7th Grade Curriculum

What’s in This Unit?
Findings about the human microbiome are all over the news and are attracting the attention of scientists from many different fields—for good reason! There is evidence to suggest that the approximately 100 trillion bacteria living on and in the human body may correlate to many different health conditions. Further, altering one’s microbiome can result in altering one’s health, for better or worse. Most notably, a treatment known as a fecal transplant—a transplant that involves using microorganisms from one person’s healthy gut microbiome to cure another person who is suffering from a potentially deadly infection—has been under review. These developments have sent many from the scientific community to further investigate the human microbiome. In this unit, students take on the role of student researchers as they work out and explain the anchor phenomenon for the unit—a fecal transplant cured a patient suffering from a potentially deadly C. difficile infection. They make arguments that justify continued research of this new treatment. By engaging in sense-making about the same types of data that professional scientists use, they work to understand how having 100 trillion microorganisms on and in the human body can keep a person healthy. In the process, they learn to examine living things at multiple scales, from molecules to single-celled organisms to the overall human body.

Why?
We chose the context of the human microbiome for this unit for several reasons. First, it provides students with the opportunity to dive into a current topic in science—something on the frontier of knowledge. Second, as students move to middle school, much of what they are studying in science is not visible to the naked eye. Learning about the human microbiome provides a compelling on-ramp to learning about the invisible. Additionally, it provides a reason to learn about the scale of the very small world that will be the focus of much of what they will study throughout middle school life science. Research evidence shows that many middle school students don’t know which is bigger: a cell or a molecule. Failure to understand these basic ideas of scale create many of the misconceptions that persist in life science. Finally, there is an irresistible allure that comes from delightfully disgusting and awesomely amazing topics, such as eyelash mites and using poop as a treatment for illnesses! What a great way to start the year.

How?
Chapter 1 provides students with an exploratory experience in which they learn about concepts related to scale. This experience invites them to learn more about the tiny microorganisms that inhabit the human microbiome. Through the use of a digital app, the Scale Tool, they work to create scale models of cells and molecules, glimpsing the very small world of microorganisms and laying a lifelong foundation for understanding issues of scale in life science.

In Chapter 2, students embrace their role as student researchers as they work to figure out why a fecal transplant cured a patient suffering from a C. difficile infection. The unit culminates in students creating evidence-based arguments to explain how fecal transplants work to cure infections. These arguments are used to address a fictional senator’s attempts to eliminate funding for fecal transplant research.

What's in This Unit?

Through inhabiting the role of medical students in a hospital, students—as they first diagnose a patient and then analyze the metabolism of world-class athletes—are able to draw the connections between the large-scale, macro-level experiences of the body and the micro-level processes that make the body function. By investigating the anchor phenomenon—a patient whose body systems are not working properly, students learn how body systems work together to provide the trillions of cells in the human body with the molecules they need. By exploring how athletic training improves the body's function, students learn how energy is released in the cells through cellular respiration and how that energy supports movement and cellular growth and repair. In the final chapter of the unit, your students will consider a new anchor phenomenon to apply what they have learned to determine whether an athlete's improved performance from increasing cellular respiration could have been the result of blood doping.

Why?

This unit has been designed to connect ideas about the human body that have often been taught in isolation from one another. In a typical curriculum, students may learn about the parts of the cell in one unit, cellular respiration in another, and body systems many months later. As a result, students are not guided to draw connections between these concepts, or to connect the abstract concepts to their actual experiences with their own bodies. They are also never provided the experience of connecting microscopic processes (how molecules from the environment are broken down and enter the cells to produce energy and to aid in cellular growth and repair) to the macro-level functions of the body systems and our overall health. We chose the medical student role because it provides a compelling and accessible context for connecting ideas about cells, body systems, molecules, and energy with phenomena that students are likely to be familiar with in their own bodies. This unit builds on students' interest in and awareness of problems like asthma and diabetes, as well as an interest in how the bodies of athletes who are competing at their peak of performance can function so well.

How?

Chapters 1 and 2 focus on how body systems work together to take molecules from the environment and get them, in usable form, to the cells. Students are presented with the challenge of helping diagnose a teenage patient, Elisa, who feels tired all the time. Through exploring the *Metabolism* Simulation, reading about different medical conditions, and participating in a classroom-sized model of the body, students learn that in a functioning body the digestive, respiratory, and circulatory systems work together to get glucose, oxygen, and amino acids to the cells. By the end of Chapter 2, students diagnose Elisa with diabetes and are able to explain how this condition affects her body systems and the molecules that get to her cells.

In Chapter 3, students learn more about what the cells do with these molecules. They explore the effects of activity on their own bodies and in the Simulation, and are then introduced to cellular respiration, the chemical reaction that releases energy in the cells. Students learn that the energy released in cellular respiration also supports growth and repair at the cellular level. Students shift their focus to considering cellular respiration in the context of high-performance athletes and read an article about a controversial practice called blood doping, which is used to enhance athletic performance. They apply what they have learned as they prepare to participate in a whole-class discussion and debate routine called a Science Seminar. Then, in Chapter 4, to prepare for the Science Seminar, students analyze evidence to determine if an athlete increased his cellular respiration and improved his athletic performance through permitted methods.

What's in This Unit?

Futura Engineering has been hired to design a series of health bars that will feed people in regions affected by natural disasters, with a particular emphasis on two populations who have health needs beyond what can be provided by emergency meals: patients and rescue workers. Can we develop nutrition bars that will provide the proper balance of protein and carbohydrates for these target populations? Students work as food engineer interns at Futura Engineering and apply their understanding of metabolism in designing recipes for bars that balance three criteria: the metabolic needs of a target population, taste, and cost. In order to address metabolic needs, interns look at protein, carbohydrates, and the glycemic index of different ingredients. Protein is broken down into amino acids, which are made into new protein molecules that aid in cellular growth and repair—how effective the body is at making these protein molecules can be measured using a Growth and Repair Test. Carbohydrates are broken down into glucose, which the body uses for energy to do all the things it needs to do. Glycemic index is a measure of how quickly these carbohydrates can be broken down. In order for the body to release energy from glucose, the glucose must be combined with oxygen in the cells; the level of oxygen available to the body affects how well the cells are able to perform this process of cellular respiration.

Students design a recipe for a health bar (FuturaBar) that addresses the needs of their target population by balancing the protein composition, carbohydrates, and glycemic index while maximizing the taste score and minimizing cost. Students complete several tests and tasks using Futura RecipeTest, a digital design tool, to collect data. They analyze this data and run iterative tests of their recipes, preparing a final proposal that justifies the choices they made relative to the criteria. This 10-day immersive Engineering Internship is intended to follow the *Metabolism* unit.

Why?

Engineering Internships engage and immerse students in the type of work that professionals do. They situate learning in the context of doing, helping students engage with science ideas and practices as well as ways of thinking—not in the abstract, but in the context of simulated real-world activities or problems. While putting students in a science and/or engineering role and providing them with a problem to solve is something done in all Amplify Science Middle School units, Engineering Internships provide a more immersive environment by leveraging digital technologies to simulate a real workplace. Futura Engineering, the company where students serve as engineering interns, has a logo, a CEO, and project directors. Students receive work direction via daily emails, and receive feedback on their work from a Futura project director. Students are likely to find the context to be highly motivating. Unlike other engineering projects and curricula, students participate in an immersive context that is designed to simulate the best features of an actual internship—learning how to think like engineers who are doing engineering work.

Engineering Internships are also designed to provide students with an opportunity to apply a concept they've learned in order to solve a problem. Application situations enable students to see how information they've learned is useful, while offering the chance to deepen their understanding of that information. In addition, these situations offer opportunities to assess students' grasp of the concept being applied.

We chose the context of developing a health bar because it provides an opportunity for students to apply what they learned in *Metabolism*—understanding where the body gets protein and glucose, and what it uses them for. Engaging students in solution-thinking around providing for the needs of target populations is important because it shows that creating solutions for problems such as these depends upon an understanding of relevant scientific concepts.

How?
Engineering Internships have three phases: Research, Design, and Proposal. In the Research phase, interns are introduced to the company, the task, and criteria (develop a bar that meets the metabolic needs of a target population, make it taste good, and minimize cost). Interns perform background research so they can better address the target population's metabolic needs. This includes reviewing information from *Metabolism* and learning new science content, as well as learning how to use RecipeTest, the digital design tool.

In the Design phase, interns use RecipeTest as a part of the design cycle. Interns build recipes, test them on a population, analyze the results, and then plan another round of tests. Interns learn about the value of iterative tests, how to balance trade-offs, and how to make sense of the results in order to inform their next decisions. Interns submit their best recipe to the project director for feedback and then have a chance to refine that recipe.

In the Proposal phase, students gather evidence to support their optimal design and write their proposals, using scientific communication skills to present and support their claim. Students first focus on the types of evidence for the design decisions that helped them address each criterion. Students submit an outline of the Design Decisions sections of the proposal to their project director for feedback. They use the feedback letter, proposal rubric, review of the Dossier and their RecipeTest data, along with peer discussion to improve the body of their proposals so it is clear how and why each decision led to the proposed optimal design. Students complete the proposal by adding an introduction that summarizes the project, and a conclusion that allows them to analyze the trade-offs of the proposed solution. The complete final proposal demonstrates their understanding of engineering practices and the science concepts that influenced their design choices to support the claim that their design is a great possible solution.

The unit concludes with an exit interview, during which students reflect on what they've learned as engineering interns. The final activity asks students to extend their understanding of engineering design by defining new problems that are related to food engineering, such as food shortages, packaging, or meeting the metabolic needs of a new target population.

What's in This Unit?
Inside virtually every cell in every organism on Earth, genes provide instructions for making proteins that govern all the functions of an organism's body. An organism inherits its genes from its parent or parents, but different combinations of genes can lead to striking variation even among closely related organisms. Understanding the role of genes and the process of inheritance has allowed researchers to explain variation in life on Earth, breed plants and animals with new traits, and develop cures for devastating diseases. In the Traits and Reproduction unit, students take on the role of student genetic researchers, working with the fictional bioengineering firm, Bay Medical Company. Bay Medical Company is attempting to breed spiders with the type of silk that can be used for medical applications (e.g., to create artificial tendons). The student genetic researchers are faced with the challenge of explaining how the silk flexibility traits of closely related spiders can vary, which serves as the anchor phenomenon for the unit. To explain this mystery, students create physical models, read articles, and observe genetics in action, using the Traits and Reproduction Simulation. This powerful and engaging digital tool allows students to observe and breed spiders, making connections between what happens inside cells and how this affects the traits of an organism. Through their research, students learn about the role proteins, genes, and sexual reproduction play in trait variation. They are able to apply what they have learned about spiders to a human context.

