Evolution of Sick Humans - Teacher Materials

Unit 3	Biology

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

Unit 3 Evolution of Sick Humans Table of Contents

Unit 3 Evolution of Sick Humans

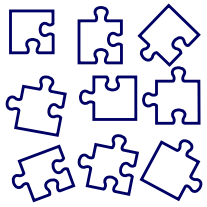
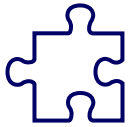
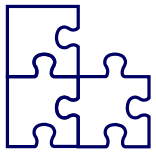
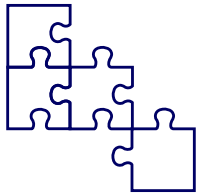
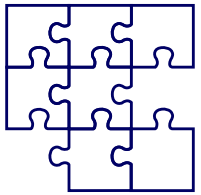
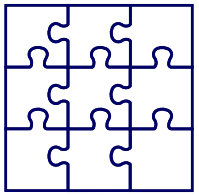
Mismatch between Human Bodies and the Modern Environment

Performance Expectations
HS-LS1-1, HS-LS3-1, HS-ETS1-2, HS-ETS1-3, HS-LS4-1

Time
31-40 days

How have our environments and culture changed over time? How have these changes impacted our health?

For the vast majority of human history, humans lived in small, primarily nomadic groups of hunter-gatherers. Human physiology and behavior is well adapted to our prehistoric lifestyle. Since the agricultural and industrial revolutions, humans have manipulated their environments, resulting in rapid changes in society. This rapid change has contributed to many of the chronic health concerns modern people face. In this unit, students will explore the possible 'mismatch' between human bodies and modern environments by investigating phenomena at the protein level.

Unit Opening	Lactase Persistence 5E	Leptin Resistance 5E	Circadian Rhythms 5E	Common Ancestry 5E	Unit Closing
Anchor Phenomenon	→	**5E Lessons connect learning to the performance task**	→		**Performance Task**
					
How have our environments and cultures changed over time? How have these changes impacted our health?	*Why are some people able to digest dairy into adulthood but others cannot?*	*Why is obesity increasing globally? Why do some people gain weight easily but others do not?*	*Why do virtually all organisms have a day-night cycle? How might disruptions or environmental changes in the day-night cycle impact our health?*	*Why aren't we just evolving to address mismatch problems?*	*How can we design a healthy school in terms of reducing mismatches between our bodies and our environment?*

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 sensemaking and deepen teacher understanding of how to teach science in an interactive way that is driven by student questions and ideas.

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

This unit was intentionally designed to build on the second unit of this course, Humans vs Bacteria, in which students evaluate possible solutions to a global problem (avoiding global infectious disease outbreaks) and develop a scientific argument on the best possible solution. In The Evolution of Sick Humans, students continue to engage with developing solutions to a global problem using the design cycle to optimize a design solution. The common, embedded group learning routines and curriculum structures introduced in the first and second unit are revisited, providing students and teachers multiple opportunities to engage in a culture of collaborative sensemaking around a phenomenon. In this unit, students are encouraged to figure out why we are experiencing mismatch diseases between our bodies and the modern environment and how best to design solutions that address this problem.

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 three-dimensional teaching and learning is brand new to them (or to the teacher!), this unit is designed to reinforce and further build on student experience with three-dimensional learning.

Unit Coherence

In Unit 3, the overall question about the mismatch hypothesis is intended to motivate student engagement across the unit. It is our intention that from the student 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 3. Each sequence builds towards figuring out something that contributes to explaining the overall unit-level question about how to design healthy environments that may avoid the mismatch problem. The phenomena, the instructional model, and the routines embedded throughout the sequences of lessons are all used in service of coherence across Unit 3.

Phenomenon-Driven Instruction

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

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

Anchor Phenomenon

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

Investigative Phenomena

Based on the Anchor Phenomenon and three-dimensional learning goals for students for the unit, each 5E instructional sequence has a related investigative phenomenon typically presented in the Engage phase. This phenomenon brings students together around a shared puzzle or experience that frames the learning for that 5E sequence. Similar to the anchor phenomenon question, the questions about the investigative phenomena are intended to be specific and contextualized rather than the traditional content questions teachers use as their lesson aims. Students 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 and Designing Solutions

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 student 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 design solution.

Storyline and Pacing Guide

Unit Opening	How have our environments and cultures changed over time? How have these changes impacted our health?	**Performance Expectations**	**Anchor Phenomenon** A high school student who recently arrived in New York City is unable to drink milk at lunch like her peers without getting sick.	**Time** 2 days

Student Questions	What Students Do	Student Ideas
These questions motivate the unit storyline. • Why are some people able to digest dairy products as adults but others are not? • How have recent changes to our environment and lifestyles impacted our health? • Why is obesity increasing globally? Why do some people gain weight easily, but others do not? • Why do we need to sleep? Why do some people have difficulty with sleep? • Why are our pets and farm animals showing similar mismatch diseases? Do pre-industrial people have these problems? WIld animals?	Students read a text in order to tell the story of a young girl who eats a NYC school lunch and then runs into digestive problems because of the high dairy content.	*These ideas are revisited throughout the unit storyline.* • Human bodies evolved under specific conditions that are common in pre-industrial societies • In the past 5-10,000 years, the environment, lifestyle, and cultural factors have changed rapidly for most human populations • The difference between the environment in which human bodies evolved and the current environment may be leading to mismatch diseases such as lactose intolerance, obesity, insomnia, and others • We may be able to design or manipulate our environment so that we can alleviate some of the mismatch diseases that cause suffering

During the Driving Question Board routine, students ask questions related to why some people are able to digest dairy products as adults but others are not. Once a category related to these questions has been articulated, let students know that they will be investigating this question over the next sequence of lessons to figure out how some people are able to digest dairy products into adulthood, while others are not.

Lactase Persistence 5E	Why are some people able to digest dairy into adulthood but others cannot?	**Performance Expectations** HS-LS3-1, HS-LS1-1	**Investigative Phenomenon** Some people are not able to consume dairy products past infancy.	**Time** 9-10 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • Why do some adults have the ability to digest dairy? • How do adults digest dairy products? • What is the role of lactase in digesting dairy products? • What role does DNA play in determining if a person can digest dairy after infancy? • Why do some populations have the ability to digest dairy past infancy but others do not? • Why would it be advantageous to consume the milk of other animals? • How could we design a school so that everyone, including those that stop producing lactase or do not produce lactase anymore, is healthy and well-nourished?	Students look for patterns in a lactose intolerance frequency world map, then generate ideas and questions based on those patterns. Students examine intestinal fluid samples from four people and see what happens to milk in their digestive system. They then study the DNA of these four people to make sense of what they observed when they analyzed the intestinal fluid samples and discover that some of the patients did not have a gene for lactase.	*Students figure out these ideas in this 5E sequence.* • Lactase is an enzyme produced in specialized cells of the small intestine that facilitates the breakdown of lactose (sugar in milk) so it can be absorbed • Examining the component parts can help us understand the importance of shape in the functioning of enzymes and other biological molecules (lock and key model of enzyme function) • Genes are found on chromosomes and are made up of sequences of DNA. Not all DNA on a chromosome is a gene: some DNA serves a regulatory function, and some has an unknown function • Everyone has a gene on chromosome 2 that provides the information to make lactase • All babies produce lactase, but only some adults do • People who persist in making lactase into adulthood have a mutation in a regulatory gene which would normally shut off the production of lactase but allows the person to continue making it and digesting dairy • The majority of teenagers and adults, including Kanna and her mother, do not have this mutation, so undigested lactose enters their large intestine, causing discomfort, diarrhea, and gas

Have students identify which categories/questions they have not addressed yet. One question category should relate to questions about obesity, access to food, and sedentary lifestyles. Tell students that in the next sequence of lessons, they will investigate these questions.

Leptin Resistance 5E

Why is obesity increasing globally? Why do some people gain weight easily but others do not?

Performance Expectations
HS-LS3-1, HS-LS1-1

Investigative Phenomenon
Storing fat is an advantageous trait; however, some people are storing more fat than they used to (obesity is increasing).

Time
7-9 days

Student Questions

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

- Why is the ability to store fat an advantageous trait?
- Why do some people store excess fat (obesity) but others do not?
- Why is the storage of excess fat (obesity) increasing globally?
- What role do genes play in excess fat storage?
- What role does the environment play in excess fat storage?
- How can we modify our environment to avoid excess fat storage?

What Students Do

Students read and discuss a text about how fat storage is a favorable trait for human babies, then generate questions regarding excess fat storage in adults and whether it's related to gene variation like lactose intolerance. Students then analyze secondary data sets to explore the role leptin plays in fat storage and notice a positive relationship between leptin in the blood and body fat. Students also conclude that some variations in the leptin gene may result in small variations in eating behavior or weight and that leptin resistance, in which the leptin receptor no longer functions properly, may be an important cause of excess fat storage. Students test their understanding by applying their learning to diabetes. Finally, students apply their understanding of the causes behind leptin resistance to develop design solutions that take into consideration important constraints.

Student Ideas

Students figure out these ideas in this 5E sequence.

- Leptin is one important hormone that is created in fat cells that helps regulate fat storage by suppressing appetite
- Some variations in the leptin gene may result in small variations in eating behavior or weight
- Leptin resistance, in which the leptin receptor (a protein) no longer functions properly (leptin no longer fits into the receptor), may be an important cause of excess fat storage
- Leptin resistance may be caused by changes in diet such as eating foods high in sugar and fat
- Variations in other genes (beyond the gene for leptin) may impact fat storage
- Environmental changes around the abundance of food, and processed food in particular, may impact fat storage
- Insulin is another hormone that plays a role in fat storage and energy regulation by allowing glucose in the bloodstream to enter the cells
- Insulin allows glucose in the cell when insulin is able to attach to an insulin receptor on the outside of the cell membrane
- Too much fat in the cells blocks or disrupts insulins ability to attach to the receptor or to signal that glucose can enter the cells -- thus leading to insulin resistance
- Eating a diet high in saturated fat may contribute to insulin resistance and the development of type 2 diabetes

Have students identify which categories/questions they have not addressed yet. One question category should relate to questions about why many people have sleep problems or even suffer from insomnia. Tell students that in the next sequence of lessons, they will investigate these questions.

Circadian Rhythms 5E	Why do virtually all organisms have a day-night cycle? How might disruptions or environmental changes in the day-night cycle impact our health?	**Performance Expectations** HS-LS3-1, HS-LS1-1, HS-ETS1-2, HS-ETS1-3	**Investigative Phenomenon** All living organisms have day and night cycles that impact biological function.	**Time** 6-8 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • Why do virtually all organisms have a day-night cycle? • How might disruptions or environmental changes in the day-night cycle impact our health? • How are day-night cycles regulated? • What role does melatonin play in making us sleepy? • How could we redesign our bedrooms to optimize our sleep?	Students start by thinking about a student named Jeffrey, who is unable to get enough sleep, surfacing their initial ideas on why many organisms have day-night cycles and how we may investigate this question further. Then students investigate day-night cycles in plants and design a survey in order to collect data on which environmental factors may cause disruptions in human day-night cycles. After engaging with various multimedia resources to learn about the role melatonin plays in sleep night cycles, students communicate scientific ideas about the genetic and environmental factors that determine the way we sleep. Finally, students apply what they have learned to designing a prototype of a room that optimizes sleep.	*Students figure out these ideas in this 5E sequence.* • Both humans and the plant we investigated have a clear day-night cycle (that may be based on light and darkness) • Melatonin is a hormone secreted from specialized cells of the pineal gland • Melatonin is one hormone that helps to regulate the circadian rhythm • Circadian rhythms are day-night/wake-sleep cycles that generally occur over a 24-hour period in most organisms • Melatonin also plays a role in making humans feel sleepy; its production is inhibited in bright light but is produced as light becomes dimmer or dark • Sleep is a very important biological function in humans; lack of sleep has been associated with chronic disease • Changes to our light exposure, such as lighting at night or using electronic devices, may disrupt our natural sleep cycle • Melatonin peaks at different times for different age groups; for teenagers it peaks at a later time at night than for children and adults

Have students identify which categories/questions they have not addressed yet. One question category should relate to why people have so many different mismatch diseases. Tell students that in the next sequence of lessons, they will investigate these questions.

Common Ancestry 5E	Why aren't we just evolving to address mismatch problems?	**Performance Expectations** HS-LS4-1	**Investigative Phenomenon** There are mismatches between our biological traits that have evolved over a long period of time and our current environment.	**Time** 5-8 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • Why are our pets and farm animals showing similar mismatch diseases? • Do pre-industrial people have these problems? • Do wild animals exhibit mismatch diseases?	Students start this final instructional sequence by generating questions they want to investigate in order to explain why day-night cycle "mismatch" disorders are shared by species as different as humans, amphibians, and insects. Student questions about how and why traits change or don't change and whether traits of other species have evolved to avoid mismatch diseases lead to an analysis of a genetic database that allows students to surface patterns of genetic evolution across different species. Students bring all their ideas together to construct a scientific explanation for human "mismatch" diseases. Finally, students apply everything they have learned throughout this unit as they revise their solutions for a school environment that addresses the unit problem and propose ideas for how they can evaluate whether their solutions are effective.	*Students figure out these ideas in this 5E sequence.* • All organisms evolved from a shared common ancestor • Comparing genes or amino acid sequences demonstrates how closely related organisms are • Human protein sequences were most similar to chimpanzees and least similar with fruit files • Genes affect the function of the proteins that are important for our survival and many of the genes that have not evolved quickly have not changed since humans first evolved • The fact that these genes are shared across a wide range of species, even if they have some differences, helps explain why mismatch diseases are shared across a wide range of species • Our bodies can't (or don't) evolve quickly enough to resolve mismatch diseases because our current environment changed relatively quickly, while the evolution of advantageous traits does not happen at the same pace

Students apply everything they have learned to design a school environment that addresses human mismatch diseases and use their criteria to develop a plan to evaluate their solutions.

Unit Closing

How can we design a healthy school in terms of reducing mismatches between our bodies and our environment?

Performance Expectations
HS-LS1-1, HS-ETS1-2, HS-ETS1-3, HS-LS3-1, HS-LS4-1

Anchor Phenomenon
A high school student who recently arrived in New York City is unable to drink milk at lunch like her peers without getting sick.

Time
2-3 days

Student Questions

These questions are addressed in the performance task.

- Why are mismatch problems occurring and why this might be a problem we need to address?
- How can schools be better designed to be friendlier to human health?

What Students Do

Students generate more ideas about why mismatch diseases occur and why we may need to address them. Students then further investigate unanswered questions from their Driving Question Board. Finally, students revisit and evaluate their designs for addressing mismatch problems at school and complete their final designs.

Student Ideas

These ideas were developed throughout the unit storyline.

- Human bodies evolved under specific conditions that are common in pre-industrial societies
- In the past 5-10,000 years, environment, lifestyle, and cultural factors have changed rapidly for most human populations, and this may be leading to mismatch diseases such as lactose intolerance, obesity, insomnia, and others
- We may be able to design or manipulate our environment so that we can alleviate some of the mismatch diseases that cause suffering
- Examining the component parts can help us understand the importance of shape in the functioning of enzymes and other biological molecules (lock and key model of enzyme function)
- Genes affect the function of the proteins that are important for our survival and many of the genes that have not evolved quickly have not changed since humans first evolved
- Our bodies can't (or don't) evolve quickly enough to resolve mismatch diseases because our current environment changed relatively quickly, while the evolution of advantageous traits does not happen at the same pace

Based on the investigations and learning throughout the unit, students generate a design solution that addresses mismatch concerns in the school environment.

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-LS1-1 **Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.**
Clarification Statement: None
Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.

In NYS the following clarification statement has been added: Emphasis should be on how the DNA code is transcribed and translated in the synthesis of proteins. Types of proteins involved in performing life functions include enzymes, structural proteins, cell receptors, hormones, and antibodies.

HS-LS3-1 **Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.**
Clarification Statement: None
Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.

In NYS the assessment boundary was removed and the following clarification statement has been added: Emphasis should be on the distinction between coding and non-coding regions of DNA.

HS-ETS1-2 * **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**
Clarification Statement: None
Assessment Boundary: None

HS-ETS1-3 * **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.**
Clarification Statement: None
Assessment Boundary: None

HS-LS4-1 **Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.**
Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.
Assessment Boundary: None

The performance expectations marked with an asterisk (*) integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Three-Dimensional Learning Goals in This Unit

Given the breadth of three-dimensional standards for high school biology, Unit 3 focuses primarily on ideas related to common ancestry, the relationship between DNA, genes, and traits, and protein synthesis. These ideas fall within the NGSS/NYSSLS Core Idea LS1 Structure and Function, Core Idea LS3 Inheritance of Traits, and Core Idea LS4 Evidence of Common Ancestry and Diversity. This unit also introduces students to 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 Structure and Function, which fits well with our selected DCIs and SEP. As students deepen their understanding of the content to understand how and why mismatch diseases have become a problem in modern society, they learn how to use an engineering and design approach to solve problems. Scaffolding across the unit supports student three-dimensional learning and will help shift classrooms to become more NGSS-aligned spaces.

Three Dimensions in Unit 3

This chart is a high-level summary of the standards for Unit 3. For more detail about specific elements, see the section on Assessment later in this document.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems	ETS1.B Developing Possible Solutions	Patterns
Developing and Using Models	ETS1.C Optimizing the Design Solution	Cause and Effect
Analyzing and Interpreting Data	LS1.A Structure and Function	Structure and Function
Constructing Explanations and Designing Solutions	LS3.A Inheritance of Traits	
Obtaining, Evaluating, and Communicating Information	LS4.A Evidence of Common Ancestry and Diversity	
	LS4.C Adaptation	

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 student prior experience. As we are in the middle of a multi-year transition, 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

Engineering Design

- Students in middle school have previous experience outlining the criteria and constraints of successful solutions to a problem. In high school, students take their engineering design skills further by engaging with more complex problems that need to be broken down into simpler problems. In this unit, students investigate the societal problem of a mismatch between the evolutionary history of our bodies and our current environment, breaking the problem down into several sub-problems that may be addressed through engineering design. Students evaluate possible solutions using limitations, criteria, and constraints in order to iteratively optimize a design solution.

Obtaining, Evaluating, and Communicating Information

- In middle school, students have previous experience critically reading scientific texts and communicating information in writing and oral presentations. In high school, they progress towards accurately summarizing information from scientific texts and communicating information in a variety of formats including written, graphical, and mathematical representations. This unit builds on the practice of Obtaining, Evaluating, and Communicating Information through scaffolded engagement with scientific literature, both written and graphical, and in communicating their ideas in multiple formats.

Disciplinary Core Ideas from Middle School

LS1.A Structure and Function

- In middle school, students learn the basic organization of life and that all organisms are made up of cells. In high school, they examine how systems of specialized cells perform the basic functions of life. In this unit, students investigate how a series of important proteins and other biological molecules secreted from specialized cells interact with receptor molecules to initiate and regulate key life processes such as lactase digestion and energy storage.

LS3.A Inheritance of Traits

- Students in middle school learn that genes determine proteins which determine traits in an individual. In high school, students greatly expand their understanding of the relationship between DNA, chromosomes, genes, proteins, and traits, as well as how some DNA functions to regulate the expression of particular genes. This unit supports students in developing a more complex understanding of the structure and function of DNA and how the expression of some genes may be impacted by the environment.

LS4.A Evidence of Common Ancestry and Diversity

- Students in middle school learn that the fossil record provides evidence of common ancestry. In high school, students consider how similarities and differences in DNA and amino acid sequences represent evolutionary relationships. In this unit, students have multiple opportunities to compare DNA and amino acid sequences between individuals and between species to better understand that important biological molecules are conserved across species and serve as evidence for common ancestry.

Crosscutting Concepts from Middle School

Cause and Effect

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

- Students in middle school learn that relationships may be causal or correlational and that correlation does not always imply causation. This unit builds on this understanding by engaging students in multiple opportunities to evaluate possible causal relationships using empirical evidence.

Structure and Function

This unit builds on the following aspects of Structure and Function in middle school.

- Students in middle school analyze many complex natural and designed structures and systems to determine how they function. In high school, students look closely at the structures of different components and their interconnections to reveal the system's function and/or solve a problem. This unit engages students in considering the components of a school and the interrelationships between those structures and components to solve the problem of a mismatch between how our bodies work and our current environment.

Assessment

Performance expectations (PEs) in the NGSS describe what students should know and be able to do. Unit 3 targets a bundle of three PEs taken from three different core ideas in high school life science (HS-LS1), *Structure and Function*; (HS-LS3), *Inheritance of Traits,* and (HS-LS4) *Evidence of Common Ancestry and Diversity;* which correspond to the standards HS-LS1-1, HS-LS3-1, and HS-LS4-1. We have also included two engineering design PEs, HS-ETS1-2 and HS-ETS1-3. 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 learning goals informed by the bundled PEs for the unit. All other evidence of learning related to the other dimensions/elements in the PEs can be found within the instructional sequences.

The SEP of Constructing Explanations and Designing Solutions, with an emphasis on the engineering practice of designing solutions, is the primary foregrounded practice for this unit. Ideally, students will generate their own design for the performance task, but as it's likely the first time they are using this SEP at high school level, teachers need to gauge student proficiency early on and allow for paired and group-level initial designs. Also in service of helping students develop this SEP

at the high school level, there is a progression of support in their use of the design process, with iterative opportunities to articulate problems, develop criteria and constraints, and evaluate possible design solutions. It is therefore the implications of these expected progressions that students might be unable to proficiently use this SEP at high school level early in the unit, but that they are able by the end of the unit.

