Science

Aligned with
the 2016 Massachusetts
Science and Technology/Engineering
Curriculum Framework and the
Next Generation Science Standards

AN INSTRUCTIONAL GUIDE

Teaching Science
in Massachusetts Department
of Youth Services classrooms

2016 Edition
Dear Colleagues:

On behalf of the Massachusetts Department of Youth Services, and in partnership with the Collaborative for Educational Services and Commonwealth Corporation, I am pleased to provide you with the 2016 edition of the DYS Science Instructional Guide. This Guide is aligned with the standards in the 2016 Massachusetts Science and Technology/Engineering Curriculum Framework, the Next Generation Science Standards (NGSS), and the Common Core State Standards (CCSS).

With the arrival of the 2016 Massachusetts STE standards, our goal is to provide DYS educators with a cutting-edge resource that informs planning and instruction of curricula and authentic assessment of student learning. The 2016 DYS Science Instructional Guide provides you with an overview of the NGSS, the differences between the Massachusetts STE and the national NGSS, and guidance for implementing the new standards in DYS schools. The Guide features standards-aligned scopes and sequences for Biology, Chemistry, and Physics, and curriculum unit exemplars adapted for both long- and short-term program settings. Finally, the Science Guide incorporates research-based instructional models that serve as the foundation for our work with DYS youth: Universal Design for Learning, Understanding by Design, Empower Your Future, and the DYS Future Ready Framework, Culturally Responsive Practice, and Positive Youth Development.

The 2016 DYS Science Instructional Guide was developed in collaboration with DYS teachers and content experts; we trust you will find it relevant and useful in planning rigorous and engaging instruction for youth in the DYS setting. Thank you for your commitment and dedication to providing youth in our care with a quality educational experience as they prepare to transition from DYS as young adults who are ready for their futures.

Sincerely yours,

Christine Kenney, Director of Educational Services
Massachusetts Department of Youth Services
Using these Materials and Resources

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Acknowledgments

This resource emphasizes teaching and learning Science, and is part of a series of instructional guides focusing on the content and delivery of educational services in Massachusetts Department of Youth Services (DYS) facilities across the Commonwealth. DYS Instructional Guides are one component of the Comprehensive Education Partnership’s Education Initiative, an education reform initiative supported by Commonwealth Corporation and the Collaborative for Educational Services.


The content within these pages has been developed through the efforts of talented and dedicated practitioners who have generously shared their expertise and best thinking about effective science and literacy instruction.

We especially want to recognize the Massachusetts Department of Youth Services, its students, and the educators and program staff who work every day to bring clarity and focus to the delivery of educational services within the DYS system.
Acknowledgments

The following individuals and organizations were instrumental in the development of this Guide:

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We are grateful for the valuable contributions provided by the DYS Education Initiative staff, including Regional Education Coordinators, Assistant Regional Education Coordinators, Instructional Coaches, and Education and Career Counselors.
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ABOUT THE WESTERN MASSACHUSETTS WRITING PROJECT

WMWP, a local site of the National Writing Project, is a university-school partnership based in the English Department of the University of Massachusetts Amherst that offers professional development and leadership opportunities for educators in Western Massachusetts designed to improve writing and learning for all students.

WMWP’s mission is to create a professional community where teachers and other educators feel welcomed to come together to deepen individual and collective experiences as writers and understanding of teaching and learning in order to challenge and transform practice.

WMWP’s aim is to improve learning in our schools—urban, rural and suburban. Professional development provided by the Western Massachusetts Writing Project values reflection and inquiry and is built on teacher knowledge, expertise, and leadership. Central to WMWP’s mission is the development of programs and opportunities that are accessible and relevant to teachers, students, and their families from diverse backgrounds, paying attention to issues of race, gender, language, class, and culture and how these are linked to teaching and learning.
Acknowledgments (continued)

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DYS Instructional Guide Purpose

The 2016 DYS Science Instructional Guide is designed to be used as a “go to” resource that helps teachers in planning robust curriculum, assessments, and instruction that maximize opportunities for youth to experience academic success.

The Guide is organized in chapters and features a Scope and Sequence for each subject, exemplar units and adaptations for both long- and short-term programs, and resources that support teachers in planning for instruction. Curriculum, planning, assessments, and instruction are organized around key themes and essential learning outcomes. All educators are responsible for creating rigorous and personalized learning opportunities and multiple access points to the curriculum. As well, teachers plan and implement instruction with an understanding of and appreciation for the richness of diversity within the student population.

The Next Generation Science Standards (NGSS) set the expectations for what students should know and be able to do. The NGSS were developed by states to improve science education for all students.

A goal for developing the NGSS was to create a set of research-based, up-to-date K–12 science standards (www.nextgenscience.org). These standards give local educators the flexibility to design classroom learning experiences that stimulate students’ interests in science and prepares them for college, careers, and citizenship.

By aligning the DYS Instructional Guides with both the NGSS and the standards in the 2016 Massachusetts Science and Technology/Engineering (STE) Curriculum Framework, and integrating these standards into our instruction, we are preparing our students to be Future Ready. (Teachers are encouraged to access the website links located in the Appendix at the end of this Guide to learn more about the NGSS, MA STE, and the Common Core). These standards and shifts are unpacked for teachers in Chapter 1 and their relationship to curriculum, planning and instruction is developed in Chapter 2. Chapter 3 emphasizes proper pedagogical practices for teaching science in DYS schools that includes building scientific knowledge and skills, student engagement, and assessment. The curriculum Scope and Sequence charts, located in each subject chapter, reflect a careful focus on Emphasized Standards for each unit that support students’ skill development, ongoing learning and mastery.

Who Are Our Youth?

Data and statistics do not tell the whole story of our youth. The DYS youth population is diverse in every aspect including educational levels, background knowledge and experiences, interests, aspirations, learning styles, multiple intelligences, and social-emotional strengths and challenges. Our youth are scientists, readers, writers, thinkers, musicians, mathematicians, artists, athletes, students, employees, and members of the community. Our youth are family members. Some of our youth are parents. Our youth are lifelong learners. Some have done well in school and will use our classes to build and expand their success as learners. Others have experienced academic challenges or frustrations in the
“We provide a personalized student plan that is standards-based and focuses on literacy and numeracy skills; education, employment and training opportunities; and transitions to the community and the workforce.”

past. Our youth learn best when actively engaged and connected to real-world experiences and contexts. Our youth are all youth.

DYS Education Mission

DYS seeks to provide a comprehensive educational system that meets the needs, experiences, and goals of our youth. Through collaboration with local schools, community-based organizations, families, and other resources, we provide a personalized student plan that is standards-based and focuses on literacy and numeracy skills; education, employment and training opportunities; and transitions to the community and the workforce.

DYS Education Programs

DYS Educational Services strives to meet all Massachusetts Department of Elementary and Secondary Education (ESE) Standards and Indicators for Effective Teaching Practice: curriculum planning and assessment, teaching all students, family and community engagement, and professional culture. These standards drive our intentional approach in providing high-quality educational services for youth. As well, we adhere to ESE policies and procedures including requirements for time on learning, highly qualified educator certification, and teacher evaluation.

Education programs operate under contract with DYS. Accountability standards have been put in place to ensure greater standardization of the educational programming

DYS Program Types

Detention programs primarily house youth who have been charged with a criminal offense and are being held on bail awaiting court action. These units may also house youth who are committed and are awaiting placement in another facility or program, or who are in the process of revocation from a community placement.

Assessment programs are designed to evaluate the needs of newly committed youth. The Department administers several risk/needs assessments in the areas of mental health and substance abuse and educational testing. This information, as well as information about families, any prior contact in the juvenile justice system, and the offense history informs placement decisions. The typical length of stay in an assessment program is 30-45 days.

Treatment programs offer supervision and treatment, and the most appropriate placement may be determined by the Department’s assessment.

Short-term treatment:
The average length of stay in this type of program unit is 90 days, but placement may be extended to 180 days.

Long-term treatment:
The average length of stay in this type of program unit is 8-12 months, although some youth may stay longer.

Revocation programs serve youth who have been released from a DYS treatment program and are having difficulty adjusting to the community. They have broken the conditions of their earlier release and are therefore revoked back into the care and custody of DYS (Massachusetts).
across the system. While size, type, location, security levels, and other factors vary a great deal among DYS programs across the Commonwealth, all DYS settings are united by shared principles, guidelines, professional development, curriculum materials and coaching. Educational programming operates on a 12-month school year and provides a minimum of 27.5 hours of instructional services per week.

**Vision of Integrated Service Delivery**

The Special Education in Institutional Settings (SEIS) program, an ESE program, delivers special education services for approximately 55% of the DYS student population in residential settings. DYS and ESE have adopted an integrated service delivery approach to guide our comprehensive educational efforts. The phrase “integrated service delivery” reflects our core belief that youth need coordinated supports in order to make progress that has a lasting, positive impact on their futures. Evidence of this core belief is found across many of our established practices, most notably such structured collaborative practices as Learning Teams and the Agency Coordination Process. Integrated service delivery is not a separate strategy. Integration of services informs all aspects of the teaching and learning process so we ensure that we are collaboratively meeting the educational needs of each youth in our setting.

Students and teachers are also supported in some programs by Literacy Specialists funded through Title I, a federal grant program. English Language Learners (ELLs) are supported by teachers, across all educational programs, who have been trained in providing instruction to that population. Through the collaborative work of all personnel, a continuum of services is planned for and implemented, responding to individual needs, and allowing for access to the general education curriculum in the least restrictive environment.

**A Personalized Approach**

We are committed to providing a personalized approach to education and transition planning for all youth so they are ready for their futures. The DYS Education Initiative describes a personalized approach as a learning process between students, educators, and other caring adults in which students are helped to assess their own strengths and aspirations, plan for and make demonstrated progress toward their own purposes, and work cooperatively with others to accomplish challenging tasks. With the individually tailored support and guidance of caring adults, students evidence their explorations, accomplishments, and work by demonstrating learning against clear and relevant standards (Clarke; Rennie Center).

Youth placed in DYS programs require a personalized approach to all aspects of their growth and development. As educators, it is our collective responsibility to both build on the strengths and meet the needs of each student who enters our classrooms. All DYS youth are placed into a course of study that best meets their individual needs.

**The DYS Approach to Curriculum Planning and Instruction**

DYS teachers use research-based instructional models to plan relevant and rigorous curriculum and instruction to address the variability of learners. These models are the very core of our instructional pedagogy. Understanding
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Courses of Study: Areas of Concentration

High School: Students who are concentrating on obtaining a high school diploma are placed in classes in accordance with the graduation requirements and their educational records from their sending districts.

High School Equivalency: Students who have met DYS policy requirements for pursuing their high school equivalency credential are placed in core content classes identified in their practice tests as requiring additional study.

Postsecondary: Students who have already earned a high school diploma or its equivalency are eligible to enroll in college coursework or other postsecondary programs as articulated in their transition plans.

Career Readiness: Students who have already earned a high school diploma or equivalency and are actively preparing for college or post-secondary opportunities, or students who are not actively pursuing college, or students who are 18 or older and have formally withdrawn from school may pursue the career opportunities articulated in their transition plans.

by Design (UbD) and Universal Design for Learning (UDL) intersect with Differentiated Instruction (DI) and the frameworks for Culturally Responsive Practice (CRP), Positive Youth Development (PYD) and Empower Your Future (EYF) to serve as a strong and effective foundation for curriculum design so that teachers may best meet the myriad of learning needs of DYS youth. Following is a brief description of each of these models.

Understanding by Design (UbD)

DYS teachers use the UbD model to develop instructional units and lessons. The principles of UbD guide DYS teachers to ask, “What do I want my students to know, understand, and be able to do at the end of this lesson or unit?” They determine at the onset of planning what the “desired result” will be based on state standards and learning objectives. Next, they ask, “How will students demonstrate their learning?” and finally they ask, “What learning experiences can I plan that support these learning goals and outcomes?” The framework includes three stages of curriculum development:

Stage 1: Identify desired outcomes and results.

Stage 2: Determine what constitutes acceptable evidence of competency in the outcomes and results (assessment).

Stage 3: Plan instructional strategies and learning experiences that bring students to these competency levels (Wiggins and McTighe).

Universal Design for Learning (UDL)

Universal Design for Learning is defined as “a set of principles for curriculum development that gives all individuals equal opportunities to learn. UDL provides a blueprint for creating instructional goals, methods, materials, and assessments that work for everyone—not a single, one-size-fits-all solution but rather flexible approaches that can be customized and adjusted for individual needs” (Center for Applied Special Technology).

At the start of the UDL planning process, when considering curriculum design, the teacher incorporates multiple means of:

“With the individually tailored support and guidance of caring adults, students evidence their explorations, accomplishments, and work by demonstrating learning against clear and relevant standards.”
Engagement
The teacher considers “how learners get engaged and stay motivated” and how he or she will “stimulate interest and motivation for learning.”

Representation
The teacher considers how and in what ways will the information and content will be presented so that individual learner needs may be met.

Action and Expression
The teacher considers what tasks will be in the lesson or unit offered to students and how those tasks will be varied so that so that students with different needs can express what they know.

Teachers apply the principles of UDL at the start of the curriculum planning process to provide effective instruction for a wide range of learners. Within that context, teachers monitor student learning and differentiate instruction further depending upon the variability of learner needs.

Differentiated Instruction (DI)
All youth benefit most from instruction that is differentiated to fit their specific learning needs and maximize their learning potential. Differentiated instruction “applies multiple approaches to instruction that identify and integrate differences in culture, family values, and academic background to help teach students of varying learning levels. Teachers need to assess students' readiness, preferences, and interests, and be responsive to these needs.” Teachers differentiate instruction by content, process and product, employing multiple instruction and assessment strategies that work to create ease of access to the general curriculum (Dreambox Learning).

Culturally Responsive Practice (CRP)
Understanding the identities and experiences of youth and the worlds that have shaped them is another form of differentiation known as Culturally Responsive Practice.

Culturally responsive teaching involves linking the curriculum to the lives of our youth in authentic and meaningful ways for the purpose of helping them achieve success. Culturally responsive teaching involves reflecting on the ways in which we interact with our youth and they interact with one another to form positive and affirming experiences. To be culturally responsive educators means getting to know our youth and learning how their experiences and identities have shaped the way they see the world. It involves developing an awareness of how teachers view their own world and how this influences their way of teaching. When we build connections between the worlds of our youth and our own and use these connections to inform our teaching, our youth can see themselves as active and valued participants in the learning community (Commonwealth Corporation, “Elements”).

Positive Youth Development (PYD)
Underlying all aspects of the approach in working with youth in DYS is Positive Youth Development, a model that focuses on the positive attributes young people need to make a successful transition to adulthood. The PYD framework revolves around the cognitive, emotional, and social needs of a young person. A strong focus on these aspects of PYD provides effective guidance for the goals and plans for each youth’s successful re-entry into the community. These include:

1. Focusing on each youth’s strengths and personal assets
2. Providing opportunities for youth empowerment and leadership
3. Cultivating community partnerships and supports that assist youth in moving successfully through the continuum of care

Learning occurs when young people perceive that they are valued as members of the learning community that teachers believe in them, and that they are expected to succeed. Teachers build caring relationships that are informed by knowledge of caring backgrounds, previous experiences, and personal strengths of all youth.

Building strong relationships with caring adults, being held to high expectations, and participating in growth opportunities are also cornerstones to a PYD approach that leads to all youth achieving positive outcomes.

Empower Your Future (EYF)
The Empower Your Future initiative is a project-based
curriculum and a future-focused approach for developing youth voice in education, career, and transition planning. DYS has included EYF within the DYS Strategic Plan goal #3: “Youth will sustain the gains they made while in DYS custody through improved transition planning and continuing community supportive partnerships.” By teaching self-advocacy skills, EYF helps youth sustain gains made in school and involves them in planning their own futures. When youth voice is integrated into planning, the Education and Career Counselors can ensure that gains made by youth are communicated to educators and other staff. Knowledge of youths’ strengths, interests, and needs serves to connect services across the DYS continuum of care.