Why?
This unit helps students connect ideas about genes, proteins, traits, and sexual reproduction to form a deep understanding of the causes of variation. Students consider intriguing examples of variation drawn from both human contexts (e.g.,

athletic ability, fraternal and identical twins, and genetic diseases such as hemophilia) and nonhuman contexts, particularly spider silk flexibility. This unit, in comparison to a more traditional heredity unit, gives greater attention to protein molecules and the connections between genes, proteins, and traits. Spider silk flexibility was carefully chosen as the central example because it provides an accessible illustration of the structure–function relationship between proteins and traits: Less flexible silk is formed from protein molecules with a greater number of connections. This focus on the role of proteins allows for a deeper, more mechanistic understanding than would an approach that glosses over the role of proteins in making the connection between genes and traits. After establishing an understanding of the relationship between proteins and traits, students move on to learn about how genes influence traits. They learn genes determine which protein molecules are produced for particular traits. Finally, students learn how sexual reproduction results in trait variation. This unit is designed to help students integrate their understanding of how genes affect traits with an understanding of how genes are inherited, topics that are sometimes presented in a disconnected way. In addition to being an excellent context for building this deep understanding, spider silk genetics and the possible uses of spider silk as a biomaterial are actual areas of cutting-edge scientific research. Throughout the unit, students have regular opportunities to apply what they have learned from their investigations of spiders to human contexts. By relating what they have learned about spider genetics to humans, students are challenged to think more deeply about the connections between genes, proteins, traits, and sexual reproduction.

How?

Students begin the Traits and Reproduction unit by learning that Bay Medical Company has been researching a species of spider: the Darwin's bark spider. This spider makes the strongest spider silk in the world. The silk of a Darwin's bark spider has many possible medical uses as well. It may, for example, be used to repair human tendons. However, the researchers at Bay Medical Company cannot explain why their efforts to breed Darwin's bark spiders with medium silk flexibility (the best silk characteristic for constructing artificial tendons) are not working. Researchers at Bay Medical Company present students with a specific spider family to investigate throughout the unit.

In Chapter 1, students focus on the question: Why do traits for silk flexibility vary within this family of Darwin's bark spiders? A fascinating video about a real spider researcher, Dr. Cheryl Hayashi, introduces students to the spider research context. Then, after reading a compelling text about variation in spiders, making physical models of proteins, and investigating traits in the Traits and Reproduction Simulation, students discover the connection between the protein molecules produced in cells and the traits of an organism. As they investigate this concept, students learn that variation in the structure of protein molecules affects their function and how they interact with other molecules, which leads to variation in observable traits.

In Chapter 2, students explore why the Darwin's bark spiders' offspring make different proteins for silk flexibility. By reading about hemophilia research and engaging with a physical model of genes and proteins, students learn that genes are instructions for building protein molecules. Using the Sim, students discover that organisms have two copies of each gene. These copies can be the same version or different versions of the gene. This means that the cell could produce one type of protein or two different types of proteins, depending on the instructions from the genes. Students synthesize the ideas from this chapter by creating a visual model that explains what they have learned about how different gene combinations result in the production of different proteins inside cells, which leads to trait variation.

In Chapter 3, students investigate why the Darwin's bark spider offspring have different gene combinations even though they have the same parents. As they investigate how genes are inherited, students consider the case of identical twins and how they compare to fraternal twins. Students learn that sexual reproduction leads to variation in the genes of offspring because an organism receives one copy of each gene from each of its parents. Students use the Sim to conduct experiments related to spider breeding. By the end of this chapter, students are able to write a complete explanation for why the Darwin's bark spider offspring in the lab had different traits for silk flexibility compared to each other and to their parents.

In Chapter 4, students apply their understanding of genes, proteins, and traits to a new anchor phenomenon about a difference in traits among members of a human family. They focus on a family of runners, investigating why one person in the family is an elite distance runner when no one else in her family has that trait. Students consider claims about whether or not the distance runner's trait could be due to gene inheritance, her environment, or a mutation in the runner's genes. After analyzing a range of evidence, students present their ideas to the whole class in a Science Seminar before constructing their final written argument.

What's in This Unit?

Chemists answer questions about what substances are and where they come from. In this unit, students take on the role of student chemists to solve mysteries that can only be solved with an understanding of fundamental chemical principles. The first mystery is a fictional yet realistic scenario in which a reddish-brown substance is coming out of the water pipes in a neighborhood that gets its water from a well. This scenario serves as the anchor phenomenon for the unit. As students learn about what makes substances different in Chapter 1, they apply their growing knowledge of properties and atomic composition to determine that the reddish-brown substance is not the same substance as either the substance that makes up the pipes or the fertilizer that has seeped into the well water. As students learn about chemical reactions in Chapter 2, their explanation builds. Students apply what they have learned about atomic rearrangement to determine that the reddish-brown substance, now identified as rust, could only have formed from a chemical reaction between the iron pipes and the fertilizer. As students learn about the conservation of matter in Chapter 3, their explanation culminates with the conclusion that the reaction between the iron pipes and the fertilizer that formed the rust must also have formed another substance, which must be present in the water. In the last chapter of this unit, students continue in their role as student chemists, working to assist in a police investigation of a robbery that involved the use of an unknown substance to steal a rare and expensive diamond. Students must use their understanding of substances, atoms, and chemical reactions to identify the unknown substance as hydrofluoric acid. They then help the police determine which of their suspects is most likely to have produced this substance.

Why?

The role of a student chemist provides a practical lens through which students can learn and practice chemistry. In this role, students can clearly see how chemistry is relevant to solving real-world problems. Presented with a realistic role and a compelling mystery to solve, students are more likely to engage enthusiastically with the content of this unit.

Many curricula present chemical reactions as abstract phenomena that only occur in the context of a laboratory and always involve unfamiliar chemicals. When chemistry content is presented in this manner, students learn to discuss the reactants and products of a chemical reaction without ever considering how these ideas explain the chemical reactions happening all around them. This unit emphasizes realistic and relatable real-world problems in order to encourage students to see chemical reactions as the ubiquitous phenomena that they are. Other chemistry units typically present students with only certain substances (e.g., water) that are composed of individual molecules and do not present substances made of large networks of atoms and atom groups. Although this approach is convenient and expedient, it is highly limiting as it ignores many types of substances that students encounter every day. This restriction impoverishes the student experience by preventing the inclusion of many substances students will find familiar. In addition, curricula that present only molecular substances do nothing to dissuade students from assuming that all matter is made up of molecules, an alternate conception that will then require remediation in future science classes. For these reasons, this unit focuses its attention on the fundamental atomic patterns that define all types of matter, emphasizing the atoms and groups of atoms that repeat as the determining factor in differentiating different substances. In doing so, this unit provides exposure to a wide range of substances, laying the foundation for students to differentiate between substances on the basis of atomic structure in subsequent science classes.

Students can be expected to enter this unit with many alternate conceptions about how matter behaves. It is likely that students have observed situations in which matter seems to behave in mysterious ways. For instance, when a log is placed in a fire, it seems to disappear as it burns. Experiences such as this one lend credence to the idea that matter can be created or destroyed, an alternate conception that is widely held and deeply entrenched in the minds of many students. In this unit, in order to combat this idea, students spend an entire chapter considering such puzzling phenomena at the atomic scale. In these cases, the unchanging nature of atoms is visible and evident in a way that allows students to account for and explain cases where matter seems to appear or disappear.

Finally, a traditional approach to a chemistry unit begins by differentiating between physical and chemical changes. However, this approach forces students to rely on memorized examples and their own intuition to decide which types of changes are physical and which are chemical. Additionally, students are often quick to point out phenomena, such as dissolving salt in water, that reveal the arbitrary nature of this overly simplistic classification system. Although this unit presents students with opportunities to experience both physical and chemical changes, it deemphasizes the need to categorize these changes, asking that students instead use properties and atoms to differentiate between substances.

How?

In order to identify the reddish-brown substance that is coming out of the water pipes in Westfield, students begin by investigating what substances are and how to tell them apart. Early in Chapter 1, students have an opportunity to closely observe substances in order to determine their properties. They use these observations as the basis for differentiating between substances. Once students have established that properties can be used to differentiate between substances, they move into an investigation of why different substances have different properties, using evidence at the atomic scale to determine that different substances are made up of fundamentally different things. This investigation includes a video on the atomic nature of matter, an article on the relationship between atomic and observable differences, and introduction to the *Chemical Reactions* Simulation. The Simulation includes a Chemical Stockroom mode that allows students to compare the properties and atomic makeup of a wide variety of substances. At the end of Chapter 1, students use their knowledge of properties and atoms to make sense of observational and atomic evidence about the reddish-brown substance, concluding that it cannot be the same substance as the substance that makes up the pipes or the fertilizer. At the end of this chapter, the reddish-brown substance is positively identified as rust.

In Chapter 2, students consider the question of how the rust formed, beginning with an investigation into whether or not it is possible for substances to change into different substances. During this investigation, students gather evidence by conducting the same experiment in the classroom as in Laboratory A mode of the *Chemical Reactions* Simulation. Having observed a chemical reaction in both these ways, students conclude that substances are indeed able to change into different substances through chemical reactions. Students then follow up on this investigation by returning to the Sim to consider the mechanism by which chemical reactions are able to form new and different substances. Through a series of detailed observations, students see that chemical reactions cause atoms to rearrange, resulting in the formation of substances that are atomically and observably different. By applying their understanding of rearrangement as the mechanism of chemical reactions, students determine that the rust could only have formed from a reaction involving both the iron pipes and the fertilizer.

In Chapter 3, students consider the possibility that the chemical reaction that formed the rust may also have formed other substances. This investigation begins with students reading an article about burning fuels, a common phenomenon in which matter seems to disappear. By reading this article and making detailed observations in the Sim, students gather evidence that, in spite of what we observe, atoms are never created, destroyed, or transformed during a chemical reaction. Using physical tokens to model atoms, students reinforce the idea that all the matter that goes into a chemical reaction must come out in some form. These experiences prepare students to account for the atoms in a chemical reaction and reason through the question of whether or not there could be another substance in Westfield's water. By the end of Chapter 3, students conclude that it is not only possible but, in fact, necessary that a chemical reaction between the iron pipes and the fertilizer would result in the formation of another substance besides the rust.

