cereal crops like corn allowed for the lifting of the carrying capacity of the environment on humans – populations increased
- Cereal crops like corn are very efficient in providing energy
- Improvements in agriculture (and technology of all kinds) has lead to the exponential growth of human populations
- Resources are finite, so growth cannot increase indefinitely

2. 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 was corn used as a primary source? What role did a diet heavy in corn play in the epidemic (if at all)? Why were some people getting sick with pellagra and others were not? A few students can share their thoughts, use examples of student work from the Explain phase to review or clarify any remaining questions.

Integrating Three Dimensions

In the performance task, students are working towards **SEP#6 Constructing Explanations and Designing Solutions.** They will have the opportunity to revise their explanation in subsequent lessons.

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!

3. Provide students with *Scientific Explanation*. Allow time for students to record new ideas they have about why societies may rely on crops like corn.
4. Provide students with *Scientific Explanation Mini Rubric* so that they can peer and self assess, and gather feedback.

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 why there was a pellagra epidemic in the US and Southern Europe in the early 1900s. Did it have something to do with the corn? Was it an infectious disease? Tell students that, in the next sequence of lessons, they will investigate these questions further.

Standards in The SuperFood that Changed the World 5E

Performance Expectations

HS-LS1-5 **Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.**
Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models
Assessment Boundary: Assessment does not include specific biochemical steps.

HS-LS2-4 **Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem**
Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.
Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.

In NYS the clarification statement has been edited as follows: Emphasis is on using a mathematical model such as a pyramid of biomass/energy to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems.

Aspects of Three-Dimensional Learning

Science and Engineering Practices

Developing and Using Models

- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. SEP2(3)

Using Mathematics and Computational Thinking

- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. SEP5(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)

Disciplinary Core Ideas

LS1.C Organization for Matter and Energy Flow in Organisms

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. LS1.C(1)
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. LS1.C(3)

LS2.A Interdependent Relationships in Ecosystems

- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. LS2.A(1)

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

Crosscutting Concepts

Energy and Matter

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. CCC5(2)
- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. CCC5(3)
- Energy drives the cycling of matter within and between systems. CCC5(4)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
	different ways. At each link in an ecosystem, matter and energy are conserved. LS2.B(2) • When matter is cycles through organisms and ecosystems, some of the matter reacts to release energy for life functions, some is stored in newly made structures, and some is eliminated as waste LS2.B(4)NYS	

Assessment Matrix

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Developing and Using Models		*How did it grow? Explanatory Model* Class consensus Discussion *Summary Task*	*Discovering Patterns in Pyramids Investigation* *Making Sense of the Discovering Patterns in Pyramids Investigation* Domino Discover *Where did the energy go?* Class consensus Discussion *Summary Task*		
Using Mathematics and Computational Thinking		*How did it grow? Explanatory Model* Class consensus Discussion *Summary Task*	*Discovering Patterns in Pyramids Investigation* *Making Sense of the Discovering Patterns in Pyramids Investigation* Domino Discover *Where did the energy go?* Class consensus Discussion *Summary Task*		
Constructing Explanations and Designing Solutions	*Story of All of Us: Corn - See-Think-Wonder* Domino Discover	*Cob Sprouting in Water: See-Think-Wonder* *How did it grow? Investigation* *Making Sense of the How did it grow? Investigation* Domino Discover *How did it grow? Explanatory Model* Class consensus Discussion *Summary Task*	*Discovering Patterns in Pyramids Investigation* *Making Sense of the Discovering Patterns in Pyramids Investigation* Domino Discover *Where did the energy go?* Class consensus Discussion *Summary Task*	*Staple Crops Around the World R-G-S-S*	*Scientific Explanation* *Scientific Explanation Mini Rubric*

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
LS1.C Organization for Matter and Energy Flow in Organisms	*Story of All of Us: Corn - See-Think-Wonder* Domino Discover	*Cob Sprouting in Water: See-Think-Wonder* *How did it grow? Investigation* *Making Sense of the How did it grow? Investigation* Domino Discover *How did it grow? Explanatory Model* Class consensus Discussion *Summary Task*		*Staple Crops Around the World R-G-S-S*	*Scientific Explanation* *Scientific Explanation Mini Rubric*
LS2.A Interdependent Relationships in Ecosystems			*Making Sense of the Discovering Patterns in Pyramids Investigation*		*Scientific Explanation* *Scientific Explanation Mini Rubric*
LS2.B Cycles of Matter and Energy Transfer in Ecosystems	*Story of All of Us: Corn - See-Think-Wonder* Domino Discover		*Discovering Patterns in Pyramids Investigation* *Making Sense of the Discovering Patterns in Pyramids Investigation* Domino Discover *Where did the energy go?* Class consensus Discussion *Summary Task*	*Staple Crops Around the World R-G-S-S*	*Scientific Explanation* *Scientific Explanation Mini Rubric*
			Making Sense of the Discovering Patterns in Pyramids Investigation		

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Energy and Matter		*Cob Sprouting in Water: See-Think-Wonder* *How did it grow? Investigation* *Making Sense of the How did it grow? Investigation* Domino Discover *How did it grow? Explanatory Model* Class consensus Discussion *Summary Task* Class consensus Discussion	*Discovering Patterns in Pyramids Investigation* *Making Sense of the Discovering Patterns in Pyramids Investigation* Domino Discover *Where did the energy go?* Class consensus Discussion *Summary Task* *Making Sense of the Discovering Patterns in Pyramids Investigation*	*Staple Crops Around the World R-G-S-S*	*Scientific Explanation* *Scientific Explanation Mini Rubric*

Common Core State Standards Connections

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Mathematics		MP3	MP3		
ELA/Literacy	WHST.9-10.2 SL.9-10.1	SL.9-10.1	SL.9-10.1		

Infectious Agent or Insufficient Diet 5E

Was pellagra caused by an infectious agent or lack of an adequate diet?

Performance Expectations
HS-LS2-3

Investigative Phenomenon
The pellagra epidemic disproportionately spread within institutionalized populations (orphanages and insane asylums) in the south.

Time
7-8 days

The pellagra epidemic lasted for approximately forty years and caused immense suffering across the southern United States.
In this 5E instructional sequence, students explore how and why this may have occurred. They consider why food, such as corn, may be industrially processed, and the impacts that processing had on institutionalized populations (and others) across the south, as well as the possible impacts of the processing of food on their own communities.