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

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

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

	Lactase Persistence 5E	Leptin Resistance 5E	Circadian Rhythms 5E	Common Ancestry 5E
Asking Questions and Defining Problems	✔	✔		
Developing and Using Models	✔			
Analyzing and Interpreting Data				✔
Constructing Explanations and Designing Solutions	✔	✔	✔	✔
Obtaining, Evaluating, and Communicating Information		✔	✔	
ETS1.B Developing Possible Solutions		✔	✔	✔
ETS1.C Optimizing the Design Solution		✔	✔	✔
LS1.A Structure and Function	✔	✔	✔	
LS3.A Inheritance of Traits	✔		✔	
LS4.A Evidence of Common Ancestry and Diversity				✔
LS4.C Adaptation	✔			
Patterns				✔
Cause and Effect		✔	✔	
Structure and Function	✔			

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 individual reflection, peer review, and teacher feedback. The Unit 3 Performance Task also includes a rubric, and the task can be considered a final summative assessment for the unit. We have not included a traditional "unit test" in our materials. Teachers may opt to create their final exam using their states' previous exam questions, however we believe that the formative assessment tasks embedded in the materials (such as the Looks and Listen For notes, the Explore phase summaries, and the modeling done in the Evaluate phases), along with the Performance Task can serve as sufficient evidence of what students know and can do.

Common Core State Standards (Mathematics)

Standards for Mathematical Practice

MP2 Reason abstractly and quantitatively.	Mathematically proficient students make sense of the quantities and their relationships in problem situations. Students bring two complementary abilities to bear on problems involving quantitative relationships: the ability to decontextualize—to abstract a given situation and represent it symbolically and manipulate the representing symbols as if they have a life of their own, without necessarily attending to their referents—and the ability to contextualize, to pause as needed during the manipulation process in order to probe into the referents for the symbols involved. Quantitative reasoning entails habits of creating a coherent representation of the problem at hand; considering the units involved; attending to the meaning of quantities, not just how to compute them; and knowing and flexibly using different properties of operations and objects.
MP3 Construct viable arguments and critique the reasoning of others.	Mathematically proficient students understand and use stated assumptions, definitions, and previously established results in constructing arguments. They make conjectures and build a logical progression of statements to explore the truth of their conjectures. They are able to analyze situations by breaking them into cases, and can recognize and use counterexamples. They justify their conclusions, communicate them to others, and respond to the arguments of others. They reason inductively about data, making plausible arguments that take into account the context from which the data arose. Mathematically proficient students are also able to compare the effectiveness of two plausible arguments, distinguish correct logic or reasoning from that which is flawed, and—if there is a flaw in an argument—explain what it is. Elementary students can construct arguments using concrete referents such as objects, drawings, diagrams, and actions. Such arguments can make sense and be correct, even though they are not generalized or made formal until later grades. Later, students learn to determine domains to which an argument applies. Students at all grades can listen or read the arguments of others, decide whether they make sense, and ask useful questions to clarify or improve the arguments.
MP6 Attend to precision.	Mathematically proficient students try to communicate precisely to others. They try to use clear definitions in discussion with others and in their own reasoning. They state the meaning of the symbols they choose, including using the equal sign consistently and appropriately. They are careful about specifying units of measure, and labeling axes to clarify the correspondence with quantities in a problem. They calculate accurately and efficiently, express numerical answers with a degree of precision appropriate for the problem context. In the elementary grades, students give carefully formulated explanations to each other. By the time they reach high school they have learned to examine claims and make explicit use of definitions.

Standards for Mathematical Content

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

Common Core State Standards (ELA/Literacy)

Reading Standards for Informational Texts

RI.11-12.7	Integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a question or solve a problem.

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.
RST.9-10.8	Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.
RST.9-10.9	Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

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.9-10.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
WHST.9-10.9	Draw evidence from informational texts to support analysis, reflection, and research.

Implementing Unit 3

This unit is designed to be the thrid 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 each 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	Lactase Persistence 5E	Leptin Resistance 5E	Circadian Rhythms 5E	Common Ancestry 5E	Unit Closing
Class Consensus Discussion		1	1	1	1	
Consensus-Building Share		1	2	1		
Domino Discover		5	1	1	1	
Idea Carousel				1		
Read-Generate-Sort-Solve		1	1			
Rumors	1		1	1	1	
Think-Talk-Open Exchange			1		1	

Literacy Strategies

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

	Unit Opening	Lactase Persistence 5E	Leptin Resistance 5E	Circadian Rhythms 5E	Common Ancestry 5E	Unit Closing
Claim-Evidence-Reasoning (CER)					1	
Sequence Chart			1			
Text Annotation	1	2	1			
Text Graffiti			1			

Videos in this Unit

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Lactase Persistence 5E	Lactose Digestion in Infants (optional)	https://www.youtube.com/watch?v=hpv2RK3nIdY	NA	NA
Lactase Persistence 5E	Cryptic DNA sequences may help cells survive starvation	https://www.nature.com/articles/d41586-019-00183-0?fbclid=IwAR0gjQx6RfmQf7uTaSVsDk8wBC_1pJDfdo-NUHWNCx6ayRwy2gF2jwiN2I8	NA	NA
Lactase Persistence 5E	Got Lactase?	https://www.biointeractive.org/classroom-resources/making-fittest-got-lactase-co-evolution-genes-and-culture	NA	NA
Lactase Persistence 5E	What is engineering, and who exactly is an engineer? (optional)	https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=10515	NA	NA
Leptin Resistance 5E	Transcription	https://dnalc.cshl.edu/resources/3d/12-transcription-basic.html	NA	NA
Leptin Resistance 5E	Translation	https://dnalc.cshl.edu/resources/3d/15-translation-basic.html	NA	NA

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Leptin Resistance 5E	How the Hormone Leptin Helps Regulate Appetite	https://www.youtube.com/watch?v=lVl84cLFpgk	NA	NA
Leptin Resistance 5E	Correlation and causality	https://www.khanacademy.org/math/probability/xa88397b6:scatterplots/estimating-trend-lines/v/correlation-and-causality	NA	NA
Leptin Resistance 5E	Podcast: Processed Food: A Load of Baloney?	https://gimletmedia.com/shows/science-vs/brhn2kz/processed-food-a-load-of-baloney	NA	NA
Leptin Resistance 5E	What Causes Insulin Resistance?	https://nutritionfacts.org/video/What-Causes-Insulin-Resistance/	NA	NA
Circadian Rhythms 5E	Timelapse Captures How House Plants Move in the Day and Sleep at Night (optional)	https://www.youtube.com/watch?v=z0I3174S8Xg	NA	NA
Circadian Rhythms 5E	How Plants Tell Time	https://www.youtube.com/watch?v=3jIW5wW2WC0	NA	NA
Circadian Rhythms 5E	Why We Sleep	https://www.npr.org/2018/07/20/630926599/why-we-sleep	NA	NA
Common Ancestry 5E	NCBI Genetic Database	https://www.ncbi.nlm.nih.gov/	NA	NA
Common Ancestry 5E	Guess the Embryo Matching Game	https://stories.wgbh.org/guess-embryo/	NA	NA

Lab Materials in this Unit

Lesson	Lab	Materials needed (per group)
Lactase Persistence 5E	Dairy Investigation Lab minutes: 45 minutes	❑ 4 beakers (or plastic cups) ❑ markers to label beakers ❑ 4 urine test strips ❑ 200 mL of water ❑ 2 g of glucose ❑ 2 mL NaOH (1 M)
Lactase Persistence 5E	DNA Comparison Investigation Lab minutes: 45 minutes	
Leptin Resistance 5E	The Role of Leptin Investigation Lab minutes: 0 minutes	
Leptin Resistance 5E	Role of Genetics & Environment Investigation Lab minutes: 0 minutes	
Circadian Rhythms 5E	Day-Night Cycle Investigation Part 1, Day-Night Cycle Investigation Part 2, Lab minutes: 90 minutes	❑ 1 Mimosa pudica seedling ❑ 1 digital camera or phone with a digital camera and a time-lapse photography app such as O'Snap pro ❑ 1 camera tripod
Common Ancestry 5E	Comparing amino acid sequences Investigation Lab minutes: 45 minutes	

Other Materials in this Unit

Lesson	Materials needed
Unit Opening	❑ Post-it notes ❑ Chart paper

Lesson	Materials needed
Lactase Persistence 5E	❑ *Labeled World Map* (optional) ❑ Patterns in the Distribution of Lactase Persistence - pg. 9 (optional) ❑ *Simple Lock-and-Key Diagram* ❑ *Detailed Lock-and-Key Diagram* ❑ *Dairy Investigation Results Key* ❑ *Lactose Digestion in Infants - Transcript* (optional) ❑ *DNA Reference Sheet* ❑ *CER Organizer* ❑ *Visuals for Mismatch Hypothesis* ❑ post-it notes
Leptin Resistance 5E	❑ Baby Fat Is About More Than Cuteness ❑ Serum Leptin Concentration Positively Correlates with Body Weight and Total Fat Mass in Postmenopausal Japanese Women with Osteoarthritis of the Knee (optional) ❑ Fructose-induced leptin resistance exacerbates weight gain in response to subsequent high-fat feeding (optional) ❑ Is fructose driving metabolic disease? | Dr Richard Johnson ❑ *Sequence Chart* ❑ Genetic Influences on Child Eating Behaviour (optional) ❑ The global childhood obesity epidemic and the association between socio-economic status and childhood obesity (optional)
Circadian Rhythms 5E	❑ Chart paper ❑ Tracking Rhythms in Plants (optional) ❑ O'Snap pro (optional) ❑ Example Sleep Questionnaire (optional)
Unit Closing	❑ Driving Question Board

Teacher Materials for Unit 3

Unit Opening

How have our environments and cultures changed over time? How have these changes impacted our health?

Performance Expectations

Anchor Phenomenon
A high school student who recently arrived in New York City is unable to drink milk at lunch like her peers without getting sick.

Time
2 days

All mammals can digest milk as infants, but modern humans are the only species that drink milk into adulthood. Consuming dairy most likely arose in some human cultures over 10,000 years ago. However, many children and adults can't digest dairy products, causing digestive problems when they attempt to drink milk. Milk and dairy products are ubiquitous in many of today's environments (such as New York City schools), causing a possible mismatch between human bodies and the current environment.

ANCHOR PHENOMENON	Why would a high school student who recently arrived in New York City be unable to drink milk at lunch like her peers without getting sick?	This is a topic that should incite student curiosity and wonder! By working with students to surface what they believe could have gone wrong with this student drinking milk at school, students will express both their prior knowledge and their curiosity, allowing them to engage with the unit and increasing student buy-in.
DRIVING QUESTION BOARD	What questions do we have?	Based on ideas that have surfaced through student discussion, students create a driving question board.
PERFORMANCE TASK	The Performance Task is not introduced during the Unit Opening.	Unlike in other units, the sensemaking that leads to student understanding of the need for the Performance Task is designed to take place in the first 5E -- Lactase Persistence. At that point, students begin thinking about the Mismatch Hypothesis and ways to make schools more suitable for health.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Anchor Phenomenon

Why would a high school student who recently arrived in New York City be unable to drink milk at lunch like her peers without getting sick?

This is a topic that should incite student curiosity and wonder! By working with students to surface what they believe could have gone wrong with this student drinking milk at school, students will express both their prior knowledge and their curiosity, allowing them to engage with the unit and increasing student buy-in.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs ❑ Table groups	None	❑ Text Annotation

Materials

Handouts	Lab Supplies	Other Resources
❑ Tell the Story	None	

Surfacing Student Ideas

1. Prompt students to discuss in pairs what they ate and drank yesterday or today in the school cafeteria for lunch. Have students share different food and drinks, and surface with the class that milk or other dairy products were an option at lunch (even if they didn't consume it themselves).

2. Surface ideas around why or why not students drank the milk or ate the dairy product(s) offered at lunch (e.g. like/don't like milk, offered chocolate milk, like pizza, it's healthy, etc.)

Telling the Story

1. Distribute the *Tell the Story* handout.
2. Remind students that they just surfaced a lot of ideas about preferences around drinking/not drinking milk in the cafeteria (or other dairy foods). Let students know that although milk is common in many NYC school cafeterias, dairy is not always a common ingredient in many parts of the world.
3. Have students read and **annotate** the text individually, circling or highlighting three details that are the most important to the phenomenon being described.
4. Ask students to share their ideas with their group, with every individual identifying the details that they thought were important, then come to an agreement about which details are most important for telling the story of the phenomenon.
5. Tell students to use those details to compose a paragraph that tells the story of the phenomenon.

Conferring Prompts

Confer with students as they tell the story.

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

Access for All Learners

Not all students may be familiar with or connect to the concept that a person can't drink milk without getting sick, or even that not all cultures include dairy as a usual lunch time food. Prompt students to think about other types of foods or activities that only some people (not everyone) have difficulty with or do not partake in because it is not a usual part of their culture. Students may discuss allergies to foods, or cultural/religious/environmental differences or preferences between different countries or geographic locations.

Driving Question Board

What questions do we have?

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

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ Rumors	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	❑ Post-it notes ❑ Chart paper

Surfacing Student Ideas

1. Prompt students to brainstorm responses to the prompt: Why did Kanna feel ill after drinking milk and eating dairy, but her classmates did not?
2. Tell students to identify their most important idea, and write it on a post-it note.
3. Using the **Rumors** routine, students share out ideas with the class.
4. Classify student ideas on the board to surface patterns.

Routine

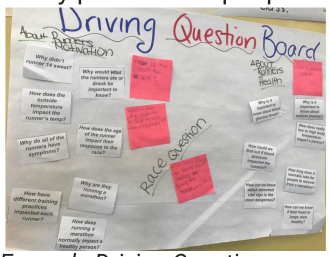
This is the first time the routine **Rumors** appears in this unit! Please read the Biology Course Guide for detailed steps about this routine.

Look & Listen For

- Kanna is not used to drinking milk, as they don't serve it at her old school
- Something is different in people's bodies or genes that impacts their ability to digest milk or dairy products
- Kanna is lactose intolerant
- Kanna's family doesn't drink milk or eat dairy products or have cultural/religious preferences
- Kanna has another illness that isn't related to dairy (a stomach virus, etc)
- Because Kanna doesn't like dairy, her body can't digest it

Generating Questions

1. At this point, students should have a lot of questions! Let them know that they will be investigating why some teenagers and adults can digest dairy after infancy, while others like Kanna cannot and that this is important to figure out so that they can ensure that school is a safe and healthy place for all people.
2. Have students independently come up with questions they think need to be answered in order to figure out why Kanna can't digest milk/dairy. Push students to consider the why behind many of their ideas from the **Rumors** activity (i.e. why is Kanna lactose intolerant but others are not?).
3. Have students write each one of their questions on a separate post-it note.
4. As a whole class or in small groups, have students share and categorize their questions onto chart paper. Ideally, students should be able to combine and categorize questions into 3-5 larger categories of questions to investigate.



Example Driving Question Board

Integrating Three Dimensions

Students have been engaging in **SEP#1 Asking Questions** during the Unit Openings from Units 1 and 2 when Driving Question Boards are launched, however as this element is part of the PE bundle, it is included in Unit 3 in the assessment matrix.

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?

Differentiation Point

This is the third opportunity in the course that students have had to develop a DQB. Ideally students should be able to generate relevant questions about the phenomenon, but if students are struggling, provide example questions or combine all of the questions generated across all classes to categorize into a few different categories of questions.

For more guidance on using the DQB throughout the unit, see the Biology Course Guide.

Performance Task

The Performance Task is not introduced during the Unit Opening.

Unlike in other units, the sensemaking that leads to student understanding of the need for the Performance Task is designed to take place in the first 5E -- Lactase Persistence. At that point, students begin thinking about the Mismatch Hypothesis and ways to make schools more suitable for health.

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	

Standards in Unit Opening

Performance Expectations

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems • Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. SEP1(1)		

Assessment Matrix

	Anchor Phenomenon	Driving Question Board	Performance Task
Asking Questions and Defining Problems		Rumors and the related questions on the Driving Question Board	

Common Core State Standards Connections

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

Lactase Persistence 5E

Why are some people able to digest dairy into adulthood but others cannot?

Performance Expectations
HS-LS3-1, HS-LS1-1

Investigative Phenomenon
Some people are not able to consume dairy products past infancy.

Time
9-10 days

In this 5E, students investigate how humans digest dairy and discover that the enzyme lactase has a unique structure that allows it to interact with and break down lactose. Students then investigate DNA base sequences of individuals that are able to digest dairy and others that are not. Through this investigation, students notice that all individuals have DNA that codes for lactase, but while most have a regulatory gene that stops it from being expressed after infancy, some people have inherited a mutation that allows lactase to persist into adulthood. Finally, students conclude that about 7000-9000 years ago some populations experienced a change in culture and environment that made digestion of milk advantageous past infancy, facilitating lactase persistence.

ENGAGE	Why are some people able to digest dairy into adulthood but others cannot?	Students **ask questions** after examining world maps representing **lactase persistence** across populations in order to surface ideas and questions **about how and why some people are able to digest dairy as adults** but others are not.
EXPLORE 1	How do different groups of people digest dairy products? What happens to dairy in different people's digestive systems?	Students **surface questions after closely examining a model** of enzyme **structure and function** in order to better understand how **a system of specialized cells allows for the digestion of lactose.**
EXPLAIN 1	How does lactase help digest milk?	Students **construct a scientific explanation** on how the **structure and function of** the enzyme lactase, which is **produced in specialized cells of the small intestine,** allows for the **digestion of lactose**.
EXPLORE 2	How can we investigate differences in DNA to better understand why some people have the ability to digest dairy?	Students consider **the structure and function** of **DNA** to **develop a model** that explains **differences in traits between individuals.**
EXPLAIN 2	Why are some people able to digest milk into adulthood but others cannot? How do some people have this ability?	Through a close examination of the **structure and function** of DNA, students **construct a scientific explanation** to address how the **noncoding portions of DNA may serve to regulate genes** such as the one for lactase, providing some people with lactase persistence.
ELABORATE	Why do some populations have the ability to digest milk into adulthood but not others? Why would it be advantageous to be able to digest the milk of other animals?	Students engage with a video to explore how the **structure and function of DNA** lends itself to the **accumulation of beneficial traits in a population.**
EVALUATE	How do we help redesign a school to better serve our health?	Students generate a potential list of other mismatches based on what they figured out about **evolution** and the **structure and function** of **DNA**. Then they **generate questions** to support **design to solve problems** found in schools.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

Why are some people able to digest dairy into adulthood but others cannot?

Students **ask questions** after examining world maps representing **lactase persistence** across populations in order to surface ideas and questions **about how and why some people are able to digest dairy as adults** but others are not.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Lactose Intolerance Frequency Map ❑ See-Think-Wonder ❑ Blank World Map	None	❑ *Labeled World Map* (optional) ❑ Patterns in the Distribution of Lactase Persistence - pg. 9 (optional)

Surfacing Student Ideas

1. Provide students with the *Lactose Intolerance Frequency Map* and have students surface patterns, ideas, and questions by completing the *See-Think-Wonder* organizer.

2. Use the group learning routine **Domino Discover** to surface student noticings, ideas, and questions.

Look & Listen For

- Most of the world cannot digest milk/eat dairy (are lactose intolerant)
- There are 'hotspots' or specific ranges where most people can drink milk/eat dairy
- Maybe some people have something in their digestive system that other people don't have
- Why are the hotspots where they are? What is the difference between these locations?
- Are the hotspots connected to families or populations of people?
- How do people digest milk at all? How is it different between babies and adults?
- What is in milk that makes it difficult to digest?
- Why are there some people who can digest the sugar in dairy as adults, but others cannot?

Access for All Learners

It may be helpful to provide some students with a *Labeled World Map* for reference when they are analyzing the *Lactose Intolerance Frequency Map*.

Differentiation Point

For students who are ready for additional data analysis: Using the data on pg. 9 of the article Patterns in the Distribution of Lactase Persistence have students calculate the frequency of lactose persistence (can drink milk) in multiple populations around the world. Then they can color code their own frequency map using a *Labeled World Map* and predetermined ranges for high, medium, and low frequency. Surface patterns and have the students generate questions about this investigative phenomenon (using the *See-Think-Wonder*)

Routine

This is the first time **Domino Discover** is being used in this unit. This routine is an opportunity to surface student 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 Course Guide for support with this routine.

Explore 1

How do different groups of people digest dairy products? What happens to dairy in different people's digestive systems?

Students **surface questions after closely examining a model** of enzyme **structure and function** in order to better understand how **a system of specialized cells allows for the digestion of lactose.**

Preparation

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

Materials

Handouts	Lab Supplies	Other Resources
❑ Dairy Investigation ❑ Making Sense of Dairy Investigation ❑ Dairy Investigation Model ❑ Dairy Investigation Rubric	❑ 4 beakers (or plastic cups) ❑ markers to label beakers ❑ 4 urine test strips ❑ 200 mL of water ❑ 2 g of glucose ❑ 2 mL NaOH (1 M)	❑ *Simple Lock-and-Key Diagram* ❑ *Detailed Lock-and-Key Diagram* ❑ *Dairy Investigation Results Key*

Launch

1. Remind students that they were interested in understanding how we digest milk, either as infants or adults. Point to or relevant student questions surfaced in the wonder category from the *See-Think-Wonder* from the Engage phase.