The EYF curriculum is standards-based and designed to help youth develop the academic/technical, workplace readiness, and personal/social competencies outlined in the Massachusetts Career Development Benchmarks. The EYF curriculum reflects the Massachusetts Department of Elementary and Secondary Education’s (ESE) approach to college and career planning. The Empower Your Future initiative provides curriculum specifically tailored for each program across the continuum of care: detention, assessment, treatment and revocation; and in the community through Bridging the Opportunity Gap programs (Commonwealth Corporation, “Empower”).

Throughout this Guide you will find this icon to indicate connections to Empower Your Future (EYF). Following each unit you will find a detailed description of those EYF connections.

**Works Cited**


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High Standards and Effective Practice
A New Generation in Science Instruction

Introduction
DYS educational programs are designed to provide a rigorous curriculum aligned with the Massachusetts curriculum frameworks and a personalized approach to instruction that meets the needs of all learners. These are ambitious goals. The students served by DYS programs are diverse and face many challenges, but they all deserve access to courses created with high standards and taught with effective practices. The purpose of this Guide is to help DYS science teachers to develop and implement high quality units and lessons.

The science Scope and Sequence charts for Biology, Chemistry, and Physics, and the 10 exemplar units in this Guide are grounded in the 2016 Massachusetts Science and Technology/Engineering Curriculum Framework, which was based on the Next Generation Science Standards (NGSS), developed by the National Research Council, the National Science Teachers Association, the American Association for the Advancement of Science, and Achieve. Massachusetts was one of 26 lead state partners that provided guidance to the NGSS writing team, which was composed of science teachers, professors, and curriculum experts from across the country. The standards have been adopted or adapted by many U.S. states. Please visit the following website for more information about and resources related to NGSS.

SEE: www.nextgenscience.org

A Shift in Science Instruction
Appendix A of NGSS, entitled “Conceptual Shifts in the Next Generation Science Standards,” asserts that the new standards “provide an important opportunity to improve not only science education but also student achievement” (1). The appendix goes on to outline a number of shifts reflected in the standards, the most important of which are listed here on pp. 1.1.1 to 1.1.2:

Shift 1
K-12 science education should reflect the interconnected nature of science as it is practiced and experienced in the real world (1).

NGSS embodies this concept by including three dimensions: Science and Engineering Practices, “behaviors that scientists engage in as they investigate and build models and theories about the natural world and the key set of engineering practices that engineers use as they design and build models and systems”; Crosscutting Concepts, “concepts [that] have application across all domains of science,” and Disciplinary Core Ideas, those that “have the power to focus K-12 science curriculum, instruction and assessments on the most important aspects of science.” Among the criteria for selecting core ideas is that they “Relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technological knowledge” (“Three Dimensional”; emphasis in original).

Shift 2
The Next Generation Science Standards are student performance expectations—NOT curriculum (2).

NGSS does not dictate curriculum organization nor how the three dimensions of science learning are linked, but many of the standards do incorporate key strategies such as modeling.

Shift 4
The NGSS focus on deeper understanding of content as well as application of content (4).

Unlike many traditional science courses, NGSS emphasizes understanding of big ideas, not isolated learning of facts and terminology. “It is important that teachers and curriculum/assessment developers understand that the focus is on the core ideas—not necessarily the facts that are associated with them. The facts and details are important evidence, but not the sole focus of instruction.”
Shift 6

The NGSS are designed to prepare students for college, career, and citizenship (5).

Scientific literacy is essential for full participation in modern life, including not only qualifying for many jobs and careers but also making informed health care and nutritional choices as well as engaging in public policy issues related to the environment, climate change, and power generation, to name a few.

These conceptual shifts make intuitive sense, but what do they mean for classroom practice? In “A New Vision for Science Education” (see graphic on p. 1.1.3), the National Research Council outlines the changes. Many teachers will recognize the approaches listed in the left column as features of their own science education: rote memorization of terms, teacher-centered lectures, heavy use of textbooks and end-of-chapter questions, “cookbook” labs, and worksheets. Shifting to the more engaging and challenging practices in the right column does not mean that traditional activities will be abandoned completely, but that there will be more opportunities for students to do science the way scientists do, thinking about and modeling systems, engaging in genuine research and investigations, engaging in deep discussions, using multiple published sources and laboratory data to construct arguments, and presenting conclusions orally and in writing.

The final shift in the table is of critical importance: these new, high-level standards are for all students. Rather than lowering expectations for students who are perceived to be less able or lacking in background knowledge, teachers should provide supports that enable all students to access big scientific ideas, engage in genuine scientific inquiry, and demonstrate scientific thinking.

For example, a unifying idea in the study of life science is the study of interactions and the flow of energy in ecosystems. A teacher could pose a guiding question such as, “What would happen to the population of hawks if the population of mice collapsed?” Working from this question, students could go online to research food chains, flow of energy within systems, and predator-prey relationships in order to construct their own model of a food pyramid for this meadow system. Rather than starting with a list of related vocabulary—such as primary producers and primary, secondary, and tertiary consumers—students would share what they learn about ecosystems and how energy is transferred from level to level, drawing the food chain and a food pyramid that shows how solar energy is converted to chemical energy in plants and how plants are eaten by herbivores that are then consumed by carnivores and omnivores. Teachers could guide this inquiry into ecosystems using mathematical and computer-based simulations to show that much of the energy is used as heat and that the energy transfer is incomplete, even though the Law of Conservation of Energy states that energy cannot be created nor destroyed, but only changed from one form into another or transferred from one object to another.

With the NGSS emphasis on authentic science, role plays can help students see what is happening by making scientific situations visible. In this case, students could begin by responding to a graphic organizer in which they define how food chains and food webs are similar and different. After sharing and reviewing this activator, students could be cast into roles (grass, mice, snakes, hawks, data collector) and use small bags of popcorn to represent energy. Paralleling what happens in nature, students representing grass would spread out and give up their energy (popcorn) when approached by mice. The goal of the mice would be to collect as much energy as possible; they would be released first to have time to gather food (energy) before the predators (snakes, hawks) begin their hunt for food.
### A New Vision for Science Education

Implications of the Vision of the Framework for K-12 Science Education and the Next Generation Science Standards

<table>
<thead>
<tr>
<th>Science Education Will Involve Less:</th>
<th>Science Education Will Involve More:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rote memorization of facts and terminology</td>
<td>Facts and terminology learned as needed while developing explanations and designing solutions supported by evidence-based arguments and reasoning</td>
</tr>
<tr>
<td>Learning of ideas disconnected from questions about phenomena</td>
<td>Systems thinking and modeling to explain phenomena and to give a context for the ideas to be learned</td>
</tr>
<tr>
<td>Teachers providing information to the whole class</td>
<td>Students conducting investigations, solving problems, and engaging in discussions with teachers’ guidance</td>
</tr>
<tr>
<td>Teachers posing questions with only one right answer</td>
<td>Students discussing open-ended questions that focus on the strength of the evidence used to generate claims</td>
</tr>
<tr>
<td>Students reading textbooks and answering questions at the end of the chapter</td>
<td>Students reading multiple sources, including science-related magazine and journal articles and web-based resources; students developing summaries of information</td>
</tr>
<tr>
<td>Pre-planned outcome for “cookbook” laboratories or hands-on activities</td>
<td>Multiple investigations driven by students’ questions with a range of possible outcomes that collectively lead to a deep understanding of established core scientific ideas</td>
</tr>
<tr>
<td>Worksheets</td>
<td>Student writing of journals, reports, posters, and media presentations that explain and argue</td>
</tr>
<tr>
<td>Oversimplification of activities for students who are perceived to be less able to do science and engineering</td>
<td>Provision of supports so that all students can engage in sophisticated science and engineering practices</td>
</tr>
</tbody>
</table>


Table 1-1, “Guide to Implementing the Next Generation Science Standards, 2015.” Reprinted with permission from the National Academy of Sciences, Courtesy of the National Academies Press, Washington, D.C.
### Disciplinary Core Ideas

#### LS1A: Structure and Function
- Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS1-1)
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (HS-LS1-1) (Note: This Disciplinary Core Idea is also addressed by HS-LS3-1.)
- Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (HS-LS1-2)
- Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (HS-LS1-3)

### Crosscutting Concepts

#### Systems and System Models
- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—with and between systems at different scales. (HS-LS1-2)

#### Structure and Function
- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-LS1-1)

#### Stability and Change
- Feedback (negative or positive) can stabilize or destabilize a system. (HS-LS1-3)

### Connections to Nature of Science

- Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. (HS-LS1-3)

### Science and Engineering Practices

<table>
<thead>
<tr>
<th><strong>Developing and Using Models</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planning and Carrying Out Investigations</strong></td>
</tr>
<tr>
<td><strong>Constructing Explanations and Designing Solutions</strong></td>
</tr>
</tbody>
</table>

### Articulation across grade-bands

- MS.L.SL.1.A (HS-LS 1-3); (HS-LS 1-2); (HS-LS 1-3); MS.LS3.A (HS-LS 1-1); MS.LS.II.3.B (HS-LS 1-1)

### Common Core State Standards Connections

- RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS1-1)
- WHST.9-12.2: Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. (HS-LS1-1)
- WHST.9-12.7: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS1-3)
- WHST.9-12.8: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overrely on any one source and following a standard format for citation. (HS-LS 1-3)
- WHST.9-12.9: Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1-1)
- SL.II.11-12.5: Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-LS1-2)

---

The time it takes for the predators to capture their prey could be measured and plotted on a spreadsheet to show the results; students could look for patterns when they interpret the results. This simulation could be repeated to show what happens with fewer mice, more hawks, drought (less grass), or other scenarios. The lesson would end with students responding to a couple of reflection questions, such as “What effect would there be on a population with no natural predators?” and “What would happen to primary producers and primary consumers if the number of secondary consumers doubled?” (adapted from Wilson).

**Unpacking the NGSS and the Massachusetts STE Curriculum Framework**

The NGSS is a valuable planning resource for teachers, but the sheer volume of information it includes can seem overwhelming. At the secondary level, the standards are organized by grade-level bands and disciplinary “storylines.”

**EXAMPLE (p. 1.1.4):**

The table on the preceding page, illustrating the beginning of the High School Life Sciences section, is typical. This section has several parts, beginning with performance standards related to the topic.

The wording of the performance standards at the top of the table is significant, as some of the shifts in science instruction discussed above are represented. Students are asked not merely to memorize but to “Construct an explanation based on evidence,” to “Develop and use a model to illustrate,” and to “Plan and conduct an investigation.” These are examples of students doing science to learn science. Note that each performance standard may be followed by a “Clarification Statement” and/or an “Assessment Boundary.” These additions can be helpful in determining the primary focus of the standards, especially the longer and more technical ones.

The expectations embedded in the performance standards are reinforced by the Science and Engineering Practices found in the blue section of the center row, which connect the content standards to the kinds of work that scientists and engineers do in the real world.

Here is the full list of practices:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information (“Appendix F” 1)

All sections of the NGSS include these practices, so over time students will come to understand that they are integral to the study of science and engineering.

**Connections to the Nature of Science** (in this case “Scientific Investigations Use a Variety of Methods”) follow the Science and Engineering Practices in the blue center section. These connections are designed to help students gain a broader view of the profession and the values and beliefs that underlie its practices.

The peach-colored section of the center row entitled Disciplinary Core Ideas represents a progression in students’ thinking about “big ideas” over time. The topics are repeated in each grade band, but with increasing sophistication. For example, the Structure and Function concept is defined for grades 6-8 as follows: “All living
1.1.6 things are made up of cells. In organisms, cells work together to form tissues and organs that are specialized for particular body functions.” But for high school it has a more complex meaning: “Systems of specialized cells within organisms help perform essential functions of life. Any one system in an organism is made up of numerous parts. Feedback mechanisms maintain an organism's internal conditions within certain limits and mediate behaviors” (“Appendix E” 4). Studying the differences between explanations for the different grade bands highlights the “value added” by instruction at each level.

The green center section of the example on p. 1.1.4 shows Crosscutting Concepts, which are intended to unite “core ideas throughout the fields of science and engineering. Their purpose is to help students … develop a coherent and scientifically based view of the world” (“Appendix G” 1). The seven Crosscutting Concepts include “big ideas” that also have applications in other content areas. The table above contains these concepts. These concepts also have progressions across the grades that are explained and illustrated in detail in Appendix G of the NGSS. To take one example, the progress from grades 6-8 to grades 9-12 in “Stability and Change” is explained as follows:

### SEVEN CROSSCUTTING CONCEPTS

<table>
<thead>
<tr>
<th></th>
<th><strong>Patterns</strong></th>
<th>Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td><strong>Cause and effect</strong></td>
<td>Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.</td>
</tr>
<tr>
<td>3</td>
<td><strong>Scale, proportion, and quantity</strong></td>
<td>In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system’s structure or performance.</td>
</tr>
<tr>
<td>4</td>
<td><strong>Systems and system models</strong></td>
<td>Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.</td>
</tr>
<tr>
<td>5</td>
<td><strong>Energy and matter: flows, cycles, and conservation</strong></td>
<td>Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems’ possibilities and limitations.</td>
</tr>
<tr>
<td>6</td>
<td><strong>Structure and function</strong></td>
<td>The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.</td>
</tr>
<tr>
<td>7</td>
<td><strong>Stability and change</strong></td>
<td>For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.</td>
</tr>
</tbody>
</table>

Source: “Appendix G—Crosscutting Concepts (1).” *Next Generation Science Standards*
In grades 6-8
Students explain stability and change in natural or designed systems by examining changes over time, and considering forces at different scales, including the atomic scale. Students learn changes in one part of a system might cause large changes in another part; systems in dynamic equilibrium are stable due to a balance of feedback mechanisms, and stability might be disturbed by either sudden events or gradual changes that accumulate over time.

In grades 9-12
Students understand much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems over very short or very long periods of time. They see some changes are irreversible, and negative feedback can stabilize a system, while positive feedback can destabilize it. They recognize systems can be designed for greater or lesser stability. (11)

In the higher grades, the concept not only takes on increasing complexity but also relies increasingly on constructing explanations, quantifying, and modeling. Finally, each section of standards in the NGSS include connections to other science standards in the same grade band and in previous grade bands, as well as to the Common Core State Standards. The Common Core connections will be examined in detail above.

It is important to note that the standards in the Massachusetts Department of Elementary and Secondary Education’s 2016 Science and Technology/Engineering Curriculum Framework incorporate many features of the NGSS, but there are also some key differences, summarized in the table above. Massachusetts’ modifications clarify some standards and streamline the document to make it easier for teachers to use.

The Scope and Sequence documents and exemplar units in this Guide are based on the Massachusetts Standards and focus on three high school courses: Biology, Chemistry, and Introductory Physics. The two other courses in the Massachusetts Framework, Earth and Space Science and Technology/Engineering, are not included as chapters in this Guide, but the Scope and Sequence charts do make connections to those subjects.
NGSS and the Common Core

A key feature of the NGSS is alignment with the Common Core State Standards (CCSS) in ELA/literacy and mathematics, which are incorporated into the 2011 Massachusetts frameworks in those subjects. According to Appendix A, “The NGSS are aligned with the CCSS to ensure a symbiotic pace of learning in all content areas. The three sets of standards overlap in meaningful and substantive ways and offer an opportunity to give all students equitable access to learning standards” (5). The Venn diagram on p. 1.1.9 shows clearly how the three sets of standards relate and converge.