ENGAGE	How can we use evidence to support a hypothesis on the cause behind the pellagra epidemic?	Students **identify evidence to support an explanation** of the **pellagra epidemic**.
EXPLORE 1	What evidence can we analyze to explain the cause of the pellagra epidemic?	Students use **mathematical representations** of historical data to explain the **pellagra epidemic at the individual and population levels.**
EXPLAIN 1	Why did a more diverse diet prevent pellagra?	Students use a text to respond to student generated questions in order to **develop an initial explanation** of the **cause behind pellagra** in terms of **energy and matter.**
EXPLORE 2	Why do different foods decompose differently?	Students **generate observations** on the **decomposition** of different types of foods to surface **how both energy and matter moves into and out of a system**.
EXPLAIN 2	How can the processing of food impact its nutrition and shelf-life?	Students **construct and revise a scientific explanation** on how the **processing of corn** to **limit decomposition** caused the pellagra epidemic.
ELABORATE	Why didn't indigenous people, whose diet also relied heavily on corn, suffer from pellagra?	Students engage with a text and video on how indigenous people processed corn in order to **revise their scientific explanation** on the **causes behind the pellagra epidemic** and why some groups of people avoided becoming ill.
EVALUATE	How can our communities have access to fresh, unprocessed food?	Using the lens of **energy and matter**, students revise their **scientific explanation** on why some populations suffered from **pellagra**, while others did not.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

How can we use evidence to support a hypothesis on the cause behind the pellagra epidemic?

Students **identify evidence to support an explanation** of the **pellagra epidemic**.

Preparation

Student Grouping	Routines	Literacy Strategies
None	Rumors	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	Post-it notes Pellagra - A Medical Mystery

Surfacing Student Ideas

1. Prompt students to revisit the DQB and point out questions about if pellagra was caused by an infection, or something else (like being diet related). Let students know that we will investigate these questions in this learning cycle.
2. Remind students that we have started to talk about two different hypotheses (or claims) about the cause behind pellagra: an infection and diet related (something to do with eating corn). Let students know that they are going to watch a video about a scientist that was looking for evidence to determine which claim to support.
3. Prompt students to choose one claim and to provide what evidence they would look for or collect to support their claim on the cause behind pellagra – based on what they know so far. Students write their best idea on a post-it note
4. Students share their ideas using the group learning routine, **Rumors.** Categorize student ideas
5. Watch the video, Pellagra - A Medical Mystery , stopping it at 4:15. While watching the video, prompt students to listen for evidence for both claims.
6. Return to the Rumors categories and prompt students to revise their ideas (or to discuss how the video supports their ideas)

Integrating Three Dimensions

In this task, students are working towards **SEP#6 Constructing Explanations and Designing Solutions,** as they are looking for additional evidence to support the revision of their explanation on the cause behind the pellagra epidemic.

Look & Listen For

- The researcher collected data on populations that had pellagra
- If it was infectious, the doctors at the asylum would also have pellagra
- Children and patients were eating different food than those that were not contracting pellagra
- If it was infectious and coming from immigrants, it would be found in the northeastern US (not just the south)
- People in the south survived on cornmeal and had the highest rates of pellagra
- Rarely affected rich people
- If it was infectious, controlled experiments could be used (on model organisms) to show it passed between individuals
- If it was diet related, it could be prevented or cured with dietary changes (controlled experiment)

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 1

What evidence can we analyze to explain the cause of the pellagra epidemic?

Students use **mathematical representations** of historical data to explain the **pellagra epidemic at the individual and population levels.**

Preparation

Student Grouping	Routines	Literacy Strategies
☒ Table groups	☒ Consensus-Building Share	None

Materials

Handouts	Lab Supplies	Other Resources
☒ Goldberger's Investigation Part 1 ☒ Goldberger's Research Summaries ☒ Goldberger's Investigation Part 2 ☒ Making Sense of Goldberger's Investigation ☒ Goldberger's Investigation Rubric	None	

Launch the Investigation

1. Revisit the ideas surfaced at the end of the Engage phase, especially around the types of evidence (data) the researcher would need to justify his claim that pellagra was caused by a diet deficiency and not an infectious agent.

2. Similarly to students' ideas, highlight that Dr. Goldberger did experiments and collected data on populations that were impacted by the disease. Provide students with *Goldberger's Investigation Part 1* and *Goldberger's Research Summaries*. Jigsaw the four research summaries by assigning each to a different student in the group.

Differentiation Point

Create expert groups for students that may struggle to independently create a representation of the data provided in their assigned research summary.

3. Pause and facilitate students sharing and discussing the data from their assigned research summary. Provide students with *Making Sense of Goldberger's Investigation* to record their ideas

Integrating Three Dimensions

In this investigation students are focused on the using **SEP#5 Using Mathematics and Computational Thinking** and **CCC#3 Scale, Proportion, and Quantity,** in service of the storyline. Students will use the appropriate disciplinary core ideas in upcoming phases as they explain the causes behind the pellagra epidemic.

4. Provide students with *Goldberger's Investigation Part 2* as additional data sources. Students record their ideas using the *Making Sense of Goldberger's Investigation*.

Making Sense of the Data

1. In table groups, students review all of the data they have engaged with and their ideas from the See-Think-Wonder graphic organizer.

2. Use the group learning routine, **Consensus Building Share** to highlight their key ideas and questions about all of the data that Goldberger collected as he investigated the pellagra epidemic

Look & Listen For

- More diverse diets resulted in the virtual elimination of pellagra from the orphanages
- Women at the mental health hospital on a more diverse diet did not show signs of pellagra
- Jailed men given a less diverse diet showed signs of pellagra
- None of the volunteers given secretions or bodily fluids or feces from people with pellagra contracted pellagra (so its most likely not infectious)
- Households that consumed the most milk had the least pellagra
- Inverse relationship between household income and prevalence of pellagra
- More women had pellagra than men
- Some factors had larger effects than others (e.g. income or diverse diet vs gender) and the impact depended on the scale at which it occurred in causing a pandemic (rather than isolated cases of pellagra)
- Why did switching to a diverse diet 'cure' or prevent pellagra?
- Why do households with more money have less pellagra?
- Why do poor women have more pellagra then poor men?

3. 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.

4. Provide students with *Goldberger's 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 **Consensus-Building Share** routine is a way to make sensemaking visible and move towards a class-wide consensus around a new idea.
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. Be sure to look at the Biology Course Guide for the action pattern for this routine.

Explain 1

Why did a more diverse diet prevent pellagra?