2. Prompt students to suggest ways we could better understand what happens to dairy products in different people after they consume it. Elevate student ideas connected to investigating digestive processes and/or contents from the digestive system (like intestinal fluid) in humans that have consumed dairy, animal models, or via a simulation.

Investigation

1. Provide students with the *Dairy Investigation* to examine intestinal fluid samples from four people and see what happens to milk in their digestive systems. Have students complete the investigation in groups. Each group will need the following lab materials:
    - Intestinal fluid sample for four people (approximately 50ml for each sample)
    - 4 beakers

- Markers to label beakers
- Test strips (cut the bottom four bands, so students are only looking at the top 6 bands)

In advance, set up the lab by creating the intestinal fluid samples.

Create the samples as follows:
- Kanna and Kanna's mother - water
- For Alissa and Kanna's baby brother: 2 mL of NaOH (1M), 2 g of glucose powder in 200 mL of water.

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

2. Provide students with *Simple Lock-and-Key Diagram* so they can make sense of the results. Changes in color indicate a positive result.

Implementation Tip

The investigation is a simulation: the urine test strips are used to demonstrate differences in intestinal fluid, not true results of the composition of the fluid samples. Variations in lab set up are possible, the main idea is to show that Kanna's brother and Alissa have glucose in their intestinal fluid, whereas Kanna and her mother do not. Also, we would expect that all individuals would have some variables in common in their intestinal fluid regardless of their ability to digest lactose (e.g. similar pH, presence of proteins, fats, etc.)

One option for the lab set up is to use the solutions described above and provide students with urine test strips containing at least 6 parameters, including glucose, pH, and specific gravity. Each of those will be different for Kanna and her mother compared with Alissa and Kanna's brother, and can be labeled for students as galactose, glucose, and lactase. The remaining parameters should be the same for all four samples, and can be called positive results for proteins, fats, and calcium. It is not important that the test strips actually test for what they are being labeled as, since this is a simulation.

Another option is to use water for Kanna and Kanna's mother, and glucose solution for Alissa and Kanna's brother, and then test each solution using glucose test strips. In this case, the data table would be edited to include only glucose, and students would observe that one difference between the samples.

Example Student Data Table

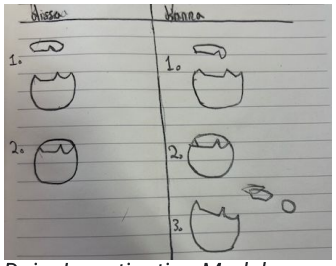
Data Table: Components of intestine contents after consuming milk

Intestine contents sample	Galactose	Proteins	Fats	Glucose	Calcium	Lactase

Kanna	-	+	+	-	+	-
Kanna's baby brother	+	+	+	+	+	+
Kanna's mother	-	+	+	-	+	-
Alissa	+	+	+	+	+	+

Example Result Key

3. After completing *Dairy Investigation*, pause and use the group learning routine, **Domino Discover**, to surface what students are seeing in the data and what questions they now have.



Dairy Investigation Model Student Work Example 1

Look & Listen For

- The baby and Alissa both had glucose in the intestine contents (while the other two did not)
- Everyone had similar intestine pH levels and protein levels
- There is something that turns milk into glucose (or takes glucose out of milk)
- What is that substance? How does it work?
- Why was Alissa able to make glucose, while the other two non-infants were not?

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

4. Elevate ideas about the differences in glucose, and ask students to elaborate on what they already know about glucose. Students may say something about sweetness or that it is a simple sugar. Listen

for ideas that help us transition to thinking about why glucose would be present in intestinal fluid after drinking milk (in some people) when milk itself is not really sweet.

Whole-Class Investigation Summary

1. Provide students with the *Making Sense of Dairy Investigation* and *Dairy Investigation Model*. Have students work individually or in pairs to make sense of a *Simple Lock-and-Key Diagram*, using a See-Think-Wonder graphic organizer to note down their ideas. Prompt students to pay close attention to the structure and properties of the model depicted in the diagram, including the different components and how they interact with each other.

Differentiation Point

If students need more information to make sense of the model of the lock and key functioning of an enzyme, provide them with *Detailed Lock-and-Key Diagram*. Alternatively, provide both versions of the model, and allow students to choose which one they would like to interact with.

2. Use the group learning routine **Consensus-Building Share** to surface high-level student observations and questions about part 2 of the investigation. Encourage students to discuss ideas about how the model, and the structure of the component parts, might help them make sense of the investigative phenomenon questions under study: Why are some people able to digest milk into adulthood but others cannot? How do some people have this ability?

Look & Listen For

- As a part of the digestive process, larger molecules can be broken down into smaller ones
- The shape of the component parts plays a role in the function of the digestive process we are looking at (lock and key model of enzyme function)
- It is possible that Kanna (people who are unable to digest milk) lacks this process or the components are missing/don't work properly OR people who can digest dairy have all the components and/or they all work properly
- We need more information about this digestive process (and its parts) to figure out why some people can digest dairy but others cannot

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 the *Dairy 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.

Integrating Three Dimensions

The prompts found in the See-Think-Wonder organizer are designed to support students in using the **CCC#6 Structure and Function.** Students should be able to start using this lens as a way to make sense of how the structure (particularly the shape) of enzymes lends itself to the function; and how the structure(s) of the enzyme/substrate complex allow us to infer its functioning in the digestive process.

Routine

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

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

Explain 1

How does lactase help digest milk?

Students **construct a scientific explanation** on how the **structure and function of** the enzyme lactase, which is **produced in specialized cells of the small intestine,** allows for the **digestion of lactose**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ Domino Discover	❑ Text Annotation

Materials

Handouts	Lab Supplies	Other Resources
❑ Digesting Dairy Text ❑ Making Sense of Dairy Investigation	None	❑ *Lactose Digestion in Infants - Transcript* (optional) ❑ Lactose Digestion in Infants (optional)

Constructing an Explanation for Lactose Intolerance

1. Return to student questions from the end of the Explore 1 phase. Chart them on the board or on poster paper.

2. Provide students with the *Digesting Dairy Text*. **Annotate** the text, looking for information that responds to our guiding question.
    - Underline information that helps us answer the guiding questions
    - Place ! next to something interesting
    - Place a ? next to something you have a question about

Differentiation Point

For students who need additional support with the *Digesting Dairy Text* text, use the Lactose Digestion in Infants video and *Lactose Digestion in Infants - Transcript* to supplement the text.

3. Ask students, in light of the text, "is there anything you'd change in your model of the two people on *Dairy Investigation Model*?" Ask students to share their responses with their group.

4. Have students revisit the *Lactose Intolerance Frequency Map*, the *See-Think-Wonder*, and the set of questions they surfaced during the Engage phase.

Integrating Three Dimensions

Keep in mind that students need to go beyond explaining how lactase helps digest milk; this Explain is designed to support them in using a crosscutting concept to do this sensemaking. Be sure to make **CCC #6 - Structure and Function** explicit for students by elevating and probing for ideas related to how the investigation of systems or structures requires a detailed examination of the structures of different components and the connections of components to reveal its function.

- Which question(s) have we answered? What do we know now?
- Which question(s) are the most important to explore to better understand what happened with Kanna?

5. Have each group choose a representative to share with the rest of the room. Use the group learning routine **Domino Discover** to surface each group's responses.

Look & Listen For

- We still don't understand why some teenagers and adults can't digest dairy when all infants can
- We know that lactase is needed to digest dairy and that lactase is a protein that is produced in cells of the small intestine
- The structure (the shape) of lactase helps us understand its' function; the shape and properties of the sugars galactose and glucose (in comparison to the sugar lactose) helps us understand its' function in the human body
- Why are there regions of people who can/can't digest dairy?
- Why are there differences between families? (why are both Kanna AND her mother unable to digest dairy?)
- Does Kanna not make lactase? And if not, why?

Explore 2

How can we investigate differences in DNA to better understand why some people have the ability to digest dairy?

Students consider **the structure and function** of **DNA** to **develop a model** that explains **differences in traits between individuals.**

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ DNA / Protein Synthesis Model ❑ DNA Comparison Investigation ❑ Making Sense of DNA Comparison ❑ DNA Comparison Investigation Rubric	None	❑ *DNA Reference Sheet*

Launch the Investigation

1. Highlight the most important unanswered questions students surfaced at the end of Explore 2.
2. Probe students on how we might further compare the trait (can/can't digest dairy) between people. If DNA, heredity, or genetics are not brought up, remind students that in Unit 2 they looked at the genetic basis of immunity, so that the idea that we can compare DNA to better understand what is going on is surfaced by the class.
3. Before diving into the lab, pause to surface student understanding of the basics of genetics / central dogma from middle school. Distribute the *DNA / Protein Synthesis Model* handout and prompt students to develop an initial model of the relationships between chromosomes, DNA, genes, and proteins.

Differentiation Point

If students struggle with attempting the model or have gaps in understanding from middle school, provide the *DNA Reference Sheet* (this scaffold can be used throughout the unit as needed)

4. Provide students with the *DNA Comparison Investigation* and have them complete it individually.

Access for All Learners

It is ok if students don't have a complete understanding of central dogma or protein synthesis yet. They will revise this model throughout the unit. Students should hold on to this model so that they can return to it.

5. After completing the investigation, provide students with the *Making Sense of DNA Comparison* for students to make sense of the data/observations they collected.

6. Give students time to independently consider the question, “what do you notice when comparing the different levels of DNA?” Prompt students to investigate the properties of the DNA they compared and the structures of the different components. Additionally, provide students the space to generate questions on the structure, properties, and function of DNA/chromosomes/genes. Then have students share their ideas in pairs.

7. Surface each pair’s ideas through the group learning routine, **Domino Discover**.

Look & Listen For

- There are no visible differences in DNA structure or in the base sequence of the lactase gene between any of the individuals
- There is a one base difference in the sequence of DNA before the lactase gene in Alissa’s DNA
- Genes are found on chromosomes and are made up of sequences of DNA. Not all DNA on a chromosome is a gene.
- Looking closely at the structure of DNA/chromosomes/genes helps us understand the function and the relationship between them
- Why is the lactase gene sequence the same, but not the region before the gene? What does that section of DNA do, and how does it confer the ability (or not) to digest lactose?

8. 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.

9. Provide students with the *DNA Comparison 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 are some people able to digest milk into adulthood but others cannot? How do some people have this ability?

Through a close examination of the **structure and function** of DNA, students **construct a scientific explanation** to address how the **noncoding portions of DNA may serve to regulate genes** such as the one for lactase, providing some people with lactase persistence.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ Class Consensus Discussion	❑ Text Annotation

Materials

Handouts	Lab Supplies	Other Resources
❑ Non-coding DNA Text ❑ CER Rubric ❑ Summary Task	None	❑ *CER Organizer* ❑ Cryptic DNA sequences may help cells survive starvation

Constructing a Scientific Explanation

1. Show students the map (from Engage) and elevate or point to unanswered questions from the Explore 2 phase and reiterate the question, "why are some people able to digest milk into adulthood but others cannot?" Let students know that they will now make further sense of what they experienced during the Explore 2 in order to answer this question.

2. Prompt students to review their initial DNA/protein model from Explore 1.

3. Provide students with the *Non-coding DNA Text* and have students **annotate** the text, highlighting or underlining information that may be useful for
    - refining or revising the DNA/Protein model
    - responding to the guiding question

4. Have students use evidence from both investigations and models presented in this learning sequence and appropriate scientific reasoning to construct a scientific explanation in response to the guiding prompt: Why are some people able to digest milk into adulthood but others cannot? How do some people have this ability, and how can medication provide a possible solution for people who do not?

Integrating Three Dimensions

Keep in mind that students need to go beyond explaining why some people are able to digest dairy into adulthood and others are not; this Explain is designed to support them in using a crosscutting concept to do this sensemaking. Be sure to make **CCC #6 - Structure and Function** explicit for students by elevating and probing for ideas related to how examining an object or systems structure can reveal how that object or system works.

Differentiation Point

Provide the *CER Organizer* as a scaffold to students who need additional support.

5. Once students have completed an initial draft of their scientific explanation, have students use the *CER Rubric* to peer or self-assess their work.

6. After students assess their models, provide time for them to revise their work.

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 unit, to learn about all the thinking in the room and come to some decisions about how some people have the ability to digest dairy in adulthood, while others do not, and how medication may be a solution for those who do not."

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 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 lactase intolerance/lactase persistence. 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

Routine

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

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

- 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.

Take Time for These Key Points

- Lactase is an enzyme produced in cells of the small intestine; its unique structure allows it to break lactose (the main sugar in milk) down into galactose and glucose
- Glucose and galactose are small enough to be absorbed into the small intestine
- Everyone has a gene on chromosome 2 that provides the information to make lactase
- All babies produce lactase, but only some adults do
- People who persist in making lactase into adulthood have a mutation in a regulatory gene that would normally shut off the production of lactase allowing the person to continue making it and digesting dairy
- The structure of DNA (non-coding DNA) allows for variations in traits without changing the structure or function of important proteins (e.g. lactase)
- The majority of teenagers and adults, including Kanna and her mother, do not have this mutation, so undigested lactose enters their large intestine, causing discomfort, diarrhea, and gas
- Lactase pills or tablets contain lactase enzymes from yeast, which can be ingested by people who are lactose intolerant, and may be a solution for some people
- The structure of lactase in pills is slightly different than human lactase, and may function slightly differently which is a drawback of that solution
- Closely investigating the properties and structures of enzymes and complex sugars (lactose) helps us understand the phenomenon and generate solutions to the problem

Classroom Supports

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

Integrating Three Dimensions

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC # 6 - Structure and Function** explicit for students by elevating and probing for ideas related to how examining an object or system's structure can reveal how that object or system works. This is an important element **CCC # 6 - Structure and Function** at the high school level.

Summary

1. Have students reflect on their learning by completing the *Summary Task* for this phase.

Differentiation Point

For students with interest in this phenomenon or have met or exceeded the standard, provide the optional text, Cryptic DNA sequences may help cells survive starvation

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; 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 do some populations have the ability to digest milk into adulthood but not others? Why would it be advantageous to be able to digest the milk of other animals?

Students engage with a video to explore how the **structure and function of DNA** lends itself to the **accumulation of beneficial traits in a population.**

Preparation

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

Materials

Handouts	Lab Supplies	Other Resources
❑ Read-Generate-Sort-Solve Organizer	None	❑ Got Lactase?

Revisit the Driving Question Board

1. Remind the class that while they now have a better understanding of why individuals, and even families like Kanna's, have difficulty digesting dairy, they still have unanswered questions about why whole regions of people are lactose intolerant and why the mutation (that confers lactase persistence) was beneficial and increased in some populations. Let them know that in order to figure out these unanswered questions, they will be watching a video about lactase.
2. Show students the video Got Lactase? , having them note ideas related to the guiding prompt: Why do some populations have the lactase enzyme that allows them to digest lactose, while others do not?
3. In groups of three, have students use the group learning routine **Read-Generate-Sort-Solve** to discuss and surface their most important ideas. Provide students with the *Read-Generate-Sort-Solve Organizer*.
4. Have each group surface ideas generated from their **Read-Generate-Sort-Solve** discussion.

Routine

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

Look & Listen For

- Something in the environment or culture changed about 7-9,000 years ago and facilitated some groups in digesting milk (in some populations); this change was most likely the domestication of animals
- The mutation (for lactase persistence) was advantageous because it provided another food source
- Being able to digest lactose is important. The structure of DNA (non-coding, regulatory regions) provides for another source of variation without changing the underlying gene. In this case that is particularly important because the production of lactase is vital for the survival of infants.

Integrating Three Dimensions

DCIs from LS4.C Adaptations are not a part of this unit's PE bundle, but this task provides a great opportunity to review and reinforce these concepts that were foregrounded in Unit 2. At the end of the elaborate, students are asked to think about the way that mutations and shared traits might help inform us about evolutionary relationships. At this point, students have not learned about common ancestry, so this is an opportunity to formatively assess their starting point with this idea.

Evaluate

How do we help redesign a school to better serve our health?

Students generate a potential list of other mismatches based on what they figured out about **evolution** and the **structure and function** of **DNA**. Then they **generate questions** to support **design to solve problems** found in schools.

Preparation

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

Materials

Handouts	Lab Supplies	Other Resources
❑ Lactase Persistence Engineering Journal ❑ Lactase Persistence Engineering Mini-Rubric	None	❑ *Visuals for Mismatch Hypothesis* ❑ post-it notes ❑ What is engineering, and who exactly is an engineer? (optional)

Surfacing Student Ideas

1. Remind students that they just examined the problem that some people experience and how the environment in a typical NYC school cafeteria is not designed to maintain their health in regards to lactose intolerance. They also just looked at an example of something that changed in our environment and lifestyle around 10,000 years ago that impacts our health today. Let them know that for people who are lactose intolerant, this is a mismatch between their body/genes and the modern western environment.

2. Prompt students to think about possible solutions to this specific mismatch problem. How could we redesign the cafeteria so that it is a safe and healthy environment for someone like Kanna? Ask students to brainstorm solutions. Chart student ideas so they can build on them later.

Look & Listen For

- Offer dairy alternatives such as nut or oat milk-based foods
- Offer lactose-free dairy alternatives
- Offer free lactase pills for those that would like to eat regular dairy foods
- Offer a wide range of dairy free foods for people to choose from
- Education campaigns in the cafeteria that encourage a variety of foods (not an over reliance on pizza) so that students feel comfortable choosing a variety of foods or dairy-free foods
- Allow off-site lunches including making space in the school day or schedule for students to buy lunch or bring lunch from home

3. Acknowledge that brainstorming solutions to this mismatch problem may not be difficult, and that there are only a limited number of possible solutions. Use this idea to transition to asking students to consider what other changes in our environment have occurred in the past 1,000+ years and how those changes might be impacting our health or how we live our lives. Have them share these ideas with a partner or in table groups.

4. Surface student ideas using the **Domino Discover** routine.

Look & Listen For

- Uber, cars, trains, and public transport - less physical movement
- Faster and further travel - contact with populations from all over the world
- Use of technology, cell phones, and internet - more communication, less interactive contact with people
- Problems with insomnia or trouble sleeping in general
- Fast food - less cooking at home, different food, access to food has changed, we typically don't grow, find, or hunt our own food
- Increased stress; increased reliance on money
- Amazon - make fewer things ourselves
- Sedentary lifestyle
- Access to medicine
- Electricity

It's ok if students do not have a clear understanding yet of the *mismatch hypothesis* - the concept that many chronic diseases are a product of a mismatch between how human bodies evolved over time (in a certain type of environment) and our current environment . They will return to this idea throughout the unit.

Differentiation Point

Students may have trouble visualizing changes in society over the past 100 or 10,000 years -- use the *Visuals for Mismatch Hypothesis* resources to support students in surfacing these ideas

Introduce the Performance Task

1. Distribute the *Lactase Persistence Engineering Journal* and *Lactase Persistence Engineering Mini-Rubric*.

2. Let students know that they will be thinking like engineers in this task. Prompt students to think about what an engineer does and how they might be both similar and different to a scientist. Generate a T-chart on board that helps students understand the work of engineers and scientists; and how they may work together to design solutions.

Example T-Chart

Work of Scientists	Work of Engineers
Construct explanations of phenomena Design experiments Ask questions about phenomena Evaluate data, explanations, and solutions to problems	Clarify/ define problems Ask questions about problems & possible solutions Design solutions based on science concepts Design prototypes Consider tradeoffs and other constraints
Common to both/ ways they work together: Collect data Test solutions Evaluate solutions using data	

3. Have students use their recent experience with designing a solution for lactose intolerance in school cafeterias (and other prior experiences with designing solutions) to surface their initial understanding of the design cycle. It's ok at this point if students do not have a clear idea of how engineering works or the design cycle, as they will return to these ideas throughout the unit.

Access for All Learners

If students are unfamiliar with the work of an engineer, use the What is engineering, and who exactly is an engineer? video to help surface ideas. Additionally or alternatively, prompt students to brainstorm how they have used Science and Engineering Practices to figure out phenomena in previous units and science classes. Use their ideas about the scientific process and Science and Engineering Practices they have engaged with to compare the work and process of engineers.

Revise and Develop Questions

1. Remind students of all the ideas they surfaced about how our environments have changed and how these changes may lead to mismatches (such as milk being served in the cafeteria). Display the list for all students to see. At this point, students should have a lot of new questions!

2. Prompt students to review their initial Driving Question Board (DQB) and determine which questions they have answered.

3. Remind students that we want to design a school environment that promotes health and ask them what they think they need to know about these lifestyle changes (mismatches) to help redesign a school to better serve their health.

4. Have students generate questions on post-it notes.

5. Facilitate students categorizing their new questions into their initial Driving Question Board, generating a revised Driving Question Board.

Standards in Lactase Persistence 5E

Performance Expectations

HS-LS1-1 **Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.**
Clarification Statement: None
Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.

In NYS the following clarification statement has been added: Emphasis should be on how the DNA code is transcribed and translated in the synthesis of proteins. Types of proteins involved in performing life functions include enzymes, structural proteins, cell receptors, hormones, and antibodies.

HS-LS3-1 **Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.**
Clarification Statement: None
Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.

In NYS the assessment boundary was removed and the following clarification statement has been added: Emphasis should be on the distinction between coding and non-coding regions of DNA.