In the NGSS, each set of science standards is followed by a list of CCSS connections. While the 2016 Massachusetts Science and Technology/Engineering Curriculum Framework does not include these lists, this Guide does make connections to the literacy and mathematics standards in the Scope and Sequence charts for each science subject, and each of the exemplar units highlights literacy and numeracy practices that reinforce them.

The Massachusetts Curriculum Framework for English Language Arts and Literacy

This framework includes “Reading Standards for Literacy in Science and Technical Subjects 6-12 (75) and “Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12” (77). Among the 10 reading standards are skills and practices frequently mentioned in the NGSS: citing evidence from texts (including non-print texts), drawing conclusions and making comparisons, following procedures, using domain-specific vocabulary, interpreting data presented in textual or visual form. The following are especially relevant to the exemplar units in this Guide (the reading standards for grades 9-10 are provided as examples):

1. Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
2. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
3. Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
4. Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
5. Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts. (75)

These reading standards, like the science standards that align with them, require evidence-based comprehension, attention to detail, flexible thinking, and high-level analysis. Similarly, the 10 writing standards include sophisticated skills related to purposes and text types, production, and research. The following are particularly pertinent to the NGSS and the exemplar units in this Guide (again, the grade 9-10 standards are provided):

1. Write arguments focused on discipline-specific content. [This standard goes on to enumerate specific aspects of effective arguments, such as claims and counterclaims, cohesion, style and tone, conclusion.]
2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. [This standard goes on to enumerate specific aspects of effective informative/explanatory texts, such as introduction and organization, development, transitions, precise language, style and tone, conclusion.]

Note: While there is no standard for narrative writing within the content-area literacy framework, there is an expectation that students will develop narrative skills: “The standards require that students be able to incorporate narrative elements effectively into arguments and informative/explanatory texts. ... In science and technical
Relationships and Convergences

1. CCSS for Mathematics (practices)
2a. CCSS for ELA & Literacy (student capacity)
2b. ELPD Framework (ELA “practices”)
3. NGSS (science and engineering practices)

**Notes:**
1. MP1–MP8 represent CCSS Mathematical Practices (p. 6–8).
2. SP1–SP8 represent NGSS Science and Engineering Practices.
4. EP7* represents CCSS for ELA student “capacity” (p. 7).

“In science and technical subjects, students must be able to write precise enough descriptions of the step-by-step procedures they use in their investigations or technical work...”

In science and technical subjects, students must be able to write precise enough descriptions of the step-by-step procedures they use in their investigations or technical work that others can replicate them and (possibly) reach the same results.

4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

7. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

10. Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

The first two of these standards refer to genres of writing frequently mentioned in the NGSS. The latter three emphasize flexibility in writing: considering the purpose and audience, incorporating research to answer specific questions, and writing in different contexts (e.g., low-stakes writing to learn and high-stakes writing to demonstrate learning).

The Massachusetts Curriculum Framework for Mathematics

This framework does not include specific standards for science as the literacy framework does, but there are many connections that teachers can make to topics ranging from units and measurements to equations and functions to geometry and trigonometry to statistics and probability. Of course, specific applications of mathematics content standards must be adapted to students’ experience and skills. However, the broader Standards for Mathematical Practice are relevant for all students. The first four are especially important for learning science:

1. Make sense of problems and persevere in solving them.
Mathematically proficient students start by explaining to themselves the meaning of a problem and looking for entry points to its solution. They analyze givens, constraints, relationships, and goals. They make conjectures about the form and meaning of the solution and plan a solution pathway rather than simply jumping into a solution attempt.

2. Reason abstractly and quantitatively.
Mathematically proficient students make sense of the quantities and their relationships in problem situations. Quantitative reasoning entails habits of creating a coherent representation of the problem at hand; considering the units involved; attending to the meanings of quantities, not just how to compute them; and knowing and flexibly using different properties of operations and objects.

3. Construct viable arguments and critique the reasoning of others.
Mathematically proficient students understand and use stated assumptions, definitions, and previously established results in constructing arguments. They make conjectures and build a logical progression of statements to explore the truth of their conjectures. They are able to analyze situations by breaking them into cases, and can recognize and use counterexamples. They justify their conclusions,
communicate them to others, and respond to the arguments of others. They reason inductively about data, making plausible arguments that take into account the context from which the data arose.

4. Model with mathematics.
Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace. … They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions. They routinely interpret their mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose. (15-16)

Like the literacy standards listed previously, these Standards for Mathematical Practice are designed to engage students in high-level thinking skills. When integrated with the NGSS Science and Engineering Practices, CCSS mathematical practices enable students to delve deeply into science content and apply it to real-world problems.

Implementing the Standards in DYS Schools

Right from the start, the NGSS emphasizes the importance of science for everyone: “There is no doubt that science—and therefore science education—is central to the lives of all Americans. Never before has our world been so complex and science knowledge so critical to making sense of it all” (“Executive Summary” 1). This document goes on to remind readers “that in the real world science and engineering is always a combination of content and practice” (2).

We strive to personalize instruction so that it aligns with students’ strengths and needs. The charge is clear in both the NGSS and the Massachusetts STE framework: “Formal education should advance students’ development of the skills necessary to engage in scientific inquiry and engineering design” (2016 Massachusetts STE Curriculum Framework 23).

Teachers need to help students see science and engineering in authentic contexts. Students need to practice science as a way to learn scientific facts, skills, and concepts. Science needs to be taught in conjunction with English language arts, mathematics, and history, in order to promote solving problems, making models, interpreting data, making claims supported by evidence, generating arguments, and evaluating research. Teaching science nowadays is about much more than just knowing the language of science; rather, it is about putting science into action and making sense of concepts when they are seen in real-world settings.

A myriad of online tools provides new ways to help students learn science. Websites such as Newsela link to current non-fiction articles that align with students’ interests, articles that can be adapted for different reading levels or translated into Spanish with a single click. PhET (phet.colorado.edu), Gizmos at ExploreLearning (explorelearning.com), and other sites provide interactive simulations that allow students to change variables and witness complex systems in action instantly and safely in classroom settings with limited access to laboratory equipment.

“Science needs to be taught in conjunction with English language arts, mathematics, and history, in order to promote solving problems, making models, interpreting data, making claims supported by evidence, generating arguments, and evaluating research.”
Having the students write claims, build models, and conduct basic research will help them see that scientists draw on the work of others and communicate and share their discoveries to advance the field. Constructing explanations of how things change and how they remain stable and looking at change over time helps promote deep thinking about how the world we live in adapts. Diagramming simple systems helps students see how ecosystems combine abiotic and biotic factors to support life, how molecules move when heat is added or pressure is reduced, and how the force of friction opposes motion when you ride a bicycle. As with any other subject, teaching science requires a variety of methods to meet students’ needs and engage their interest.

So, while the classroom situation in DYS schools does not offer ideal conditions for teaching science, there is much that teachers can do to help students rise to the challenge of the NGSS and the Massachusetts framework.

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Curriculum Planning and Instruction
Goal-Driven Units with Access for All

Introduction

This Guide includes 10 exemplar units: one for each of the six “seasons” of Biology, two for Chemistry, and two for Physics. All exemplars have been developed using the DYS unit template, which is based in part on Grant Wiggins and Jay McTighe’s “Understanding by Design” (UbD) model of backward planning.

Backward planning is, in essence, the simple and sensible idea that curriculum development should begin with identifying the Desired Results of a course of study and working backward from those goals to the Assessment Evidence that will determine whether they have been met and ultimately to the Learning Plan that will move students toward achieving them. The DYS unit template includes these three planning stages, and their various sections are annotated below as an aid to understanding and curriculum development.

Stage 1

Starting at the end may seem counterintuitive, but the backward planning process works like a GPS: setting

DYS UNIT TEMPLATE: STAGE 1 | SCIENCE GUIDE

<table>
<thead>
<tr>
<th>DESIRED RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emphasized Standards</strong> (Content and College and Career Readiness Anchor Standards):</td>
</tr>
<tr>
<td>The Scope and Sequence charts for each subject identify one or more Emphasized Standards from the 2016 Massachusetts Science and Technology/Engineering Curriculum Framework for each curriculum season; an additional standard (or more) may be included if it will truly be a focus of instruction. The targeted standards must all be assessed in the unit.</td>
</tr>
<tr>
<td><strong>Essential Question(s)</strong> (Open-ended questions/concepts that lead to deeper thinking and understandings):</td>
</tr>
<tr>
<td>The Scope and Sequence charts also provide Essential Questions for each season. Each unit should include one or more of these questions (modified as needed), plus unit-specific questions as appropriate. Essential Questions should be open-ended and spur inquiry, not lead to set answers.</td>
</tr>
<tr>
<td><strong>Transfer Goal(s)</strong> (How will students apply their learning to other contexts?):</td>
</tr>
<tr>
<td>Each exemplar unit includes examples of Transfer Goals appropriate to the Emphasized Standards, Essential Questions, and themes of the season. Note that the goals provided are at the higher levels of Bloom’s taxonomy. Each unit should include similar long-range, college- and career-ready goals.</td>
</tr>
<tr>
<td><strong>Learning and Language Objectives (Mastery Objectives)</strong> Students will...</td>
</tr>
<tr>
<td><strong>Know:</strong> factual knowledge, key vocabulary</td>
</tr>
<tr>
<td>Know objectives include relevant facts, background information, general academic vocabulary, and the terminology needed for success in the unit. A helpful rule of thumb: knowledge items could be assessed on a quiz.</td>
</tr>
</tbody>
</table>
the destination comes first, then determining the route. Emphasized Standards establish the broad aims for all units, but the UbD approach to goal setting also places high value on “big ideas” represented by Essential Questions and understandings as well as on long-term Transfer Goals. Deciding what students should know and be able to do as a result of instruction is important, as always, but considering how they will make meaning from the unit, understand and apply what they have learned in real life is crucial. Developing these higher-order goals is a thoughtful way of anticipating the challenging but legitimate student question, “Why do we have to learn this?” A teacher who sets authentic, relevant, thought-provoking learning goals always has a satisfactory answer.

**Stage 2**

The most critical step in the backward planning process is designing the assessments that will provide evidence of student learning. In the UbD model, the principal assessment is a Performance Task that serves as the culminating experience of the unit (or the entire season). Unlike a traditional Summative Assessment such as a test, a Performance Task asks students to transfer their learning to a new, authentic problem. Wiggins and McTighe recommend the “GRASPS” method of creating authentic Performance Task scenarios.

- **Goal:** Establish the goal, problem, challenge, or obstacle in the task.
- **Role:** Define the position or job of the students in the scenario.
- **Audience:** Identify the target audience, client, or constituency within the scenario.
- **Situation:** Set the context of the scenario. Explain the situation.
- **Product:** Clarify what the students will create and why they will create it.
- **Standards:** Provide students with a clear picture of success by issuing rubrics to the students or developing them with the students.

(Adapted from McTighe and Wiggins 172)

Because it is the direct result of instruction in the unit, the Performance Task actually drives the Learning Plan, as explained in the next section. But each unit should also include several related assessments that enable the teacher—and the students—to monitor progress toward the performance goals.

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**DYS UNIT TEMPLATE: STAGE 2 | SCIENCE GUIDE**

<table>
<thead>
<tr>
<th>ASSESSMENT EVIDENCE</th>
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</thead>
<tbody>
<tr>
<td><strong>Performance Task(s)—Summative Assessment(s)</strong> (Align with CCR &amp; Content Standards):</td>
<td></td>
</tr>
<tr>
<td>The Performance Task(s) or Summative Assessment(s) are the culmination of the unit, the occasion for students to show that they can transfer what they have learned to new situations or challenges. The Performance Task should be linked to the Emphasized Standards and the Transfer Goals, and, when possible, it should be authentic, that is, completed for a real purpose and audience. The criteria for evaluating the Performance Task should be aligned with the Mastery Objectives.</td>
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<table>
<thead>
<tr>
<th>Pre-Assessment(s)</th>
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<tbody>
<tr>
<td>A Pre-Assessment may be formal or informal, but it should be aligned with the content and skills required in the unit. A Pre-Assessment can build confidence and engagement if it activates students’ prior knowledge and experience as well as indicating areas for growth and learning.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Formative Assessment(s)</th>
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</thead>
<tbody>
<tr>
<td>Formative Assessments are the backbone of an effective unit plan, as they serve not only as the mini-tasks through which students develop knowledge, understanding, and skill, but also as the means by which they demonstrate their progress. Formative Assessments provide vital data for the teacher, who can learn from them what aspects of the unit plan need to be reinforced or retaught.</td>
</tr>
</tbody>
</table>
Pre-Assessments administered one or more times at the start of a unit can serve to activate prior knowledge, stimulate interest in the topic, and establish a baseline of skills. Pre-Assessments can range from low-stakes writing and informal group tasks to scaled-down versions of the culminating Performance Task, but they should be constructed to allow students to demonstrate what they know and can do, not highlight their shortcomings.

Formative Assessments placed strategically throughout the unit can serve not only as checks on students’ acquisition of knowledge, understanding, and skills, but also as the means for developing their capabilities. A well-designed Formative Assessment is a mini-task that moves students toward successful completion of the Performance Task by building a particular capacity—such as formulating a claim or citing relevant evidence.
Stage 3

The final step in unit development is creating the sequence of lessons that constitute the Learning Plan. Sequence is the key word at this stage of the process. Lessons should not be just a series of “interesting activities” or merely based on moving to the next chapter of a book. Rather, they should be organized into introductory, instructional, and culminating experiences that foster continuous progress toward the performance goals. The best designed lessons focus on what the students will learn, not what the teacher will teach, and they include mini-tasks that serve as Formative Assessments, as noted in the Learning Plan. (see Stage 3 table on p. 2.1.3.)

Providing Access for All

The Learning Plan section of the unit template includes a section labeled Universal Design for Learning/Access for All. UDL is the foundation to the overall curriculum planning process. This section represents a key consideration in curriculum development: making the content and skills instruction accessible to all students, whatever their learning styles, special needs, levels of English proficiency, school experiences, or degrees of engagement. Addressing this aspect of curriculum design is a major challenge for teachers but essential for student success.

The DYS philosophy and framework for providing access for all is based on Universal Design for Learning (UDL), “a set of principles for curriculum development that give all individuals equal opportunities to learn” from the Center For Applied Special Technology (CAST). These principles, represented in the graphic organizer on p. 2.1.5, call for instruction that includes:

Multiple means of engagement, to tap into learners’ interests, offer appropriate challenges, and increase motivation. This principle involves the brain’s affective networks and concerns the “why” of learning: how learners get engaged and stay motivated; how they are challenged, excited, or interested. The goal is to stimulate interest and motivation for learning.

Multiple means of representation, to give diverse learners options for acquiring information and knowledge. This principle involves the brain’s recognition networks and concerns the “what” of learning: how we gather facts and categorize what we see, hear, and read. Identifying letters, words, and an author’s style are recognition tasks. The goal is to present information and content in different ways.

Multiple means of action and expression, to provide learners options for demonstrating what they know. This principle involves the brain’s strategic networks and concerns the “how” of learning: how we plan and perform tasks, how we organize and express our ideas. Writing an essay is a strategic task. The goal is to differentiate the ways that students can express what they know. (Adapted from CAST)

These UDL guidelines, developed by the Center for Applied Special Technology in Wakefield, Massachusetts, extend to education the architectural concept of universal design—the idea that buildings and landscapes should be constructed to accommodate a wide spectrum of users rather than retrofitted to address particular needs. Incorporating UDL principles in the classroom means planning for diversity rather than coping with it. Giving
students a variety of options for receiving, processing, and engaging with content helps ensure that they have equal opportunity for success. The CAST website offers a wealth of resources for creating access in units.