Students use a text to respond to student generated questions in order to **develop an initial explanation** of the **cause behind pellagra** in terms of **energy and matter.**

Preparation

Student Grouping	Routines	Literacy Strategies
☒ Table Groups	☒ Domino Discover	☒ Text Annotation

Materials

Handouts	Lab Supplies	Other Resources
☒ Pellagra Text ☒ The Role of Niacin ☒ Niacin Deficiency Cause and Effect Model Student Work	None	

Reading a Complex Text

1. Review or highlight student questions raised during the Explore 1 phase. Prompt students to choose 1-2 of those questions as their purpose for reading a text on Pellagra. Ensure that at least some students are focusing on a question that highlights the role of a diverse diet in eliminating pellagra or what the cause of the pellagra epidemic was.
2. Provide students with *Pellagra Text* and prompt students to annotate the text based off of their guiding questions.
3. In table groups. students discuss what information in the text helped them better understand their guiding question(s). Provide students with *The Role of Niacin* and have students respond to the prompts individually based on their discussions.
4. Use the group learning routine **Domino Discover** to surface student ideas and questions on what they understand so far about the cause(s) behind the pellagra epidemic.

Integrating Three Dimensions

In this task, students demonstrate their understanding of the cellular respiration portion of **DCI LS2.B Cycles of Matter and Energy Transfer in Ecosystems.** The portion of the element referring to photosynthesis is discussed in the previous 5E, The SuperFood that Changed the World.

Look & Listen For

- Confirmed that pellagra is NOT caused by an infectious agent
- Scientists had determined that the people with pellagra were niacin deficient
- Niacin is crucial for the process of cellular respiration, without it ATP (energy) cannot be produced thus cells cannot function properly and people get sick – for example, a lack of ATP energy lead to neurological system disruption because neurons could not send electrical messages
- The epidemic worsened after they discovered the cause
- After the government mandated the addition of niacin in milled corn and wheat the number of cases decreased

Questions:

- Why did more women suffer from pellagra than men?
- Why did pellagra start in the early 1900's when people ate corn before that time?
- Why is niacin found in other foods, but not the corn they were eating?
- If they knew what the problem was in 1937, why were there still so many cases of pellagra for another 10 years?

Routine

The **Domino Discover** 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 Biology Course Guide for support with this routine.

Explore 2

Why do different foods decompose differently?

Students **generate observations** on the **decomposition** of different types of foods to surface **how both energy and matter moves into and out of a system**.

Preparation

Student Grouping	Routines	Literacy Strategies
☒ Table Groups	☒ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
☒ Decomposition Investigation ☒ Making Sense of the Decomposition Investigation ☒ Decomposition Investigation Rubric	None	☒ Time Lapsed Fruit and Vegetable Decomposition Video ☒ The Decomposition Of McDonald's Burgers And Fries

Launch the Investigation

1. Highlight remaining student questions from the Explain 1 phase, such as: Why is niacin found in other foods, but not the corn they were eating? Let students know that we can compare different types of food to get a better understanding of why something like niacin might be missing from some types of food. One variable we can compare is the rate of, and general process of, decomposition in different types of food.

2. Provide students with *Decomposition Investigation*. Prompt students to make predictions about how decomposition may differ in whole fruits and vegetables and in fast food items such as hamburgers and french fries.

3. Show each of the following videos, with pause time for students to record their ideas in the See-Think-Wonder graphic organizer. As students watch Time Lapsed Fruit and Vegetable Decomposition Video and The Decomposition Of McDonald's Burgers And Fries they generate observations and questions. Provide time for students to discuss their observations and questions with their table mates.

Whole-Class Investigation Summary

4. Provide students with *Making Sense of the Decomposition Investigation*. Have them work independently to complete it, then use these completed pages to discuss the findings from the investigation with their group.

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

6. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups. 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 phenomenon.

Look & Listen For

- The fruit and vegetables decayed at a much faster rate than the mcdonalds hamburger and fries
- The fruit and vegetables decomposed into 'mush' whereas the burger and fries looked almost new
- New plants began to grow on on the decayed mass of the fruit and vegetables (matter & energy was transferred to the new plants and recombined to create new tissues)
- Originally the energy was from the sun captured during photosynthesis
- The fruit and vegetables seemed to 'lose' mass (although this is discussed further in the Explain phase)
- Gasses (as source of mass) were released into the system
- Decomposers (bacteria, fungi) broke down the food, to create ATP for their own life processes
- Why didn't the burger and fries visibly decompose like the fruit and vegetables did?
- Will the burger and fries ever decompose? Do they need specific conditions to decompose? Does it make a difference that they are cooked and the fresh food is not?
- How does decomposition help us explain the issue with the corn and the niacin?

7. 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.

8. Provide students with *Decomposition 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** 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 Biology Course Guide for support with this routine.

Explain 2

How can the processing of food impact its nutrition and shelf-life?

Students **construct and revise a scientific explanation** on how the **processing of corn** to **limit decomposition** caused the pellagra epidemic.

Preparation

Student Grouping	Routines	Literacy Strategies
☒ Pairs	☒ Class Consensus Discussion	☒ Chunking with partner reading ☒ C-E-R graphic organizer

Materials

Handouts	Lab Supplies	Other Resources
☒ Decomposition Text ☒ C-E-R Graphic Organizer ☒ C-E-R Rubric ☒ Summary Task	None	

Accessing a Text

1. Remind students of their observations and questions that were surfaced at the end of the Explain 1 and Explore 2 phases. Highlight ideas or questions about why the niacin was missing from cornmeal and why the fruit and vegetables decomposed at a much faster rate than the fast food.

2. Provide students with *Decomposition Text*. Chunk the text by heading or paragraph. Prompt students to read with a partner, pausing after each chunk to discuss the guiding questions (why the niacin is missing and/or why the vegetables decomposed quickly)

Constructing a Scientific Explanation

1. Provide students with *C-E-R Graphic Organizer*. Prompt students to first individually, use the graphic organizer to respond to the prompt:

Construct a scientific explanation, using appropriate evidence and reasoning, that addresses why there was a pellagra epidemic in the early 1900's in the southern United states.

2. After students have had the opportunity to write their initial draft, provide students with *C-E-R Rubric* so they can do a peer review, using the rubric.

3. Provide students time to revise as needed, after receiving feedback from their peer.

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 the causes behind the pellagra epidemic in the southern United States."

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 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 why the germ was removed and why removing the corn germ led to a severe illness in specific populations of people. 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.

4. 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.