Aspects of Three-Dimensional Learning

Science and Engineering Practices

Asking Questions and Defining Problems

- Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. SEP1(2)

Constructing Explanations and Designing Solutions

- Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. SEP6(1)
- 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)
- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. SEP6(5)

Disciplinary Core Ideas

LS1.A Structure and Function

- Systems of specialized cells within organisms help them perform the essential functions of life. LS1.A(1)
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. LS1.A(2)

LS3.A Inheritance of Traits

- Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. LS3.A(1)

LS4.A Evidence of Common Ancestry and Diversity

- Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. LS4.A(1)

Crosscutting Concepts

Patterns

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

Structure and Function

- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. CCC6(1)

Assessment Matrix

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Asking Questions and Defining Problems		*Making Sense of Dairy Investigation*			Driving Question Board
Constructing Explanations and Designing Solutions		*Dairy Investigation Model* *Dairy Investigation Model* Domino Discover	Scientific Explanation Class Consensus Discussion *Summary Task* Class Consensus Discussion	*Read-Generate-Sort-Solve Organizer*	*Lactase Persistence Engineering Journal* *Lactase Persistence Engineering Journal* *Lactase Persistence Engineering Mini-Rubric*
LS1.A Structure and Function	*See-Think-Wonder*	Domino Discover	Scientific Explanation *Making Sense of DNA Comparison* Scientific Explanation Class Consensus Discussion *Summary Task*		*Lactase Persistence Engineering Journal* *Lactase Persistence Engineering Journal* *Lactase Persistence Engineering Mini-Rubric*
LS3.A Inheritance of Traits			*Making Sense of DNA Comparison* Scientific Explanation Class Consensus Discussion *Summary Task*		*Lactase Persistence Engineering Journal* *Lactase Persistence Engineering Mini-Rubric*
LS4.A Evidence of Common Ancestry and Diversity				*Read-Generate-Sort-Solve Organizer*	
Patterns				*Read-Generate-Sort-Solve Organizer*	
Structure and Function		*Making Sense of Dairy Investigation* *Dairy Investigation Model* Consensus-Building Share (CCC6(1)) *Dairy Investigation Model* Domino Discover (CCC6(1))	*Making Sense of DNA Comparison* (CCC6(1)) Scientific Explanation Class Consensus Discussion *Summary Task* (CCC6(1))		*Lactase Persistence Engineering Journal* *Lactase Persistence Engineering Mini-Rubric*

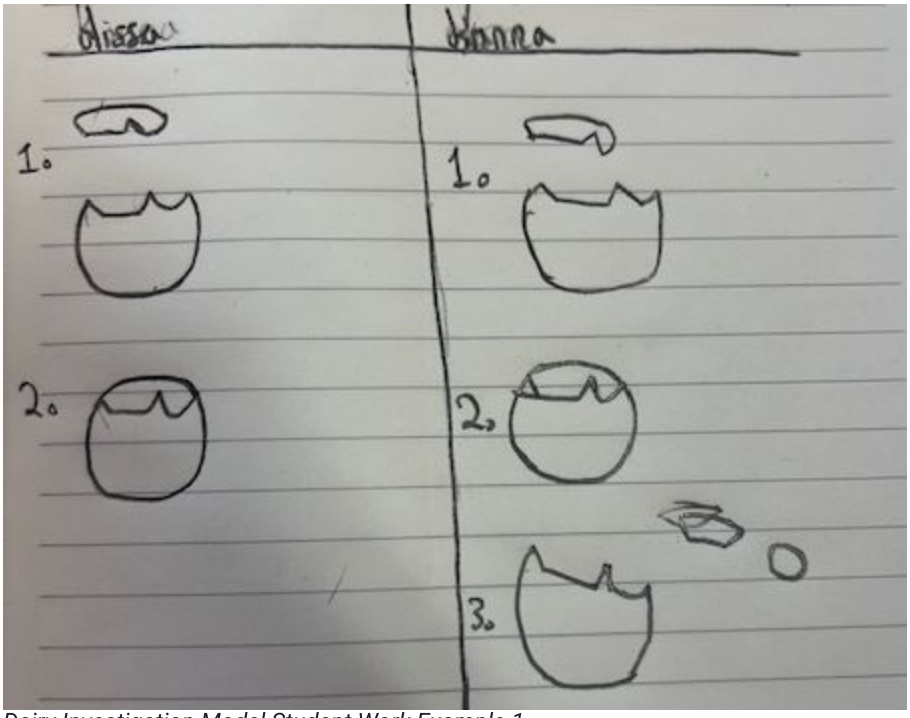
Common Core State Standards Connections

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Mathematics		MP2 MP3	MP2 MP3		
ELA/Literacy	RST.9-10.4	WHST.9-10.7 RST.9-10.1 RST.9-10.8 WHST.9-10.2 WHST.9-10.9 SL.9-10.4	WHST.9-10.7 RST.9-10.1 RST.9-10.8 WHST.9-10.2 WHST.9-10.9 SL.9-10.4	WHST.9-10.7 SL.9-10.1	SL.9-10.4

Student Work for Lactase Persistence 5E

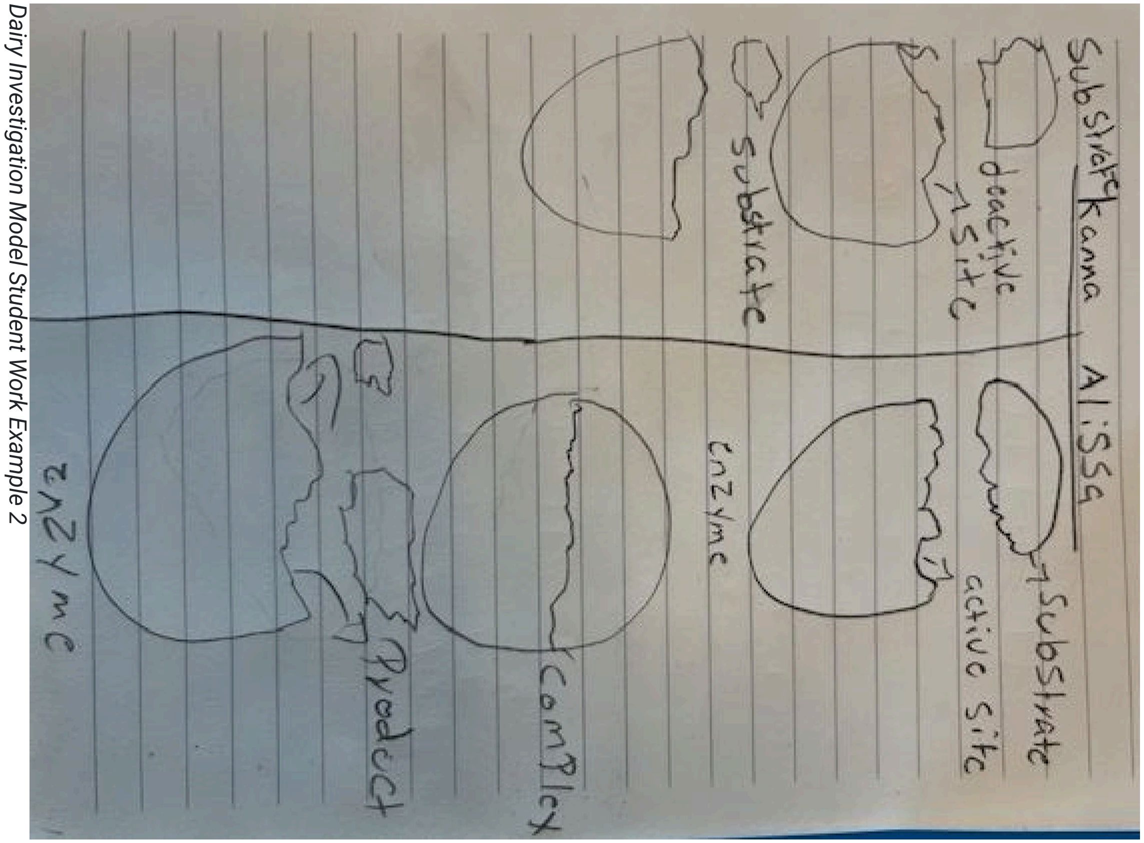
Example Dairy Investigation Model

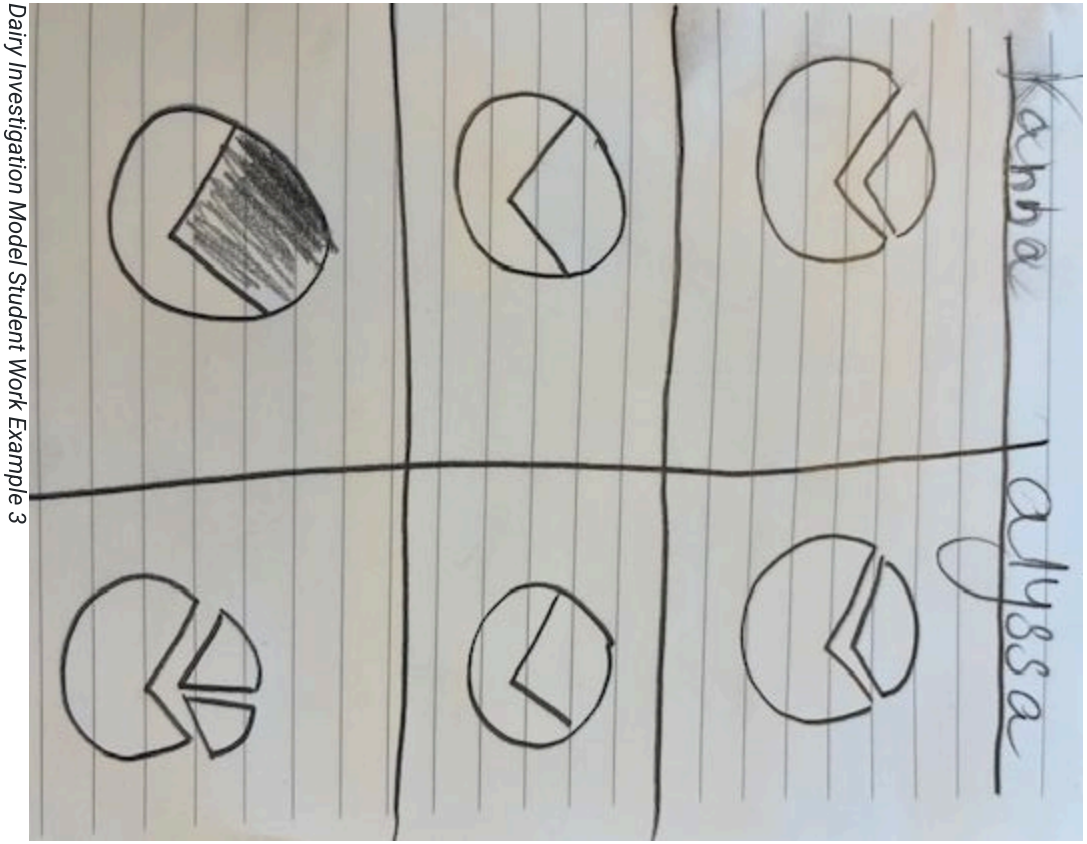
Example Models



Dairy Investigation Model Student Work Example 1

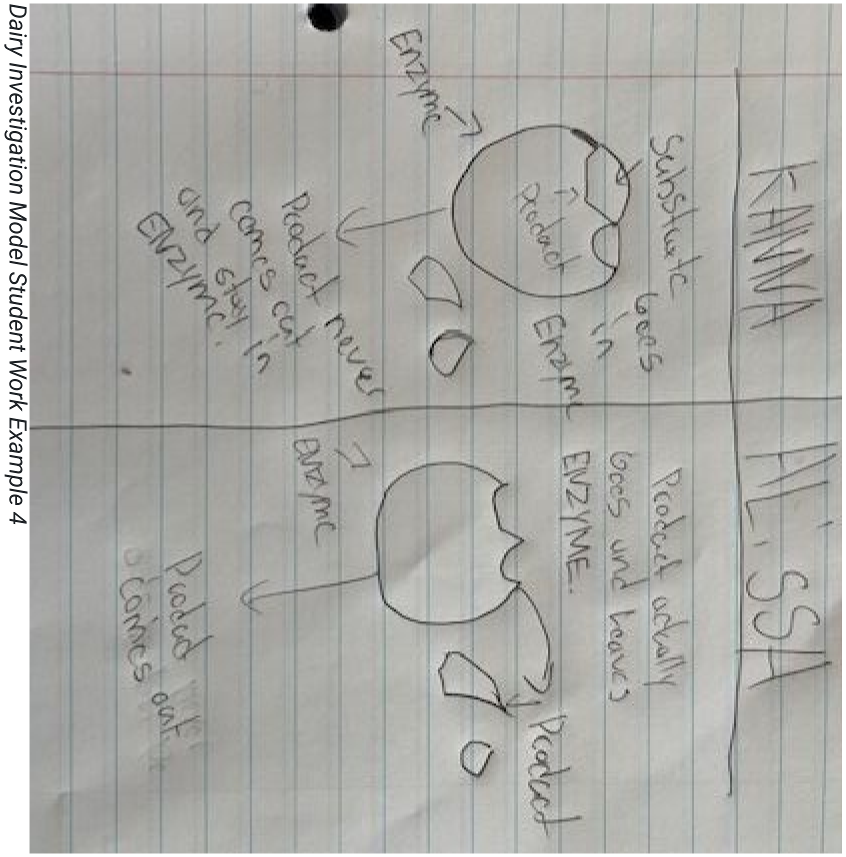
Dairy Investigation Model Student Work Example 2





Dairy Investigation Model Student Work Example 3

Dairy Investigation Model Student Work Example 4

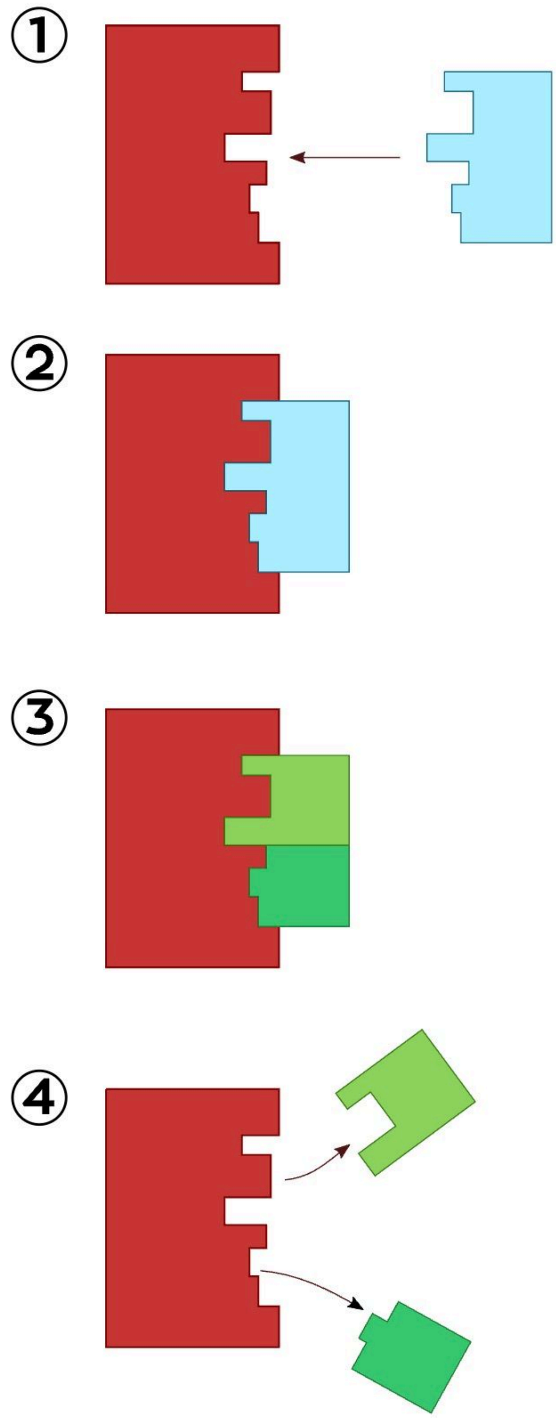


Classroom Resources for Lactase Persistence 5E

Labeled World Map
Simple Lock-and-Key Diagram
Detailed Lock-and-Key Diagram
Dairy Investigation Results Key
Lactose Digestion in Infants - Transcript
DNA Reference Sheet
CER Organizer
Visuals for Mismatch Hypothesis

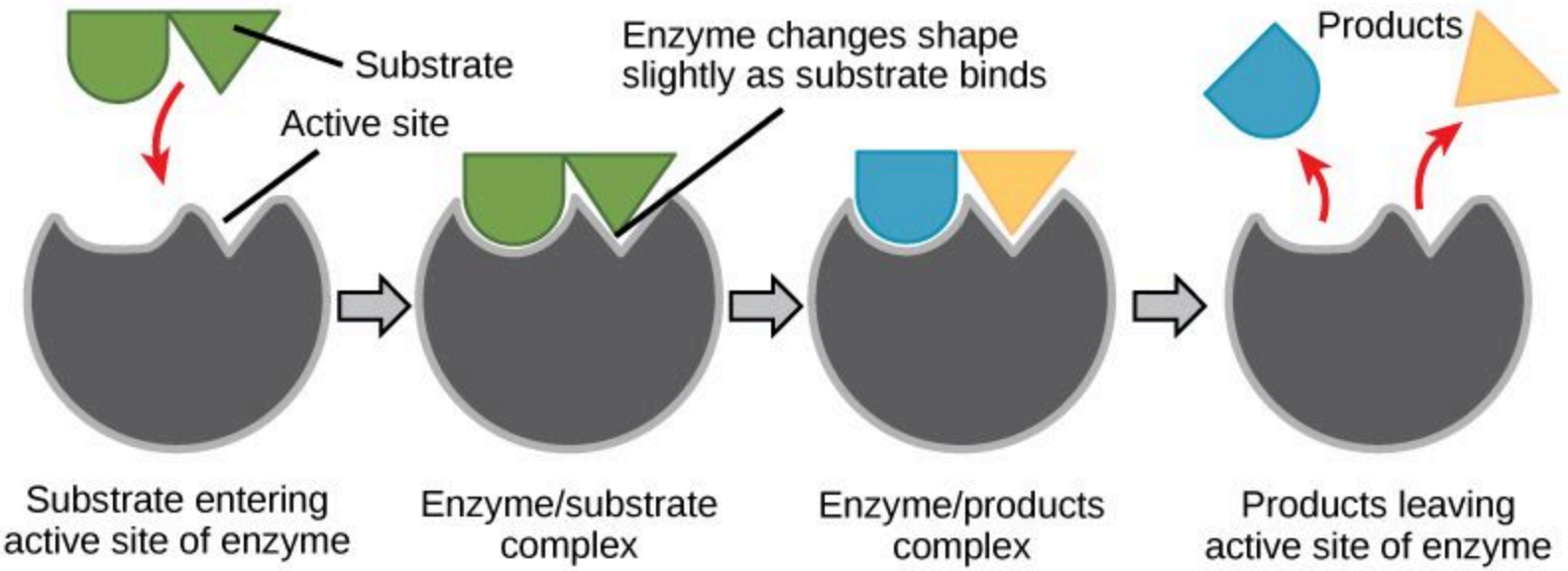
Labeled World Map

Simple Lock-and-Key Diagram



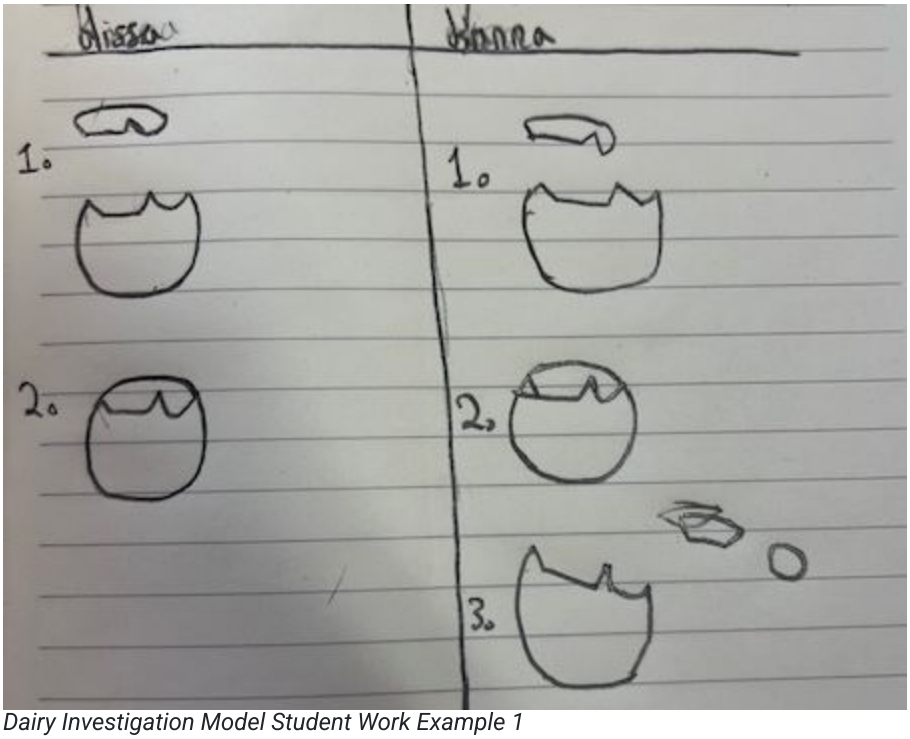
A simple diagram of the lock-and-key mechanism of enzymes.