In Chapter 4, students explore a new anchor phenomenon: an unknown substance was used to corrode glass to steal a diamond. Students begin by using the Evidence Criterion to evaluate observations of the unknown substance made by the police officers at the crime scene. Once students have chosen the most detailed observations, they use this evidence to identify the unknown substance as hydrofluoric acid, a corrosive substance capable of making a hole in a pane of glass. Based on this information, police identify three suspects who purchased substances they believe could have been used to make hydrofluoric acid. Students are then asked to determine whether or not each suspect could have produced hydrofluoric acid by using the substances they purchased as reactants. Applying their knowledge of chemical reactions, students create atomic-scale models to show that only two of the suspects in question could have made the hydrofluoric acid. Following this discovery, the police search the homes of the two suspects, providing students with new evidence about the substances discovered. Students conclude Chapter 4 and the unit by using this evidence to construct oral and written arguments for the police about which suspect is more likely to have made the hydrofluoric acid.

What's in This Unit?

In the *Ocean, Atmosphere, and Climate* unit, students investigate how ocean currents behave and what effect they have on the climate of different locations around the world, specifically the air temperature of various locations. Energy flow from the sun is what drives this story. The sun transfers energy unevenly across Earth, with the most energy transferred at the equator and the least transferred at the poles. This energy from the sun is the main factor in what determines the air temperature of a place. Winds push the ocean surface, which contributes to the behavior of ocean currents. As surface ocean currents move around Earth—warm water is carried away from the equator and cold water is carried away from the poles—they gradually exchange energy with the atmosphere of the regions they pass. This results in the warming or cooling of the air affecting the overall temperature and climate of a region. When changes in the atmosphere or oceans occur that affect the patterns of these ocean currents, the effects can be felt around the world.

In the role of climatologists, students investigate changes in air temperature in Christchurch, New Zealand during El Niño years. This serves as the anchor phenomenon that students will investigate throughout the unit. Students are called upon by the New Zealand Farm Council, who have noticed a climate change that has affected their crops. During El Niño years, the air temperature is cooler than usual. Students are tasked with explaining what causes the change in air temperature. By analyzing temperature fluctuations caused by changes in wind and surface ocean currents that occur during El Niño years, students learn about the relationship between atmosphere and ocean and its effects on regional climate/temperature patterns.

How?

Students begin Chapter 1 by learning that Earth is heated unevenly because different amounts of incoming energy from the sun are absorbed by the surface, depending on latitude. Students observe a heating experiment and use the Sim to gather evidence about how energy is transferred to the air. They learn that energy from the sun is not transferred directly to the air but, instead, is transferred first to the surface and then to the surrounding air. After looking at maps that show incoming energy from the sun and air temperatures around the world, students come to the realization that the air temperature of different locations is determined by the amount of energy transferred from the surface to the air, which is ultimately determined by latitude and by the amount of incoming energy absorbed from the sun.

After receiving data that the ocean temperature near Christchurch changes during El Niño years, students learn that other factors, such as proximity to ocean currents, can affect a location's air temperature. Students spend Chapter 2 investigating how ocean currents can transport water from one part of the world to another, bringing warm or cool water to a particular location and affecting the amount of energy in the air and, therefore, the air temperature. Ocean currents that form near the equator are warm because they gain a lot of energy from the sun. When these warm currents move away from the equator, they carry the energy from the sun with them and then exchange energy with the air of the places they pass. Locations that are situated near warm ocean currents thus have more energy in the air and will be warmer than places that are far from warm ocean currents. When cold ocean currents pass a location, they have the effect of cooling the air. If the air of the location is warmer than the passing cold ocean current, the air will transfer energy to the current, which cools the air. To investigate this idea, students compare Buenos Aires, Argentina (near a warm current), and Cape Town, South Africa (near a cold current).

In Chapter 3, students are introduced to prevailing winds, winds that move in one direction and are large enough in scale to push ocean currents. Along with the positions of the continents, winds determine the movement of ocean currents. Students learn that changes in winds cause changes in ocean currents and thus, changes in the amount of energy that currents can bring to places far from the equator. This allows students to conclude that a change in air temperature during El Niño years is caused by a change in prevailing winds. By the end of Chapter 3, students will be able to explain why

Christchurch, New Zealand's air temperature is cooler than usual during El Niño years. Prevailing winds at the equator can slow down or reverse during the months leading up to and at times during, an El Niño event. This causes ocean currents coming from the equator to bring less energy to places far from the equator. Christchurch is far from the equator. The currents that normally bring more energy from the equator slow down, bringing less energy to transfer to the air, and thus, making Christchurch's air temperature cooler.

In Chapter 4, students are presented with a new problem to solve which requires them to apply all their *Ocean, Atmosphere, and Climate* content knowledge: *In South China during the late Carboniferous period, was the air temperature warmer or cooler than the air temperature in that location today?* This is the focus of the culminating Science Seminar sequence. Students investigate what the air temperature was like during a time when Earth's continents were in different positions. They examine a map that shows continent positions and prevailing wind patterns to draw conclusions about the movement of ocean currents around Earth. By analyzing evidence about energy from the sun, the location of South China, prevailing winds, and ocean currents, they apply their knowledge to engage in scientific argumentation to answer the Science Seminar question.

Why?
This unit has been designed to help students develop a better understanding of the connection between energy and temperature. The majority of the energy on Earth comes from the sun. Ocean currents help to distribute this energy around Earth. Though ocean currents affect many factors, such as weather patterns, precipitation, and major storms, this unit focuses on how they affect air temperature. Temperature is a measure of the amount of energy in the air, making it the most accessible way to illustrate how energy flows from the sun to different places on Earth. This unit builds on students' natural fascination with the ocean and they learn about other interesting places on Earth. The idea that they are investigating the causes and effects of El Niño is highly motivating, as this phenomenon is something students may have heard about in the news. The *Ocean, Atmosphere, and Climate* unit uses many different types of activities to tell this energy story. Students examine energy, temperature, and ocean current maps; engage in hands-on activities, such as the Currents Tank and the Ocean Currents game; read interesting articles; and use the amazing applications designed for this unit—the *Ocean, Atmosphere, and Climate*Simulation and Modeling Tool. Students will have the opportunity to learn about energy, ocean currents, and regional climate in a meaningful and engaging way, while building their skills in scientific investigation and argumentation.

What's in This Unit?
Weather is a complex system that affects our daily lives. Understanding how weather events, such as severe rainstorms, take place is important for students to conceptualize weather events in their own community. In the role of student forensic meteorologists, your students will investigate severe rainstorms in a fictional town called Galetown, which serves as the anchor phenomenon for the unit. They investigate how water vapor, temperature, energy transfer, and wind influence local weather patterns and how these factors can lead to severe rainstorms. Using physical models, a digital simulation, and hands-on activities as well as information gathered from data and science texts, students will investigate the mechanisms by which a warm weather rainstorm can be generated, through the lens of energy transfer. Building on their understanding of the sun as a source of energy, coupled with their knowledge of evaporation and condensation as mechanisms by which water transfers energy to the atmosphere, students will investigate multiple variables that contribute to rainstorm severity. From their investigations, students will learn about how differences in the amount of water vapor, temperature, and air pressure can affect the amount of rain. The unit concludes with a Science Seminar, in which students use what they have learned in the unit to analyze evidence and participate in a discussion about whether one large

rainstorm or several moderate-sized rainstorms are responsible for the damage done to the fictional Carson Wilderness Education Center.

Why?
Rainstorms are complex weather events. When they are severe they can have a great impact on communities and livelihoods by causing flooding and other damage. Understanding the general components and mechanisms of the formation of rainstorms supports understandings of local, regional, and global weather phenomena. Many students have difficulty conceptualizing how rainstorms are generated and often have a variety of alternate conceptions about energy transfer, cloud formation, and wind. The purpose of this unit is to scaffold students' understandings of why rain occurs and how different factors work together to create storms of varying severity. The unit is framed by energy transfer events to bolster students' understanding that energy is a major driver of weather events and ties to many other Earth science topics.

How?
Students will investigate energy transfer as the mechanism that supports the generation of rainstorms on a local level by tracing the path of energy specifically through the processes of condensation, evaporation, and temperature change. Students will determine how energy moves within the troposphere (where weather is formed) from warm, humid air parcels to the colder, surrounding atmosphere. Using a simulation, students will manipulate variables—such as the amount of surface water, air temperature, and the air pressure surrounding an air parcel—to create rainstorms with more or less energy. Students will leave the unit with enough understanding to explain the factors that cause a rainstorm, and which factors in combination can make a rainstorm more or less severe.

In Chapter 1, students focus on the question: *What causes the rainfall in Galetown?* Students watch an intriguing video that presents the mystery of the rainstorms in Galetown, describes the damage that the storms are causing, and introduces students to some of the claims the residents have about what is causing the severe storms. Then, after doing a hands-on activity about condensation, reading an interesting article about clouds, completing activities in the *Weather Patterns* Simulation, and building models, students discover that the creation of a lake near Galetown has contributed to the severity of the storms. Students learn that the lake is causing an increase in water vapor in air parcels near the lake, which, as energy transfers out of these air parcels, can lead to more condensation that can later fall as rain.

In Chapter 2, students explore why the amount of rain in Galetown is different from storm to storm. They begin by discovering the temperature gradient in the troposphere and see a demonstration that shows how an air parcel will rise when it is warmer than the air that surrounds it. Students continue their investigations by reading about a disaster in California caused by severe rainstorms and investigate their ideas further in the *Weather Patterns* Simulation by trying to model creating severe storms to explain the relationship between warmer air temperatures and the amount of rain. Finally, students create a model to explain how the warmer air temperatures in Galetown also contributed to the severe storms. Students explain how an air parcel that is warmer than the surrounding air will rise higher in the troposphere. As the air parcel is rising higher, its temperature will continue to decrease until it becomes stable with the surrounding air. Through this process, more energy is transferred out of the air parcel, which leads to more condensation and more rainfall.

In Chapter 3, students investigate why the most recent storm in Galetown had the most severe rainfall. Students begin to consider the role of wind in the formation of rainstorms by watching a video that explains how wind can move air parcels higher into the troposphere. They then use the Sim to explore this concept further. By looking at data from real storms from all over the world, students are able to identify the factors that lead to severe storms, including wind. A model is used to give students the opportunity to apply their understanding that wind contributes to more severe rainfall by moving an air parcel higher into the troposphere where it will lose more energy, leading to more condensation and an increase in the amount of rain.

In Chapter 4, students apply their understanding of the ways that water vapor, temperature, and wind contribute to more severe rainstorms to a new anchor phenomenon. They focus on the Carson Wilderness Education Center, investigating whether the Center was damaged during one severe storm or a series of more moderate storms. Students are presented with a range of evidence and begin by deciding which evidence comes from a reliable source. They then analyze the evidence and create a table that tracks the factors throughout May that could have contributed to severe storms during that time. After analyzing all the evidence, students present their ideas to the whole class in a Science Seminar before constructing their final argument.