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. Refer to the Biology Course Guide for support with 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.

Take Time for These Key Points

- Niacin is a required part of the diet, as it facilitates cellular respiration (the creation of ATP)
- Without niacin, people will suffer from pellagra because their cells do not have sufficient ATP to complete cellular processes
- Most of the niacin found in corn is in the germ layer.
- The germ of the corn was removed (de-germinated) to slow down decomposition (the recycling of matter)
- Whole foods (like a whole corn kernel) decompose faster because they provide optimal food for decomposers
- By removing the germ, and slowing decomposition, the corn was more shelf-table and was easier to store and transport without spoiling
- People eating a monotonous diet, mainly consisting of the processed corn, were not getting sufficient niacin

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 #5 - Energy and Matter** explicit for students by elevating and probing for ideas related to how energy drives the flow of matter and how energy and matter are flowing within and between systems. This is an important element **CCC #5 - Energy and Matter** at the high school level.

Summary

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

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** to make sense of a phenomenon, 2) ideas about how they and their peers are building knowledge together, and 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

Why didn't indigenous people, whose diet also relied heavily on corn, suffer from pellagra?

Students engage with a text and video on how indigenous people processed corn in order to **revise their scientific explanation** on the **causes behind the pellagra epidemic** and why some groups of people avoided becoming ill.

Preparation

Student Grouping	Routines	Literacy Strategies
None	Domino Discover Read-Generate-Sort-Solve	None

Materials

Handouts	Lab Supplies	Other Resources
RGSS Organizer	None	Malnourished: Cultural ignorance paved the way for pellagra What is Nixtamalization?

Using Multimedia to Understand a Process

1. In this learning cycle, students figure out that the processing of corn to remove the germ left the food less nutritious. Also, students may have lingering questions about why indigenous populations in South and North America relied on corn but did not get ill with pellagra. Introduce the idea to students that indigenous people also processed corn, but in a very different way.

2. Provide students with *RGSS Organizer*, and What is Nixtamalization? , and Malnourished: Cultural ignorance paved the way for pellagra . Use the **Read-Generate-Sort-Solve** routine to facilitate student collaboration as they respond to the guiding prompt: How did indigenous knowledge protect many populations from diet related diseases such as pellagra?

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. Refer to the Biology Course Guide for planning support.

Evaluate

How can our communities have access to fresh, unprocessed food?

Using the lens of **energy and matter**, students revise their **scientific explanation** on why some populations suffered from **pellagra**, while others did not.

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
Ultra-processed Food Data Revised Explanation Revised Explanation Mini Rubric	None	

Making Connections

1. At the end of Explain 2, students discussed one negative outcome (pellagra) of processing corn. In order to surface student connections to the food available in their community, provide students with *Ultra-processed Food Data*.

2. Remind students that Dr. Goldberger recommended that leaders make a diversity of foods “cheap and readily accessible” to prevent or cure pellagra as early as 1916. Prompt students to consider whether or not we follow that advice today? What types of foods are cheap and readily available in your community?

Implementation Tip

Unit 3 introduces the concepts of whole, processed, and ultra-processed food and the health impacts associated with eating a lot of processed/ultra-processed food. If students need clarity on these terms, pause to define them and post them in the classroom.

3. After students have had time to reflect on their own community, transition to the data table that represents the % of the American diet that is from processed foods. Students use the graphic organizer to record their ideas and questions.

4. Use the group learning routine **Domino Discover** to share out student ideas

Look & Listen For

- Cheap and easily available food may include things like: chips, snacks, fast food, frozen food, fried food, breads (mostly ultra-processed foods)
- Fresh, whole foods are often not as cheap or easily available (or not prepared in a way that is perceived as tasting good)
- Americans as a whole are eating more processed food from 2007 to 2012
- In 2012, americans on average get about 60% of their calories from ultra-processed food

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 were people getting sick with pellagra? Why did some populations suffer disproportionately from pellagra than others? Why didn't indigenous people that ate a diet heavy in corn not suffer from pellagra? 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. Provide students with *Revised Explanation*. Allow time for students to record new ideas they have on the cause behind the pellagra epidemic, and how a similar lack of fresh, unprocessed foods may be impacting their communities or the US as a whole.

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 why only specific groups seemed to get ill from pellagra and it did not impact everyone. Tell students that, in the next sequence of lessons, they will investigate this question further.

Standards in Infectious Agent or Insufficient Diet 5E

Performance Expectations

HS-LS2-3 **Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.**
Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.
Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.

In NYS the entire PE has been edited as follows: Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in ecosystems. [Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration and photosynthesis within ecosystems.] [Assessment Boundary: Assessment does not include the specific chemical processes of aerobic respiration, anaerobic respiration, and photosynthesis.]

Aspects of Three-Dimensional Learning

Science and Engineering Practices

Developing and Using Models

- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. SEP2(3)

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)

Disciplinary Core Ideas

LS1.C Organization for Matter and Energy Flow in Organisms

- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. LS1.C(3)

LS2.B Cycles of Matter and Energy Transfer in Ecosystems

- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. LS2.B(1)

- When matter is cycles through organisms and ecosystems, some of the matter reacts to release energy for life functions, some is stored in newly made structures, and some is eliminated as waste LS2.B(4)NYS

Crosscutting Concepts

Scale, Proportion, and Quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. CCC3(1)

Energy and Matter

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. CCC5(2)
- Energy drives the cycling of matter within and between systems. CCC5(4)

Assessment Matrix

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Developing and Using Models		*The Role of Niacin*	*Summary Task*		
Constructing Explanations and Designing Solutions		Domino Discover Discussion [material:BIO.U5.L3.Explain1.H2]	*C-E-R Graphic Organizer* Class Consensus Discussion	*RGSS Organizer*	*Revised Explanation* *Revised Explanation Mini Rubric*
LS1.C Organization for Matter and Energy Flow in Organisms			*Decomposition Investigation* *Making Sense of the Decomposition Investigation* Domino Discover *C-E-R Graphic Organizer*	*RGSS Organizer*	*Revised Explanation* *Revised Explanation Mini Rubric*
LS2.B Cycles of Matter and Energy Transfer in Ecosystems		Domino Discover Discussion *The Role of Niacin*	*Decomposition Investigation* *Making Sense of the Decomposition Investigation* Domino Discover *C-E-R Graphic Organizer* *Summary Task* Class Consensus Discussion		*Revised Explanation* *Revised Explanation Mini Rubric*
			Summary Task		
Scale, Proportion, and Quantity		*Making Sense of Goldberger's Investigation* Consensus Building Share Discussion *The Role of Niacin*			
Energy and Matter		Domino Discover Discussion	*Decomposition Investigation* *Making Sense of the Decomposition Investigation* Domino Discover *C-E-R Graphic Organizer* [material: BIO.U5.L3.Explain2.H4] *Summary Task*	*RGSS Organizer*	*Revised Explanation* *Revised Explanation Mini Rubric*