Detailed Lock-and-Key Diagram



Induced-Fit Lock & Key Model

Dairy Investigation Results Key



Dairy Investigation Model Student Work Example 1

Lactose Digestion in Infants - Transcript

Like all young mammals, human infants depend on milk for nutrition. Milk is rich in lactose, a disaccharide made from two sugar molecules. Lactose cannot be directly absorbed in the small intestine. To digest lactose, mammals produce the enzyme lactase. The lactose binds to the active site of lactase enzyme. The enzyme hydrolyzes lactose and produces two simple sugars, glucose and galactose. These sugars are then absorbed into the capillaries of the small intestine and redistributed to the rest of the body.

DNA Reference Sheet

Larger → Smaller

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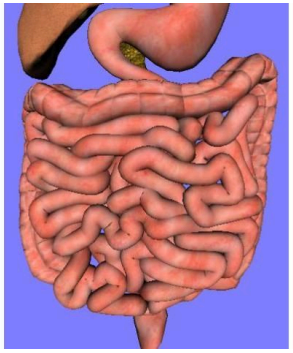
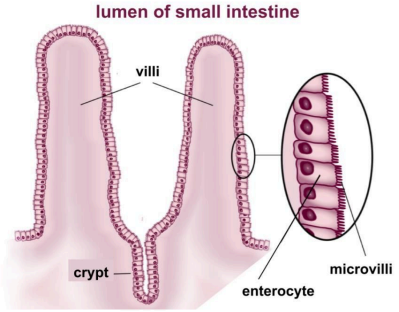
<td>  </td>
<td> 
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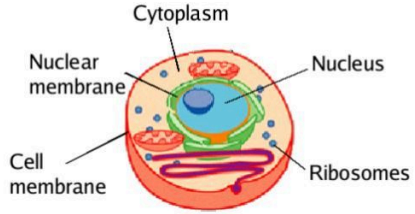
<td> 
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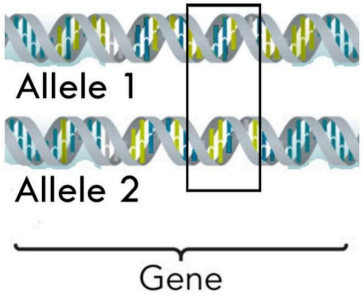
<td> 
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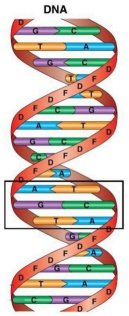
<td> 
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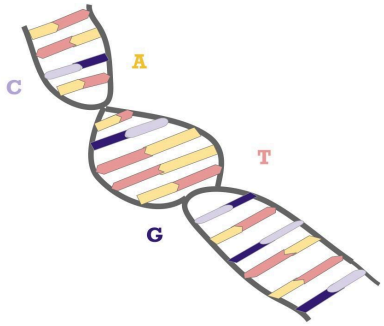
<td> 
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<tr><td colspan="4">Zooming in →</td></tr>
</table>

CER Organizer

1. Prewriting:

What is your question?

Support for your explanation

Claim based on the evidence (What is the answer to your question based on your evidence?)	Evidence (Observations/data that answers your question)	Scientific Reasoning (Why you think this happened based on background research)

2. Peer Review

Have a peer read your work and provide comments on what you plan to write.

3. Drafting

Write your explanation in paragraph form.

Scientific Explanation = Claim + Evidence + Science Reasoning

My claim is (fill in with above claim) because (evidence and science reasoning)

Visuals for Mismatch Hypothesis

Fat cat

Bacon cheeseburger and french fries

Man falling asleep at his desk

The San Bushmen

Man having trouble falling asleep (insomnia)

Woman planting seeds

New York City streets

Leptin Resistance 5E

Why is obesity increasing globally? Why do some people gain weight easily but others do not?

Performance Expectations
HS-LS3-1, HS-LS1-1

Investigative Phenomenon
Storing fat is an advantageous trait; however, some people are storing more fat than they used to (obesity is increasing).

Time
7-9 days

In this 5E instructional sequence, students are investigating the questions about obesity surfaced during the Driving Question Board launch: Why is obesity increasing globally? Why do some people gain weight easily, but others do not? While the ability to store fat was very advantageous when humans lived as hunters and gatherers, as a society, we have become increasingly sedentary, and obesity rates are increasing globally. By investigating this phenomenon, students gain a deeper understanding of the role leptin plays in regulating fat storage and how levels of leptin in our body can be impacted by variation in genes, diet, and lifestyle.

ENGAGE	Why is energy or fat storage advantageous?	Students **ask questions** based on examining a theory on why it might be **advantageous for human babies** to store excess fat.
EXPLORE 1	Why do some people store excess fat but others do not?	Students **engage with research excerpts to communicate ideas** **on possible causal relationships between excessive fat storage, diet, and the protein leptin.**
EXPLAIN 1	What role does the hormone leptin play in regulating fat storage?	Students use a sequence chart to **construct an explanation** on how **leptin resistance may be caused** by a variety of factors including diet.
EXPLORE 2	What is the role of both genetics and environmental influences in developing leptin resistance?	Students **engage with research excerpts to communicate ideas** on the **possible causal role genetics and the environment may play in excessive fat storage**.
EXPLAIN 2	How do genetic and environmental factors impact how leptin functions to regulate energy storage?	Students collaboratively generate a **scientific explanation** that describes **the relationship** between **genetics, the environment and the function of leptin in regulating fat storage.**
ELABORATE	What are other examples of resistance that inhibit important biological processes in the body?	Using the lens of **structure and function**, students consider how **dietary factors** impact the development of insulin resistance.
EVALUATE	How can we design a healthy school?	Students apply their understanding of the **causes** behind **leptin resistance** to **develop design solutions** that **take into consideration important constraints.**

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

Why is energy or fat storage advantageous?

Students **ask questions** based on examining a theory on why it might be **advantageous for human babies** to store excess fat.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs	❑ Rumors	❑ Text Graffiti

Materials

Handouts	Lab Supplies	Other Resources
❑ Text Graffiti Quotes	None	❑ Baby Fat Is About More Than Cuteness

Surfacing Student Ideas

1. Prompt students to revisit the DQB and point out questions about obesity, people getting larger, easier access to food, or sedentary lifestyles. Let students know that we will investigate these questions in this learning cycle.

2. Initiate the topic by prompting students to think about babies. Ask students to describe human babies; what they look like, what characteristics they have. Listen for the idea that human babies are often chubby. Use follow-up questions such as, "Why do you think that is?" to surface students' initial ideas about the utility of fat storage, particularly in babies. In order to explore this idea in more depth, students will read a text on baby fat.

3. Before providing the online text Baby Fat Is About More Than Cuteness , engage students with the literacy strategy, **text graffiti.** In groups of four, distribute one of the four quotes per student. Students have 1-2 minutes to quietly respond to their first quote by doing the following:
    - Highlight or circle words that they don't understand
    - Ask a question
    - Add a thought or idea about the quote
    - Underline and annotate an interesting idea

4. Ask students to pass their annotated quote to the person on their right. Provide 1-2 minutes for students to respond, letting students know they can respond to previous comments.

5. Have students continue to pass quotes and respond for 1-2 minutes until they receive their original quote.

Classroom Supports

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

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.

6. Have students read all of the annotations on the quote, and as a group, clarify any confusion or unanswered questions.

7. Prompt students to discuss what they think the text will be about and the information they will be able to extract from the text.

Differentiation Point

If students are reading at or above grade level, you may decide not to use the **text graffiti** scaffold to engage students in the text. Alternatively, provide the guiding question in advance, and prompt students to predict what information related to the prompt may be in the text before reading.

8. Distribute the online text Baby Fat Is About More Than Cuteness . Have students read the text in order to answer the guiding question “What theory does the author propose that explains why fat storage is advantageous for human babies?” and write down their ideas in their notebooks.

9. Ask students to review their ideas on the author’s theory, and prompt them to brainstorm a set of questions about the theory or points discussed in the text.

10. Have students identify their most important question, and use the group learning routine **Rumors** for students to share out their questions. Categorize questions as a class to surface important patterns and questions about fat storage.

Look & Listen For

Students may surface these questions:

- Is too much fat storage in adults similar to lactose intolerance (as fat storage is good for babies?)
- In the study of lactose intolerance, we learned about a protein, lactase. Is there a similar important protein involved in fat storage?
- Are genes involved in fat storage?
- Is it advantageous for teenagers and adults to store fat like babies?
- If fat storage is advantageous, why do we hear about so many negative health impacts about being overweight?
- Why are some babies chubby and others are not?

Access for All Learners

It's important to stress that fat storage is a trait that evolved because it is advantageous. Conveying the positive and physiological aspects of fat storage is a good way to counteract fat-shaming and insensitive or inappropriate discussion around body weight. Be sure to be sensitive to thoughts from all students on this topic and keep the discussion positive and inclusive.

Explore 1

Why do some people store excess fat but others do not?

Students **engage with research excerpts to communicate ideas** **on possible causal relationships** **between excessive fat storage, diet, and the protein leptin.**

Preparation

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

Materials

Handouts	Lab Supplies	Other Resources
❑ The Role of Leptin Investigation ❑ See-Think-Wonder Organizer ❑ The Role of Leptin Research Excerpts	None	❑ Serum Leptin Concentration Positively Correlates with Body Weight and Total Fat Mass in Postmenopausal Japanese Women with Osteoarthritis of the Knee (optional) ❑ Fructose-induced leptin resistance exacerbates weight gain in response to subsequent high-fat feeding (optional) ❑ Is fructose driving metabolic disease? | Dr Richard Johnson

Launch the Investigation

1. Revisit the key questions from the Engage phase that surfaced from the **Rumors** routine. Ask students to identify which ones are the most relevant and testable. Surface ways in which these questions could be investigated in the classroom. Listen for students to say they can be investigated either through an experiment or through analyzing secondary data sets. If students do not bring up looking at the differences in genes or proteins between people, prompt them to remember the cause behind lactose intolerance.

Look & Listen For

- When investigating lactase persistence, regulatory genes played an important role in determining if people continued to make lactase into adulthood because it regulated the creation of an important protein, lactase
- Perhaps one place to start investigating fat storage (or obesity) is examining if there is an important protein and if the gene for that protein is somehow different in either babies or between people or if differences in a regulatory gene might be important

2. Elevate student ideas to transition to the investigation that will use secondary data sets to explore the role of a protein called leptin in fat storage.

3. Distribute the *The Role of Leptin Investigation*, and a *See-Think-Wonder Organizer* graphic organizer to each student.

4. Have students engage with *The Role of Leptin Research Excerpts* (brief summaries of scientific articles that include graphs or data sets) through a jigsaw.

    a. Starting from a home group of four, assign pairs to one of two different expert groups, and provide them with the appropriate research excerpt.

    b. Have students work with their partner to generate observations and questions about the assigned study and data set using a see-think-wonder organizer.

    c. When students finish reading and have completed the *See-Think-Wonder Organizer*, prompt them to collaborate with their partner to develop a written summary of the assigned study (using the sentence frames given in the handout).

    d. Ask students to return to their home groups; each pair shares out about their study, using the written summary as a guide. Group members should be taking notes in the space provided as they listen to each summary.

    e. Finally, prompt students to collaboratively decide on high-level observations and questions about the two studies.

Access for All Learners

Fructose-induced leptin resistance exacerbates weight gain in response to subsequent high-fat feeding describes a complex experimental design. It may be helpful to work with the group(s) engaging with this article to generate a visual representation of the experimental design to ensure all students in the group are able to access the research summary.

Differentiation Point

Depending on student interest and readiness, provide students with the full scientific article to read or read portions of Serum Leptin Concentration Positively Correlates with Body Weight and Total Fat Mass in Postmenopausal Japanese Women with Osteoarthritis of the Knee and Fructose-induced leptin resistance exacerbates weight gain in response to subsequent high-fat feeding ; additionally group students intentionally as the data in Fructose-induced leptin resistance exacerbates weight gain in response to subsequent high-fat feeding is the most complex.

Investigation: Whole-Class Investigation Summary

1. Use the group learning routine, **Consensus-Building Share,** to surface high-level observations and questions from each groups' discussion.

Look & Listen For

- Both studies demonstrate a positive correlational relationship between leptin in the blood and body adiposity (weight)
- In the rats, a high fat diet and a high-fat + high fructose diet had a greater impact on weight and leptin levels than high fructose or the control diet
- Rats eating a diet high in fructose had greater food intake
- The data does not provide enough evidence to determine if leptin causes an increase in body fat (or vice versa); further investigation and empirical evidence would be needed
- What role does leptin play in regulating body weight? How does it work?
- How might the role of DNA/genes impact which people become obese?
- Do people have mutations in the leptin gene, or genes regulating the production of leptin?

2. If students don't surface any of the important observations named in the Look and Listen For, direct students back to the appropriate section of *The Role of Leptin Research Excerpts* 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 *The Role of Leptin 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.

Integrating Three Dimensions

Question frames provided in the *The Role of Leptin Investigation* and prompts in *See-Think-Wonder Organizer* are designed to support students in building towards proficiency in the **CCC #2 Cause and Effect.** Many of the question frames have been modified from **STEM Teaching Tool #41**

Explain 1

What role does the hormone leptin play in regulating fat storage?

Students use a sequence chart to **construct an explanation** on how **leptin resistance may be caused** by a variety of factors including diet.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	None	❑ Sequence Chart ❑ Text Annotation

Materials

Handouts	Lab Supplies	Other Resources
❑ Protein Synthesis Handout ❑ Protein Synthesis Text ❑ Leptin Resistance Text ❑ Leptin Resistance Sequence Chart Summary	None	❑ *Sequence Chart* ❑ Transcription ❑ Translation

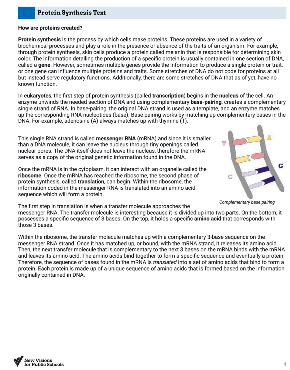
Complex Text

1. Remind students of the questions they surfaced during the Explore phase and elevate questions specifically about leptin, how it is made, and how it might work in the body. In order to start investigating these questions in more depth, we can first look at where and how leptin is made.

2. Provide students with the *Protein Synthesis Handout*, and after they have had an opportunity to watch the animations and write down their observations, provide them with the *Protein Synthesis Text*. Students use the text to summarize what they observed in the animation in the right hand column of the organizer.

Access for All Learners

If students need more time to make sense of the animations, allow them to watch them several times with the sound on. Additionally, students can follow along with the transcript that is provided below each animation.


Protein Synthesis Text

How are proteins created?

Protein synthesis is the process by which cells make proteins. These proteins are used in a variety of biochemical processes and play a role in the presence or absence of the traits of an organism. For example, through protein synthesis, skin cells produce a protein called melanin that is responsible for determining skin color. The information detailing the production of a specific protein is usually contained in one section of DNA, called a **gene**. However, sometimes multiple genes provide the information to produce a single protein or trait, or one gene can influence multiple proteins and traits. Some stretches of DNA do not code for proteins at all but instead serve regulatory functions. Additionally, there are some stretches of DNA that as of yet, have no known function.

In **eukaryotes**, the first step of protein synthesis (called **transcription**) begins in the **nucleus** of the cell. An enzyme unwinds the needed section of DNA and using complementary **base-pairing**, creates a complementary single strand of RNA. In base-pairing, the original DNA strand is used as a template, and an enzyme matches up the corresponding RNA nucleotides (base). Base pairing works by matching up complementary bases in the DNA. For example, adenosine (A) always matches up with thymine (T).

This single RNA strand is called **messenger RNA** (mRNA) and since it is smaller than a DNA molecule, it can leave the nucleus through tiny openings called nuclear pores. The DNA itself does not leave the nucleus, therefore the mRNA serves as a copy of the original genetic information found in the DNA.

Complementary base pairing

Once the mRNA is in the cytoplasm, it can interact with an organelle called the **ribosome**. Once the mRNA has reached the ribosome, the second phase of protein synthesis, called **translation**, can begin. Within the ribosome, the information coded in the messenger RNA is translated into an amino acid sequence which will form a protein.

The first step in translation is when a transfer molecule approaches the messenger RNA. The transfer molecule is interesting because it is divided up into two parts. On the bottom, it possesses a specific sequence of 3 bases. On the top, it holds a specific **amino acid** that corresponds with those 3 bases.

Within the ribosome, the transfer molecule matches up with a complementary 3-base sequence on the messenger RNA strand. Once it has matched up, or bound, with the mRNA strand, it releases its amino acid. Then, the next transfer molecule that is complementary to the next 3 bases on the mRNA binds with the mRNA and leaves its amino acid. The amino acids bind together to form a specific sequence and eventually a protein. Therefore, the sequence of bases found in the mRNA is *translated* into a set of amino acids that bind to form a protein. Each protein is made up of a unique sequence of amino acids that is formed based on the information originally contained in DNA.

Sequence Charts

1. After students have had the opportunity to engage with the concept of how all proteins are made, re-orient the class to focus on leptin. Provide students with the cut out cards for the *Sequence Chart* that explains the production and role of leptin. In pairs, students use the cards to develop an initial sequence of events.

2. Provide students with the *Leptin Resistance Text*. Have students read and **annotate** the article in order to revise their **sequence chart**:
    - ✔ for information that may help revise the sequence chart
    - **?** for information that seems confusing or you need clarification for
    - **!** for surprising or new information

3. Pairs revise the sequence chart using information from the article and student understanding of leptin resistance.

4. Provide students with *Leptin Resistance Sequence Chart Summary* and have them individually summarize their sequence chart and respond to the prompts that follow.

5. Students should make a note of their sequence in their notebooks, take a picture, or otherwise document their ideas as they will build on this concept for the remainder of the learning sequence.

Integrating Three Dimensions

Although feedback mechanisms are not a part of the PE bundle for this unit, this may be a good opportunity to review LS1.A that was addressed in Unit 1.

Explore 2

What is the role of both genetics and environmental influences in developing leptin resistance?

Students **engage with research excerpts to communicate ideas** on the **possible causal role genetics and the environment may play in excessive fat storage**.

Preparation

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

Materials

Handouts	Lab Supplies	Other Resources
❑ Role of Genetics & Environment Investigation ❑ Role of Genetics & Environment Research Summaries ❑ See-Think-Wonder Organizer	None	❑ Genetic Influences on Child Eating Behaviour (optional) ❑ The global childhood obesity epidemic and the association between socio-economic status and childhood obesity (optional)

Launch the Investigation

1. Revisit unanswered student questions from the Engage and Explore 1 phases. Students should have a better understanding of how proteins, like leptin, are created and the role leptin plays in regulating fat storage. However, students may still wonder about:
    - The genetic and environmental reasons why some people store excess fat
    - Why leptin resistance is a problem in some people (but not everyone)
    - Why fat storage is advantageous in some environments but not in others

2. In order to build on what students figured out in the Explore 1 phase, provide students with the *Role of Genetics & Environment Investigation*. Students will follow a similar process of engaging with research summaries to investigate what other factors may impact fat storage regulation.

3. In pairs, students will engage with two *Role of Genetics & Environment Research Summaries* (brief summaries of scientific articles that include graphs or data sets). Provide students with the appropriate research excerpt and a *See-Think-Wonder Organizer*.

    a. Starting from a home group of four, assign pairs to one of two different expert groups and provide them with the appropriate research excerpt.

b. Students work with their partner to generate observations and questions, using a see-think-wonder organizer about the assigned study and data set.

c. Students collaborate with their partner to develop a written summary of the assigned study (using the sentence frames given in the handout).

d. Students return to home groups; each pair shares out about their study using the written summary as a guide.

e. Group members take notes in the space provided as they listen to each summary.

f. Students collaboratively decide on high-level observations and questions about the two studies.

Differentiation Point

Depending on student interest and readiness, provide students with the full scientific article to read or read portions of Genetic Influences on Child Eating Behaviour and The global childhood obesity epidemic and the association between socio-economic status and childhood obesity

Investigation: Whole-Class Investigation Summary

1. Use the group learning routine, **Consensus-Building Share** to surface high-level observations and questions.

Look & Listen For

- Both food supply and genetic variations contribute to some eating behaviors and excessive fat storage (obesity)
- There is some empirical evidence presented in these studies for the role of genetics in general body and weight and some feeding behaviors; therefore genetics may be a contributing factor to excessive fat storage; but there needs to be additional research
- Mutations or variations in the gene for leptin do not cause most cases of excess fat storage
- There are strong associations between some environmental factors such as food supply and fat storage; but more evidence is needed to identify causality
- Obesity is increasing globally, but not all populations are increasing in obesity prevalence
- Socio-economic factors may play a role in which children & adults are storing excessive fat

2. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate sections of *Role of Genetics & Environment Research Summaries* 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 **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.

3. Provide students with *The Role of Genetics & Environment 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

How do genetic and environmental factors impact how leptin functions to regulate energy storage?

Students collaboratively generate a **scientific explanation** that describes **the relationship** between **genetics, the environment and the function of leptin in regulating fat storage.**

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Triads	❑ Think-Talk-Open Exchange ❑ Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Think-Talk-Open Exchange + Buzzwords Organizer ❑ Summary Task	None	❑ How the Hormone Leptin Helps Regulate Appetite ❑ Correlation and causality ❑ Podcast: Processed Food: A Load of Baloney?

Constructing a Scientific Explanation

1. Prompt students to reflect on the ideas and questions generated in the Engage phase. For example, students figured out that the ability to store fat is advantageous (especially in babies) but may have wondered about why, in some cases, storing excess fat (obesity) can lead to health problems.

2. Students will use the group learning routine, **Think-Talk-Open Exchange + Buzzwords** to share their ideas about this phenomenon with their peers.