What's in This Unit?
Earth's climate is changing, with average temperatures increasing by about 0.8°C since 1880. While the increase may sound small, the result is not. One of the many observable changes is that ice on Earth is vanishing, which is the anchor phenomenon for this unit. Students adopt the role of climatologists who help the fictional World Climate Institute research causes of ice loss and climate change with the goal of educating the public about their findings. In order to delve into the mechanism of climate change, students investigate with a computer simulation, data, physical models, and science texts. They refute claims based on common misconceptions—an increase in solar energy or direct heating from human activities cause global warming. Students learn how energy from the sun interacts with Earth's atmosphere and surface. They learn that the amount of energy absorbed at the surface controls global average temperature and that the increase in Earth's temperature correlates with an increase in the amount of carbon dioxide and methane in the atmosphere. So what is causing the temperature increase? Students figure out that whenever more energy enters the atmosphere than exits, the amount of energy absorbed by the surface increases. Then they discover the cause of Earth's energy imbalance—increased carbon dioxide or methane in the atmosphere redirects outgoing energy back to Earth's surface, reducing the flow of energy that exits the Earth system. Through investigations, they learn that human activities, including increased combustion of fossil fuels and greater numbers of livestock kept for the benefit of humans, are responsible for increasing amounts of carbon dioxide and methane in the atmosphere. Along the way, students learn some of the effects of climate change, some possible solutions, and compare our current climate change to other climate changes in Earth's history. The unit concludes with a Science Seminar where students analyze evidence and debate whether large volcanic eruptions cool or warm Earth.

Why?
Climate change represents one of the most critical realities for our planet and the organisms that inhabit it. Earth's Changing Climate provides students with the opportunity to investigate claims about why Earth's temperature is increasing. Though global warming is a well-established phenomenon in the scientific community, one can still hear non-scientists who doubt that Earth is warming, or if it is, that it matters. As such, having the opportunity to figure out what is known and how it is known is an essential topic of study for all citizens of the planet. In this unit, students have the opportunity to investigate and refute common alternative and inaccurate claims as they sort through data for themselves. We chose to lead the unit with an actual observable phenomenon—the melting of Earth's ice. It's much easier for students to initially visualize a concrete indicator, such as melting ice, than to ask them to imagine an increase in invisible gases in the atmosphere. Unlike most curricula that take on this topic, Earth's Changing Climate helps students understand the mechanism of how carbon dioxide and methane lead to higher temperatures, not just the correlation between carbon dioxide, methane, and temperature. Understanding how this occurs results in a deeper understanding of climate change.

How?
In Chapter 1, students are introduced to their role as student climatologists and begin their investigation of what can cause global temperature to increase or decrease. They explore the Earth's Changing ClimateSimulation, test effects of changes to the atmosphere, and examine data about the atmosphere. They conclude that increases in carbon dioxide and methane correlate with increases in energy absorbed by the surface and increases in temperature. In Chapter 2, students focus on the flows of energy, both entering and exiting the Earth system. They read about climate change in Earth's history, run tests in the Simulation, and use a simple physical model. They discover that if the amount of carbon dioxide or methane increases in the atmosphere, more energy enters the Earth system than exits, and this is why increased amounts of these gases cause warming. They discover that these gases redirect outgoing energy back toward Earth's surface, thereby decreasing the amount of energy that leaves the system. In Chapter 3, students figure out that human activities such as

combustion, keeping of livestock, and deforestation cause these gases to increase in the atmosphere. They also see evidence that increasing population increases human activities, and that has a direct effect on our planet. Students read an article about different strategies for reducing the amount of carbon dioxide and methane in the atmosphere. In Chapter 4, students investigate and debate what the effect of a large volcanic eruption is on Earth’s climate. Students apply what they have learned during the unit as they analyze evidence and make arguments about this question.

What's in This Unit?

The Earth is warming due to a dramatic increase in the amount of carbon dioxide and other greenhouse gases. Buildings are primary producers of greenhouse gases due to the amount of fuel needed to generate the electricity required to cool and heat them. Engineers are using their understanding of scientific concepts to make improvements to existing buildings or to design new technologies to minimize the amount of carbon dioxide released into the atmosphere. Two current strategies for reducing the carbon dioxide output of buildings are increasing albedo (the amount of light from the sun that is reflected away from the surface) and increasing the use of solar panels, which generate energy without burning fuels.

In this unit, students are immersed in an Engineering Internship. As civil engineering interns at Futura Engineering, they learn about The Design Cycle and apply their understanding of energy and climate science to create roof modification designs for a city in the desert. Students consider two roof types, white and solar, and design a proposal of roof modifications the city could implement to reduce the city’s climate impact. The project asks students to consider three criteria: reducing climate impact, preserving the city’s historical character, and keeping costs low. Students use the RoofMod Design Tool to collect and analyze data, complete iterative tests, and learn about isolating variables. By the end of this unit, students can describe engineering practices and compose a written proposal that supports their optimal design for making the city more environmentally responsible, while managing the trade-offs of each of the project criteria. This 10-lesson immersive Engineering Internship is intended to follow the Amplify Science *Earth's Changing Climate* unit.

Why?

Engineering Internships engage students by immersing them in the type of work that engineers do. They situate learning in the context of doing, helping students engage with science ideas and engineering practices. While putting students in a role and providing them with a problem to solve is something done in all Amplify Science Middle School units, the Engineering Internships provide a more immersive environment by leveraging digital technologies to simulate a real workplace. Futura Engineering, the company for whom students serve as interns, has a logo, a CEO, and project directors. Students receive work direction via daily messages, and receive feedback on their work from the project director. Students find the context to be highly motivating. Unlike other engineering projects and curricula, students participate in an experience that is designed to simulate the best features of an actual internship, all while learning how to think like engineers in the context of doing engineering work.

The Engineering Internships are also designed to provide students with an opportunity to apply a concept they’ve learned to solve a problem. Application situations like these enable students to see how information they’ve learned is useful and offer the chance to deepen their understanding of that information. In addition, an application situation provides a way to assess students’ grasp of the concepts being applied. We chose the context of roof modifications because it provides an opportunity for students to apply what they learned in the *Earth’s Changing Climate*unit as they explore ways to reduce a known cause of Earth’s increasing temperature—increased carbon dioxide in the atmosphere. By putting those concepts to work in making design decisions about which roof modifications to suggest for a city, students are immersed in science and engineering practices, while they deepen their understanding of complex science. Engaging students in solution-oriented thinking around serious environmental issues helps them explore positive as well as negative effects that humans cause on Earth's systems.

How?

In Phase 1, the Research phase, students are introduced to the Engineering Internship in which they will prepare roof modification designs that address three project criteria: reducing the city's climate impact, preserving the city's historic value, and keeping costs low. Students investigate albedo in a firsthand experience and perform background research by reading articles in a Dossier to understand how white and solar roofs can contribute to reducing climate impact. This includes reviewing information from the *Earth's Changing Climate* unit and learning new science content about albedo and energy conversion in solar panels. In addition, students learn how to use the RoofMod Design Tool to isolate variables in order to better understand how each roof type affects the model city.

In Phase 2, the Design phase, students use the RoofMod Design Tool as a part of The Design Cycle. Students plan roof modifications for the city of Solton, build and test them, analyze the results, and then plan another round of tests. Students learn the value of iterative tests, how to balance trade-offs, and how to make sense of the results to inform their next decisions. Students submit an early version of their roof modification design to the project director for feedback. They then have a chance to refine these designs to create an optimal design that appropriately addresses all the project criteria.

In Phase 3, the Proposal phase, students select their optimal design and are ready to write their proposals. Students first focus on the trade-offs and identify evidence to explain how their designs address each of the criteria. Students submit an outline of the Trade-offs and Design Decisions sections of the proposal to their project director for feedback. They use the feedback letter, proposal rubric, the Dossier, and peer discussion to improve the body of their proposals. They then complete a final proposal demonstrating their understanding of engineering and the science that influenced their design choices.

The unit concludes with an Internship Exit Survey, during which students reflect on what they've learned as interns. The final activity asks students to extend their understanding of engineering design by defining new problems that are related to reducing climate impact in modern cities.

8th Grade Curriculum

What's in This Unit?

Scientists continue to devise new ways to harness human energy. Energy-harvesting backpacks, bikes, rocking chairs, and knee braces are just a few of the innovative devices that have been created to capture human energy and use it to power electrical devices. In this unit, students assume the role of student energy scientists in order to help a team of rescue workers with an energy problem. Students work to find a way to get energy to the batteries in the rescue workers' electrical devices, even during power outages, and this serves as the design problem for the unit. First, students are motivated to explore relationships between different types of energy—with an emphasis on kinetic energy and potential energy—and the ways energy is transferred and converted. To solve the rescue team's energy problem, students research various ways to capture and store energy. Then, students apply their knowledge about energy to design an energy system that can use human kinetic energy to power an electrical device.

Why?

We chose the context of harnessing human energy for this unit, the first of a year-long physical science (or integrated science) course, for several reasons. First, it provides students with the opportunity to dive into a current topic that is on the frontier of technological innovation. People are devising innovative and sometimes surprising ways to capture human energy to power electrical devices. Some of them involve cutting-edge science, such as clothing that gathers energy from static electricity each time the fabric flexes. Some methods use tried-and-true technology in new ways, such as incorporating an electric generator into a backpack or a shoe. What's particularly exciting in this do-it-yourself era is that inventions are being created not just by scientists, but by non-scientists, some of whom are as young as your students. It's both inspiring and empowering for students to read about, for instance, a 15-year-old girl who invented a flashlight powered by the heat of her hand.

Another reason for focusing on harnessing human energy is that the subject of energy is important and ubiquitous; it runs through all of science and engineering. This unit capitalizes on students' intuitive ideas about energy—that energy makes things go or makes things happen— and advances those ideas to include an understanding that there are different types of energy—in living systems, in physical apparatuses, in fuels—and that all of these types of energy are forms of the same thing. This unit is designed to help students build a useful framework for their understanding of energy and provide an invitation to explore, leaving students with questions that will be addressed in future units.