Common Core State Standards Connections

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Mathematics		MP4 HSS-ID.A.1 MP3	MP4 HSS-ID.A.1 MP3		
ELA/Literacy	RST.9-10.1 SL.9-10.1	RST.9-10.1 RST.9-10.2 WHST.9-10.4 WHST.9-10.5 SL.9-10.4	RST.9-10.1 RST.9-10.2 WHST.9-10.4 WHST.9-10.5 SL.9-10.4		SL.9-10.1

Food for Plants 5E

What communities were impacted most by the pellagra epidemic?

Performance Expectations
HS-LS1-6

Investigative Phenomenon
Despite living in agriculturally productive areas, tenant farmers in the Southeastern U.S. experienced extremely high rates of pellagra.

Time
5 days

Black Americans suffered from pellagra cases and deaths at a disproportionately higher rate than their white counterparts. In this 5E instructional sequence, students explore how and why this may have occurred. They consider the circumstances of many Black people in the southern US before and during the epidemic and learn how farming practices imposed on Black sharecroppers and tenant farmers degraded soil, impacting supply and health of food crops, further contributing to a huge inequity in access to diverse foods.

ENGAGE	What communities were impacted most by the pellagra epidemic?	Students analyze rates of pellagra by state and by racial and gender demographics, then **generate questions** about access to diverse diets and **agricultural practices** among those most affected by pellagra.
EXPLORE	Does growing cotton alone or all of any one crop damage the soil?	Students **analyze molecular structures of niacin and amino acids formed in plants**, as well as **soil composition** data in order to collect **evidence to explain** how different farming practices impact **flow of matter into and out of a crop plot system** and impact plant growth.
EXPLAIN	Why do differences in soil composition due to different farming practices impact the quantity and nutritional value of crops grown in those soils?	Students **use evidence from a variety of resources to explain** how **overexploitation of land** through the practice of monocropping affects **flow of matter into and out of a crop plot system** and plant growth, including **the formation of molecular structures such as niacin and amino acids**.
ELABORATE	How did pellagra impact other communities?	Students engage with historical documents in order to **revise their explanations** on the systemic **causes** behind **pellagra at different scales**.
EVALUATE	How can we revise our explanations on the root causes behind the pellagra epidemic?	Using the lens of **energy and matter**, students revise their **scientific explanation** of the **causes behind the pellagra epidemic**

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

What communities were impacted most by the pellagra epidemic?

Students analyze rates of pellagra by state and by racial and gender demographics, then **generate questions** about access to diverse diets and **agricultural practices** among those most affected by pellagra.

Preparation

Student Grouping	Routines	Literacy Strategies
None	Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
Inequity of Pellagra	None	

Launch

1. Remind students that the class has already established the idea that people eating a monotonous diet, mainly consisting of processed corn, were not getting sufficient niacin, which led to people suffering from pellagra. Prompt students to revisit the DQB and point out questions about which communities were most impacted by pellagra and why. Let students know that we will investigate these questions in this learning cycle.

2. Provide students with the handout, *Inequity of Pellagra*. Have students independently complete a See-Think-Wonder.

Surfacing Student Ideas

1. In table groups, students review all of the data they have engaged with and their ideas from the See-Think-Wonder graphic organizer.
2. Use the group learning routine, **Domino Discover** to surface student ideas.

Look & Listen For

- There were no pellagra cases reported in some parts of the northern central and west of the US, but the rest of the country did report cases of pellagra.
- Pellagra cases were common or prevalent across the entire Southeastern US, and there were sporadic cases across most of the US (a large proportion of the country)
- Black females were dying from pellagra at a much higher rate than Black males and white females and males.
- Black people were dying from pellagra at a much higher rate than white people.
- White females were dying at a higher rate than white males, but at a lower rate than Black males.
- This may have been because at the time, black people may not have had as much access to a diverse diet as white people.
- Why did females die at a higher rate than males?
- Were most Black people living in the Southeastern US?
- What was life like in the Southeastern US compared to other parts of the country?
- What access to diverse foods did Black people have?
- What access to diverse foods did people in the Southeastern US have?

3. Tell students that they will have the opportunity to analyze data related to their questions in the next part of the investigation.

Routine

The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. In the Engage phase, it is often used to surface student ideas that can be used to transition the class to the investigation.

Explore

Does growing cotton alone or all of any one crop damage the soil?

Students **analyze** **molecular structures of niacin and amino acids formed in plants**, as well as **soil composition** data in order to collect **evidence to explain** how different farming practices impact **flow of matter into and out of a crop plot system** and impact plant growth.

Preparation

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

Materials

Handouts	Lab Supplies	Other Resources
☒ Agricultural Practices in the SE US Investigation Launch ☒ Agricultural Practices in the SE US Investigation ☒ Making Sense of Agricultural Practices in the SE US Investigation ☒ Agricultural Practices in the SE US Investigation Rubric	None	☒ Life in the South After the Civil War

Launch the Investigation

1. Remind students of some of the questions they had, such as: *What was life like in the Southeastern US compared to other parts of the country? What access to diverse foods did Black people have? What access to diverse foods did people in the Southeastern US have?* Share with them that they will be learning about life for Black people in the early 1900s and looking at data regarding farming practices in the Southeastern US to see if it helps them answer some of their questions.

2. Provide students the handout, *Agricultural Practices in the SE US Investigation Launch*. Show only the first two minutes of the video, Life in the South After the Civil War , asking students to note observations in response to the question: What was life like for Black people after the civil war? What do they notice about the map and images?
3. Ask groups to come up with one important idea to share with the whole class, from their discussion.

4. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups. 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 phenomenon.