3. Provide students with the *Think-Talk-Open Exchange + Buzzwords Organizer* so they can first individually write down their ideas to the guiding prompt:
    - From an evolutionary perspective, being able to store fat is an advantageous trait. However, the number of people (including children) that are storing excess fat is increasing. Using evidence and scientific reasoning from this learning cycle, construct an explanation on why some populations of people might be experiencing an increase in excess fat storage (obesity). Be sure to use the following words and ideas in your explanation: leptin resistance, gene(s), DNA, protein, cause/causal, empirical evidence.

4. After students have had an opportunity to individually write a response, group students into triads so they can discuss their ideas using the **Think-Talk-Open Exchange + Buzzwords** routine.

Routine

This is the first time the routine **Think-Talk-Open Exchange** appears in this unit! Please consult the Biology Course Guide for detailed steps about this routine. Be sue to note the details of the **+ Buzzwords** variation of this routine.

Differentiation Point

Students have had multiple opportunities in the course to use **SEP#7 Constructing Explanations**. If students need additional support in writing an explanation, provide students with a CER organizer and CER rubric.

Integrating Three Dimensions

Keep in mind that students need to go beyond explaining how genetic and environmental factors impact how leptin functions to regulate energy storage; this Explain is designed to support them in using a crosscutting concept to do this sensemaking. **CCC #2 - Cause and Effect**, specifically the idea that empirical evidence is needed to distinguish between cause and correlation, is made explicit for students by including the terms cause and empirical evidence in the 'Buzzwords' list. Assess for students' understanding of **CCC #2 - Cause and Effect** by listening to how they use the terms in context. Plan forward based on what you observe.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a **Class Consensus Discussion**. You may say something like this:
    - "We are going to use a **Class Consensus Discussion**, just like we did a few days ago, to learn about all the thinking in the room and come to some decisions about why an advantageous trait like fat storage may be leading some people to experience an excess of fat storage (obesity)."

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

Class Consensus Discussion Steps

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

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

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

3. Select written responses from two or three groups 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 proteins work in the body and the genetic and environmental factors that influence the generation or expression of the protein and its associated trait. The decision about which responses to share with the class should be based on both the ideas circulating in the classroom *and* the goals of this part of the 5E sequence.

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

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

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.

Integrating Three Dimensions

This learning sequence supports students in building proficiency in **CCC#2 Cause and Effect**. The current global problem of obesity (and the phenomenon of leptin resistance) is most likely multifactorial, and it may be challenging for students to differentiate between correlation and causation, and to identify what data or evidence they would need to make claims about causality. This video, Correlation and causality may be helpful in leading a conversation on this topic.

Take Time for These Key Points

- Leptin is one important protein that is created in fat cells that helps regulate fat storage by suppressing appetite
- Some variations in the leptin gene may cause small variations in eating behavior or weight
- Leptin resistance, in which the leptin receptor no longer functions properly (leptin no longer fits into the receptor), may be an important cause of excess fat storage
- Leptin resistance may be caused by changes in diet such as eating foods high in sugar and fat
- Variations in other genes (beyond the gene for leptin) may impact fat storage
- Environmental changes around the abundance of food, and processed food in particular, may impact fat storage
- In this learning sequence we noticed correlational relationships (e.g. leptin in blood and body weight); in making claims on causality empirical evidence (e,g, randomized controlled trials) is needed to differentiate between cause and correlation

Differentiation Point

Based on student interest and readiness, they may want to explore more about leptin and how scientists discovered the function of this protein. Prompt students to watch the optional video - How the Hormone Leptin Helps Regulate Appetite , and add new ideas to their explanation.

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.
2. The results of this task can be used to make determinations about which students need more time to engage in sensemaking about how proteins are created and do the work of maintaining life functions in the body.

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**, 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.

Differentiation Point

Students may wonder more about the role of processed food in promoting excess fat storage. Based on student interest, prompt students to listen to Podcast: Processed Food: A Load of Baloney? and discuss the evidence presented in small groups.

Elaborate

What are other examples of resistance that inhibit important biological processes in the body?

Using the lens of **structure and function**, students consider how **dietary factors** impact the development of insulin resistance.

Preparation

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

Materials

Handouts	Lab Supplies	Other Resources
❑ Read-Generate-Sort-Solve Organizer	None	❑ What Causes Insulin Resistance?

Launch Investigation

1. Students have figured out that sometimes people's bodies have become resistant to leptin which may contribute to obesity. Students may wonder if other important biological processes are impacted by the phenomenon of resistance and if it is related to our modern environment. Have students watch the video: What Causes Insulin Resistance? , with the guiding question: "Are other important biological processes impacted by the phenomenon of resistance and if so, is it related to our modern environment?"

2. Using the group learning routine **Read-Generate-Sort-Solve**, in groups of three, have students investigate the role of resistance in another important protein in the body, insulin, and how insulin resistance contributes to the prevalence of type 2 diabetes. Provide students with the *Read-Generate-Sort-Solve Organizer*.

Surface the most important ideas from each group, using the group learning routine, **Domino Discover**.

Look & Listen For

- Insulin is a protein-based hormone that allows glucose in the bloodstream to enter the cells
- Insulin allows glucose in the cell when insulin is able to attach to an insulin receptor on the outside of the cell membrane (the receptor and insulin have complementary shapes & binding sites)
- Too much fat in the cells blocks or disrupts insulins ability to attach to the receptor or to signal that glucose can enter the cells
- Eating a diet high in saturated fat may be one contributor to insulin resistance and the development of type 2 diabetes

type	Routine
text	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 support with this routine.

Evaluate

How can we design a healthy school?

Students apply their understanding of the **causes** behind **leptin resistance** to **develop design solutions** that **take into consideration important constraints.**

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs	None	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Leptin Resistance Engineering Journal ❑ Leptin Resistance Engineering Mini-Rubric	None	

Revisit the Performance Task

1. Remind students that we are concerned with how to design a healthy school, and return to students' initial ideas on the mismatch hypothesis introduced in the first 5E learning sequence (*Lactase Persistence*). Facilitate students identifying the sub-problem we are focusing on in this learning cycle – Some people have developed leptin resistance due to a combination of environmental mismatch (overabundance of processed and high fat food, lack of physical exercise) and genetic variations. Leptin resistance (along with other factors) may lead to excess fat storage.

2. Brainstorm solutions (What can we do about it to improve our schools?)
    - Brainstorm is specifically addressing the obesity problem
    - Point out that the solution should be sensitive to all members of the school community
    - Allow students to brainstorm and collaborate, but don't give a 'final' answer. Students will individually identify a solution(s) to elaborate on

3. What are the constraints when thinking about these solutions?
    - Generate a list of three or more realistic criteria and two or more constraints, including such relevant factors as cost, safety, environmental concerns, and aesthetics that specify an acceptable solution to a complex real-world problem

4. Provide students with some examples of limitations and constraints:
    - Limitation: You cannot send a message in Whatsapp faster than the speed of light. Limitations are confined by the physical possibilities.

- Constraint: You cannot send a message in Whatsapp Web with your phone's data/wifi off. This is a design-enforced constraint within Whatsapp. Constraints are enforced by human intervention.

5. Provide students with the handout *Leptin Resistance Engineering Journal* for the 2nd 5E learning sequence: Leptin Resistance. Students work individually to make sense of how the learning from this 5E sequence contributes to the overall task. Confer with students while they are working.

6. After completing their response, use the *Leptin Resistance Engineering Mini-Rubric* as self, peer, or teacher feedback on their initial design ideas.

Standards in Leptin Resistance 5E

Performance Expectations

HS-LS1-1 **Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.**
Clarification Statement: None
Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.

In NYS the following clarification statement has been added: Emphasis should be on how the DNA code is transcribed and translated in the synthesis of proteins. Types of proteins involved in performing life functions include enzymes, structural proteins, cell receptors, hormones, and antibodies.

HS-LS3-1 **Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.**
Clarification Statement: None
Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.

In NYS the assessment boundary was removed and the following clarification statement has been added: Emphasis should be on the distinction between coding and non-coding regions of DNA.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems • Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. SEP1(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) • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. SEP6(5) Obtaining, Evaluating, and Communicating Information • Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). SEP8(5)	ETS1.B Developing Possible Solutions • When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts. ETS1.B(1) LS1.A Structure and Function • Systems of specialized cells within organisms help them perform the essential functions of life. LS1.A(1) • All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. LS1.A(2)	Cause and Effect • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CCC2(1)

Assessment Matrix

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Asking Questions and Defining Problems	Rumors	*The Role of Leptin Investigation*	*Role of Genetics & Environment Investigation*		
Constructing Explanations and Designing Solutions		*Sequence Chart Leptin Resistance Sequence Chart Summary*	*Think-Talk-Open Exchange + Buzzwords Organizer* *Summary Task* Class Consensus Discussion	*Read-Generate-Sort-Solve Organizer*	*Leptin Resistance Engineering Journal* *Leptin Resistance Engineering Journal* *Leptin Resistance Engineering Mini-Rubric*
Obtaining, Evaluating, and Communicating Information		*The Role of Leptin Investigation* *See-Think-Wonder Organizer* Consensus-Building Share *Leptin Resistance Sequence Chart Summary*	*Role of Genetics & Environment Investigation* *See-Think-Wonder Organizer* Consensus-Building Share		
ETS1.B Developing Possible Solutions					*Leptin Resistance Engineering Journal*
LS1.A Structure and Function	Rumors	*Sequence Chart Leptin Resistance Sequence Chart Summary* Consensus-Building Share *Leptin Resistance Sequence Chart Summary*	*Summary Task* Class Consensus Discussion *See-Think-Wonder Organizer* Consensus-Building Share *Think-Talk-Open Exchange + Buzzwords Organizer*	*Read-Generate-Sort-Solve Organizer* Domino Discover *Read-Generate-Sort-Solve Organizer*	*Leptin Resistance Engineering Journal* *Leptin Resistance Engineering Mini-Rubric*

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Cause and Effect		*The Role of Leptin Investigation* *See-Think-Wonder Organizer* Consensus-Building Share *Sequence Chart Leptin Resistance Sequence Chart Summary*	*Role of Genetics & Environment Investigation* *See-Think-Wonder Organizer* Consensus-Building Share *Think-Talk-Open Exchange + Buzzwords Organizer* *Summary Task* Class Consensus Discussion	*Read-Generate-Sort-Solve Organizer* Domino Discover	*Leptin Resistance Engineering Journal* *Leptin Resistance Engineering Mini-Rubric*

Common Core State Standards Connections

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Mathematics		MP3 MP6 HSS-ID.C.9	MP3 MP6 HSS-ID.C.9		HSS-ID.C.9
ELA/Literacy	RST.9-10.1 WHST.9-10.9	RST.9-10.1 RST.9-10.2 WHST.9-10.7 WHST.9-10.9 SL.9-10.4	RST.9-10.1 RST.9-10.2 WHST.9-10.7 WHST.9-10.9 SL.9-10.4	RST.9-10.2 WHST.9-10.9 SL.9-10.1	RST.9-10.2 WHST.9-10.7

Classroom Resources for Leptin Resistance 5E

Text Graffiti Quotes
Sequence Chart

Text Graffiti Quotes

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

“Like my mom, many scholars have proposed that a thick layer of fat helps keep babies warm. But there isn’t much evidence that supports this theory.”

“BAT (brown adipose tissue) is a special kind of fat that’s present in all neonatal (newborn) mammals and is especially important in humans, who are unable to raise their body temperature through shivering.”

"A human baby's brain is massive relative to its body size and is estimated to use around 50 to 60 percent of a baby's energy budget. That means if there are any shortfalls in energy or if an infant's nutrition is poor, there can be serious consequences."

“While some of us can now acquire manufactured baby foods designed to do just that, such shortcuts weren’t available for the majority of human history.”

Sequence Chart

Leptin is a protein that plays a role in regulating hunger	Leptin is produced in fat cells	The leptin gene is a stretch of DNA that codes for leptin (a protein)
The leptin gene is transcribed; a copy of the gene is created called messenger RNA (mRNA)	mRNA is translated into a specific sequence of amino acids	A specific sequence of amino acids, once completed, becomes the leptin protein
Because it is made up of a specific sequence of amino acids, leptin has a specific shape	Leptin is secreted by fat cells during or right after a meal	The hypothalamus in the brain has a specific receptor for leptin; leptin fits into the receptor

Through the use of receptors, the hypothalamus can detect how much leptin is in the bloodstream	When there is a high amount of leptin in the bloodstream, the hypothalamus decreases hunger signals	When there is a low amount of leptin in the bloodstream, the hypothalamus increases hunger signals
Sometimes, the leptin receptor is overstimulated or damaged, and it can no longer detect leptin. This is called leptin resistance.	When leptin receptors do not function properly, the hypothalamus does not send signals that a person is full	Some research has found a link between leptin resistance and high-fat and high-sugar diets
The creation of leptin (protein synthesis) is made possible through the process of complementary base pairing, in which bases (A, C, G, T, U) match up with a specific partner base		

Circadian Rhythms 5E

Why do virtually all organisms have a day-night cycle? How might disruptions or environmental changes in the day-night cycle impact our health?

Performance Expectations
HS-LS3-1, HS-LS1-1, HS-ETS1-2, HS-ETS1-3

Investigative Phenomenon
All living organisms have day and night cycles that impact biological function.

Time
6-8 days

Sleep is essential to cognitive function and health in humans, yet rates of sleep problems and chronic sleep deprivation are increasing in developing countries, where aging populations, transitions to market economies, and adoption of Western lifestyles are altering sleep patterns. In this 5E students investigate day-night cycles and make conclusions about the genetic and environmental factors that affect the way human beings and other species sleep. Students apply what they learn to the development of a prototype of a bedroom that optimizes sleep.

ENGAGE	Why do virtually all organisms have a day-night cycle?	Students surface their initial ideas on what factors contribute to bad sleep, leading them to consider **why many organisms have day-night cycles** and how we may investigate this question further.
EXPLORE	How can we investigate why most organisms display a day-night cycle?	Students **investigate** **day-night cycles** in plants and **design a survey** in order to collect data on **which** environmental factors **may cause disruptions** in human day-night cycles.
EXPLAIN	How are day-night cycles regulated?	Students engage with multimedia resources to **communicate scientific ideas** on the **causality** between **genetic and environmental factors** on the regulation of the sleep-wake cycle.
ELABORATE	How could we redesign our bedrooms to optimize our sleep?	Students apply their understanding of the **molecular basis of sleep regulation** and the **structure and function** of the important components of their bedroom to **develop a bedroom design** that **optimizes** sleep.
EVALUATE	How can we design a healthy school?	Students apply their understanding of the **causes** behind **disruptions to circadian rhythms** to **develop design solutions** that **take into consideration important constraints and tradeoffs**.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

Why do virtually all organisms have a day-night cycle?

Students surface their initial ideas on what factors contribute to bad sleep, leading them to consider **why many organisms have day-night cycles** and how we may investigate this question further.

Preparation

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

Materials

Handouts	Lab Supplies	Other Resources
❑ Jeffrey's Story	None	❑ Chart paper

Surfacing Student Ideas

1. Return to the DQB and elevate questions about how sleeping patterns may have changed over time. Students may have also brought up the connection between sleep and obesity in the previous 5E learning sequence. Revisit these questions and prompt students to consider why humans (and all organisms that live longer than 24 hours) have distinct times when they are awake and when they sleep or enter a sleep-like state.
2. Provide students with the handout *Jeffrey's Story* and have them read the story of Jeffrey. This story should resonate with students, and give them an opportunity to make connections to times they have had trouble falling asleep or times they've been tired in school. Ask students to brainstorm what could be causing Jeffrey's exhaustion.
3. Use the group learning routine **Rumors** to surface and categorize student ideas.

Look & Listen For

- His body wasn't tired that early
- Using the phone kept him awake
- Blue light disrupted his sleep
- He is stressed from school

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.

4. In groups, have students brainstorm ways in which we can investigate how, when, and why most living things have periods of time they are awake and periods of time in which they sleep (or rest in some way), and what contributes to the transitions between wake time and sleep time.

5. Use the group learning routine **Consensus-Building Share** to surface high-level ideas. It may be helpful to use a graphic organizer on the board or chart paper to record student ideas.

Example poster:

How	When	Why
Use a model organism to observe how they sleep or what in the environment changes to make them sleep (or change from day activity to night activity) Investigate proteins related to sleep or being awake and how they work	Survey people on when they are awake and asleep Observe a model organism and time when they are sleeping or awake (day-night cycles) Look at research studies that tell us the usual timing of sleeping or being awake (day-night cycles)	Stop an organism from sleeping and record the changes in their functioning Look at studies that show what happens to people when they do not sleep or sleep enough Investigate if proteins are working more during sleep or other changes that happen in the body (or in a model organism) during sleep (or night cycle)

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 Example Poster as possible. Be sure to look at the Biology Course Guide for the action pattern for this routine.

Explore

How can we investigate why most organisms display a day-night cycle?

Students **investigate** **day-night cycles** in plants and **design a survey** in order to collect data on **which** environmental factors **may cause disruptions** in human day-night cycles.

Preparation

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

Materials

Handouts	Lab Supplies	Other Resources
❑ Day-Night Cycle Investigation: Part 1 ❑ Day-Night Cycle Investigation: Part 2 ❑ Making Sense of the Day-Night Cycle Investigation	❑ 1 Mimosa pudica seedling ❑ 1 digital camera or phone with a digital camera and a time-lapse photography app such as O'Snap pro ❑ 1 camera tripod	❑ Tracking Rhythms in Plants (optional) ❑ O'Snap pro (optional) ❑ Example Sleep Questionnaire (optional) ❑ Timelapse Captures How House Plants Move in the Day and Sleep at Night (optional)

Launch

1. In the Engage phase, students surfaced ideas on how to investigate why, how, and when almost all living things have a sleep-wake cycle. Using class ideas or a combination of ideas across all classes, introduce the investigation and how it is based on student suggestions. Students will use a model organism, a plant, to investigate the timing of its day-night cycle, and use both a survey and a secondary data set to investigate the day-night cycle in humans.

Investigation: Day-Night Cycle Investigation Part 1

1. Provide students with the *Day-Night Cycle Investigation: Part 1*.

2. For this part of the investigation, students will create a time-lapse video of a *M. pudica* seedling over a 24-hour period. Materials per group:
   ❑ 1 Mimosa pudica seedling
   ❑ 1 digital camera or phone with a digital camera and a time-lapse photography app such as O'Snap pro
   ❑ 1 camera tripod

Note: If you obtain *M. pudica* seeds to germinate, rather than seedlings, keep in mind that the seeds can take 8-10 days to germinate.

Implementation Tip

If it is difficult to obtain and set up the time-lapse photography for every group, this can be done as a demonstration, with all students having the opportunity to view the final video. Alternatively, use the video, Timelapse Captures How House Plants Move in the Day and Sleep at Night , for students to generate observations.

Differentiation Point

Depending on readiness and interest, students could use the online journal article, Tracking Rhythms in Plants , to read and analyze advanced data on plant day-night cycles.

Day-Night Cycle Investigation Part 2

1. In the Engage phase, students considered why a particular student might be having trouble getting enough sleep. Ask students if they have had similar experiences, and if they think other people in their communities might have had these experiences as well.
2. Provide students with the *Day-Night Cycle Investigation: Part 2*.
3. In their groups, have students design a survey, using Google Forms to collect data on their peers and their communities' day-night cycles and sleep quality. Facilitate students coming to a consensus on the form and questions with their class (or even across multiple classes) so that sufficient data can be collected. If students need support designing a form, provide the Example Sleep Questionnaire to get them started.
4. After collecting the data, have students look at the responses in groups and use the See-Think-Wonder organizer to make sense of the data they collected.

Integrating Three Dimensions

In this investigation, students design a survey in order to collect data that will inform their possible solutions to a mismatch problem, building towards the **DCI ETS1.C Optimizing the Design Solution**

Investigation: Whole-Class Investigation Summary

1. Provide students with the *Making Sense of the Day-Night Cycle Investigation*. After they have an opportunity to do the data analysis individually, prompt students to discuss their responses to summary questions #1 and #3. Use the group learning routine **Domino Discover** to surface and highlight important ideas and questions.

Look & Listen For

- Both humans and the plant we investigated have a clear day-night cycle (that may be based on light and darkness)
- Plants do not appear to 'sleep' in the same way humans do but do change their position based on the time of day (day or night time)
- Environmental variables (including light) may impact day-night cycles and sleep patterns in humans because people in the US report different levels of sleep quality than do people in pre-industrial societies
- We still need to understand why organisms have day-night cycles, and why animals (humans) sleep
- We still need to understand how different environmental variables may impact cycles and sleep quality -- and if we can evaluate causality between an environmental variable and sleep quality

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 *Day-Night Cycle Investigation Rubric*. Ask students to use the investigation rubric to self and peer assess their progress on engaging with the investigation individually and as a group.

Routine

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

Explain

How are day-night cycles regulated?

Students engage with multimedia resources to **communicate scientific ideas** on the **causality** between **genetic and environmental factors** on the regulation of the sleep-wake cycle.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ Idea Carousel ❑ Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Day-Night Cycle Notetaker ❑ Melatonin Text ❑ Summary Task	None	❑ How Plants Tell Time ❑ Why We Sleep

Launch

1. Elevate unanswered student questions from the end of the Explore phase and from student questions documented on the See-Think-Wonder organizer. Connect student questions to the 5E level questions: Why do virtually all organisms have a day-night cycle? How might disruptions or environmental changes in the day-night cycle cause our health concerns?