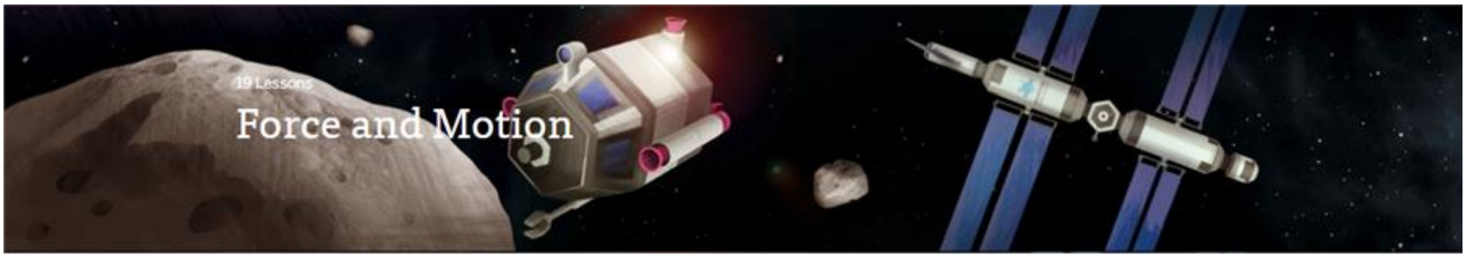
How?

The first chapter of the Harnessing Human Energy unit introduces students to their roe as student energy scientists at the Energy Research Lab. They focus on foundational energy concepts that they will draw on to design an energy solution for the rescue team. Students explore the Harnessing Human Energy Simulation and use physical materials to build energy systems. Students are introduced to the categories of potential energy, kinetic energy, and light energy, and read about inventors who are applying ideas about energy to design cutting-edge energy innovations. These activities are intended to help students build on what they intuitively know and have heard about energy, and make the transition from thinking about energy in an everyday sense to thinking about energy as scientists do.

In the second chapter, students investigate energy transfer: in order to figure out how the rescue workers can get energy to the batteries in their equipment during rescue missions, students need to know how objects get energy. Students use the Simulation to learn about how energy is transferred. Once they have established that when something has energy, the energy must have been transferred from something else, students research possible sources of energy for the rescue team.

To conclude Chapter 2, students write a report to the rescue workers explaining how they can get energy from an energy source to the batteries in their equipment during rescue missions.

In the final chapter of this unit, students converge on human-powered generators as the best source of energy for the rescue team. Working in groups, students design and build physical models of energy systems that harness human energy. As a culminating experience, students apply the expertise they've gained as student energy scientists to evaluate evidence and critique an energy-harnessing device that has been proposed as an energy solution for a school.



What's in This Unit?
Scientists send research instruments into space to collect data on astrophysical objects such as stars, planets, moons, and asteroids. These missions are incredibly expensive and require precise and meticulous planning to avoid failure. The teams of scientists and engineers who work together to design and build the spacecraft usually plan successful missions, but occasionally, costly mishaps occur. When these happen, scientists carefully investigate what went wrong, wanting to avoid future mistakes. In this unit, students engage in authentic work as they take on the role of student physicists working for the fictional Universal Space Agency (USA). They are called upon to assist in the investigation of one recent mishap. Students apply their developing knowledge of force and motion to explain why a space pod failed to dock at the space station as planned. This mystery serves as the anchor phenomenon for the unit. As they investigate, students will learn about the relationship between force, change in velocity, mass, and the equal and opposite forces exerted during collisions. This complex physics reasoning will be reinforced by the Force and Motion Simulation, a digital environment in which students can manipulate the mass of objects, their initial velocities, and the forces exerted on them as they observe the resulting change in motion. Students can also use this digital tool to simulate collisions and see how different objects are affected during these events. With this digital tool, students gather data about how forces affect the motion of objects, which they use as evidence to explain what happened to the pod. By the end of the unit, students will understand how forces can affect the motion of objects.

Why?
This unit provides students with an exciting context in which to consider forces, motion, and collisions: outer space. Students are naturally curious about space and the new frontier of innovation in space exploration. They are fascinated by the fictional problem of the docking mishap, and they are motivated to apply their understanding of the relationship between mass, force, and changes in velocity to this mystery. The setting of deep space allows us to create a scenario where students can think deeply about one-dimensional collisions without the complications of friction or strong gravitational attraction. Most middle school physics units use a series of narrowly defined contexts, such as hockey and billiards, for creating their examples. This unit provides one broad, central context for the content knowledge and puts meaningful application of Newton's laws within the reach of middle school students' understanding by inviting them to explain a mystery through engaging in the reasoning and practices of a real-world science role. Throughout the unit, examples of earthly forces, especially those cited in the articles, give students opportunities to apply their thinking to more familiar situations.

How?
The Force and Motion unit begins as students are introduced to the fictional problem. Scientists at the Universal Space Agency lost communication with an asteroid-sample-collecting pod, just as it was preparing to dock and deliver its samples to a space station. Students are challenged to figure out why the pod ended up moving in the opposite direction rather than

docking. Explaining this unexpected result in the pod's motion is broken down into smaller problems over the course of three chapters.

In Chapter 1, students work to answer the question, What caused the pod to change direction? They begin by investigating the relationship between the force exerted on an object and the object's change in velocity. Students apply forces to stationary and moving objects and observe the resulting changes in velocity, using both physical materials and the digital simulation. They conclude that forces exerted in different directions will cause different types of velocity changes and different strength forces will cause different amounts of velocity change. Students consider how the force exerted by the thrusters might have played a role in the pod's unexpected velocity change.

In Chapter 2, students work to determine why this pod moved differently when its thrusters exerted the same strength force as thrusters on other pods. Students follow up by asking whether the pod's mass might be a consideration since the thrusters had a very different effect on this pod's velocity. In the digital simulation and in hands-on tests using physical materials, students apply equal strength forces to objects of different mass and observe the resulting changes in velocity. Students also read an article about designing wheelchairs for different purposes in order to gather additional evidence about the relationship between mass, force, and changes in velocity. Students conclude that if the same strength force is exerted on objects of different mass, the force will cause the greatest velocity change in the object with the least mass. Students learn that this pod was more massive than pods on previous missions, which allows them to conclude that the same strength force exerted by the thrusters only slowed the pod, so it collided with the space station.

In Chapter 3, students learn that not only is the pod moving, but the space station is also moving as a result of the collision. Students then gather evidence about the pod's motion compared to the motion of the space station. Students read an article about collisions and directly observe collisions between objects of equal mass and objects of different mass in the digital simulation and in a hands-on test using physical materials. Students learn that every collision involves a pair of forces that are equal in strength, but opposite in direction. Students use concepts from all three chapters to develop an explanation for why the Universal Space Agency's asteroid-collecting pod moved quickly away from the space station after the collision.

In Chapter 4, students apply all they have learned about force, mass, and velocity to explain a new phenomenon. They are tasked to determine the difference between a collision scene in a film and a film student's attempt to recreate that scene. Students analyze evidence provided by the film student as they reason through the possibilities and try to pin down why her attempt to recreate the movie scene failed. In the Science Seminar, students cite their evidence and reasoning as they debate the differences between the test scene and the film.

What's in This Unit?
When natural disasters strike, it can be difficult to reach the affected areas since roads may be blocked or destroyed. Supplies can be dropped from aircraft, but this has its own challenges. The *Force and Motion Engineering Internship* allows students to apply knowledge that they've learned about forces and collisions to an authentic problem—designing an emergency supply drop pod. The unit assumes that students know about gravity, a force that causes objects to fall to the earth. Through readings and a hands-on model, students learn that mass of the object does not affect its velocity at impact, but does affect the amount of impact force the object experiences when it hits the ground. The velocity of a falling object can be reduced by adding air resistance, which will result in lower impact force. The materials from which the object is made can extend the amount of time over which the collision occurs, which also reduces the impact force. Reading about these topics, along with an exploration of the properties of various physical materials, helps students apply their

understanding of forces and motion to a fictional but realistic problem. Students work as mechanical engineering interns at Futura Engineering to design a supply pod that will deliver humanitarian aid packages to people in disaster-stricken locations. Specifically, they learn about engineering practices and deepen their understanding about collision forces. They explore how to manipulate mass and falling speed in the design process, using the SupplyDrop Design Tool to run iterative tests and collect data. They then focus on data analysis, noting the structure and function of different design features, in order to design a pod that survives the impact of colliding with the ground. Students strive to meet the design criteria: minimizing cargo damage, maximizing shell condition, and keeping costs low. By the end of the unit, students are able to explain the features, trade-offs and science behind their optimal design in a written proposal. This 10-day immersive Engineering Internship is intended to follow the Amplify Science *Force and Motion* unit.

Why?

Engineering Internships engage students by immersing them in the type of work that real engineers do. They situate learning in the context of doing, helping students engage with science ideas and engineering practices. While all Amplify Science middle school units put students in a role and provide them with a problem to solve, the Engineering Internships provide a more immersive environment by leveraging digital technologies to simulate a real workplace. Futura Engineering, the company for whom students serve as engineering interns, has a logo, a CEO, and project directors. Students receive work direction via Daily Messages, and receive feedback on their work from the Futura mechanical engineering project director. Students find the context to be highly motivating. Unlike other engineering projects and curricula, students participate in an experience that is designed to simulate the best features of an actual internship, all while learning how to think like engineers in the context of doing engineering work.

The Engineering Internships are also designed to provide students with an opportunity to apply a concept they've learned to solve a problem. Application situations like these enable students to see how information they've learned is useful, and offer the chance to deepen their understanding of that information. In addition, an application situation provides a way to assess students' grasp of the concept being applied. We chose the context of supply pod design because it provides an opportunity for students to apply what they learned in the *Force and Motion* unit as they consider a humanitarian aid delivery system. Engaging students in solution-oriented thinking around a serious issue helps them understand that concepts learned in physics are highly relevant in creating inventive solutions for real-world challenges.

How?

In the first phase—the Research phase—interns are introduced to the Engineering Internship during which they learn about the emergency supply delivery project and concepts they need to design and test pods. Their designs should address three criteria: minimizing cargo damage to ensure the safety of the cargo, maximizing the shell condition so that the pod can be used for shelter, and keeping pod costs low so that more pods can be built and dropped to help as many people in need as possible. In the multimodal Research phase, students review information from the *Force and Motion* unit and work to understand more about the concepts of force, motion, and impact force. Additionally, they learn how to manipulate objects' mass, velocity, and duration of experienced collision as ways to reduce impact force. Students perform a hands-on application of these concepts by designing and testing a pod for an egg drop. They also read detailed supporting articles in the Futura Mechanical Engineer's Dossier, and work with the digital Design Tool—SupplyDrop—to conduct iterative tests and better understand how each pod material and structure functions to affect the outcomes.