**SEE:** [www.cast.org](http://www.cast.org)

One of the most difficult aspects of implementing UDL is clarifying the aims of instruction. For example, if a unit Performance Task requires writing an argument or explanation related to a scientific concept, does the principle of providing “multiple means of action and expression” mean that a student can create a PowerPoint or give a speech instead of writing a paper? Probably. If the objectives in this unit include stating a claim and marshalling supporting evidence, those expectations certainly can be met in a visual or oral format. But integrating the elements of argument into several paragraphs of coherent prose would also be a legitimate objective, and in that case the options for action and expression could include how the prose gets written: with the aid of a graphic organizer or essay template, speech-to-text software, teacher conferencing and scribing, or other means of reaching the goal. The key is to focus on that goal and to remove as many barriers as possible.
The options for action and expression listed in the previous paragraph are examples of Differentiated Instruction (DI), a set of teaching practices that encourage teachers to “adjust the curriculum and presentation of information to learners rather than expecting students to modify themselves for the curriculum” (Hall et al.). Three elements of the curriculum may be differentiated:

1. Content (materials, tasks, instruction)
2. Process (student grouping, classroom management strategies)
3. Products (ongoing assessment, exploration, expectations for student responses)

DI’s theoretical framework is different from UDL’s, and it focuses more on accommodating individual needs than on building in accessibility, but many of its techniques are consistent with UDL principles. For example, the DI practice of giving students the option to work in pairs as they search for evidence in a text is consistent with the UDL teaching method of providing opportunities to practice with support (see other examples in Hall et al.).

Driven by changes already happening at the higher education levels and the need to prepare students for the 21st century workplace, Blended Learning provides teachers with a variety of ways to address student needs, differentiate instruction, and provide data for instructional decision-making. Blended Learning is the combination of digital content and activity with face-to-face content and activity. Some options available to DYS teachers to use as digital tools include Gizmos at ExploreLearning and NBCLearn, which can help introduce a topic or reinforce students’ understanding of it. To encourage a blended learning approach, DYS teachers may use a content management system such as Edmodo or PBWorks to host online learning activities that they have designed. These tools allow for independent learning as well as opportunities for students to share their work with the class community and receive feedback or have conversations with other students.

There is a blurred line between Technology Integration and Blended Learning. The video “Blended Learning and Technology Integration” can help teachers understand the difference.

Technology Integration and Blended Learning are both great ways to get students engaged and motivated to learn.

SEE: www.youtube.com/watch?v=KD8AUFQsCKg

All students benefit from curriculum designed using UDL principles and implemented using DI practices, but these inclusive approaches are especially helpful for English Language Learners (ELLs), of whom there are many in DYS schools. To better serve ELLs, Massachusetts has joined the World-Class Instructional Design and Assessment Consortium (WIDA), which promulgates English Language Development Standards (aligned with the Common Core), Performance Definitions for English proficiency levels (see chart on p. 2.1.7), Model Performance Indicators for particular standards and levels, formal assessments, and much more. One essential element of the WIDA initiative is its focus on academic language: “Everything we do at WIDA revolves around the significance of academic language and how to empower language learners to reach for success” (WIDA, Academic Language). Another is its “Can Do Philosophy,” which “embraces inclusion and equity” and focuses on expanding students’ control of academic language, as illustrated in the performance definitions chart.
Performance Definitions for the Levels of English Language Proficiency in Grades K-12

At the given level of English language proficiency, English language learners will process, understand, produce, or use:

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
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<tbody>
<tr>
<td>6</td>
<td>Reaching</td>
</tr>
<tr>
<td></td>
<td>• specialized or technical language reflective of the content areas at grade level</td>
</tr>
<tr>
<td></td>
<td>• a variety of sentence lengths of varying linguistic complexity in extended oral or written discourse as required by the specified grade level</td>
</tr>
<tr>
<td></td>
<td>• oral or written communication in English comparable to English-proficient peers</td>
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<tr>
<td>5</td>
<td>Bridging</td>
</tr>
<tr>
<td></td>
<td>• specialized or technical language of the content areas</td>
</tr>
<tr>
<td></td>
<td>• a variety of sentence lengths of varying linguistic complexity in extended oral or written discourse, including stories, essays, or reports</td>
</tr>
<tr>
<td></td>
<td>• oral or written language approaching comparability to that of English-proficient peers when presented with grade-level material</td>
</tr>
<tr>
<td>4</td>
<td>Expanding</td>
</tr>
<tr>
<td></td>
<td>• specific and some technical language of the content areas</td>
</tr>
<tr>
<td></td>
<td>• a variety of sentence lengths of varying linguistic complexity in oral discourse or multiple, related sentences, or paragraphs</td>
</tr>
<tr>
<td></td>
<td>• oral or written language with minimal phonological, syntactic, or semantic errors that do not impede the overall meaning of the communication when presented with oral or written connected discourse with sensory, graphic, or interactive support</td>
</tr>
<tr>
<td>3</td>
<td>Developing</td>
</tr>
<tr>
<td></td>
<td>• general and some specific language of the content areas</td>
</tr>
<tr>
<td></td>
<td>• expanded sentences in oral interaction or written paragraphs</td>
</tr>
<tr>
<td></td>
<td>• oral or written language with phonological, syntactic, or semantic errors that may impede the communication, but retain much of its meaning, when presented with oral or written, narrative, or expository descriptions with sensory, graphic, or interactive support</td>
</tr>
<tr>
<td>2</td>
<td>Beginning</td>
</tr>
<tr>
<td></td>
<td>• general language related to the content areas</td>
</tr>
<tr>
<td></td>
<td>• phrases or short sentences</td>
</tr>
<tr>
<td></td>
<td>• oral or written language with phonological, syntactic, or semantic errors that often impede the meaning of the communication when presented with one- to multiple-step commands, directions, questions, or a series of statements with sensory, graphic, or interactive support</td>
</tr>
<tr>
<td>1</td>
<td>Entering</td>
</tr>
<tr>
<td></td>
<td>• pictorial or graphic representation of the language of the content areas</td>
</tr>
<tr>
<td></td>
<td>• words, phrases, or chunks of language when presented with one-step commands, directions, WH-, choice, or yes/no questions, or statements with sensory, graphic, or interactive support</td>
</tr>
<tr>
<td></td>
<td>• oral language with phonological, syntactic, or semantic errors that often impede meaning when presented with basic oral commands, direct questions, or simple statements with sensory, graphic, or interactive support</td>
</tr>
</tbody>
</table>

The WIDA website (www.wida.us) includes many helpful resources for teachers, including a search page (WIDA, Search) that allows the user to enter a grade level cluster, framework (formative or summative), language domain (listening, speaking, reading, writing), and other search criteria, and receive a set of model performance indicators for various levels of English proficiency. For example, a search using the criteria 9-12, summative, writing, and claim yields an example on critical commentary. The performance indicators range from “Reproduce critical statements on various topics, illustrated models, or outlines” for Level 1 to “Provide critical commentary on a wide range of issues commensurate with proficient peers” for Level 5. This kind of detail can help teachers set challenging but realistic expectations for ELLs in their classrooms.
"...curriculum planning is not just about what is taught but also about who is learning."

Accessibility as a Lens

Sorting out all the details of complex initiatives such as Universal Design for Learning (UDL), Differentiated Instruction (DI), and WIDA can be daunting, so it is helpful to focus on what they have in common: an understanding that curriculum planning is not just about what is taught but also about who is learning.

The main goal of all three programs is equity—making instruction accessible and relevant to all students—and all are compatible with the Understanding by Design (UbD) method of unit design. But rather than using UDL, DI, and WIDA as checklists for evaluating the accessibility of a Learning Plan, it is better to use accessibility as a lens for viewing assessments and lessons as they are being created. That way, UDL, DI, and WIDA principles can be infused throughout the unit. During implementation, the teacher can feel secure in knowing that tools and scaffolds and options are already in place and concentrate on monitoring progress.

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Jonson, Jen. Blended Learning and Technology Integration. www.youtube.com/watch?v=KD8AUFgsCKg.


WIDA. Academic Language. wida.us/aboutUs/AcademicLanguage.

WIDA. Search the ELP Standards. wida.us/standards/ELP_StandardLookup.aspx.


Acronym Recap

DI Differentiated Instruction
UbD Understanding by Design
UDL Universal Design for Learning
WIDA World-Class Instructional Design and Assessment Consortium
Teaching Science to Student Scientists

Science Pedagogy

The Student as Scientist

Merriam-Webster on science:

“knowledge about or study of the natural world based on facts learned through experiments and observation”

“the state of knowing: knowledge as distinguished from ignorance or misunderstanding”

Everyone is a born scientist—we emerge from the safety of the womb into an unknown world. From that moment on, we are constantly trying to figure out how the world works. While our methods may become more sophisticated as we age, our understanding of the world is built from observations and data, formal and informal. Asking who, what, where, when, why, and how is our natural state. As teachers, we encourage students to ask more questions and help them develop the skills to find answers. Helping students develop their thinking processes and maintain their curiosity is one of our most difficult tasks, but if we get a reaction like, “whoa, that’s crazy” or “hmmm, I never thought of it that way before,” we’re on the right track. We need to seize those opportunities to extend the discussion.

We can see science (and math) everywhere in the world around us:

- Sine waves on a graph and Slinky waves in the playroom
- Levers and fulcrums (simple machines) in everyday tools
- Geometry, forces, and vectors in bridges
- Waves in the ocean and ripples on the beach
- Electromagnetic radiation—colors (wavelengths) of light, radio waves, microwaves, Wi-Fi
- UV-blocking sunglasses and sunscreen
- Parts of our anatomy and physiology that allow perception of the world

Science is how we understand and explain our world. The bottom line: “It’s fun to know stuff!”

When thinking about how to teach science, we should keep these scientific concepts in mind:

- Tentativeness: Knowledge is constantly changing, so what we think we know today may be different tomorrow.
- Empirical evidence: Knowledge is gathered from experimentation and observation.
- Observation and inference: We make observations and draw conclusions based on those observations.
- Scientific laws and theories: As experimental and observational evidence mounts, ideas become solidified and are eventually taken as facts. These become scientific laws and theories—until the next discovery modifies or disproves them.
- Scientific method: We follow a logical process for data/information gathering, analyzing, and drawing conclusions.
- Creativity: Out-of-the-box thinking, developing new theories, and looking at problems in novel ways leads to novel conclusions.
- Objectivity and subjectivity: We recognize that observations and conclusions may be both objective and subjective.
These concepts should be no less evident in the classroom than in the lab. The 2016 Massachusetts Science and Technology/Engineering Curriculum Framework, based on the Next Generation Science Standards, reflects a new emphasis in science teaching, moving from recall to process and logic, to higher levels of Bloom’s Taxonomy. Our challenge as teachers is to develop knowledge and extend thinking about that knowledge.

Engaging Students and Teaching Concepts

Engaging students is all about the relationships we develop with them. On any given day, when those relationships work, students agree to work with us; and when those relationships don’t work, we recognize the illusion of classroom control and engagement.

When teaching science, we must realize that what we don’t know far exceeds what we do know. Our students will occasionally ask us questions that we don’t know the answer to. No problem. If we admit that we don’t know the answer, they won’t hold it against us. But we must take the next step—to ask students where they might find the answer, or to think out loud and reason out the answer together, or to say, “I don’t know, but I’ll find out for you”—then actually do it: find the answer, share it with them, and acknowledge that everyone learned something new. We can use opportunities like this as launching points for other discussions. Responding to students’ ideas and interests shows our curiosity, flexibility, and willingness to engage in students’ questions (we just have to be sure to bring them back to the original point).

There is a concept in Zen Buddhism known as shoshin, which means “beginner’s mind.” “Shoshin refers to the idea of letting go of your preconceptions and having an attitude of openness when studying a subject” (Clear). As adults, we have years of education and life experience that our students don’t have. Then again, they’ve had experiences that we haven’t. As learners, we are just like our students, with knowledge, misconceptions, and our own views of the world. Having a “beginner’s mind” reminds us to back up just a little, remember what it was like to be learning something for the first time, and consider what prior knowledge was required. We can then ensure that our students have the requisite understanding before introducing new material. This section describes some strategies that can help students connect to challenging scientific concepts.

Telling Stories

Teachers can create contexts for content by using stories. History, particularly events that led to discoveries, show the progression of thinking, the stumbling blocks, and the controversies that lead to new theories. Case studies typically present a problem to be resolved. The process of solving a problem forces students to gather their own background information, analyze their findings, and develop their solutions.

A historical example related to evolution is the story of Charles Darwin. His dad, Robert, was a doctor, and his grandfather, Erasmus, was a naturalist. Charles grew up in an environment of wealth and privilege, and his father hoped he would become a doctor. Sadly, Charles couldn’t bear the sight of blood. His father proposed the church as a respectable alternative. As Darwin saw it, life in the parsonage would allow him time for his keen interest in natural history.

One of his professors recommended him for a position on the HMS Beagle, as a companion to Captain FitzRoy and also as the ship’s naturalist. During his five-year voyage (1832-1836), Darwin observed, wrote, and collected, amassing a huge body of information and observations, plus an extensive collection of specimens, primarily from South America and the Galapagos. Decades later (1859) he published On the Origin of Species by Means of Natural Selection (Van Wyhe). Darwin’s theory of natural selection is the basis for evolutionary thinking—characteristics that confer fitness (better survivability) are passed on to future
generations. Populations change over time, reflecting higher fitness.

A mini-case study in human anatomy and physiology is the story of a 35-year-old woman who reports shortness of breath and dizzy spells when she exercises. Her doctor tests her breathing with a peak flow meter, and the flow is surprisingly low. Also, her blood pressure is low and she is anemic. How do these findings relate to her symptoms? Students should first think about which systems are involved and then research various pathologies:

Respiratory: Shortness of breath may indicate asthma. Asthma can lead to a lack of oxygen in the blood. A lack of oxygen in blood overall includes less oxygen to the brain, resulting in dizziness.

Cardiovascular: If blood pressure is low, blood flow to the brain may be impaired, resulting in dizziness. Anemia reflects hemoglobin levels in blood and the blood’s ability to carry oxygen. Severe anemia can cause dizziness.

Science in the News
Finding current items in the news, both online and in print, demonstrates the relevance and timeliness of science. One year it’s the Ebola virus; another year, it’s Zika. There is always news about topics related to what’s being studied in the classroom:

• The annual return of cold and flu season shows the importance of understanding viruses and how they are spread.

• Drug-resistant bacteria show the consequences of antibiotics being used indiscriminately, resulting in untreatable infections.

• Google’s development of contact lenses for diabetics that measure blood glucose levels and send the data to a smart phone shows the intersection of science and engineering.

• The unearthing of new fossils that force scientists to rewrite the story of human evolution or the evolution of life on earth shows the scientific process at work.

New findings present a perfect opportunity to discuss the dynamic nature of science: This is what we know today based on current research, but that could change with tomorrow’s new discovery. This dynamic nature is what makes science so exciting. Websites such as Student Science and Newsela can provide relevant, up-to-date examples.

Connecting Science to Other Disciplines
Science is an integral part of all disciplines. The trick is to tease out the science elements. For example:

Art
Students can look into the development of the wide range of media and pigments. Or they can research techniques that allow a two-dimensional work to be perceived as representing a three-dimensional object and the neuroscience behind that perception. Optical illusions are a fascinating realm of neuroscience.

Ethics
Students can ponder how the development of new technologies forces society to struggle with new moral and ethical dilemmas. For example, reproductive technologies are advancing at an astounding rate, making possible new ways to create a family: in vitro fertilization, reproductive cloning, gene manipulations. The question is less and less “Can we?” and more and more, “Should we?”

History
Students can learn how the Stone Age, Bronze Age, and Iron Age reflected the available technologies of their days. Those technologies determined the progressions of their respective cultures and societies.

Literature
Students can investigate the neuroscience related to creativity and the connection of mental illness to creativity. Or they can study the sciences of publishing: paper-making processes, ink formulas, bookbinding techniques. Our best archival medium is still ink on paper. Books and documents that are 300 years old are still perfectly legible and functional, but there isn’t yet an equivalent in digital media.