2. In order to further investigate these questions, have students work in triads to jigsaw the following resources. Students should note down ideas related to the guiding questions in their *Day-Night Cycle Notetaker*.

Resources:
- How Plants Tell Time video
- *Melatonin Text*
- Why We Sleep podcast - this podcast is about 45 minutes long and a great resource, but to target the important ideas within a shorter period of time, students can skip through some of the podcast. It is recommended that students listen to the following segments: 9:00-16:20; 22:15-25:00; 26:28-29:25; 32:00-34:30.

3. Use the group learning routine **Idea Carousel** to surface the thinking in the room. Prompt triads to generate a poster that best represents their ideas on the guiding question, using the CCC of Cause and Effect as a lens to explain their ideas. Students have a choice of how they visually represent their ideas

Integrating Three Dimensions

Keep in mind that students need to go beyond explaining how day-night cycles are regulated; this Explain is designed to support them in using a crosscutting concept to do this sensemaking. Be sure to make **CCC #2 - Cause and Effect** explicit for students by elevating and probing for ideas related to the concept of empirical evidence being needed to distinguish between cause and correlation.

but the following could be appropriate formats: cause & effect chart, flow chart, graphs, and annotated diagrams.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:
    - "We are going to use a **Class Consensus Discussion**, just like we did a few days ago, to learn about all the thinking in the room and come to some decisions about why organisms have a day-night (sleep-wake) cycle and how changes in environmental conditions may cause disruption in this cycle that are detrimental to our health."

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

Class Consensus Discussion Steps

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

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

5. Everyone confers in 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' poster 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 the role of melatonin in the regulation of circadian rhythms and how disruptions, particularly in sleep patterns, cause health concerns. The decision about which responses to share with the class should be based on both the ideas circulating in the classroom *and* the goals of this part of the 5E sequence.

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

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

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.

Integrating Three Dimensions

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #2 - Cause and Effect** explicit for students by elevating and probing for ideas related to the concept of empirical evidence being needed to distinguish between cause and correlation. This is an important element **CCC #2 - Cause and Effect** at the high school level.

Look & Listen For

- Melatonin is a hormone secreted from specialized cells of the pineal gland
- Melatonin is one hormone that helps to regulate the circadian rhythm
- Circadian rhythms are day-night/wake-sleep cycles that generally occur over a 24-hour period in most organisms
- Melatonin also plays a role in making humans feel sleepy; its production is inhibited in bright light but is produced as light becomes dimmer or dark out
- Sleep is a very important biological function in humans; lack of sleep has been associated with chronic disease
- Changes to our light exposure, such as lighting at night or using electronic devices, may disrupt our natural sleep cycle
- Melatonin peaks at different times for different age groups; for teenagers it peaks at a later time at night than for children and adults

6. Provide a moment for students to reflect back on the Engage and think about Jeffrey. Prompt them to consider how we can apply what we've learned about day-night cycles and the transitions between sleep and waking states to help Jeffrey feel less exhausted in school.

Summary

1. Provide students with the *Summary Task* to complete 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**, including the relationship between DNA, genes, proteins, and traits 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 could we redesign our bedrooms to optimize our sleep?

Students apply their understanding of the **molecular basis of sleep regulation** and the **structure and function** of the important components of their bedroom to **develop a bedroom design** that **optimizes** sleep.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	None	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Developing a Bedroom Prototype	None	

Developing a Prototype

1. In groups, provide students with the *Developing a Bedroom Prototype* handout.
2. Have students collaboratively return to the design process and design a prototype bedroom that addresses the mismatch between how our bodies regulate our sleep-wake cycle and our home environment.
3. After groups have generated their prototypes, choose 1 or 2 to elevate for the class based on strong examples of design components that are high leverage (address 2 or more subproblems at once). An example could be adjustable black-out shades that at evening or night block all outside light but can be opened completely to leverage morning sunlight.

Evaluate

How can we design a healthy school?

Students apply their understanding of the **causes** behind **disruptions to circadian rhythms** to **develop design solutions** that **take into consideration important constraints and tradeoffs**.

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Circadian Rhythms Engineering Journal ❑ Circadian Rhythms Engineering Mini-Rubric	None	

Revisit the Performance Task

1. Remind students that in this learning sequence, they have investigated a new subproblem: The majority of organisms have a day-night cycle.
2. Ask students to recap what they have learned through this investigation. Listen for students to share what they learned about the role melatonin plays in regulating our day-night cycle and how changes in our environment may be disrupting how melatonin regulates the cycle, resulting in the mismatch problem of disrupted sleep.
3. Building off of students' ideas from the elaborate or from their engineering journal from the previous learning cycle (Leptin Resistance), introduce the idea of developing a prototype design.
4. Facilitate students surfacing their prior understanding of a prototype (a first, typical, or preliminary model of something, from which other forms are developed or copied.)
5. Provide students with the *Circadian Rhythms Engineering Journal* for the 3rd 5E learning sequence: Circadian Rhythms.
6. Have students work individually to make sense of how the learning from this 5E sequence contributes to the overall task and confer with students while they are working.

7. After students complete their responses, use the Circadian Rhythms *Circadian Rhythms Engineering Mini-Rubric* as a tool for self, peer, or teacher feedback on their initial design ideas.

Standards in Circadian Rhythms 5E

Performance Expectations

HS-LS1-1 **Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.**
Clarification Statement: None
Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.

In NYS the following clarification statement has been added: Emphasis should be on how the DNA code is transcribed and translated in the synthesis of proteins. Types of proteins involved in performing life functions include enzymes, structural proteins, cell receptors, hormones, and antibodies.

HS-LS3-1 **Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.**
Clarification Statement: None
Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.

In NYS the assessment boundary was removed and the following clarification statement has been added: Emphasis should be on the distinction between coding and non-coding regions of DNA.

HS-ETS1-2 * **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**
Clarification Statement: None
Assessment Boundary: None

HS-ETS1-3 * **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.**
Clarification Statement: None
Assessment Boundary: None

The performance expectations marked with an asterisk (*) integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems • Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. SEP1(2) Constructing Explanations and Designing Solutions • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. SEP6(5) Obtaining, Evaluating, and Communicating Information • Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). SEP8(5)	ETS1.B Developing Possible Solutions • When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts. ETS1.B(1) ETS1.C Optimizing the Design Solution • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. ETS1.C(1) LS1.A Structure and Function • Systems of specialized cells within organisms help them perform the essential functions of life. LS1.A(1) • All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. LS1.A(2)	Patterns • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. CCC1(1) Cause and Effect • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CCC2(1) Structure and Function • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. CCC6(1)

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Asking Questions and Defining Problems		• *Making Sense of the Day-Night Cycle Investigation*			
Constructing Explanations and Designing Solutions			*Summary Task*	*Developing a Bedroom Prototype*	*Circadian Rhythms Engineering Journal* *Circadian Rhythms Engineering Mini-Rubric*
Obtaining, Evaluating, and Communicating Information			Idea Carousel Class Consensus Discussion *Summary Task*		
ETS1.B Developing Possible Solutions				*Developing a Bedroom Prototype*	*Circadian Rhythms Engineering Journal* *Circadian Rhythms Engineering Mini-Rubric*
ETS1.C Optimizing the Design Solution				*Developing a Bedroom Prototype*	*Circadian Rhythms Engineering Journal* *Circadian Rhythms Engineering Mini-Rubric*
LS1.A Structure and Function	Consensus-Building Share		Idea Carousel Class Consensus Discussion *Summary Task*	*Developing a Bedroom Prototype*	*Circadian Rhythms Engineering Journal* *Circadian Rhythms Engineering Mini-Rubric*
Patterns		• *Making Sense of the Day-Night Cycle Investigation*			
Cause and Effect		*Making Sense of the Day-Night Cycle Investigation*	Idea Carousel Class Consensus Discussion *Summary Task*		*Circadian Rhythms Engineering Journal* *Circadian Rhythms Engineering Mini-Rubric*
Structure and Function				*Developing a Bedroom Prototype*	

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics		MP2 HSS-ID.C.9	MP3		HSS-ID.C.9
ELA/Literacy		RST.9-10.9 WHST.9-10.7 SL.9-10.1	WHST.9-10.9 SL.9-10.4	WHST.9-10.2	WHST.9-10.7 SL.9-10.1

Common Ancestry 5E

Why aren't we just evolving to address mismatch problems?

Performance Expectations
HS-LS4-1

Investigative Phenomenon
There are mismatches between our biological traits that have evolved over a long period of time and our current environment.

Time
5-8 days

Throughout this unit students have investigated several "mismatches" between human traits and our current environment. In this 5E instructional sequence, students explore how and why these mismatches and others may have occurred by analyzing patterns of evolution at different time scales. From these patterns, students are able to conclude that human traits don't evolve quickly enough to resolve mismatch diseases because our current environment has changed too quickly relative to the pace of human evolution. Students then consider this learning as they refine and evaluate their ideas for designing a school environment that addresses human mismatch diseases.

ENGAGE	Why are animals as different as humans and insects experiencing day-night cycle related mismatch diseases?	Students surface their initial ideas on why there are shared **mismatches between animal bodies and the current environment**.
EXPLORE	How can we investigate genetic variations for important molecules across different species to better understand how traits evolve over time?	Students use the NCBI **genetic database to analyze patterns** in **amino acid sequences** in order to compare similarities and differences in important proteins across different species.
EXPLAIN	Why do we experience mismatch diseases, and why can't we evolve quickly to solve them?	Students consider how **patterns** in the **fossil record, embryology, and amino acid sequences provide evidence for common ancestry** in order to **construct a scientific explanation** on the evolutionary context for mismatch diseases.
ELABORATE	What other mismatch diseases are impacting society?	Students investigate additional diseases looking for **patterns** of **common ancestry** and the **conservation of important biological molecules** to **construct explanations** for these potential mismatch diseases.
EVALUATE	How can we design healthy schools?	Students apply their understanding of the **causes** behind **mismatch diseases** to **develop and optimize design solutions** that **take into consideration important constraints and tradeoffs**.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

Why are animals as different as humans and insects experiencing day-night cycle related mismatch diseases?

Students surface their initial ideas on why there are shared **mismatches between animal bodies and the current environment**.

Preparation

Student Grouping	Routines	Literacy Strategies
None	❑ Rumors	None

Materials

Handouts	Lab Supplies	Other Resources
❑ A Shared Mismatch	None	

Surfacing Student Ideas

1. Prompt students to list the different things we've seen so far in this unit that are examples of humans having traits that don't "match" well to our current environment.

Look & Listen For

- Leptin resistance
- Melatonin and regulating circadian rhythms
- Insulin resistance
- Lactase persistence (or intolerance)

2. Ask students to consider whether other organisms might have mismatches, and if so, why they might exist Provide students with *A Shared Mismatch* handout.

3. Use the group learning routine **Rumors** to surface and categorize student ideas about why there are shared mismatches across the animal kingdom.

4. Listen for the ideas related to evolution, natural selection, or the speed at which traits change in our genomes. Students may wonder if our bodies, molecules, or receptors for important molecules can change to be better adapted to our current environment. If students do not bring these ideas up, provide further probing questions such as:
    - Where do traits come from?
    - How do traits change?

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.

- Do other organisms share these molecules or traits? Do they cause mismatches in other organisms?
- How do traits change in response to the environment? Provide examples.
- Reflect on any of the examples of natural selection discussed in unit 2 (rock pocket mice, human immune systems, animal behaviors) and prompt students to discuss those examples, looking for ideas on how it connects to the mismatch hypothesis.

Explore

How can we investigate genetic variations for important molecules across different species to better understand how traits evolve over time?

Students use the NCBI **genetic database to analyze** **patterns** in **amino acid sequences** in order to compare similarities and differences in important proteins across different species.

Preparation

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

Materials

Handouts	Lab Supplies	Other Resources
❑ Comparing Amino Acid Sequences Investigation ❑ Making Sense of the Comparing Amino Acid Sequences Investigation ❑ Comparing Amino Acid Sequences Investigation Rubric	None	❑ NCBI Genetic Database

Launch

1. Remind students that we are interested in understanding why evolutionary mismatches occur, and why our and other organisms' bodies aren't evolving to address these mismatches. In order to investigate these questions, students will use the NCBI Genetic Database to compare important molecules (or their receptors) to better understand variations in these molecules across different species.

2. Have students work in groups and provide each student with the *Comparing Amino Acid Sequences Investigation*. Confer with students as they complete the investigation using the database.

Differentiation Point

The NCBI Genetic Database provides multiple opportunities for students to investigate protein structure and to compare amino acid sequences. Depending on student interest and readiness, provide students time to pose questions and explore the database

Implementation Tip

It may be helpful to run the investigation using the NCBI Genetic Database in advance. There are steps that are easy to get lost in the database, being familiar with the database and steps to run the analysis is very helpful. Example student results are found below.

Example Student Data Tables

Table 1. Amino Acid Sequence comparison from NCBI Database

	Amino acid sequence for leptin receptor	Amino acid sequence for insulin receptor	Amino acid sequence for lactase	Amino acid sequence Melatonin receptor
Humans	100%	100%	100%	100%
mouse	75.30%	80.00%	83.11%	80.91%
chimpanzee	98.80%	95.45%	98.81%	98.90%
Rainbow trout	31.85%	48.28%	54.57%	67.77%
Fruit fly	No data	27.78%	47.45%	25.54%

Data Table 2. Divergence Times

Organism	Divergence time from humans (estimated time in million years ago)
Humans	0 mya
Mouse	89 mya
Chimpanzee	6.4 mya
Rainbow Trout	433 mya
Fruit fly	736 mya

Investigation: Whole-Class Investigation Summary

1. After students have completed the investigation, provide them with the *Making Sense of the Comparing Amino Acid Sequences Investigation* to complete individually.

2. Have students discuss their responses to the *Making Sense of the Comparing Amino Acid Sequences Investigation* in pairs.

3. Prompt students to identify their most important pattern and most important question to share with the class. Use the group learning routine, **Domino Discover** to surface students' ideas.

Look & Listen For

All of the proteins show a similar pattern when comparing the a.a. Sequence to humans; with most similar to least similar: Chimpanzees, Mouse, Rainbow trout, Fruit fly

All of the times of divergence also show a similar pattern; with closest divergence time to the farthest divergence time to humans: Chimpanzees, Mouse, Rainbow trout, Fruit fly

The fact that all the organisms studied have similar melatonin receptors helps explain why they all experience day-night cycle-related mismatch disorders

Students may wonder:

- Why do both of these data sets show a similar pattern?
- Why do all of these organisms have the same proteins as humans?
- What does divergence time mean? How is it calculated?
- How do these patterns help us understand mismatches between our genes and the current environment?
- How do these patterns help us understand why we haven't evolved fast enough to solve mismatch problems?

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

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

Routine

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

Explain

Why do we experience mismatch diseases, and why can't we evolve quickly to solve them?

Students consider how **patterns** in the **fossil record, embryology, and amino acid sequences provide evidence for common ancestry** in order to **construct a scientific explanation** on the evolutionary context for mismatch diseases.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ Think-Talk-Open Exchange ❑ Class Consensus Discussion	❑ Claim-Evidence-Reasoning (CER)

Materials

Handouts	Lab Supplies	Other Resources
❑ Common Ancestry Text ❑ Think Talk Open Exchange + Buzzwords Organizer	None	❑ Guess the Embryo Matching Game

Investigation: Constructing an Explanation for Mismatch Diseases

1. Elevate unanswered student questions from the end of the Explore phase. Prompt students to identify 2-3 of their most important questions.
2. Provide students with the *Common Ancestry Text*. Have students annotate the text looking for information relevant to their top 2-3 questions.
3. Provide students with the *Think Talk Open Exchange + Buzzwords Organizer* and have students respond individually before engaging in conversation in triads.
4. Support students in using the group learning routine, **Think-Talk-Open Exchange + Buzzwords** to discuss their ideas related to the following prompt:
    - Construct a scientific explanation using evidence and scientific reasoning from the unit that explains the phenomenon under study: Why do we have mismatches between our genes (and traits) and our current environment?

Access for All Learners

Students may struggle to visualize how embryo structure can be used to understand evolutionary relationships. Use this Guess the Embryo Matching Game to engage students in comparing embryos of different organisms.

Differentiation Point

Students have had multiple opportunities to construct a scientific explanation. If needed, continue to provide the CER Organizer and CER Rubric as scaffolds.

Integrating Three Dimensions

Keep in mind that students need to go beyond explaining why we experience mismatch diseases, and why we can't evolve quickly to solve them; this Explain is designed to support them in using a crosscutting concept to do this sensemaking. **CCC #1 - Patterns**, specifically the idea that patterns at each of the scales at which a system is studied provide evidence for causality in explanations of phenomena, is made explicit for students by including the terms timeframe and patterns at different scales in the 'Buzzwords' list. Assess for students' understanding of **CCC #1 - Patterns** by listening to how they use the terms in context. Plan forward based on what you observe.

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 unit, to learn about all the thinking in the room and come to some decisions about why we experience mismatch diseases, and why we can't evolve quickly to resolve them."

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.

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

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

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

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

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.

Integrating Three Dimensions

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #1 - Patterns** explicit for students by elevating and probing for ideas related to the concept of patterns at each of the scales at which a system is studied provide evidence for causality in explanations of phenomena. This is an important element **CCC #1 - Patterns** at the high school level.

Take Time for These Key Points

- All organisms evolved from a shared common ancestor.
- One line of evidence for this is shared DNA, particularly genes. Comparing genes or amino acid sequences demonstrates how closely related organisms are. This was shown in our lab in which all of the protein sequences were most similar to chimpanzees and least similar with fruit flies.
- Because we inherited these genes from a common ancestor, it demonstrates that:
    - It is an important gene (the function of the protein is very important for survival).
    - It has not changed very much from the original, or it doesn't tend to change especially over shorter time periods.
    - Mismatches between our genes and our environments may affect other organisms because they have similarities in their genes and also do not change over shorter time periods
- Looking closely at patterns of evolution at different time scales helps us understand the pace of evolution and why our bodies can't (or don't) evolve quickly enough to resolve mismatch diseases because our current environment changed relatively quickly, while the evolution of advantageous traits does not happen at the same pace.

Summary

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

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

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**, 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 other mismatch diseases are impacting society?

Students investigate additional diseases looking for **patterns** of **common ancestry** and the **conservation of important biological molecules** to **construct explanations** for these potential mismatch diseases.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs	None	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Additional Mismatch List ❑ Mismatch Analysis	None	

Investigation: Investigating and Explaining an Additional Mismatch Disease

1. Provide students with the document *A Shared Mismatch*. Give students time to review and discuss the list of mismatch diseases.
2. Provide students with *Mismatch Analysis*. Prompt students to investigate one example of their choice in more depth.
3. Students should work in pairs to identify at least one protein or other important biological molecule (or a trait that is primarily genetic in nature) that is connected to the mismatch, so they can explain the scientific concept behind the mismatch.

Evaluate

How can we design healthy schools?

Students apply their understanding of the **causes** behind **mismatch diseases** to **develop and optimize design solutions** that **take into consideration important constraints and tradeoffs**.

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Common Ancestry Engineering Journal ❑ Common Ancestry Engineering Mini-Rubric	None	

Revisit the Performance Task

1. Remind students that in this learning sequence, they have investigated a new subproblem: There are many examples of the mismatch between our bodies, particularly specific molecules and proteins, and our current environment. It is unlikely that these molecules will evolve quickly enough to solve our mismatch diseases because they are highly conserved across a wide range of organisms.

2. Build off of student ideas from the previous learning cycle in which they developed an initial prototype design. Encourage students to suggest ways in which they could evaluate or test their initial design. If needed, remind students that they created a survey in the 2nd learning cycle that could be used to gather data on the elements of their design or to optimize their design.

3. Provide students with the *Common Ancestry Engineering Journal* for the 4th 5E learning sequence: Common Ancestry. Students work individually to make sense of how the learning from this 5E sequence contributes to the overall task. Confer with students while they are working.

4. After completing their responses, have students use the Common Ancestry *Common Ancestry Engineering Mini-Rubric* as a tool for self, peer, or teacher feedback on their initial design ideas.

Standards in Common Ancestry 5E

Performance Expectations

HS-LS4-1 **Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.**
Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.
Assessment Boundary: None

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems • Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. SEP1(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) • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. SEP6(5)	ETS1.B Developing Possible Solutions • When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts. ETS1.B(1) ETS1.C Optimizing the Design Solution • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. ETS1.C(1) LS1.A Structure and Function • Systems of specialized cells within organisms help them perform the essential functions of life. LS1.A(1) • All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. LS1.A(2) LS4.A Evidence of Common Ancestry and Diversity • Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. LS4.A(1)	Patterns • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. CCC1(1)

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Asking Questions and Defining Problems		*Making Sense of the Comparing Amino Acid Sequences Investigation* Domino Discover			
Constructing Explanations and Designing Solutions			*Think Talk Open Exchange + Buzzwords Organizer* Think-Talk-Open Exchange + Buzzwords Class Consensus Discussion	*Mismatch Analysis* *Mismatch Analysis*	*Common Ancestry Engineering Journal* *Common Ancestry Engineering Mini-Rubric*
ETS1.B Developing Possible Solutions				*Mismatch Analysis*	*Common Ancestry Engineering Journal* *Common Ancestry Engineering Mini-Rubric*
ETS1.C Optimizing the Design Solution				*Mismatch Analysis*	*Common Ancestry Engineering Journal* *Common Ancestry Engineering Mini-Rubric*
LS1.A Structure and Function				*Mismatch Analysis*	
LS4.A Evidence of Common Ancestry and Diversity	Rumors	*Making Sense of the Comparing Amino Acid Sequences Investigation* Domino Discover			*Common Ancestry Engineering Journal* *Common Ancestry Engineering Mini-Rubric*
Patterns		*Making Sense of the Comparing Amino Acid Sequences Investigation* Domino Discover	*Think Talk Open Exchange + Buzzwords Organizer* Think-Talk-Open Exchange + Buzzwords Class Consensus Discussion	*Mismatch Analysis*	*Common Ancestry Engineering Journal* *Common Ancestry Engineering Mini-Rubric*

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics		MP2	MP3 MP6		
ELA/Literacy		WHST.9-10.7	RST.9-10.1 RST.9-10.2 WHST.9-10.2 SL.9-10.1	WHST.9-10.7	RI.11-12.7 WHST.9-10.7

Unit Closing

How can we design a healthy school in terms of reducing mismatches between our bodies and our environment?