Look & Listen For

- Most of the Southeastern US had over 40% of their farms operated by tenant farmers and sharecroppers. It's a much higher percentage than most of the rest of the country.
- The image shows just cotton - no food.
- The soil looks really dry and not healthy.
- soil might not be great for growing stuff like healthy vegetables and fruits.
- Tenant farmers may not have had access to diverse nutrition like fruits and vegetables.
- Deaths from pellagra are lower in regions where cotton is not grown compared to regions in South and North Carolina where cotton is grown.
- I think crops like cotton might be bad for the soil and that might relate to pellagra cases and deaths in the Southeast.
- Was cotton grown throughout the Southeastern US?
- Does growing cotton or all one crop damage the soil? If so, how?
- What other crops are grown in the Southeastern US during the pellagra epidemic that may damage soil?
- How does soil affect plant growth? Does the soil affect the amount of energy and essential nutrients like niacin that they have?

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.

Analyzing data

1. Provide students with *Agricultural Practices in the SE US Investigation* Students analyze the different types of data, and note down their observations.

Whole-Class Investigation Summary

1. Provide students with *Making Sense of Agricultural Practices in the SE US Investigation*. Have them work independently to complete it, then use these completed pages to discuss the findings from the investigation with their group.

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

3. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups. 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 phenomenon.

Routine

The **Domino Discover** 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 Biology Course Guide for support with this routine.

Look & Listen For

- Niacin and amino acids contain nitrogen,
- I think the nitrogen may be coming from the air or soil.
- The soil where only one crop is grown has less nitrogen or other nutrients than soil where multiple crops are grown.
- The soil where multiple crops are grown and / or rotated and grown with ground cover has the most nitrogen and organic carbon
- the amount of nitrogen and carbon might have an impact on the amount of glucose, amino acids, and niacin crops provide to people that eat them.

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 *Agricultural Practices in the SE US 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.

Explain

Why do differences in soil composition due to different farming practices impact the quantity and nutritional value of crops grown in those soils?

Students **use evidence from a variety of resources to explain** how **overexploitation of land** through the practice of monocropping affects **flow of matter into and out of a crop plot system** and plant growth, including **the formation of molecular structures such as niacin and amino acids**.

Preparation

Student Grouping	Routines	Literacy Strategies
☒ Pairs ☒ Table groups	☒ Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
☒ How do Agricultural Practices Impact Crops? ☒ Summary Task	None	

Explaining Disparities During the Pellagra Epidemic

1. Tell students that they will now have a chance to revisit their models for how plants recombine chemical elements to make other important molecules and add to them based on any new evidence they obtained from the data they examined in the Explore phase.
2. Provide students with the handout, *How do Agricultural Practices Impact Crops?*. Have students recreate their models (photosynthesis) from the previous investigation, then add to their model to show how plants recombine chemical elements to make molecules like niacin and amino acids. These can be simple input-output models, they do not need to include specifics of the chemical reactions involved.
3. After students have completed their first model, prompt them to develop a model that shows how different farming practices impact the amount and size of corn produced.
4. Have students work in table groups of 3-4. Ask them to take turns sharing their models for how different farming practices impact the amount and size of corn produced, then develop a group model on poster paper.

Integrating Three Dimensions

Keep in mind that students need to go beyond explaining how farming practices impact the quantity and nutritional value of crops grown in soils; this Explain is designed to support them in using a crosscutting concept to do this sensemaking. Be sure to make **CCC #5 - Energy and Matter** explicit for students by elevating and probing for ideas related to how energy drives the flow of matter and how energy and matter are flowing within and between systems.

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 how a focus on cash crops affected the health of the tenant farmers, 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 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 how a focus on cash crops affected the health of the tenant farmers. 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:
    - 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. Refer to the Biology Course Guide for support with 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.

Take Time for These Key Points

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

- Cash crops are typically grown through monoculture practices.
- Sharecroppers and tenant farmers, often Black, were forced to grow cash crops like corn or cotton through a monoculture approach which made the soil unhealthy, with low nitrogen and carbon levels
- Food crops did not produce easily on tenant farms and they were unhealthy because of the soil.
- Sharecroppers and tenant farmers had to give most of the money they made from farming to the landowner and did not have enough to buy food they needed for a diverse diet.
- Lack of access to a diverse diet because of the circumstances was why pellagra cases and deaths were most common among Black people in the Southeastern US in the early 1900s.

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 #5 - Energy and Matter** explicit for students by elevating and probing for ideas related to how energy drives the flow of matter and how energy and matter are flowing within and between systems. This is an important element **CCC #5 - Energy and Matter** at the high school level.

Summary

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

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** to make sense of a phenomenon, 2) ideas about how they and their peers are building knowledge together, and 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 did pellagra impact other communities?

Students engage with historical documents in order to **revise their explanations** on the systemic **causes** behind **pellagra at different scales**.

Preparation

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

Materials

Handouts	Lab Supplies	Other Resources
▯ Ella May Story Notecatcher ▯ Ella May Story Texts	None	▯ Mill Mother's Lament

Surfacing Student Ideas

1. Remind students that we investigated why people living on cotton plantations suffered disproportionately from pellagra. However, people outside of institutions (like orphanages) also had pellagra, even after the scientific community knew about the need for niacin and a diverse high-quality diet to prevent the disease. Let students know that we are going to be introduced to a woman named Ella May and how pellagra impacted her and her family.

2. Provide students with *Ella May Story Notecatcher* and *Ella May Story Texts*. Jigsaw the three possible texts based on student interest and readiness:
    a. Text #1: Historical description of Ella May's life
    b. Text #2: Images of Ella May's family
    c. Text#3: Song lyrics written by Ella May (*Mill Mother's Lament)*

Differentiation Point

Students engaging with the Lyrics from *Mill Mother's Lament*, could listen to the song in addition to reading the lyrics, using Mill Mother's Lament . Alternatively, the song could be played for the entire class in order to foster connections to the content.

3. Students discuss their text at their table groups. Students decide on one key idea that they want to share with the class and one question. Use the Group Learning Routine, **Domino Discover.**

Integrating Three Dimensions

Throughout the unit, students have had the opportunity to engage with elements from **LS1C: Organization for Matter and Energy Flow in Organisms.** In this Elaborate task, students are deepening their understanding of the systemic, cultural, and social components of this phenomenon.

Evaluate

How can we revise our explanations on the root causes behind the pellagra epidemic?