Mathematics
Students can complete calculations and mathematical computations found in scientific principles and theories. For example, students can calculate the potential trajectory of a rocket, predict the possible
traits of offspring based on genetic information, or determine the proper ratios of compounds in a chemical reaction to reduce greenhouse gases. Mathematics and science are fundamentally linked and sound science depends on accurate mathematical computation and modeling.

Interdisciplinary connections within science are more obvious. What caused the extinction of the dinosaurs? Paleontology describe fossils, geology describes the sediments in which they were found, chemistry describes the composition of those sediments, and physics calculates the size of the extinction event that caused the same sediment layers to form around the world. Conclusion: An asteroid six miles across hit the earth at 20,000 miles per hour in the Yucatan peninsula, creating a crater 100+ miles across, throwing millions of tons of ejecta into the atmosphere, fundamentally changing the climate worldwide, wiping out the dinosaurs, allowing the age of mammals—and eventually us!

Living the Scientific Method

Though not explicitly, we use and experience the scientific method when making decisions for just about everything:

- **Problem**: I’m hungry.
- **Hypothesis**: Eating a Pop Tart will satisfy my hunger.
- **Experimental Materials**: Pop Tart.
- **Experimental Procedure**: Eat the Pop Tart.
- **Observation/Data/Result**: I’m still hungry.
- **Conclusion**: The Pop Tart did not satisfy my hunger.
- **Implications**: Next time I’ll eat two Pop Tarts.

This example is a bit silly, but the core ideas are there: The scientific method is essentially decision-making based on evidence, and students are making decisions hundreds of times a day. There are consequences for each decision, both minor and major.

Learning in the Lab

Doing science is a fundamental part of learning science. Even if there are only supermarket materials available, they can be used to illustrate many scientific concepts.

Making lemonade from a mix is an experiment in solubility and concentration. Dropping food coloring into water illustrates diffusion, and comparing diffusion of food coloring in hot and cold water illustrates the effects of kinetic energy (temperature) on diffusion.

While students perform “cookbook” activities, questions will arise, and those are opportunities for inquiry, where students ask a question, design the experiment to answer that question, perform the experiment, gather data, and draw conclusions.

Working with actual scientific lab equipment may allow for more precise quantitation, but these tools are not essential.

Getting It Wrong

Anticipating the possible outcomes of experiments and decisions can be difficult since natural systems are so complex. Unanticipated consequences are a part of the scientific process. Indiscriminate use of lifesaving antibiotics leads to antibiotic-resistant infections, as noted above. DES, a miscarriage prevention drug, and Hormone Replacement Therapy result in a higher incidence of certain cancers. Thalidomide was administered for morning sickness until scientists linked it to severe birth defects. Many other medications have adverse interactions and harmful side effects. Also, introduction of non-native (invasive) species such as the European starling, Ailanthus (Tree of Heaven), zebra mussels, and Australian cane toads—even for benign purposes—creates ecological havoc. International travel and trade spreads diseases throughout the world.

We must remember, too, that scientists are people. Though we like to think of science as an objective discipline, it is not just experiments and data. Science is done by people. People have their own biases, agendas, and emotional baggage. They are susceptible to outside influences. These influences may lead some scientists to alter, fabricate, or manipulate data. “Publish or perish” is a common phrase in academic circles. Scientists are often under pressure to publish papers because they know that further funding for their research (a.k.a. their jobs) depends on it. They may be aware of research going on in other labs around the world and want to be the
first to make a claim. They may be up for tenure, and publication in peer-reviewed journals is required for eligibility. Submission to the top peer-reviewed journals is no guarantee that the science is sound. Journals print retractions all the time, and it is becoming more frequent (“Publish or Perish”).

The gold standard for scientific study is reproducibility. Unfortunately, until other labs try to reproduce experiments and get similar data, poor science may go unchecked for some time, as was the case with the cold fusion hypothesis (see “Cold Fusion: A Case for Scientific Behavior”). Even data that is carefully gathered can be manipulated. Ancel Keys, the driving force behind our decades long anti-dietary fat movement, drew his conclusions from incomplete data. He surveyed 22 countries but only used the data from seven. Those countries’ data confirmed his hypothesis of dietary fat leading to heart disease, but when all countries were included, the correlation disappeared (Teicholz). This situation recalls a quotation popularized by Mark Twain: “There are three kinds of lies: Lies, damned lies, and statistics.” Sound statistics strengthen scientific arguments, but unreliable statistics weaken them. Students should learn how to question scientists’ methods and motives when evaluating their findings and conclusions.

Building Scientific Knowledge and Skills

The preceding section focuses on strategies for engaging students in science and developing their conceptual understanding. But how do we help them build knowledge and skills?

Knowing, Understanding, and Doing Science

Determining whether students have the requisite background information is essential. Gaps need to be filled in for students to get the most from the lessons. Once students have the necessary knowledge, they can begin asking questions to be answered by investigations that they designed themselves. Having enough background knowledge also allows for deeper discussions about topics. The more students know, the more they will want to know. Promoting curiosity is essential.

A common experiment in biology is following the germination of seeds and plant growth.

Scenario

Show students some beans. Beans are a good choice because they are cheap, easy to germinate, and easy to manipulate and measure. Begin your guided inquiry process: What are these? Where do they come from? What is their function for the plant? What do they need to grow? At this point, the experimental design process can begin. Students will decide on materials and procedures to observe the germination of beans and the ensuing growth of the plant. What does it need to grow? How will you know if it is growing? What can you measure? How will you measure? When will you measure?

Experimental design

As students develop their procedures, they will invariably decide that some liquid (most will say water), is necessary for seed growth. Ask about the water: how much, temperature, type (spring/tap/distilled). As you work through these conversations, students will see that it is not as simple as dropping some beans in a cup of water and seeing what happens. Some students may ask about different liquids: soda, vinegar, juice, etc. Here’s another opportunity for students to explore even more variables. For example, if a student wants to use Pepsi, ask about other colas. Does brand matter? Concentration, temperature, volume, etc.? Every one of these variables is a “what if” question waiting to be answered.

Data analysis

It is often challenging to decide what to calculate, what to graph, how to present the data. Bar graphs are typically familiar to students but there are situations
where a line graph (e.g., tracking bean germination over time) or scatter plot (e.g., determining whether arm span equals height) may be appropriate.

**Drawing conclusions**

Scientific thinking is logical thinking. We can model logical thinking by thinking out loud with students, elaborating on our own thought process to arrive at a conclusion. Using the Claim, Evidence, Reasoning framework can help structure that process. Pushing students to explain why and how goes well beyond “having the right answer” and is essential to developing student thinking about questions and conclusions. When drawing conclusions from their wide variety of experiments, it is important to emphasize that each experiment answered a specific question. Therefore, the conclusion must also be specific. A conclusion may be “red kidney beans germinate faster in water than in apple juice” (Claim). The data and analysis must support that claim (Evidence). The thinking that led to the conclusion/claim must be logical (Reasoning). Students may be tempted to broaden that conclusion to include other beans, but they didn’t test other beans. Germinating a different bean could be their next experiment.

**Reading Science**

Close reading and observation allows valid conclusions to be drawn. Data interpretation can be done using tables but is often clarified by graphing, a visual translation of data. Developing skills in close reading takes practice. Starting small, with a passage of just a few paragraphs, allows students to develop their note taking skills, whether using sentence frames, two-column notes, or another construct that provides organization for information. Modeling the skills of identifying key terms, ideas, and concepts will allow students to follow the process. Close reading of data, or data interpretation, generally involves some calculations and graphing. Here again, practice is essential. Start with smaller data tables, preferably with student-gathered data, determine what chart style to use, then create the chart. Google Sheets makes it easy to use different chart styles.

Practicing close observation of phenomena can begin with a teacher demonstration. An endothermic reaction is easily demonstrated by adding vinegar to baking soda. Prior to the demo, you can discuss what kinds of observations can be made—appearance, sound, temperature, gas produced—and how these might be measured.

**Writing Science**

Novelist Flannery O’Connor said, “I write to discover what I know.” We must ask students to write to discover and express what they know. Low-stakes writing-to-learn activities enable students to explore and clarify ideas as they are learning. Students may have a superficial knowledge of a scientific phenomenon but when asked to write about it, they often reveal their misconceptions and the gaps in their understanding, helping the teacher and student understand what further intervention is needed. Writing-to-learn is intended to develop critical thinking skills as well as student thinking about a topic. Brief daily writing prompts can become a routine practice, thereby developing comfort with writing. Student writing can be integrated into the curriculum using frameworks like Claim/Evidence/Reasoning, or a formal essay format can structure their writing.

**Speaking and Listening Science**

Class discussions and student presentations allow for a different kind of interaction in the science classroom than the traditional lecture and demonstration. Allowing students time to discuss their experimental results or their research findings gives them another opportunity to make sense of them. Peer teaching provides an opportunity for them to hear from someone other than the “expert,” and explanations that may have been unclear coming from the teacher may be better understood coming from another student.

**Language in Science**

Studying the etymology of scientific terms not only helps students decipher new words by looking at roots, but also reveals the thinking of the times at which they were coined. Every discipline has specialized vocabulary. We shouldn’t be afraid of it but rather embrace it and take advantage of opportunities to analyze words and derive their meanings. After repeatedly seeing the same roots,
students will begin to use them to understand new vocabulary. For example, in taxonomy, the species name *Ictidomys tridecimlineatus* describes the 13-lined ground squirrel (*Tri* = 3, *deci* = 10, and *lineatus* = lines.) In cell biology, there are numerous terms based on the root cyto (“cell”): *cytoplasm*, *cytosol*, *cytoskeleton*. Having learned this root, students will have a better idea what happens in the cytology lab in a hospital. And if students learning the metric system roots, they can apply them to all units: *milli*—(one thousandth), *centi*—(one hundredth), and *kilo*—(one thousand), for example, mean the same thing whether the units refer to volume (milliliter), length (centimeter), or mass (kilogram).

**Numeracy in Science**

Data gathering is an integral part of science practice. Translating that data into graphical form allows students to analyze the data and see trends within it. Mathematical formulas and calculations are used in all disciplines, though less frequently in biology and more frequently in chemistry and physics. Graphing data on the growth rates of plants under different conditions or recording the differences in oscillation rates of springs with different masses attached allows easy visualization of differences. One of the most important aspects of graphing is setting appropriate scales on the y-axis. If the y-axis scale is too large, differences will be minimized; if the scale is too small, differences can be exaggerated. Observational data, though often subjective in nature, may also be important. In a hospital ER, patients may be asked to rate their pain on a scale of 1 to 10, 10 being the worst pain imaginable. A patient who says 4 may be kept for observation, while one who says 3 may be sent home. The data is completely subjective, but hospital staff couple those ratings with test results to decide on a course of treatment.

**Assessment in Science**

As illustrated in the exemplar units in this Guide, Formative Assessments can be integrated throughout a unit. Often these take the form of mini-tasks that allow the students to build capacity and demonstrate growth, and that inform teaching. They may be as informal as Exit Tickets that describe something learned in that lesson or brief writing prompts (based on the prior class) at the beginning of each class. Games like *Jeopardy* and online sites like *Kahoot* and *Socrative* are fun for students and provide feedback to the teacher on their progress.

Formal assessments may take the form of projects or presentations. Offering some degree of choice in the final product can lead to better engagement. Performance Tasks are authentic assessments that demonstrate transfer of knowledge and skills in realistic scenarios. These may include oral and written presentations. Often these assessments require a combination of presentation (oral) and written product (board game, comic strip, poster board, infographic, video, etc.).

While quizzes and tests should not be the predominant forms of assessment, they may be appropriate and useful. These assessments should include both multiple choice and open-response questions, as students look ahead to preparing for high-stakes testing. Structuring tests similarly to state assessments is part of preparing students for high-stakes tests when they return to their sending districts.

Teachers should use various forms of assessment to collect needed information about the range of students entering the class. At times, a Summative Assessment may also function as a Pre-Assessment or a Formative Assessment for some students. Teachers should be prepared to provide needed scaffolding for new students who arrive during the middle or at the end of a unit. Through differentiating the assessment for various students’ needs during planning, the teacher will have material appropriate for all students.

**Teaching Science in DYS**

Exploring career opportunities in science can spark motivation and provide students with a goal. When possible, offer hands-on lab opportunities to “do science.” Fortunately, many concepts may be demonstrated through “supermarket science,” that is, with materials that are readily available in local supermarkets. They are accessible, relatively safe, and generally inexpensive. If materials are limited, the teacher should at least do a demonstration, maybe with student volunteers. Before conducting the experiments in class, a teacher should
check with program supervision and staff about the materials and provide a plan for how to implement the lab and the safety measures that will be put in place.

Because students experience varying lengths of stay, organizing units into shorter modules will meet the needs of shorter-term residents. The exemplar units provided in this Guide are intended to guide teachers’ unit creation. They will likely need revision to meet the specific needs of each facility, but adaptations and scheduling options are provided.

Making science accessible to all students can be challenging. “Universal Design for Learning in the Science Classroom,” by Jeremy Forest Price, Mindy Johnson, and Michael Barnett (in Hall et al. 55-69), addresses potential barriers to learning under the categories “Thinking Science,” “Talking in Science,” and “Doing in Science” and offers strategies for overcoming barriers through technology, especially in assessment, because it is easier to use and more flexible: “students can be assessed in a variety of ways, both explicitly and through embedded assessments” (68). Other recommended tools include the following:

- CAST Science Writer
  sciencewriter.cast.org
- CAST UDL Book Builder
  bookbuilder.cast.org
- The Why? Files: The Science Behind the News
  www.whyfiles.org

While teaching in DYS, it is important to honor the students’ abilities and continue to support the students’ academic skills to encourage them to grow to their full potential. Teachers should create lessons and activities that will engage the students and interest them in learning the content. Moreover, teachers need to maintain high standards for the students to complete the work. Students should have access to differentiated materials, but teachers need to work in the zone of proximal development for the student. Work shouldn’t be so hard that students can’t start the work, nor so easy that it offers no challenge or growth opportunity. Teachers should provide questions and activities that meet the students where they are and apply their knowledge and skills to more complex and real-life Performance Tasks, as found in the provided units.

While learning about the science content, it is important for students to discuss what they know about the material and make connections about the topics to their personal lives. Teachers should provide as many real-life examples as possible and introduce current articles to show the applications of what they are learning. In addition, teachers could have students research scientists working in areas in which they show interest.

In science there is an opportunity for Culturally Responsive Practice by creating meaningful lessons and providing students opportunities to share their cultural experiences and acknowledge all cultures’ contribution to the field. For instance, while discussing genetically modified food, the teacher may providing readings showing that American Indians accomplished this feat in the 1400s (Mann 191-200). However, teachers should not add pieces of unconnected knowledge in their units just to have it there; teachers should appreciate all scientists’ contributions during each unit to make the information more powerful for the students.

In the units, the Performance Tasks are based on real-life situations or assessments that apply Future Ready skills. During the unit, it is important to connect the learning to the Transfer Goals that can be used in everyday life and, especially, utilized in a job or career. Teachers should highlight the skills the students are practicing while thinking and acting like a scientist. In addition, during the lessons, the teacher can include non-scientific jobs and the qualifications needed to succeed in that career field to personalize to the students’ interests. To increase the students’ skills, the teacher should include opportunities for the students to present to the class or other audiences, work collaboratively with peers to complete the tasks, and

“With any experiments or activities used in the science classroom, it is vital to keep safety a top priority.”
have chances to show their initiative and self-direction with the learning.