Performance Expectations
HS-LS1-1, HS-ETS1-2, HS-ETS1-3, HS-LS3-1, HS-LS4-1

Anchor Phenomenon
A high school student who recently arrived in New York City is unable to drink milk at lunch like her peers without getting sick.

Time
2-3 days

Based on the investigations and learning throughout the unit, students generate a design solution that addresses mismatch concerns in the school environment.

ANCHOR PHENOMENON	Why are mismatch problems occuring, and why is this a problem we may need to address?	Students generate more ideas that explain mismatch diseases.
DRIVING QUESTION BOARD	What questions about mismatch diseases have we not answered yet?	Based on the investigations and learning throughout the unit, students return to the Driving Question Board to reflect on questions generated throughout the unit.
PERFORMANCE TASK	How can we design a healthy school in terms of reducing mismatches between our bodies and our environment?	Based on the investigations and learning throughout the unit, students generate a design solution that addresses mismatch concerns in the school environment.
UNIT REFLECTION	How can we evaluate our progress on using a design process to solve a problem?	Students reflect on their learning and use of a design process throughout the unit.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Anchor Phenomenon

Why are mismatch problems occuring, and why is this a problem we may need to address?

Students generate more ideas that explain mismatch diseases.

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	

Generating Ideas about Anchor Phenomenon

1. Students return to the anchor phenomenon of Kanna, and recall the other mismatches presented across the unit. They review their ideas on the mismatch hypothesis, why mismatch problems are occuring, and why this might be a problem we need to address.

Driving Question Board

What questions about mismatch diseases have we not answered yet?

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

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	❑ Driving Question Board

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.

Performance Task

How can we design a healthy school in terms of reducing mismatches between our bodies and our environment?

Based on the investigations and learning throughout the unit, students generate a design solution that addresses mismatch concerns in the school environment.

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Final Design Task ❑ Final Design Rubric	None	

Generate a Design Solution

1. Prompt students to review all of the mismatch problems and design elements that they have investigated and evaluated throughout the unit.
2. Students will decide on which design elements are the best supported, using scientific reasoning, outside research, and the collaborative design process they have iterated on throughout the unit.
3. Provide students with the *Final Design Task*, the *Final Design Rubric*, and the opportunity to review all of the initial designs and associated feedback from throughout the unit.
4. Students individually develop their final design and rationale.

Integrating Three Dimensions

Throughout this unit, students have used both **CCC#2 Cause and Effect** and **CCC#6 Structure and Function** to both understand the phenomena and to design solutions to the mismatch problem. In the final design task, students may choose to explain how they use one or both of these cross-cutting concepts in the rationale for their design.

Unit Reflection

How can we evaluate our progress on using a design process to solve a problem?

Students reflect on their learning and use of a design process throughout the unit.

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Argument Evaluation ❑ Final Design Rubric	None	

Reflecting on the Engineering Design Process

1. Remind students that they started the unit by generating an initial set of design ideas and ideas about how engineers and scientists work together to solve problems.
2. Prompt students to identify how their thinking has changed on the work of engineers and how an iterative design process can be used to solve societal problems. Support the generation of student ideas by showing examples of initial designs or initial ideas on the design process.
3. Provide students with the *Argument Evaluation* to complete individually.
4. Use the *Final Design Rubric* to provide feedback as students are working.

Standards in Unit Closing

Performance Expectations

HS-LS1-1 **Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.**
Clarification Statement: None
Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.

In NYS the following clarification statement has been added: Emphasis should be on how the DNA code is transcribed and translated in the synthesis of proteins. Types of proteins involved in performing life functions include enzymes, structural proteins, cell receptors, hormones, and antibodies.

HS-LS3-1 **Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.**
Clarification Statement: None
Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.

In NYS the assessment boundary was removed and the following clarification statement has been added: Emphasis should be on the distinction between coding and non-coding regions of DNA.

HS-LS4-1 **Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.**
Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.
Assessment Boundary: None

HS-ETS1-2 * **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**
Clarification Statement: None
Assessment Boundary: None

HS-ETS1-3 * **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.**
Clarification Statement: None
Assessment Boundary: None

The performance expectations marked with an asterisk (*) integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Aspects of Three-Dimensional Learning

Science and Engineering Practices

Asking Questions and Defining Problems
- Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. SEP1(2)

Analyzing and Interpreting Data
- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. SEP4(1)

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)
- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. SEP6(5)

Obtaining, Evaluating, and Communicating Information
- Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). SEP8(5)

Disciplinary Core Ideas

ETS1.B Developing Possible Solutions
- When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts. ETS1.B(1)

ETS1.C Optimizing the Design Solution
- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. ETS1.C(1)

LS1.A Structure and Function
- Systems of specialized cells within organisms help them perform the essential functions of life. LS1.A(1)
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. LS1.A(2)

LS3.A Inheritance of Traits
- Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. LS3.A(1)

LS4.A Evidence of Common Ancestry and Diversity
- Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by

Crosscutting Concepts

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

Structure and Function
- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. CCC6(1)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
	comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. LS4.A(1) LS4.C Adaptation • Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. LS4.C(1) • Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. LS4.C(2)	

Assessment Matrix

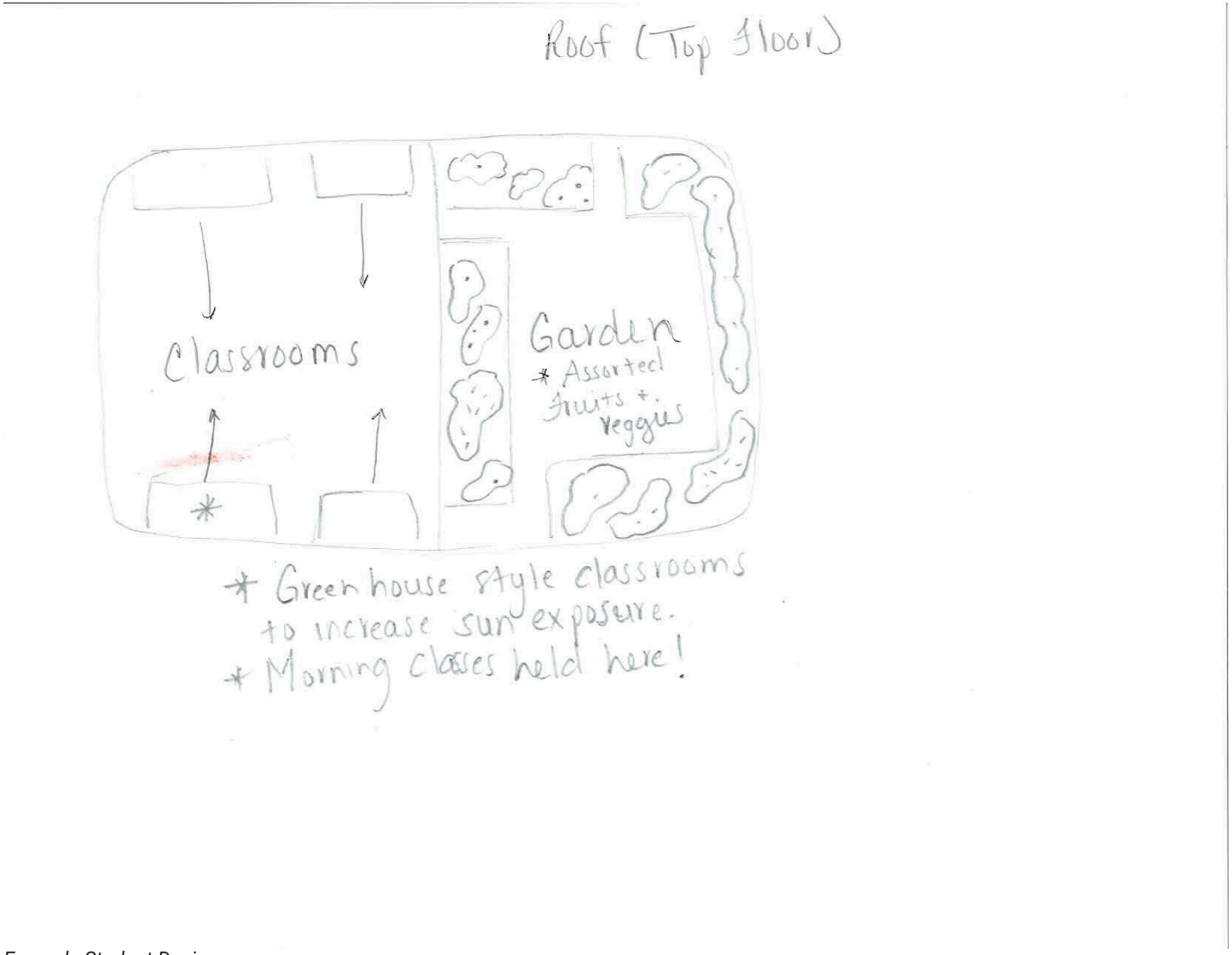
	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Asking Questions and Defining Problems			*Final Design Task*	
Analyzing and Interpreting Data			*Final Design Task*	
Constructing Explanations and Designing Solutions			*Final Design Task*	*Argument Evaluation*
Obtaining, Evaluating, and Communicating Information			*Final Design Task*	
ETS1.B Developing Possible Solutions			*Final Design Task*	*Argument Evaluation*
ETS1.C Optimizing the Design Solution			*Final Design Task*	*Argument Evaluation*
LS1.A Structure and Function	Student generated ideas		*Final Design Task*	
LS3.A Inheritance of Traits			*Final Design Task*	
LS4.A Evidence of Common Ancestry and Diversity	Student generated ideas		*Final Design Task*	
LS4.C Adaptation			*Final Design Task*	
Cause and Effect			*Final Design Task*	
Structure and Function			*Final Design Task*	

Common Core State Standards Connections

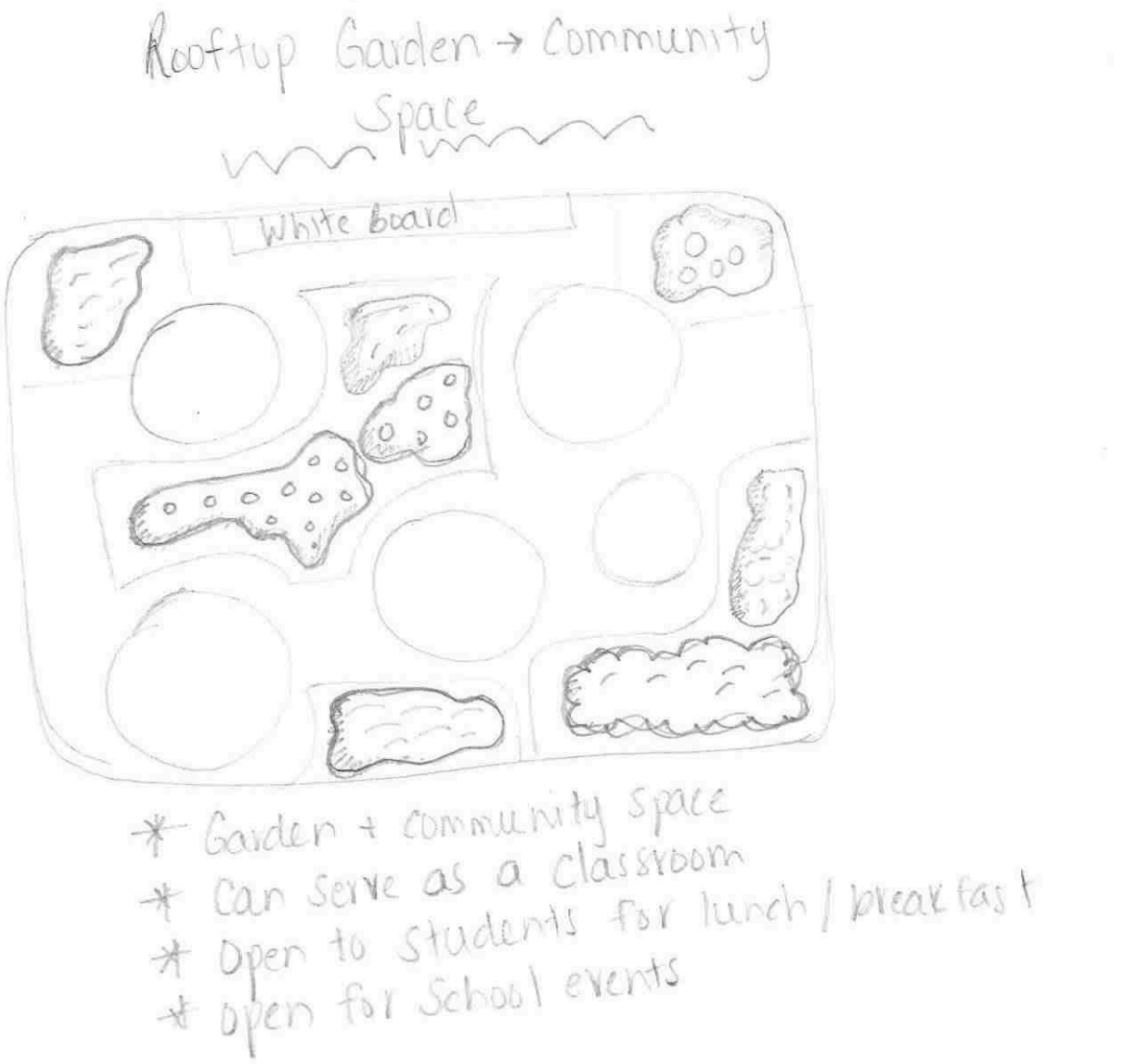
	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Mathematics				
ELA/Literacy				

Student Work for Unit Closing

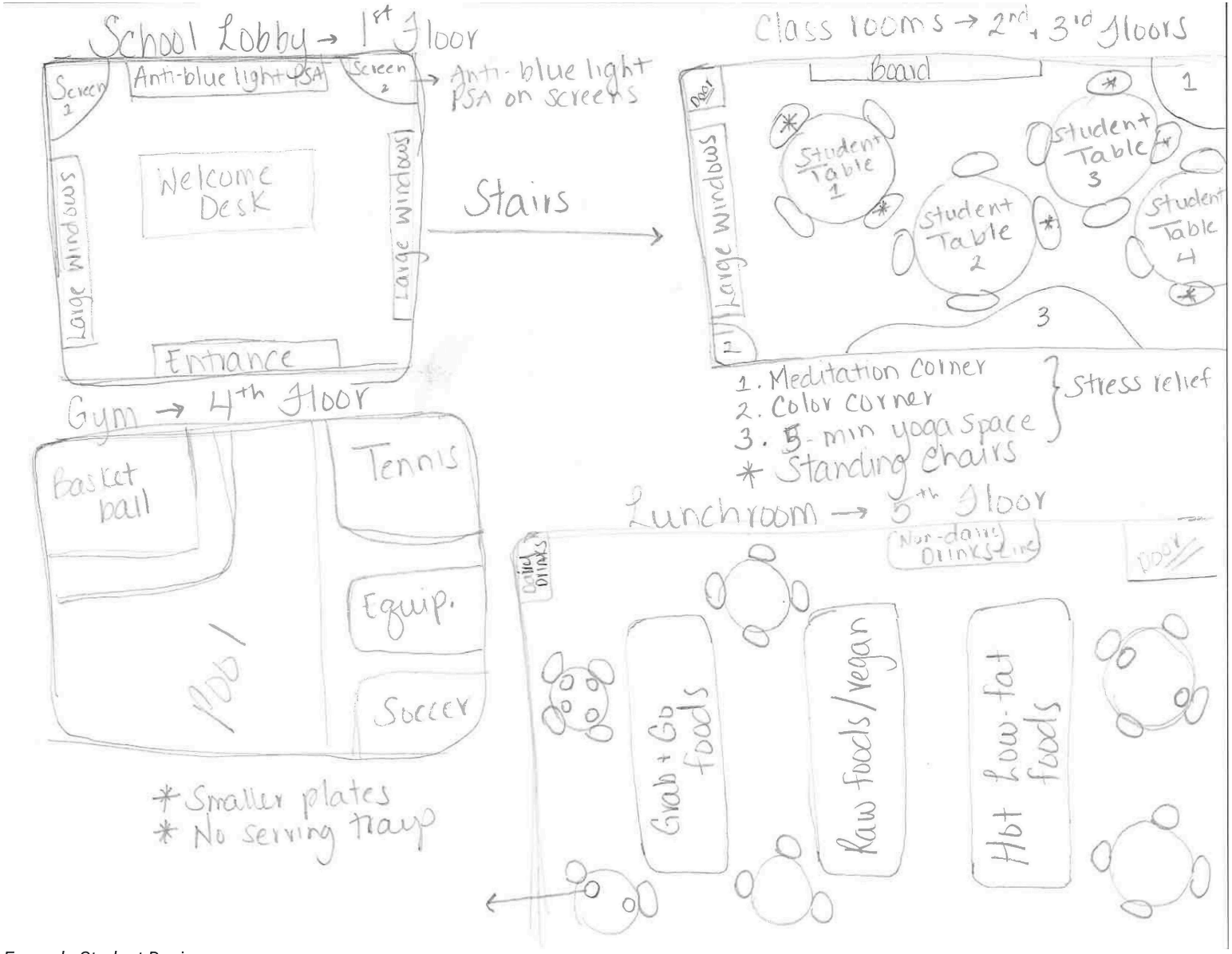
Example Designs



Example Student Design



Example Student Design



Example Student Design

Example Written Response

1. The overall problem is that our bodies evolved for a different environment. Our bodies do not match our current environment causing health problems.
2. For example, almost all living organisms have a circadian rhythm that is regulated by sunlight. Because we live in-doors and use artificial lights, we have a mismatch problem because many people have trouble sleeping. This is a sub-problem because it is one example of a mismatch problem.

3. My design elements:

A. I included a salad bar in the cafeteria. This addresses the subproblems of lactose intolerance and leptin resistance (fat storage). Students can choose to eat vegetables from the salad bar which are low calorie. This is important because eating too much food or high fat food stimulates the production of leptin in fat cells and can cause leptin resistance (it doesn't work anymore) and obesity, a serious health problem. I think high fat food causes obesity because of the data we used to investigate this sub-problem, which demonstrated that mice eating high sugar and high fat food were more obese. Salad bars also provide food for teenagers that are lactose intolerant. People that are lactose intolerant lack a mutation in a regulatory gene. Their lactase gene stops working and they can't digest the sugar in milk.

B. I included opportunities for more morning sunlight exposure. The school schedule is changed to start a little later so that students can sleep more in the morning and use the outdoor community space before class to get sunlight. This way, students get a lot of sunlight in the morning. Sunlight inhibits melatonin production in the pineal gland of the brain. So, with less melatonin, students are more awake at school. This also sets the 'clock' and tells the brain to start releasing melatonin 12 hours later, so kids can sleep at night. Additionally, we saw that teenagers sleep later in the morning from our sleep survey, providing evidence that starting later would provide more sleep.

C. I included a meditation corner because one sub-problem was the overproduction of cortisol due to chronic stress, lack of sleep, and poor food environment. Having the option to mediate or do yoga in this space will reduce stress and reduce the production of cortisol.

4) One of the criteria I used to evaluate the design elements was to think about what students in the school would like to have or do. I used a survey to identify which elements students were interested in. This helped me narrow down some elements.

One of the constraints that I thought about was cost. I tried to keep cost in mind as I designed the school.

Lactose: design element of salad bar at first when entering the cafeteria. Two separate lines for dairy and non dairy products. Some people cannot consume dairy products because they contain a big sugar called lactose. All babies produce lactase in the cells of their small intestine that breaks down lactose into smaller sugars. As adults, some people do not produce lactase, so they get sick because the large lactose cannot be absorbed in their intestine. Other people have a mutation in a regulatory gene that continues to make lactase into adulthood. People with lactose intolerance (they don't make lactase as adults) cannot eat dairy, so the line in the cafeteria includes only non-dairy foods.

Leptin: Gym on high floor so students are forced to do stairs. Longer gym periods, gym divided in sections with different sports/activities. No trays will be provided to students, and plates will be smaller for portion control, salad bar is positioned in a way so that students see it first.

Circadian Rhythm: Garden on the roof to address the issue of sun exposure (2-10 minutes of sun exposure in the morning is needed for melatonin). Bright light exposure will keep students awake during class time. Using a PSA to tell students about blue light/sun exposure/sleep during the day.

Common Ancestry: use more raw/hard food to keep your wisdom teeth well. Add this to the cafeteria. Stress level will be reduced by acting on cortisol. Use meditation corner, color corner, 5 min yoga corner.