In the second phase—the Design phase—interns use the SupplyDrop Design Tool as a part of The Design Cycle. SupplyDrop is a digital model that allows students to plan pods, build and test them, analyze the results, and then plan another iteration of tests. Interns learn the value of iterative tests, how to balance trade-offs, and how to analyze the results in order to inform their next decisions. Students submit their optimal pod design to the project director for feedback. They then have a chance to refine these designs in order to create an optimal design that appropriately addresses all the project criteria.

In the third and final phase—the Proposal phase—students gather evidence to support their optimal design and write their Final Proposals, using scientific communication skills to present and support their claim of the optimal solution. Students first focus on the types of evidence for the design decisions that helped them address each criterion. Students submit an outline of the Design Decisions section of the proposal to their project director for feedback. They use the feedback letter, Proposal Rubric, review of the Dossier, and peer discussion to improve the body of their proposals so it is clear how and why each decision led to the proposed optimal design. Students complete the proposal by adding an introduction and conclusion, which allows them to summarize the project and analyze the trade-offs of the proposed solution.

The unit concludes with an intern exit survey, during which students reflect on what they've learned as interns about engineering practices, science content, and attitudes toward science and engineering. The final activity asks students to extend their understanding of engineering design by defining new problems that involve understanding force, motion and collisions.

What's in This Unit?
Space exploration generates excitement and captures imaginations, while also leading to major breakthroughs in science and technology. However, the rockets used to launch spacecraft are very expensive, and most can only be used one time. To prepare for future large-scale space projects, such as space colonization, scientists must find a cheaper and faster launch system. NASA scientists believe that a promising technology already exists in the form of electromagnetic launch systems, but the technology needs further development. In the role of physicists working for the Universal Space Agency, a fictional agency that resembles NASA, students investigate the unexpected results from one test launch of a magnetic spacecraft. While scientists at the USA were testing the launch system, they found that the spacecraft in their third test traveled much faster than expected, and it's this unexpected outcome that serves as the anchor phenomenon for student investigations in the unit. Was there an error in magnet alignment? Was there an unexpected energy increase in the launcher system, or was there more magnetic force? Motivated to understand what affects the movement of magnets, students use the Magnetic Fields Simulation, hands-on activities, and evidence from science articles to learn about magnetic force. Student gain an understanding of how magnetic force causes motion and the relationship of magnetic force to kinetic and potential energy. Students use this newfound understanding, as well as evidence about the spacecraft test launches, to explain what they think happened in the third test. They then apply their knowledge to analyzing three designs for a magnetic roller coaster launcher.

Why?
We chose the context of a model magnetic launching system for several reasons. First, it allows students to engage with an area of current technology development—magnetic propulsion systems—for roller coasters and high-speed magnetic levitation trains, along with potential advances in propulsion for spacecraft, ships, and elevators. Second, this context provides a compelling reason for students to grapple with abstract concepts such as non-contact forces, magnetic fields, and potential energy. Investigating the magnetic spacecraft launcher motivates students to integrate two previous areas of study: (1) force and motion, and (2) energy. The Magnetic FieldsSimulation allows students to observe potential energy, kinetic energy, and field lines in real time as a system of magnets attracts or repels. Students can then relate changes in force to changes in potential and kinetic energy. Through the Simulation, hands-on activities, and engaging texts in this unit, students develop a broadly useful understanding of the causal relationships between force, potential energy, and kinetic energy.

How?
The Magnetic Fields unit begins by introducing students to a fictional scenario: scientists at the Universal Space Agency can't explain why their model spacecraft far exceeded the target speed in its third magnetic spacecraft launcher test. To help the USA plan their next text launch, students are challenged to figure out why the spacecraft went so much faster than expected, which is the anchor phenomenon for the unit. To help students explain the unexpected results of the third launch, the problem is broken down into smaller questions.

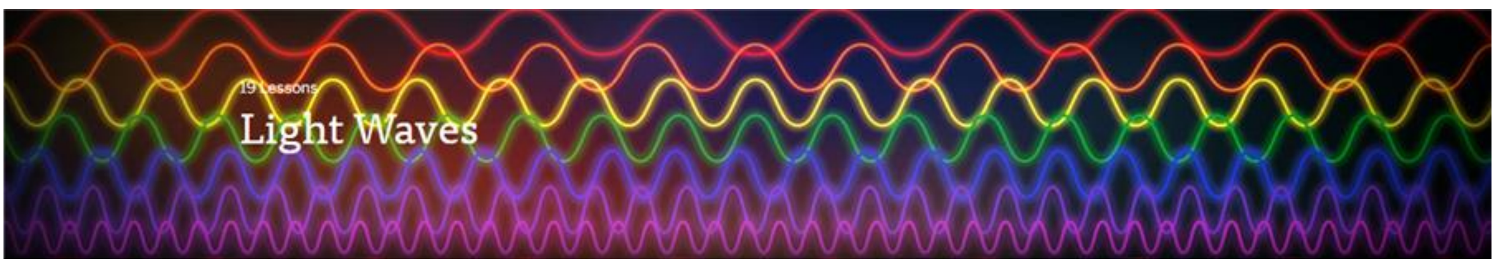
In Chapter 1, students work to answer the question How can the launcher make the model spacecraft move without touching it? They begin by investigating how magnets move other objects at a distance and then move on to investigating how field lines model magnetic force. By analyzing their data from hands-on activities, the Simulation, and an article about

Earth's geomagnetism, students observe that magnets can attract or repel other magnets based on the orientation of the poles. They also learn that magnetic field lines model attracting and repelling forces.

In Chapter 2, students focus on the question Where did the energy to launch the model spacecraft come from? To investigate how magnets cause objects to have kinetic energy, students first determine how all objects get kinetic energy and then apply it to magnets. Through reading articles about energy transfer in different sports and conducting hands-on investigations, students learn that potential energy converts to kinetic energy. Students then investigate how magnets get potential energy. By running tests in the Simulation, students learn that moving a magnet against a magnetic force transfers energy to the magnetic field.

In Chapter 3, students investigate the question Why was there so much more potential energy stored in the launcher system on Wednesday than on Tuesday? Students investigate what could cause the amount of potential energy in a spacecraft launcher system to vary between tests. By gathering additional evidence from hands-on and Simulation activities, students learn that the strength of magnetic forces affects the amount of potential energy that can be stored in a magnetic field. Students also discover that magnetic force is stronger closer to a magnet. Students use concepts from all three chapters to evaluate evidence about the model spacecraft launch tests and then develop an explanation for the unexpected results in the third test.

In Chapter 4, students apply what they have learned to evaluate competing electromagnetic roller coaster designs by considering the question Which design will launch the roller coaster car the fastest? After evaluating evidence from launch tests based on how well variables were isolated, students retest design variables in the Simulation in order to gather reliable data and apply that data to analyzing three design claims. Students then discuss the design claims in a Science Seminar with their peers and write a scientific argument supporting their ideas about which design will launch the roller coaster car the fastest.



What's in This Unit?
The Light Waves unit helps students gain a deeper understanding of how light interacts with materials and how these interactions affect our world, from the colors we see to changes caused by light from the sun, such as warmth, growth, and damage.

In this unit, students investigate a specific change caused by light: skin cancer. Australia has one of the highest skin cancer rates in the world: More than half of the people who live there will be diagnosed with skin cancer in their lifetime. Scientists have investigated the factors that place Australia's population at such an exceptionally high risk of skin cancer. They have found that less ultraviolet light is absorbed as it passes through the atmosphere above this region due to ozone depletion. They have also found that the Australian population is more susceptible to skin cancer because of the large proportion of people with light skin tones. This is because people with lighter skin tones have less melanin in their skin cells than people with darker skin tones. Melanin absorbs ultraviolet light before it damages genetic material inside skin cells, providing some protection against damage caused by light from the sun. Therefore, people with low levels of melanin in their skin cells are at a greater risk of developing skin cancer than people with higher levels of melanin in their skin cells.

Taking on the role of student spectroscopists working for the fictional Australian Health Alliance, students investigate why Australia's cancer rate is so high, analyzing real data that scientists might consider. This problem serves as the anchor phenomenon that students focus on throughout the unit. Students use the Light Waves Simulation, conduct hands-on activities, read articles, and watch videos to gather evidence about how light interacts with materials. The Sim allows students to observe how light carries energy and how this energy causes materials to change when it is absorbed. Students can simulate manipulating the wavelength of light, observing that different types of light have different wavelengths and that different types of light can change a material in different ways. Students also learn that when energy from light is not absorbed by a material, it can be either reflected or transmitted. Students apply these ideas to construct an argument explaining the high skin cancer rate in Australia, citing both low ozone levels in the atmosphere and low levels of melanin in the population.

Why?

Students intuitively know that light can cause changes: they have felt the light from the sun warm their skin and have probably experienced sunburns. The Light Waves unit helps students draw on fundamental science ideas about how light interacts with materials to explain these observations. Focusing specifically on Australia's skin cancer rate invites students to apply their newfound understanding of light to investigate an authentic question that scientists have studied. It allows students to arrive at a multicausal, complex explanation, taking into account how ultraviolet light interacts with different substances in the atmosphere and how ultraviolet light interacts with melanin.

The discussion of ultraviolet light in this unit provides an opportunity for students to consider a type of light that is invisible to the human eye. Unlike a unit on vision, which might marginalize the impact of invisible light in students' lives, this unit reinforces the idea that invisible wavelengths—which make up most of the electromagnetic spectrum—have an impact on our world.

How?

The Light Waves unit begins by introducing students to their role as student spectroscopists tasked with explaining why the skin cancer rate in Australia is so high. In Chapter 1, students work to answer the question, Why does light from the sun cause skin cancer? They receive data indicating that light from the sun can cause skin cancer and that Australia's skin cancer rate is the highest in the world. To learn about how light from the sun can cause skin cancer, students investigate how light can cause materials to change. Through a hands-on activity with solar-powered toys, liquid crystal paper, and thermometers, students gather evidence that light carries energy and conclude that energy from light can cause materials to change. Students then use the Light Waves Simulation to observe that these changes happen only when energy from light is absorbed by a material. Students apply this understanding to their investigation of skin cancer, using the Light WavesModeling Tool to show that energy carried by light from the sun is absorbed by genetic material inside skin cells, causing damage that can lead to skin cancer. At the end of the chapter, students compare the amount of sunlight Australia receives and its skin cancer rate to other countries. They observe that Brazil and Australia receive the same amount of sunlight per year. This means that something besides the amount of sunlight must be affecting the skin cancer rate in Australia.