With any experiments or activities used in the science classroom, it is vital to keep safety a top priority. Conversations with staff and program supervisors must occur to ensure safety for the teacher, students, and program personnel. During these communications, the teacher should stress what materials are being utilized, what the expected outcomes for the activity are, and how the materials will be accounted before, during, and after the lesson. Besides materials, a teacher must discuss how students will be configured during an experiment. If the classroom is set up such that students do not have the flexibility to move about or partner with other students, teachers may not be able to offer hands-on experience. Teachers who cannot provide experiments in the classroom could show online videos to demonstrate the concepts and/or utilize programs such as Gizmos on ExploreLearning to provide a form of hands-on experience.

In addition to balancing different needs according to students’ skill levels, a teacher may have four different science contents occurring in one class to satisfy students’ graduation grids or post-high school studies. In science classes, teachers may meet this challenge by personalizing the learning through courses like Edgenuity for a student in a certain science. While personalizing, a teacher must also acknowledge students’ needs. Some students do not learn well using technology, and the teacher and students should work together to find other means to have the material presented to them.

Teachers may also try to connect science ideas for a more integrated approach. This style of teaching permits the teacher to present to all students in the class and creates a deeper connection among the different disciplines of science. A teacher may discuss biology’s concept of homeostasis with chemistry’s concept of balancing an equation. With an integrated approach, the teacher could provide a small presentation to the class about a general science topic that connects to the students’ work. After the mini-lesson, students would work individually or in small groups for the rest of the class focusing on their own content. Using this teaching method may take a greater amount of preparation; however, presentations and other personalized modes of instruction aid students’ learning.

Works Cited


# 4 Biology

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Massachusetts DYS Education Initiative—Science—2016 Edition
Introduction to Biology

Everywhere we look there is biology at work. Biology provides opportunities for students to explain processes, create persuasive arguments, develop logical thinking skills, solve problems, and engage their world.

Introduction

Why should we learn biology? Biology is a part of our everyday lives—getting enough sleep, being in a bad mood if we don’t, drinking enough water or we will be dehydrated, eating enough or we will be starving, staying warm when it’s cold and staying cool when it’s warm—it’s all human biology. Taking care of pets, whether it’s a tank of fish or a cat or dog—it’s all biology (and some chemistry and physics, too). If we think about it just a little, we will see biology throughout our lives.

Biology can be studied at the macro scale, though there are, of course, the disciplines of microbiology and molecular biology. Whether watching a David Attenborough/BBC natural history video or just listening to birdsong, the ability to observe nature and living things in and around our own homes means ready access, and access allows study. Ever watch a squirrel walk DOWN a tree? Look at their hind limbs … they turn almost completely backwards to allow the squirrel to hang down from the trunk. Nice adaptation, huh?

There are some unusual creatures roaming the planet on land and in the sea and air. Deep sea creatures (such as anglerfish and giant squid) are some of the strangest living things on earth. In the natural world, truth is often stranger than fiction. Students often find all this “weirdness” inherently engaging.

They will need biology to understand:
• nutrition and how it affects our health (nutrition and food science)
• how our environment works and how our behaviors affect it (environmental science)
• how to take care of animals (veterinary science)
• the diversity of sea creatures (marine science)
• how fossils form and what they tell us (paleontology)
• how to take care of people in the hospital (nursing, physical therapy, occupational therapy)
• how to help people recover after sports injuries (physical therapy)
• how to run scanning machines like CTs and MRIs (diagnostic imaging)
• how our bodies work (human anatomy and physiology)
• how to create the next generation of medical technology (biomedical engineering)


Lately, it has become more relevant to pay attention to what’s on the inside: cells, tissues, organs—parts of the body that could become hosts to the next fast-moving
super virus, such as H1N1, Ebola, or Zika. Here in the United States, nobody really thinks those diseases will happen to them, but it was less than a century ago in 1918-19 when more than one-quarter of the U.S. population and one-third of the world’s people contracted Spanish flu; the pandemic killed an estimated 20 to 50 million people (“1918 Flu Pandemic”). This was at a time before planes and cars criss-crossed the continents. If there was ever a time to care about cells, the time is now.

Another bombshell: Medical errors are the third leading cause of death in the United States (Cha). No longer is it expected that we take a doctor’s diagnosis without question. We all have the power to be advocates for our health and wellness, so it really is important to know how our bodies work, from the cellular level to the interaction of major systems such as respiration and circulation. Maybe we aren’t interested in phospholipid membranes, but when our doctor talks to us about issues with our colon, it would be helpful to know he or she isn’t talking about our throat. If we don’t speak the language of biology, then all the “free” medical advice on WebMD et al. won’t be of much use. High school biology can introduce students to new ways to think about their well-being, the welfare of populations, and the physical condition of the biosphere. Each organism plays a role (niche) in the world we live in, and good and bad health is interconnected, from the atoms that create matter to the solar systems that form the universe.

**Biology Course Content**

The Next Generation Science Standards (NGSS), on which the 2016 Massachusetts science standards are based, represent a major shift in emphasis from scientific facts to scientific thinking in that students are now asked to evaluate, predict, develop, debate, and conclude based on information they are presented with—or information they gather themselves from first-hand observations. The exemplar units in Biology provide opportunities for students to explain processes, create persuasive arguments, develop logical thinking skills, and participate in the curriculum as scientists who have problems to solve, to learn the relevant factual knowledge (whether gathering data or doing research) and then present logical

**The Six Seasons of Biology: 1-3**

**SEPTEMBER**

**Chemistry of Life: Organic Molecules and Enzymes**

focuses on the atoms, molecules and processes that allow living things to function.

This season includes units on the organization of living things, from atoms and molecules up to an entire organism. Biochemistry focuses on the biomolecules and chemical reactions that are necessary for life. An examination of enzymes will focus on the many enzymes essential to the structure and function of living things. This season will also serve as a review of basic chemistry which will be revisited in ecology and while studying DNA.

**OCTOBER TO MID-NOVEMBER**

**Ecology: Food Web, Cycles, and Trophic Levels**

focuses on organisms, the environment in which they live, and their interactions.

This season includes units on food webs, biogeochemical cycles, and trophic levels. Energy transfer is a central recurring theme.

**MID-NOVEMBER TO MID-JANUARY**

**Cell Biology**

focuses on cell structures, their functions and cellular reproduction.

This season includes units on organelles and other cell structures, their functions, and the processes of mitosis and meiosis.
The Six Seasons of Biology: 4-6

**Genetics and Heredity**

Focuses on DNA, its function, and how genetic information is passed on.

This season includes units on DNA and RNA structure, protein synthesis (transcription and translation), and using Punnett squares to model genetic crosses.

**Evolution and Biodiversity**

Focuses on the changes that a population may undergo over time and the resulting biodiversity.

This season includes units on the history of evolutionary thought (Darwin and Lamarck), the process of natural selection and how it leads to evolution in a population, taxonomy and classification (binomial nomenclature), and speciation as it connects to environmental changes (global climate change, natural disasters).

**Anatomy and Physiology**

Focuses on human organ systems, their functions, their interactions, and how the body maintains homeostasis and feedback systems.

This season includes units on organ systems such as skeletal, muscular, nervous, cardiovascular and respiratory and their interactions. Other systems such as integumentary (skin), endocrine, lymphatic, urinary, reproductive should be included as time allows.

Arguments. Emphasis is placed on developing students’ writing and reasoning skills, whether through informal prompts or more formal tasks such as creating an argument for a debate. Students are encouraged to present their learning in more ways than end-of-unit tests. They are encouraged to be creative in their presentations and incorporate technology when available and feasible.

The Biology course addresses several broad questions:

- *What are living things made of, how are they organized, and how do the parts work together?*
  - Unicellular organisms (bacteria) and complex multicellular organisms (humans)

- *What determines the traits of living things and how are they passed on?*
  - Genes, heredity, and mutations

- *As traits change, how does that change a population?*
  - Natural selection and evolution

- *How do populations interact with each other and their environment?*
  - Ecological interactions and relationships

The year starts with defining what exactly qualifies as a living thing and looking at its basic molecular building blocks. (The exception, of course, is viruses, and that’s an interesting conversation to have with students.) The next move is looking at those molecules and how they affect living things in ecosystems. This includes recycling of materials (biogeochemical cycles like the water and carbon cycles). Ecosystem interactions (producer, consumer, decomposer) determine how energy is transferred throughout an ecosystem and ultimately how well an ecosystem functions. All those living things in an ecosystem are composed of a basic functional unit—the cell. All living things maintain homeostasis at the cellular level, and those functions are all scaled up in complex multi-cellular organisms. In order for a species to continue, genetic material must be passed from generation to generation. When genetic material is copied, errors are sometimes introduced, and these errors may result in a change in the organism. Changes over time result in the evolution of a population. Finally, we come to humans as a culmination of evolutionary processes.
that result in an organism that, in many ways, is not so different from our single-cell ancestors. We have the same basic biochemistry. We have complex interactions with each other and the environment, sometimes changing it drastically. We must pass on our genes in order for our species to continue, and our evolution continues in response to our environment.

**Teaching Biology in DYS Schools**

Safety during lab activities is a primary concern. Some activities may be accomplished with readily available materials from grocery and hardware stores, while others may be better suited to online simulations and paper-based activities.

The timing of the units within the seasons provided in this Guide is an estimate. Any unit can be modified for short- or long-term programs, and adaptations are provided. However, teachers should maintain the Scope and Sequence for a number of reasons, including the timing constraints imposed by the sending school districts’ standardized exam schedules and the transient student population.

Timing of units may also depend upon students’ prior knowledge. Teachers must get a sense of what they have already studied and/or what gaps they have in their knowledge. If they have a strong grounding in a particular topic, the time saved may allow delving deeper or moving on to other content. Anticipating interruptions to the year and/or to students’ stays can be challenging, so breaking up units into smaller chunks will allow students to complete smaller sections when necessary.

Long-term residential programs afford continuity to the classroom and allow for extended activities. Given the wide grade and age range in many classrooms, teachers can consider leveraging technology to use class time more efficiently. For example, if Google Drive is available, using the free suite of tools is a way for students to stay organized, with everything in one place, safe-guarding their work when they need to come back to it. If technology is available and a level of independence is allowed, students may be able to work on their own research and create various “products.”

A station-based approach or workshop model may suit the single classroom with students taking any one of the three sciences, physics, chemistry, or biology.

Teachers should emphasize the following concepts:

- All living things are made from a set of chemical elements, and those elements, interacting in chemical reactions, are life.
- There is a common chemical language among all living things, DNA, that codes for proteins which allow for those chemical reactions to take place. Changes (mutations) may alter the expression of that DNA (genes) and result in a different set of characteristics for the organism.
- DNA is the genetic code passed between organisms and passed on from generation to generation.
- Depending on the DNA passed on, resulting organisms will have certain characteristics. These characteristics (traits) will determine the survival of the organism, and more importantly, the ability of the organism to pass on its genes to the next generation.
- Diversity in genetics results in diversity of organisms. Organisms will interact with each other and may have an effect on populations.
- All organisms can have a profound effect on their environments and each other. This is especially true for humans.

**Works Cited**


_Next Generation Science Standards._

http://www.nextgenscience.org/.

Reading the Biology Scope and Sequence Chart

The amount of information contained in the Scope and Sequence on the following pages may seem overwhelming at first. The best way to study it is to read across from left to right. The keys on both the left and right hand columns below on this page offer guidance on how to properly access the Scope and Sequence Chart on pp. 4.2.2 to 4.2.5.

The Scope and Sequence is COLOR-CODED. Each color is important and its meaning is described in detail in the key in the LEFT column below. The key in the RIGHT hand column below is information you would see in the first column in the Scope and Sequence. This key lists out the biology topics (seasons) and the approximate timeframe in which they may be taught during the academic year.

Emphasized Standards listed with an asterisk (*) in the Scope and Sequence are utilized in units in this Guide.

### Scope and Sequence Chart Key

- **The GREEN columns provide the focus for each season.** This focus includes the title, timeframe, Essential Questions, and Emphasized Standards.

- **The BLUE column indicates the Miller and Levine Biology textbook sections that apply to the topic and timeframe.**

- **The GOLD column indicates the ELA and Math standards that are connected or could be connected to the Topic/Season indicated.**

- **The RED column indicates other science disciplines that are connected to the Topic/Season indicated.**

- **The PURPLE column indicates possible Performance Tasks which can be used during the Topic/Season indicated.**

- **The GRAY row across the bottom indicates Crosscutting Science Concepts that should be emphasized throughout the entire subject year.**

### Biology Topics (Seasons)

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### SCOPE AND SEQUENCE

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| **Chemistry of Life: Organic Molecules and Enzymes**  
*September* | What are living things made of?  
How do biomolecules contribute to the building of all living things? (including human nutrition)  
Why do elements matter when choosing food to eat? | *HS-LS1-6.* Construct an explanation based on evidence that organic molecules are primarily composed of six elements, where carbon, hydrogen, and oxygen atoms may combine with nitrogen, sulfur, and phosphorus to form monomers that can further combine to form large carbon-based macromolecules. | Chapter 1: 18-19  
Foundation: 14-15 |
| **Ecology: Food Web, Cycles, and Trophic Levels**  
*October to Mid-November* | How does the environment affect living things? How do living things affect each other?  
How is energy changed and transferred from one level of an ecosystem to another?  
Why do structures, like buildings or business models, require more support at the bottom than at the top?  
How do you impact the health of an ecosystem? | *HS-LS1-1.* Analyze data sets to support explanations that biotic and abiotic factors affect ecosystem carrying capacity.  
*HS-LS2-1.* Use mathematical representations to support explanations that biotic and abiotic factors affect biodiversity, including genetic diversity within a population and species diversity within an ecosystem.  
*HS-LS2-2.* Use a model that illustrates the roles of photosynthesis, cellular respiration, decomposition, and combustion to explain the cycling of carbon in its various forms among the biosphere, atmosphere, hydrosphere, and geosphere.  
*HS-LS2-3.* Analyze data to show ecosystems tend to maintain relatively consistent numbers and types of organisms even when small changes in conditions occur but that extreme fluctuations in conditions may result in a new ecosystem. Construct an argument supported by evidence that ecosystems with greater biodiversity tend to have greater resistance to change and resilience.  
*HS-LS2-4.* Analyze direct and indirect effects of human activities on biodiversity and ecosystem health. | Chapter 3: 66-86  
Foundation: 56-74  
Chapter 4: 94-127  
Foundation: 80-105 |
| **Cell Biology**  
*Mid-November to Mid-January* | Why are cells important?  
What is the purpose of DNA?  
How do cells fit into the organization of living things?  
How is cell division important to the maintenance, growth, and reproduction of living things?  
Where do plants and animals get the energy they need to grow and reproduce?  
How do plants and animals depend on each other? | *HS-LS1-5.* Use a model to illustrate how photosynthesis uses light energy to transform water and carbon dioxide into oxygen and chemical energy stored in the bonds of sugars and other carbohydrates.  
*HS-LS1-6.* Use a model to illustrate that aerobic cellular respiration is a chemical process whereby the bonds of food molecules and oxygen atoms may combine with nitrogen, sulfur, and phosphorus to form monomers that can further combine to form large carbon-based macromolecules.  
*HS-LS1-7.* Use a model to illustrate that the energy stored in the bonds of sugars and other carbohydrates is transferred from one trophic level to another. Explain how the inefficiency of energy transfer between trophic levels affects the relative number of organisms that can be supported at each trophic level and necessitates a constant input of energy from sunlight or inorganic compounds from the environment. | Chapter 7: 188-223  
Foundation: 158-189  
Chapter 8: 224-247  
Foundation: 190-209  
Chapter 9: 248-271  
Foundation: 210-231  
Chapter 10: 272-304  
Foundation: 232-257  
Related: 23.4 and 831 |
| **Cross-Cutting Concepts** | Patterns  
Fractals in nature; Fibonacci series in nature, complex structures being made of simpler building blocks  
Patterns may vary based on the scale being used | Cause and Effect  
Feedback mechanisms in living and nonliving systems  
Scale, Proportion, and Quantity  
"Golden" ratios in nature, body proportions |
**ELA Season 1 standards:**
- W1. Write arguments
- R1. Cite textual evidence
- R2. Determine central ideas

**Related Math standards:**
- A-CED. Create equations that describe relationships
- S.ID.1. Summarize and interpret data

**Earth and Space Science:**
- The role of water and minerals in the health of organisms; origins of organic molecules

**Chemistry:**
- Conservation of matter

**Technology/Engineering:**
- Liquid food replacement used in TPN (Total Parenteral Nutrition) and complete food substitutes such as Soylent

**Performance Assessment Ideas**
- Compare different kinds of diets and their allowances of carbohydrates, lipids, and proteins. Create arguments about which diet is healthiest. The arguments must include what the macromolecules in the diets are composed of and their functions in the human body.
- Categorize nutrition labels based on content, explain how they relate to health, and explain the negatives and positives of each item.