Using the lens of **energy and matter**, students revise their **scientific explanation** of the **causes behind the pellagra epidemic**

Preparation

Student Grouping	Routines	Literacy Strategies
☒ Table groups	None	None

Materials

Handouts	Lab Supplies	Other Resources
☒ Inequitable Food Systems Resources ☒ Final Pellagra Explanation ☒ Final Pellagra Explanation Mini Rubric	None	

Making Connections

1. Prompt students to recall or discuss the different populations of people that suffered from pellagra, and those that did not. If students have not had the opportunity to discuss the systemic injustice involved in this story, prompt them to reflect on this aspect now in triads or small groups. Prompts that may be helpful in framing the discussion:
    - In each case, why were specific populations eating the nutrient poor diets based on heavily processed corn?
    - In each case, who was profiting from maining the status quo?
    - Why would a scientific innovation (making corn more shelf-stable) end up harming some people?
    - Why did those in power not listen to the African American doctor that knew how to treat pellagra early on in the pandemic?
    - Why would agricultural systems be in place that destroy nutrients in the soil and lead to poor diets in many people?

2. Transition the conversation for students to brainstorm similar systemic injustice in today's food system (either in their communities or in the US as a whole). Let students know that in the final performance task, they will have the opportunity to evaluate innovations that may be helpful in improving food systems and/or access to healthy food in communities that lack access.

Implementation Tip

If students are struggling to make connections to their own community, provide *Inequitable Food Systems Resources* for students to read and discuss.

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 were people getting sick with pellagra? Why did some populations suffer disproportionately from pellagra than others? 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. Provide students with *Final Pellagra Explanation*. Allow time for students to record new ideas they have on the cause behind the pellagra epidemic, and how a similar lack of fresh, unprocessed foods may be impacting their communities or the US as a whole.

3. Provide *Final Pellagra Explanation Mini Rubric* for students to self and peer review.

Integrating Three Dimensions

Students will draw upon their use of **LS2.B Cycles of Matter and Energy Transfer in Ecosystems**, assessed in an earlier 5E cycle, as they complete their final explanation in the Performance Task.

Standards in Food for Plants 5E

Performance Expectations

HS-LS1-6 **Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.**
Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.
Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.

In NYS the entire PE has been edited as follows: Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements such as nitrogen, sulfur, and phosphorus to form amino acids and other carbon-based molecules. [Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations for the synthesis of lipids, starches, proteins, and nucleic acids.] [Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of structural and molecular formulas for macromolecules.]

Aspects of Three-Dimensional Learning

Science and Engineering Practices

Developing and Using Models
- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. SEP2(3)

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)

Disciplinary Core Ideas

LS1.C Organization for Matter and Energy Flow in Organisms
- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. LS1.C(1)
- The sugar molecules thus formed contain carbon, hydrogen, and oxygen; their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. LS1.C(2)
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. LS1.C(3)

Crosscutting Concepts

Scale, Proportion, and Quantity
- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. CCC3(1)

Energy and Matter
- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. CCC5(2)

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Developing and Using Models			*How do Agricultural Practices Impact Crops?* Class Consensus Discussion *Summary Task*		
Constructing Explanations and Designing Solutions				*Ella May Story Notecatcher*	*Final Pellagra Explanation* *Final Pellagra Explanation Mini Rubric*
LS1.C Organization for Matter and Energy Flow in Organisms		*Agricultural Practices in the SE US Investigation* *Making Sense of Agricultural Practices in the SE US Investigation* Domino Discover	*How do Agricultural Practices Impact Crops?* Class Consensus Discussion *Summary Task*	*Ella May Story Notecatcher*	*Final Pellagra Explanation* *Final Pellagra Explanation Mini Rubric*
Scale, Proportion, and Quantity	*Inequity of Pellagra* Domino Discover			*Ella May Story Notecatcher*	
Energy and Matter		*Agricultural Practices in the SE US Investigation* *Making Sense of Agricultural Practices in the SE US Investigation* Domino Discover	*How do Agricultural Practices Impact Crops?* Class Consensus Discussion *Summary Task*		*Final Pellagra Explanation* *Final Pellagra Explanation Mini Rubric*

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics			MP3		
ELA/Literacy		RST.9-10.1 SL.9-10.1	WHST.9-10.4 WHST.9-10.5 SL.9-10.4	RST.9-10.1 RST.9-10.2 SL.9-10.1	WHST.9-10.4 WHST.9-10.5

Unit Closing

How can we use what we have learned about science and social injustices to explain the causes of the pellagra epidemic and to identify and solve challenges in our own communities today?

Performance Expectations
HS-LS1-5, HS-LS2-4, HS-LS2-3

Anchor Phenomenon
In the Southeastern United States during the early 20th century, pellagra impacted different groups of people disproportionately.

Time
2-3 days

Students have conducted an investigation about the use of corn as staple crop and why some people and societies thrived with corn as a staple crop and others became ill and suffered from pellagra. For their final task students will have the opportunity to review how historical challenges relate to current challenges and in their own community, then explore potential solutions using the science they have learned and knowledge of their communities as a lens to evaluate the merits of each solution.

PERFORMANCE TASK	What solutions can address inequities in access to a diverse nutritious diet within our local communities?	Students use what they learned about how **energy drives the cycling of matter** through **plants and the surrounding environment** to **explain** how a local innovation addresses challenges with inequities in access to a diverse nutritious diet within our local communities.
DRIVING QUESTION BOARD	What questions 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.
UNIT REFLECTION	What did we learn and how did we learn it?	Students are asked to reflect on how their knowledge evolved throughout this unit and what caused their knowledge to evolve, with a focus on the evidence they gathered from multiple sources in order to construct explanations.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Performance Task

What solutions can address inequities in access to a diverse nutritious diet within our local communities?

Students use what they learned about how **energy drives the cycling of matter** through **plants and the surrounding environment** to **explain** how a local innovation addresses challenges with inequities in access to a diverse nutritious diet within our local communities.

Preparation

Student Grouping	Routines	Literacy Strategies
☐ Pairs or Table groups	☐ Idea Carousel	☐ Text Annotation

Materials

Handouts	Lab Supplies	Other Resources
☐ Final Task ☐ Final Task Rubric	None	☐ *How Vertical Farming Works* ☐ NYC's Biggest Outdoor Aquaponic Farm ☐ AQUAPONICS Animated Introduction ☐ Brooklyn Grange and the Farm at the Javits Center ☐ Rooftop farm at Bronx healthcare center supports wellness focus

Making Connections Between the Past and Present

1. Have students work in pairs to complete the 'Part 1' of the *Final Task*.
2. Use the **Domino Discover** routine to surface one response to each question from each group.