In Chapter 2, motivated by evidence that Australia and Brazil have different rates of skin cancer even though they receive the same amount of sunlight, students investigate whether the light in Australia could be different somehow than the light in Brazil, focusing on the question, Is all light the same?Students conduct a hands-on investigation and read an article to gather evidence that different types of light can change materials in different ways. After establishing that all light is not the same, students turn their attention to investigating what makes types of light different. They create different types of light in the Sim and watch an animated video about the properties of waves to learn that different types of light have different wavelengths. Students then gather evidence that the light in Australia is different from the light in Brazil: Australia receives more ultraviolet light, the specific type of light that damages genetic material in skin cells. They also gather evidence that the there are more people with low levels of melanin in their skin cells in Australia than in Brazil. By the end of Chapter 2, students can apply what they have learned to analyze this evidence and explain how the same amount of sunlight can lead to different rates of skin cancer in the two countries.

By the beginning of Chapter 3, students know that Australia receives more ultraviolet light than Brazil, and they turn their attention to investigating why Australia receives more ultraviolet light than other parts of the world. Is it possible that something different is happening to the light as it travels from the sun to Earth's surface in Australia? To answer this question, students investigate what can happen to light as it travels. Through investigations and Active Reading, students learn that light can be absorbed by a material, transmitted through a material, or reflected off a material. They also learn that when light is transmitted or reflected, the energy goes with the light. Next, students receive evidence about how light interacts with different substances in the atmosphere, including ozone, which absorbs ultraviolet light. Students learn that the atmosphere above Australia has less ozone than the atmosphere above Brazil, and use the Light Waves Modeling Tool to show how this allows more ultraviolet light to reach Australia. By the end of the chapter, students are ready to use the evidence about ultraviolet light, ozone levels in the atmosphere, and melanin levels in the population to write a final argument to the Australian Health Alliance about why the skin cancer rate in Australia is so high.

In Chapter 4, students apply what they have learned about how light interacts with materials to a new phenomenon: Scientists from the fictional Australian Institute of Marine Biology want to know whether a species of crab that lives near the ocean floor can see the plankton it eats. Students analyze evidence about how different types of light interact with ocean water and the dense mass of algae above where the crabs live. Students present their ideas and evidence to the whole class in the Science Seminar, and by the end of the chapter they are prepared to apply their knowledge of what happens to light as it travels and their analysis of the evidence to construct a final written argument.

What's in This Unit?
Most students and many adults have no idea why the Moon looks different from night to night. For many, the predictable pattern of moon phases is just a mysterious and beautiful part of our night sky. In fact, understanding why we see the Moon as we do requires some fairly challenging spatial reasoning. This unit helps students gain a deeper understanding of everyday observations of the Moon, transforming the experience of Moon gazing into an act of profound and expansive perception.

The *Earth, Moon, and Sun* unit begins as students take on the role of student astronomers, tasked with advising an astrophotographer who needs to take photographs of the Moon for a fictional magazine called *About Space*. The astrophotographer can only take pictures of specific features on the Moon at certain times, and this serves as the anchor phenomenon for the unit. In order to provide advice about when to take photographs of the Moon as well as how to take photographs of a lunar eclipse, students will need to investigate where the Moon's light comes from, what causes the characteristic changes in the appearance of the Moon that we observe, and what conditions are required to view phenomena, such as particular moon phases and lunar eclipses. As students conduct these investigations, they will use a hands-on Moon Sphere Model, the digital *Earth, Moon, and Sun* Simulation, and the *Earth, Moon, and Sun* Modeling Tool to gather and represent information about the movement of and light patterns on the Moon. The Sim allows students to explore and manipulate the movement and relative positions of Earth and the Moon, observing these changing arrangements in space from various solar-system perspectives that are otherwise very difficult to imagine. The Modeling Tool allows students to explain what they find in the Sim. Through developing hypotheses and engaging in argumentation, students will come to an understanding about the phases of the Moon and its orbital positions, which they will then apply to their advice to the astrophotographer. By the end of the unit, students will be able to explain the mechanisms behind patterns of light and dark on the Moon, moon phases, and lunar eclipses.

Why?
Studying planetary science in the context of the Earth, Moon, and sun system gives students an accessible and familiar starting point from which they can begin to understand the principles of illumination and orbit. These ideas are applicable to a broader understanding of star systems and planetary movement. Our ever-changing view of the Moon from Earth, which we characterize by naming phases of the Moon, is a phenomenon we all observe almost daily, but few of us ever examine it in any detail. Helping students to understand and predict the movement of Earth and the Moon and how this movement affects what we observe from Earth gives them a deeper experience as a resident on Earth and helps them to see how science is applicable to their daily lives.

The challenge to help an astrophotographer predict when certain lunar events will take place invites students to consider questions that scientists first studied many centuries ago. This context adds motivation and interest to the unit. Moreover, it provides motivation for students to understand the light patterns on the Moon, which necessitates a thorough understanding of the movement of the Moon around Earth and the relative positions of the Moon, Earth, and the sun.

Envisioning these three-dimensional relationships between planetary bodies is a challenging aspect of planetary science. The *Earth, Moon and Sun* unit, with its in-depth focus on relative positions of Earth and the Moon in space and how their alignment affects what we observe and experience, is a perfect opportunity for students to develop and deepen their spatial reasoning. This ability can sometimes be overlooked in academic settings but will serve students well in life.

Another aspect of planetary science that can be challenging is the sheer vastness of space. Students will grapple with large numbers throughout their education: the number of cells in a body, the millions or billions of years in the history of life, of Earth, and of the solar system; the incomprehensibly large and small size of things from subatomic particles to star systems and galaxies. The *Earth, Moon and Sun* unit prompts students to consider some of these issues of scale by highlighting how models of the solar system must take into consideration the enormous size of planetary bodies and the distances between them. This also provides an opportunity for students to experience the value of models in science by demonstrating the utility of "not to scale" models in understanding a system we can't take apart or manipulate ourselves.

How?

In their role as student astronomers, students begin by helping the astrophotographer learn when to take pictures of three distinctive Moon features. Students learn that they are most easily viewed when they are near the *terminator*, the border between light and dark on the Moon. This launches them into an investigation of light and dark on the Moon, which lays the foundation for learning about the mechanisms behind the Moon's changing appearance as it is viewed from Earth.

In Chapter 1, students work to answer the question: *Why is there a border between light and dark on the Moon?* Students discover that the sun illuminates half of the Moon in the same manner that it illuminates Earth, and that the half of the Moon that faces away from the sun is always dark. By the end of the chapter, students establish a fundamental grasp of how and why the Moon appears to be both light and dark.

In Chapter 2, students investigate the question: *Why does the border between light and dark on the Moon change location?* By using the digital *Earth, Moon, and Sun* Simulation and the physical Moon Sphere Model to help with challenging spatial concepts, students find that the Moon moves into different positions around Earth on a monthly cycle, which causes the phases of the Moon to follow a consistent pattern. By the end of this chapter, students will have learned about how the orbital motion of the Moon creates the monthly pattern of moon phases that we observe from Earth.

In Chapter 3, students work to find an answer to the question: *What are the conditions that cause a lunar eclipse?* By using the Moon Sphere Model, they discover that lunar eclipses are caused when Earth casts a shadow on the Moon. However, lunar eclipses do not happen every time Earth is between the Moon and the sun. By reading an article and using the Sim, students find evidence that this is due to the fact that the Moon's orbit around Earth is not in the same plane as Earth's orbit around the sun, which makes it unusual for Earth's alignment to be directly in between the sun and the Moon. By the end of this chapter, students understand that a lunar eclipse is a rare event that only occurs when Earth is positioned in between the sun and the Moon, blocking the sun's light from hitting the Moon.

In Chapter 4, students consider a new anchor phenomenon, synthesizing what they have learned to help an artist at *About Space* magazine decide whether a lunar eclipse will occur in a distant planetary system with two stars. To do this, they answer the question: *During a year, will there be a lunar eclipse of the moon of Kepler-47c?* Students examine evidence comparing the planet Kepler 47c and its moon and stars to what they already know about Earth, the Moon, and the sun. They discuss the strength of the evidence during a Science Seminar with their peers, and by the end of the chapter they are ready to write a scientific argument supporting their ideas about the likelihood of a lunar eclipse occurring on Kepler 47c.

What's in This Unit?

In 1979, friends dared a 29-year-old man in Oregon to swallow a living, rough-skinned newt. What the man did not know is that rough-skinned newts can be extremely poisonous. A lethal, fast-acting poison called tetrodotoxin (TTX) oozes from their skin. The man swallowed the newt whole and started feeling weak a few minutes later. He described a numb feeling all over his body. His friends tried to take him to a hospital, but he refused. Just 20 minutes later, the man was dead. In the role of student biologists, students investigate what caused this newt population to become more poisonous—which serves as the anchor phenomenon for the unit. Using the *Natural Selection* Simulation, students investigate how the population of newts changed over time. Over the course of the unit, they gather evidence from the Simulation, hands-on activities, and texts to construct their own explanations of how the newts came to be so poisonous.

Why?

This unit helps students connect ideas about how the environment determines which traits are adaptive and non-adaptive, and how this affects the likelihood of survival and reproduction, to form an understanding of natural selection. The rough-skinned newt phenomenon motivates students to figure out concepts, such as variation, differential rates of survival and reproduction, adaptive traits, and mutations. By relating these ideas to changes in populations, students are challenged to think more deeply about why the distribution of traits in a population can change over time. Students' hands-on role as student biologists adds a sense of responsibility and curiosity to this unit and inspires active, student-led learning in the classroom.

How?

The *Natural Selection* unit begins with a focus on genetic variation in populations. A series of tests in the *Natural Selection* Simulation highlight the important roles trait variation and the environment play in determining whether traits will be adaptive. Students tend to have the alternate conception that a helpful trait will become more common in a population over time—even if that trait is not present in the population. Students' Sim tests in Chapter 1 are designed to address this common alternate conception. In the Simulation, they observe that new traits do not appear based on what would be ideal for the environment. Instead, the variation present in the population at any given time is the raw material for change. Once students are given information about the genetic variation of a population and the environment, they make and test predictions about how populations will change over time. Through these investigations, students learn that adaptive traits are the key to survival in an environment. Students apply these ideas to support and refute claims about the cause of the change in the rough-skinned newt population.

In Chapter 2, students deepen their understanding of how populations change over time by focusing on survival and reproduction. They observe that individuals with adaptive traits are more likely to survive. Investigating this pattern further, students observe that because individuals with adaptive traits are more likely to survive longer they also have a better chance of reproducing and passing on their traits to their offspring. At this point, students are able to point to adaptive and non-adaptive traits, specific environmental conditions, survival, and reproduction to explain how populations change over time.