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**ELA Season 1 standards:**
- W1. Write arguments
- R1. Cite textual evidence
- R2. Determine central ideas

**Related Math standards:**
- A.REI.11. Represent equations graphically
- A-CED. Create equations that describe relationships
- S.ID.1. Summarize and interpret data

**Earth and Space Science:**
- Impact of weather and geography on ecosystems

**Chemistry:**
- Biogeochemical cycles, conservation of matter

**Physics:**
- Conservation and transfer of energy

**Technology/Engineering:**
- Environmental effects of recycling, waste water treatment, wind, and renewable energy

**Performance Assessment Ideas**
- Write or create presentations to elected officials explaining solutions to environmental issues. Argue positions through data and facts using knowledge about cycles of biotic and abiotic factors, interdependent relationships in ecosystems, and the impact of humans on the environment.
- Create a model ecosystem and include explanations of how all the components interact.
- Conduct a debate about an ecological issue (e.g., the use of ethanol in fuel, hydroelectric power generation, biomass power generation, biodiesel fuel).

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**ELA Season 2 standards:**
- W3. Write narratives
- R5. Analyze text structures

**Related Math standards:**
- F.LE.1a,b,c. Construct and compare models to solve problems
- S.ID.5. Summarize and represent data

**Chemistry:**
- Balanced equations for photosynthesis and cellular respiration; conservation of matter

**Physics:**
- Transfer of energy in photosynthesis and cellular respiration

**Technology/Engineering:**
- Human Genome Project, genetic testing

**Performance Assessment Ideas**
- Students will tell the story of protein synthesis, as a narrative, comic strip, play, etc., using the appropriate vocabulary. The conflict of the story will be an interruption of the process of protein synthesis with either a happy or tragic ending.
- Write a story of an oxygen molecule traveling from a plant cell into the organelles of an animal cell.
- Explain how the primary dietary macromolecules (carbohydrates, protein, lipids) relate to cellular structure and functions.
### Essential Questions

**Focus of inquiry in unit**

- **Genetics and Heredity**
  - How are parents and offspring connected?
  - Why is there often a resemblance between parents and children?
  - How do characteristics get passed on from parent to child?
  - How can events in life affect what genes are passed on to children?
  - How do your genetics affect your health?
  - How can where we live impact our health?

- **Evolution and Biodiversity**
  - Why aren’t living things today the same as they were in the past?
  - How do we know that living things have changed over time and how do we communicate that information?
  - Why do living things changes over time?
  - Why are variations important to populations?
  - How do we use evidence to support or refute an argument?
  - How can newly found evidence affect previously drawn conclusions?

- **Anatomy and Physiology**
  - How does the human body work?
  - How do the body systems work together to maintain good health?
  - How does the body regulate itself?
  - Why do living things “get sick”?

### Emphasized Standards

**Massachusetts STE Framework**

- **HS-LS3-1.** Develop and use a model to show how DNA in the form of chromosomes is passed from parents to offspring through the processes of meiosis and fertilization in sexual reproduction.
- **HS-LS3-2.** Make and defend a claim based on evidence that genetic variations (alleles) may result from (a) new genetic combinations via the processes of crossing over and random segregation of chromosomes during meiosis, (b) mutations that occur during replication, and/or (c) mutations caused by environmental factors. Recognize that mutations that occur in gametes can be passed to offspring.
- **HS-LS3-3.** Apply concepts of probability to represent possible genotype and phenotype combinations in offspring caused by different types of Mendelian inheritance patterns.
  
### Pearson Biology Textbook Sections

- **Chapter 11:** 260-286
- **Foundation:** 306-329
- **Chapter 34:** 988-1001
- **Foundation:** 817-829
- **Chapter 12:** 336-359
- **Foundation:** 286-305
- **Chapter 13:** 360-389
- **Foundation:** 306-331
- **Chapter 14:** 390-415
- **Foundation:** 339-341

- **Chapter 16:** 448-479
- **Foundation:** 378-403
- **Chapter 17:** 480-507
- **Foundation:** 404-425
- **Chapter 18:** 506-535
- **Foundation:** 426-447
- **Chapter 19:** 538-545
- **Foundation:** 448-455
### Connections to Literacy and Math Standards

**ELA Season 3 standards:**
- W2. Write explanatory texts
- R9. Compare related texts

**Related Math standards:**
- A.REI.11. Represent and solve equations graphically
- F.BF.2. Create a function to model a relationship between two quantities

**Chemistry:**
- The structure of DNA and its bonding, including protein structure and the enzyme/substrate complex
- **Technology/Engineering:**
  - Creation of genetically modified organisms; “designer babies”; reproductive technologies, (e.g. IVF, ICSI, cloning)

**Performance Assessment Ideas**
- Malaria project: Educate your audience about malaria. Create infographics using sufficient, accurate research that explains who can contract the disease, how it’s transmitted, and where it came from.
- Produce a presentation explaining the processes that lead to mutation and/or genetic variation.
- Assume the role of a genetic counselor. Explain why determining your genetic risk can help in family planning.
- Debate the pros and cons of genetic testing.

**ELA Season 4 standards:**
- W7. Conduct research
- R8. Evaluate arguments

**Related Math standards:**
- F.LE.3. Construct and compare models and solve problems
- S.ID.5. Summarize and represent data

**Earth and Space Science:**
- Changes to Earth’s surface causing changes to other systems; relationships among natural resources, sustainability, and biodiversity.

**Chemistry:**
- Biochemical analysis to determine evolutionary lineage

**Physics:**
- Global extinction events affecting temperature and radiation

**Technology/Engineering:**
- Cloning technology to revive extinct species

**Performance Assessment Ideas**
- After studying the various lines of evidence supporting evolutionary theory, evaluate contradictory claims. Craft a response using evidence from this unit. The response may take the form of an argumentative paper, audio response, blog post, podcast, comic strip, etc.
- Create a field guide to local plants and animals, including changes through time and the significance of those changes.
- Illustrate and explain plant and animal adaptations (e.g. leaf shape & color, camouflage, beaks, diet, etc.).
- Simulate a predator/prey relationship in a model ecosystem. Include mathematical analysis (PhET simulations).

**ELA Season 5 standards:**
- W6. Use technology to write
- R4. Interpret words/phrases

**Related Math standards:**
- S.IC.3,4,5,6. Make inferences and justify conclusions from experiments and studies

**Chemistry:**
- Chemical interactions in the body; nutrition (biomolecules)

**Physics:**
- Human anatomy/skeletal system/levers and fulcrums

**Technology/Engineering:**
- Development of vaccines, advanced prosthetics, and 3D printing of organs and body tissues

**Performance Assessment Ideas**
- Research an antibiotic-resistant infection, explain how that disease evolved, what the symptoms are, how it progresses, and what the treatment is. Explore alternative treatments. Explain how this disease impacts one or more of the body systems. Create a flipbook or an accordion book to showcase their findings.
- Create a multimedia presentation that illustrates and models the connectedness of two or more body systems (e.g., cardiovascular/respiratory, digestive/ cardiovascular, muscular/skeletal, nervous/ muscular).

### Connections to Other Science Disciplines

**Chemistry:**
- Structure of DNA and its bonding, including protein structure and the enzyme/substrate complex

**Technology/Engineering:**
- Creation of genetically modified organisms; “designer babies”; reproductive technologies, (e.g. IVF, ICSI, cloning)

**Performance Assessment Ideas**
- Malaria project: Educate your audience about malaria. Create infographics using sufficient, accurate research that explains who can contract the disease, how it’s transmitted, and where it came from.
- Produce a presentation explaining the processes that lead to mutation and/or genetic variation.
- Assume the role of a genetic counselor. Explain why determining your genetic risk can help in family planning.
- Debate the pros and cons of genetic testing.

### Systems and System Models

<table>
<thead>
<tr>
<th>Systems and System Models</th>
<th>Energy and Matter</th>
<th>Structure and Function</th>
<th>Stability and Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organ systems</td>
<td>Metabolism, conservation of energy and matter (photosynthesis and cellular respiration), balanced equations</td>
<td>Form follows function</td>
<td>Maintaining homeostasis</td>
</tr>
</tbody>
</table>
Chemistry of Life: Macromolecules and DNA

**TOPIC SEASON: Chemistry of Life**

This unit is designed for use in long-term programs. Sections may be adapted for short-term settings.

Unit Designers: H. Lee, K. Miele, and E. White

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**Introduction**

It may seem odd to begin the Biology course with chemistry, but this unit will help students develop an understanding of the basic building blocks of life, organic molecules. This understanding is the foundation for everything else they will learn during the year. The unit uses kinesthetic activities and labs to illustrate and immerse students in the scientific method, and it asks them to create a persuasive product, developing and reinforcing real-life skills. Students will also learn concepts that will encourage them to live a healthy lifestyle and make healthy choices regarding the foods they put in their bodies for fuel. They will develop an understanding of how “fad diets” can impact their health in the long term.

*Chemistry of Life: Macromolecules and DNA* is designed to fill the entire first season of Biology, taking about four weeks to complete. If a teacher has students with prior knowledge in the topic, the class could spend more time on building molecules and learning about chemical elements. Students might also devote more time to working with the DNA structure and studying nucleotides. The teacher might also extend the unit by focusing on diet trends and how food choices impact lifestyle.

The Emphasized Standard **HS-LS1-6** focuses on the six elements found in macromolecules, or large molecules, which include proteins, carbohydrates, nucleic acids, and lipids. The importance of carbon is highlighted in this standard and within the unit. Students will work to develop an understanding of the elements and the concept of building molecules. As the unit progresses, this standard is reinforced by focusing on different groups of carbon-based molecules and connecting them to examples found in everyday food items. In the final assessment, students are asked to describe what macromolecules are composed of and how they function in the body. The shape of DNA is a result of the nucleotide structure, which is discussed during the study of macromolecule nucleic acids.

Prior knowledge that would be helpful for this unit includes a basic understanding of food groups and nutrition. If students do not have this background, the teacher could provide practice with the food groups by discussing the menu for breakfast or lunch and saying which food belongs to which category. For the Summative Assessment, students should have the skills to create a persuasive essay. If students do not have those skills, the teacher could provide examples of persuasive essays and work with the ELA teacher on a cross-curricular project, since persuasive writing is the focus of the first ELA season.
Some students may struggle with chemistry concepts, especially because it is impossible to see an atom or the bonding that occurs in molecules. Creating models provides students with visual and kinesthetic activity to increase their learning of those concepts. Students may also find the vocabulary and scientific reading challenging, but the teacher can provide support through a word wall, graphic organizers, and other scaffolds. Labs are encouraged in the unit, but it is important, and in some programs may be difficult, to obtain permission to bring chemicals or food items into the classroom. The teacher may need to take extra time to prepare for those classes to ensure safety.

Throughout all lessons, the teacher is encouraged to support note taking with graphic organizers and open/closed note options. The teacher may also change the reading material to ensure students’ understanding. During the unit, the teacher may increase the use of technology for the students. In Lesson 4, teachers are able to assign students different molecules to assemble, which can vary in difficulty to meet the student’s readiness for the material. In Lesson 10, two activities are presented to accommodate different programs’ security requirements. One keeps students in their seats, and the other encourages students to move throughout the room. For the article presentation to the class in Lesson 11, the teacher is given articles from Newsela.com. This website allows teachers to alter the Lexile level of the articles to match the students’ reading abilities. Changing the readability allows all students to participate in the activity. For the Summative Assessment, the teacher may increase the number of diets the students can research or alter the format of the presentation that will take place.

The unit was written for long-term programs, but it may be adapted effectively in short-term facilities by displaying the information on the wall as the class moves through the unit and utilizing a graphic organizer, included in the resources for the unit, that can help new students process content from previous classes.
## Overview

During this unit, students will be discovering the building blocks of life, while highlighting that macromolecules are comprised of six main elements: carbon, nitrogen, hydrogen, oxygen, sulfur, and phosphate. Discussing basic chemistry and providing scaffolding for reading the periodic table and introducing the students to elements is very helpful to provide a broad scope to the detention students in various sciences. Going beyond knowing the importance of macromolecules, students will be applying their knowledge of macromolecules to their personal diets and completing a research project at the end of the unit. For a short-term program, the macromolecule and chemistry lessons provide practical places to assess students and to introduce students at different places in the instruction.

## Desired Results

The desired results remain the same; however, in the standards, students may obtain only pieces of the required knowledge of the different types of macromolecules depending on their stay in the program. The teacher may find that each macromolecule becomes its own section as the students rotate. Many of the Do’s are capable of standing alone as Summative Assessments for the two or three lessons needed to accomplish each Know, Understand, and Do in the unit. For example, the lipid Do allows the students to compare and contrast the amount of lipids in different foods using food labels or utilizing a lab to determine the information. Lesson 10 permits students to build on background information from previous lessons or allows students to have a rich education experience around lipids and a Summative Assessment based on the lab from this one piece of the unit if the student leaves the program before the next lesson.

## Assessment Evidence

Please present an overview of the unit prior to instructing lesson-by-lesson. To accommodate any students who have not been present, teachers may provide more developed research to the students to guide them in completing the task. Instead of the teacher having the students state the different macromolecules while analyzing the diets, some teachers have listed the macromolecules totals in the diet to scaffold the task. In addition, teachers may need to evaluate each Formative Assessment as a summative for their rotating roster, which they are able to do while following the unit plan.

## Learning Plan

The teacher should be able to complete the unit as written. However, if the class does not have any students who completed earlier lessons, it may be helpful to eliminate Lesson 12, since the class will not have the needed background knowledge to determine the macromolecules in the lab. During the unit, the teacher should stress the connection of ideas by posting previous assignments on the wall and completing a large graphic organizer for each macromolecule while teaching the unit. The organizer will be helpful for the students who are entering the unit at a later time or students who need help remembering the information. The teacher should encourage students to summarize what they are learning with newer students to foster discussion and comprehension checks in the classroom.
Emphasized Standards *(High School Level)*

**HS-LS1-6:** Construct an explanation based on evidence that organic molecules are primarily composed of six elements, where carbon, hydrogen, and oxygen atoms may combine with nitrogen, sulfur, and phosphorus to form monomers that can further combine to form large carbon-based macromolecules.

**Clarification Statements:**
- Monomers include amino acids, mono- and disaccharides, nucleotides, and fatty acids.
- Organic macromolecules include proteins, carbohydrates (polysaccharides), nucleic acids, and lipids.

**State Assessment Boundary:**
- Details of specific chemical reactions or identification of specific macromolecule structures are not expected in state assessment.

**Essential Questions** *(Open-ended questions that lead to deeper thinking and understanding)*

Why do elements matter when choosing food to eat?