Look & Listen For

- People got pellagra because their diet was primarily based on corn that was processed.
- Corn was a staple crop because growing food lower on the food web (plants) is more efficient – plants convert energy from the sun through photosynthesis, eating at this level reduces loss of energy and matter moving up each link in the food web
- People did not understand that processing / degerming the corn so that it does not spoil quickly, takes out the niacin.
- Many people also did not have access to other foods that provide balanced nutrition, including nutrients like niacin.
- Niacin is an essential part of cellular respiration (generating ATP energy), so people got sick because their bodies could not produce new cells at the rate that is needed to stay healthy.
- Many communities in our city have access to food that is predominantly processed.
- Many communities in our city do not have access to healthy and fresh fruits and vegetables.
- People often have to travel far for diverse foods that are not processed and that's a barrier to eating healthy.
- Even when people can find unprocessed foods like fresh fruits and vegetables, many cannot afford it because they are expensive.
- The overall lack of access to some communities in our city can lead to more people having health problems.

Exploring Current Innovations

1. Tell students they will now work on 'Part 2' of the *Final Task*, during which they will have an opportunity to explore and evaluate a few different innovations that may address some of the problems with access to healthy, unprocessed foods like fresh fruits and vegetables. Briefly review the following innovations and the corresponding resources below;
    - Rooftop Farming: Brooklyn Grange and the Farm at the Javits Center , Project Eats: Farming on a Rooftop
    - Aquaponic Farming: NYC's Biggest Outdoor Aquaponic Farm , AQUAPONICS Animated Introduction
    - Vertical farming: Growing Up: How Vertical Farming Works , *How Vertical Farming Works*
    - Community Gardens: Project EATS 2021 Video , Project EATS: Growing Community on the Concrete of Brownsville

2. Prompt students to select one of the innovations to focus on with their partner or small group, so that all four innovations are explored and evaluated collectively.

3. Ask students to read through the text about the innovation they have chosen and **annotate** using the following:
    - Underline ideas that relate to the problems within their community or neighboring communities.
    - Circle ideas that relate to the science learned during the investigations in this unit.
    - Write a question next to ideas they would like to clarify with classmates.

4. Ask groups to create posters that explain how their innovation of focus addresses a problem in their (or a nearby) community. Their posters should include:

- ideas about how the innovation addresses the challenge of access to healthy, unprocessed foods like fresh fruits and vegetables
- ideas about how the innovation leads to the conversion of energy from the sun to energy people can consume
- how the health of the soil is taken into consideration so that what is grown has sustainable yield over time and is healthy for people to eat

5. Facilitate sharing of ideas about each innovation through the routine, **Idea Carousel**.

Implications for the Future

1. Have students work in pairs to complete the 'Part 3' of the *Final Task*.
2. Use the **Domino Discover** routine to surface one response to each question from each group.
3. Provide students with *Final Task Rubric* to peer and self assess.

Driving Question Board

What questions 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	

Revisit the 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.

Unit Reflection

What did we learn and how did we learn it?

Students are asked to reflect on how their knowledge evolved throughout this unit and what caused their knowledge to evolve, with a focus on the evidence they gathered from multiple sources in order to construct explanations.

Preparation

Student Grouping	Routines	Literacy Strategies
☒ Pairs	☒ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	

Self-Evaluation in the Practice of Constructing Explanations

1. Remind students that they started the unit out generating an initial explanation for why some people suffered from pellagra and why others were not sick, and in some cases thrived. Then after completing a series of investigations across the unit, they refined their explanations, using their scientific knowledge and reliable evidence from a variety of sources. Prompt students to reflect upon the evidence that caused them to change or refine their explanations. Have them consider:
    a. What was the evidence?
    b. Where did it come from?
    c. How and why did it change my thinking?

2. Ask students to take turns sharing their responses in pairs and to come up with one important idea to share with the whole class.

3. Use the group learning routine **Domino Discover** to surface ideas with the whole class.

4. Prompt students independently reflect on the following:
    a. How has your thinking changed about what it takes to construct a strong scientific explanation?
    b. Why is constructing an explanation about something that happened in the past useful to us and local communities today?
    c. What do you want to consider when you encounter new phenomena in the future?

5. Ask students to take turns sharing their responses in pairs and to come up with one important idea to share with the whole class.

6. Use the group learning routine **Domino Discover** to surface ideas with the whole class.

Standards in Unit Closing

Performance Expectations

HS-LS1-5 **Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.**
Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models
Assessment Boundary: Assessment does not include specific biochemical steps.

HS-LS2-3 **Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.**
Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.
Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.

In NYS the entire PE has been edited as follows: Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in ecosystems. [Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration and photosynthesis within ecosystems.] [Assessment Boundary: Assessment does not include the specific chemical processes of aerobic respiration, anaerobic respiration, and photosynthesis.]

HS-LS2-4 **Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem**
Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.
Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.

In NYS the clarification statement has been edited as follows: Emphasis is on using a mathematical model such as a pyramid of biomass/energy to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems.

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)	LS1.C Organization for Matter and Energy Flow in Organisms • The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. LS1.C(1) LS2.B Cycles of Matter and Energy Transfer in Ecosystems • Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. LS2.B(1) • 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)	Energy and Matter • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. CCC5(2) • Energy drives the cycling of matter within and between systems. CCC5(4)

Assessment Matrix

	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Constructing Explanations and Designing Solutions	*Final Task* Idea Carousel		Domino Discover	
LS1.C Organization for Matter and Energy Flow in Organisms	*Final Task* Idea Carousel		Domino Discover	
LS2.B Cycles of Matter and Energy Transfer in Ecosystems	*Final Task* Idea Carousel Idea Carousel		Domino Discover	
Energy and Matter	*Final Task* Idea Carousel		Domino Discover	

Common Core State Standards Connections

	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Mathematics				
ELA/Literacy	RST.9-10.1 SL.9-10.1			

Classroom Resources for Unit Closing

How Vertical Farming Works

How Vertical Farming Works


RECIRCULATING HYDROPONICS
Nutrients are delivered to plants in irrigation water, eliminating soil and sharply increasing yield. Water is recirculated and none is wasted.
EVAPORATIVE COOLING
In very hot weather, air is drawn into the greenhouse across large pads soaked with fresh or salt water.
VENTILATION
Generous openings in the walls and roof provide natural ventilation. When needed, extractor fans draw air through the greenhouse.
RENEWABLE ENERGY
Power for irrigation pumps and ventilation systems can be provided by onsite solar panels.
RAINWATER CAPTURE
Rain falling on the greenhouse roof is stored in large tanks, providing irrigation throughout dry periods.
WASTE HEAT CAPTURE
In cold weather and at night, exhaust air from the building help keeps the greenhouse warm.

Vertical Farming System