In Chapter 3, students add more complexity to their understanding of natural selection by learning about the role of mutations in introducing new traits into populations. By reading case studies of different populations as well as making observations in the Simulation, students learn that if a randomly-introduced mutation is adaptive in a particular environment, this new trait is more likely to become more common in a population over time.

During Chapter 4, students apply what they have learned to examine a new anchor phenomenon by asking why a population of stickleback fish found in a lake has become faster and less armored over time. As students prepare for and engage in a Science Seminar about this phenomenon, they gather and analyze evidence, consider competing claims, and use scientific language to argue about the most plausible explanation for the change in the stickleback population.

What's in This Unit?

Malaria infects millions and kills hundreds of thousands of people every year, making it one of the world's largest public health problems. Even more concerning is the malaria-causing parasite's ability to develop resistance to the drugs we use to treat it, which is foiling efforts to eradicate the disease. Part of the threat stems from the rapid life cycle of the *Plasmodium* parasite that causes the disease, allowing natural selection to quickly select for adaptive traits in the parasite population—in this case, drug resistance. Monotherapy (or single-drug treatments) has acted as a strong selection pressure, shifting the distribution of traits towards drug resistance for the particular drug used. In fact, many parasites today have multiple, existing resistances to available antimalarial drugs. Combination therapy (using two or more drugs) is currently the recommended course of action by the World Health Organization. In this Engineering Internship, students will explore the effects of various combinations of antimalarial drugs, carefully monitoring the type of drug, number of treatment days, and the dosage size in order to minimize drug resistance in the overall parasite population.

The *Natural Selection Engineering Internship* asks students to design a treatment that does not cause an increase in the malaria parasite population while considering three criteria: minimizing drug resistance in the malaria parasite population; minimizing patient side effects; and keeping costs low. Students use the MalariaMed Design Tool to collect and analyze data, complete iterative tests, and learn about optimizing designs. By the end of this unit, students can describe engineering practices and compose a written proposal that supports their optimal design for making a safe and effective malaria treatment, one that also manages trade-offs between the project criteria. This 10-day immersive Engineering Internship is intended to follow the *Natural Selection* unit.

Why?

Engineering Internships engage students by immersing them in the type of work that real engineers do. They situate learning in the context of doing, helping students engage with science ideas and engineering practices. While all Amplify Science middle school units put students in a role and provide them with a problem to solve, the Engineering Internships provide a more immersive environment by leveraging digital technologies to simulate a real workplace. Futura Engineering, the company for whom students serve as engineering interns, has a logo, a CEO, and multiple project directors. Students receive work direction via Daily Messages, and receive feedback on their work by the Futura project director. Unlike other engineering projects and curricula, students participate in an experience that is designed to simulate the best features of an actual internship, all while learning how to think like engineers in the context of doing engineering work.

The Engineering Internships are also designed to provide students with an opportunity to apply a concept they've learned to solve a problem. Application situations like these enable students to see how information they've learned is useful, and offer the chance to deepen their understanding of that information. In addition, an application situation provides a way to assess students' grasp of the concept being applied. We chose the context of malaria and drug resistance, since both are pressing and important problems; this context provides an opportunity for students to apply what they learned in the *Natural Selection* unit as they explore ways to prevent certain traits in a parasite population from increasing—in this case, the trait for high resistance to an antimalarial drug. By putting those concepts to work in making design decisions about which combinations of drugs to use for a malaria treatment, students are immersed in science and engineering practices while deepening their understanding of complex science. Engaging students in solution-oriented thinking around serious health and medical issues helps them explore how biological science and engineering can work together to improve the quality of life for people around the globe.

How?
In the first phase—the Research phase—students are introduced to the Engineering Internship during which they design malaria treatments that address three project criteria: minimizing the drug resistance in the malaria parasite population; minimizing patient side effects; and keeping costs low. In the multimodal Research phase, students work to understand more about malaria and learn about the various antimalarial drugs, which includes reviewing information from the *Natural Selection* unit and learning new science content about how natural selection can lead to drug resistance. They read detailed supporting articles in the Dossier; complete a physical, hands-on simulation; and work with the digital Design Tool—MalariaMed—to isolate variables and better understand how each drug affects the model population of malaria parasites and the project criteria.

In the second phase—the Design phase—students use the MalariaMed Design Tool as a part of The Design Cycle. Students design malaria treatments by completing several iterative tests. They determine a sequence of drugs, then they *build* and *test* them, *analyze* the results, and continue by planning another iteration. Students learn the value of iterative tests, how to balance trade-offs, and how to make sense of the results in order to inform their next decisions. Interns submit an early version of their malaria treatment to the project director for feedback. They then have a chance to refine these designs in order to create an optimal design that appropriately addresses all the project criteria.

In the third and final phase—the Proposal phase—students gather evidence to support their optimal design and write their proposals, using scientific communication skills to present and support their claim of the best solution. Students first focus on the types of evidence for the design decisions that helped them address each criterion, and submit an outline of the Design Decisions sections of the proposal to their project director for feedback. They use the feedback letter, Proposal Rubric, review of the Dossier, and peer discussion to improve the body of their proposals so it is clear how and why each decision led to the proposed optimal design. Students complete the proposal by adding an introduction and conclusion, which allows them to summarize the project and analyze the trade-offs of the proposed solution.

The unit concludes with an intern exit survey, during which students reflect on what they've learned as interns about engineering practices. The final activity asks students to extend their understanding of engineering design by defining new problems that are related to controlling malaria without antimalarial drugs.

What's in This Unit?
Fossils are millions—even billions—of years old. New fossil discoveries can provide cutting-edge evidence about the history of life on Earth. In fact, in addition to fossils of other early species, paleontologists discover about 14 full dinosaur specimens every year.

In the *Evolutionary History* unit, students will take on the role of student paleontologists investigating a Mystery Fossil, which serves as the anchor phenomenon for the unit. This fossil is based on a real cetacean (whale) fossil excavated in Pakistan in 2000. The students' task is to determine the Mystery Fossil's evolutionary history so that they can accurately place the specimen in a museum exhibit. To gain an understanding of how paleontologists determine relationships between species, students use the *Evolutionary History* Simulation to analyze real fossil evidence and explore relationships on an interactive evolutionary tree. With a fossil collection at their fingertips, students identify similarities and differences among the skeletal structures of both extinct and living species. Students also use the *Natural Selection*Simulation to revisit principles of natural selection, applying this concept to understanding how one species becomes two. They read several articles about evolution, speciation, and natural selection, and they create models to show their thinking. By the end of the unit, students can use their analysis of skeletal structures to determine where they should place the Mystery Fossil in the museum, according to what type of organism the evidence shows it to be most closely related to—whales or wolves.

Why?

Investigating the relationships between a newly discovered fossil and other species via the anchor phenomenon motivates students to analyze evidence just as paleontologists do. Throughout the *Evolutionary History* unit, students are asked to make comparisons between skeletal structures of the Mystery Fossil, whales, and wolves. The unit builds on students' questions and initial observations about the fossils in order to engage in advanced, careful analysis of fossil evidence. Their role as student paleontologists motivates them to make more complex and sophisticated comparisons between the Mystery Fossil and other species. Through their analyses of the Mystery Fossil and numerous other species in the *Evolutionary History* Simulation, students learn that species share similar structures because they descended from a common ancestor. They also learn that differences in structure arise due to natural selection and speciation over vast amounts of time. Immersing students in the anchor phenomenon by placing them in the role of preparing a museum exhibit that accurately introduces the Mystery Fossil to the world motivates them to present evidence for evolution to an outside audience. This encourages students to think deeply about how structural similarities and differences among fossils provide evidence for evolution.

How?

Evolution is a complex and dynamic topic. Single-celled life formed in the ocean over 3.5 billion years ago. Over time, life diversified (forming algae, sea sponges, jellyfish, and sharks) and moved to land (forming amphibians, reptiles, birds, fungi, and plants). Some land animals eventually evolved characteristics that brought them back into the ocean (e.g., whales). In this unit, students explore the unity and diversity of life through their investigations of the body structures of living and extinct species.

In Chapter 1, students are introduced to the Mystery Fossil and begin to address the Chapter 1 Question: *Where in the museum does this new fossil belong?* Students learn that paleontologists need to use careful and precise observations when they examine evidence from bone structures and are asked to follow this paleontological practice themselves. Using Species Cards, students examine body structure similarities between living and extinct organisms. Establishing that all living organisms have at least some similar body structures provides a starting point for students to understand that all living things are related and that species inherit their body structures from their ancestor populations. Students compare body structures using Species Cards and the *Evolutionary History* Simulation. They read the article "How You Are Like a Blue Whale," which describes how paleontologists use body structures to explain that whales and humans are related even though they appear to be very different. At the end of the chapter, students consider similarities between the body structures of whales, wolves, and the Mystery Fossil.

In Chapter 2, students begin to consider why similar body structures (e.g., the hand bones of different species) can be very different, and address the Chapter 2 Question: *How did wolves, whales, and the Mystery Fossil become so different from their common ancestor population?* Students review concepts of natural selection and then consider how the mechanism of natural selection would play out over time, leading to speciation. Each student reads one of three articles describing a unique instance of speciation from the article set *Where Do Species Come From?* Students then use the *Natural Selection* Simulation to model speciation. Next, they explore how small changes that can result in speciation can accumulate over evolutionary time, resulting in very large differences between species. They end the chapter by considering differences in the same bone structures of whales, wolves, and the Mystery Fossil.

In Chapter 3, students set out to answer the Chapter 3 Question: *How can we tell if the Mystery Fossil is more closely related to wolves or to whales?* This chapter is focused on placing species on an evolutionary tree. Students consider similarities and differences in the shared structures of common ancestors and descendants as they build physical models of hypothetical species on a model evolutionary tree. Using the *Evolutionary History*Simulation, students investigate shared structures, and differences in shared structures, to determine how to place a variety of ancient whales on the Cetacea branch of the evolutionary tree. Students learn that certain diagnostic structures (structures that are shared by two species but not by a third) can be used to determine relative relatedness. By the end of the chapter, students are prepared to argue for which species they think the Mystery Fossil is more closely related to: wolves or whales.

Chapter 4 introduces students to a new anchor phenomeon to explore: *Is the Tometti fossil more closely related to ostriches or to crocodiles?* The Tometti fossil is based on the *Sinosauropteryx* fossil found in China. Students are asked to analyze evidence about ostriches, crocodiles, and the Tometti fossil and then discuss their understanding of the possible relationship between these three species during the Science Seminar. Students are encouraged to argue for either possibility, and it is acceptable for them to reach either conclusion as long as they support their argument with evidence. Students then write a complete argument for homework.