**Transfer Goals** *(How will students apply their learning to other content and contexts?)*

Students will apply their understanding of macromolecules to choose a healthy diet and understand food labels.
### Learning and Language Objectives

By the end of the unit:

- Understand content-specific vocabulary provides access to ideas about scientific concepts.
- Use vocabulary in class discussions and writing to support explanations and analyses.
- Create a carbohydrate monomer.
- Identify foods with carbohydrates using iodine.
- Describe the importance and function of proteins for the body.
- Predict the effects of heat on an enzyme/protein during the process of denaturing.
- Compare and contrast different food molecules and the amount of lipid found within without using a nutrition label.
- Create a nucleotide, labeling its components.
- Explain how nucleotide building blocks form DNA and RNA.

### Students should know...  
understand...  
and be able to...

| Tier III Vocabulary: biochemistry, carbohydrate, monosaccharide, disaccharide, polysaccharide, protein, amino acids, lipid, fatty acids, macromolecule, element, monomer, polymer, hydrolysis, dehydration synthesis, enzymes, denature, nucleotide | Understanding content-specific vocabulary provides access to ideas about scientific concepts. | Use vocabulary in class discussions and writing to support explanations and analyses. |
| Tier II Vocabulary: predict, analyze, compound, nutrition, organization | Understanding academic language promotes language acquisition in other subjects. | |

| Carbohydrates are:  
- sugars and starches  
- made of monosaccharides | Carbohydrates supply energy for all living things. | Create a carbohydrate monomer.  
Identify foods with carbohydrates using iodine. |
| Proteins are:  
- made of amino acids | Proteins can be both structural (building muscle and hair) and functional (catalyzing reactions). | Describe the importance and function of proteins for the body.  
Predict the effects of heat on an enzyme/protein during the process of denaturing. |
| Enzymes are a type of protein | Proteins can be affected by temperature and pH. | |
| Lipids are:  
- Fats and oils  
- Made of triglycerides  
- storage for energy | Lipids are structural components of every cell.  
Lipids store energy. | Compare and contrast different food molecules and the amount of lipid found within without using a nutrition label. |
| Nucleic Acids:  
- are made of nucleotides.  
- make up DNA and RNA | Nucleic acids are the building blocks for genetic codes. | Create a nucleotide, labeling its components.  
Explain how nucleotide building blocks form DNA and RNA. |
Assessment Evidence
Quality questions raised and tasks
designed to meet the needs of all learners

Performance Task and Summative Assessment (see pp. 4.4.21-4.4.22)
Aligning with Massachusetts standards

Students will be asked to compare different kinds of diets and their allowances of carbohydrates, lipids, and proteins. They will create arguments about which diet is healthiest. The arguments must include what the macromolecules in the diets are composed of and their functions in the human body.

Pre-Assessments (see p. 4.4.7)
Discovering student prior knowledge and experience

Students will be asked to explain what biology means and what it includes.

Given a restaurant menu, students will be challenged to create a four-course meal that would be the healthiest for their bodies. Students will receive the nutrition information from the menu and reflect on their choices.

Formative Assessments (see pp. 4.4.12, 4.4.15)
Monitoring student progress through the unit

Graphic organizer for the macromolecules
Foldable on the characteristics of life
Creation of molecules
Gizmos dehydration lab
Lab reports (with flexible means of expression)
• Carbohydrate lab
• Lipid lab
• Protein lab
• Discover the Macromolecule
Label the Bucket activity with food
Article analysis presentation to the class (or teacher)
Nucleic acid notes
Access for All
Considering principles of Universal Design for Learning (UDL), Positive Youth Development/Culturally Responsive Practice (PYD/CRP), differentiation, technology integration, arts integration, and accommodations and modifications

Multiple Means of Engagement
During this unit, students will be engaged through interesting media, such as a song about DNA played over a pop song’s tune in Lesson 12. Also, students will watch videos that will catch their attention using humor, like a funny commercial in Lesson 8, or interesting graphics. Moreover, students will be able to engage in kinesthetic activities to work with real-life samples. If able, students will be testing foods for carbohydrates (Lesson 7), proteins (Lesson 9), and lipids (Lesson 10), and have opportunities to create foldables in Lesson 1. Students will also have an opportunity to play games and connect activities and learning to realistic scenarios they will encounter. For the Summative Assessment in Lesson 14, the students will be examining diets that will be engaging as they evaluate their own food choices.

Multiple Means of Representation
During the lessons, the teacher will provide many alternatives for students to access the content, including two-column note formats, PowerPoint presentations, textbook readings, real-world articles, and demonstrations of computer graphics or labs. In addition, the textbook may be differentiated by using Pearson’s regular text or the Foundations version. Students may also read the text on the computer. Real-world articles may be differentiated by using Newsela in Lesson 11 to provide students reading material within their zone of proximal development. In the lessons, there are suggestions for technological opportunities for students who need access, such as using the computer to read the material for the student if needed.

Multiple Means of Action and Expression
Students will be able to express the knowledge they have gained through this unit in various ways. Students will be able to utilize graphic organizers, foldables, different note formats that work for their needs, quick writes, or answering questions aloud for assessments. Also, students can use computers or NEOs for completing notes or assignments. Students will be able to demonstrate their knowledge through hands-on labs and using pictures or words to explain natural processes. Some assessments include using art and sculpture in Lesson 12 while making DNA origami that will demonstrate students’ understanding of the content. In the Summative Assessment in Lesson 14, students may use assistive technology or teacher support to create their arguments. The teacher will scaffold the process throughout the unit to ensure that the students have the knowledge and skills to set goals, monitor progress, and complete the assignment. The teacher may alter it, if necessary, while still having the students demonstrate their mastery of the standard(s).
Literacy and Numeracy
Across Content Areas

Reading
Throughout the unit, students will read a variety of texts aimed at their zone of proximal development. The teacher will provide different types of nonfiction texts including textbooks, government-issued health bulletins, current news articles, electronic texts, and various other informational texts as students research their topics.

Writing
While engaging in the unit, students will take notes, journal their thoughts through Exit Tickets, complete lab reports, and compose a product utilizing persuasive form. In addition, students will complete a reflection about the work they completed for the unit.

Speaking and Listening
During this unit, students will speak to discuss ideas presented in class, questions that arise and conclusions they have about lab activities. Students will also present the Summative Assessment to the class. The teacher should include turn-and-talk activities to encourage students to share their ideas and practice holding scientific conversations. Students will listen to high-interest teacher demonstrations and lessons, peers’ thoughts and ideas about the topic, and media such as videos, songs, podcasts, and commercials.

Language
An important relationship exists between language and learning science. Students will think critically using evidence and develop a deeper understanding of how language, including academic vocabulary, functions in different contexts while studying this scientific material. Supports for vocabulary development include highlighting key concepts, word walls, guiding questions for texts while reading the textbook, and charts like the graphic organizer to be completed through the unit.

Numeracy
During labs and investigations, students will use measurement to ensure proper scientific procedure. Students will also use numeracy to balance equations and to explain chemical reactions.

Resources (in order of appearance by type)

Print
Resources (continued)

Websites

“Introduction to Biochemistry HD.” Yahoo.  (Yahoo search)

“Battleship Periodic Table Game.” N.P. 2016.
www.idodi.org/files/blog/Periodic_Table_Battleship.pdf.

www.youtube.com/watch?v=RAFcZo8dTcU-.

www.explorelarning.com/.


www.youtube.com/watch?v=ReLGpe17TLc.


http://fold.it/portal/.

“School cafeteria favorites could disappear as food rule take hold.” Newsela.  Kansas City Star.  2014.


“PRO/CON: Should parents support the new school meal standards?” Newsela. McClatchy-Tribune News Service
https://newsela.com/articles/healthylunch-procon/id/5197/.

“DNA Song.” Mr. Parr.  2011.
www.youtube.com/watch?v=ckZEds5taX4.

www.youtube.com/watch?v=35FwmiPE9tl.


Materials (Teacher created or in the Supplement)

Healthy Enjoyable Meal Creation (p. 4.6.1), The Macromolecule Graphic Organizer (p. 4.6.2),
Starch Lab: Carbohydrate Test (p. 4.6.3), Catalase Lab: Enzyme Test (p. 4.6.4)
Denaturation Lab: Enzyme Test (p. 4.6.5), The Fat Lab: Lipid Test (p 4.6.6),
Summative Assessment: Comparing Two Diets Rubric (p. 4.6.7)
Outline of Lessons
Introductory, Instructional, and Culminating tasks and activities
to support achievement of learning objectives

INTRODUCTORY LESSONS
Stimulate interest, assess prior knowledge, connect to new information

Lesson 1
Biology and Life

Goal
Students will identify characteristics of living things and the purpose of studying biology.
This lesson is an introduction to the Biology course.

Do Now (time: 5 minutes)
Students will explain, using words or pictures, what they think biology means and what the subject includes.

Hook (time: 15 minutes)
Students will research the etymology of biology (bio = life, logy = study), the “study of living things.” The students will respond to what “study” means and brainstorm characteristics of what “living things” means.

Presentation (time: 15 minutes)
The teacher asks:
What are living things?
Activating prior knowledge, students will brainstorm characteristics of living things.
• Think of it as completing the sentence “All living things ____________________________.”
• Brainstorm: Students should think individually, on small sheets of paper/index cards.
• Think-Pair-Share: Have students compare ideas, think critically about each idea, decide on the best ones, and give an explanation and example for each one.
• Each group picks a presenter, and they share their conclusions. The teacher will post characteristics, so that the class can see. This could be completed through an ELMO device or on a board or chart paper.
• After all are posted, individuals or the whole class groups similar/related characteristics.

Practice and Application (time: 8 minutes)
The class will read the “Visual Summary of the Characteristics of Living Things” in the Miller and Levine Biology textbook, pp. 18-19 (or students may use the online version). The teacher and class will compare what is on the list to what is on the board (from the presentation) The teacher will ask:
1. How did you do?
2. Which ones did you miss and why?
3. Which ones were wrong and why?
Review and Assessment (time: 12 minutes)
Students will create a “foldable”—a mini flip chart—about living characteristics.
Steps to create a foldable flip chart:
1. Gather materials: cardstock or notecards, tape, writing utensils
2. Have students position notecards down a line with ¾ inch between the bottoms of each card.
3. Tape the tops of the card in this formation.
4. At the bottoms of the cards, label the categories of characteristics.
5. Students write examples or explanations on the back of each card, which are then revealed when the card is lifted.

Lesson 2
If You Are What You Eat, What Is Food Made of?

Goal
Students will demonstrate their knowledge of the periodic table and molecules involved in digestion.

Do Now (time: 10 minutes)
Students will write down their favorite foods to order in a restaurant. The class will have a quick discussion on students’ choices.

Hook (time: 15 minutes)
The teacher will administer the Pre-Assessment found in the Supplement on p. 4.6.1 for the Emphasized Standard. The students will be challenged to create a four-course meal that would be the healthiest for their bodies. The teacher may need to pre-teach skills that students would need to read a menu.

The teacher will need a menu from a restaurant that includes nutritional information. Students will receive the nutrition information from the menu and reflect on their choices.

Presentation (time: 10 minutes)
After the students look at their assessments, the teacher should explain to the students what the unit will include and begin questioning them about the building blocks of matter. The overarching question for this lesson is, “What are we made of?” The teacher will then discuss organization within living things, such as: atoms, molecules, cells, tissues, organs, organ systems, organisms, etc. The teacher will discuss the lowest level of organization: elements.

Practice and Application (time: 15 minutes)
The teacher will show the students the periodic table of elements and discuss common elements they may find in everyday items. The students will label the parts of the periodic table and note basic characteristics in the different categories on the table.
Review and Assessment (time: 5 minutes)
The teacher will ask students to list two things they have learned and one question they want answered in this unit.

Extension
Students may look at other menus to look at nutritional information and what foods have the most types of macromolecules.

INSTRUCTIONAL LESSONS
Build upon background knowledge, make meaning of content, incorporate ongoing Formative Assessments

Lesson 3
Atoms, Elements, Chemical Compounds

Goal
Students will demonstrate their ability to evaluate key chemistry components and building blocks of living things.

Do Now (time: 5 minutes)
The teacher will ask students, “What do you think biochemistry means?” Students then research the etymology of biochemistry (bio = life, chemistry = atoms, molecules, and their interactions), “the chemistry of living things.”

Hook (time: 5 minutes)
The teacher will show the following Introduction to Biochemistry:

Note: During the video, the teacher should stop at locations where s/he feels students may need more explanation or pull out information that students may need clarified.

The teacher should ask the students the following three questions:
1. Why is biochemistry important in your life?
2. What career shown in the video would you be interested in?
3. What was shown that you may have not related to biology or chemistry?

Presentation (time: 20 minutes)
The teacher will give a presentation on chemistry basics. The students will write down information in either open or closed two-column notes as the teacher explains chemistry concepts from teacher-created PowerPoint slides. The slides should cover the following concepts:

 atoms, atomic particles, elements, molecules, chemical compounds and bonds, and periodic table of the elements
Practice and Application (time: 20 minutes)
The students will practice the words or play a vocabulary game. The students could make their own note cards to practice the words and quiz each other. Another option is writing the vocabulary words and definitions on separate note cards and have the students play a memory game with the words and match them to their definitions.

Review and Assessment (time: 5 minutes)
Students should rank the two most important concepts or vocabulary words in their thinking and defend their decision in writing.

Extension
SEE: “Battleship Periodic Table Game”
www.idodi.org/files/blog/Periodic_Table_Battleship.pdf

Goal for students:
The students will understand the construction of the periodic table and where the elements are located on it. The students will then have an easier time identifying if an element is more reactive depending on its location on the table.

The teacher could make the game by laminating four periodic tables and posting them inside of two folders for one board. Then the teacher can glue one side of the folders together or clip them together.

In class, the teacher pairs the students to play the game. The teacher then hands out and monitors use of dry erase markers as students play the game.

One student must mark four sets of elements that are horizontal, diagonal, or vertical:
- Two elements
- Three elements
- Four elements
- Five elements

The other student tries to guess what elements are marked to eliminate each of the sets.
The regular rules and game play of Battleship by Milton Bradley apply.
Lesson 4

Six Essential Elements for Macromolecules

Goal
The students will utilize models to demonstrate the bonding of molecules.

The teacher should prepare as follows.

Assemble plastic jars:

- C—Carbon (charcoal powder)
- H—Hydrogen (colorless gas)
- N—Nitrogen (colorless gas)
- O—Oxygen (colorless gas)
- P—Phosphorus (dark red powder)
- S—Sulfur (yellow powder)

Do Now (time: 5 minutes)
As students enter the class, they are asked to identify terms like element, atom, and chemical compound, and match them to pictures as a Pre-Assessment.

Hook (time: 7 minutes)
The teacher will explain that common table salt is NaCl (show the white crystalline solid). Na, sodium, is a soft, silvery gray metal and highly explosive when it comes in contact with water (see video on exploding sodium). Cl, chlorine, is a colorless toxic gas. Normally, you should stay away from both of them. But when the two are chemically combined to form NaCl, the result is a molecule essential to life.

SEE: [www.youtube.com/watch?v=RAFcZo8dTcU](https://www.youtube.com/watch?v=RAFcZo8dTcU)

Presentation (time: 18 minutes)
After the students review the assessment and video, the teacher will hold up six small jars, labeled C, H, N, O, P, S. Students may recognize the chemical symbols and be able to give the name of the elements.

The teacher will reinforce that these six elements, in a multitude of combinations, make up almost all biomolecules.

In addition, the teacher will demonstrate how elements bond together to create molecules. The teacher may use models (if possible), a drawing, or a written explanation in the textbook.

Practice and Application (time: 20 minutes)
Using paper atoms or modeling equipment appropriate to the setting, students will build the molecules below. Teachers may differentiate the number of molecules based on the students’ needs.

- Water (H₂O), hydrogen peroxide (H₂O₂), methane (CH₄), oxygen (O₂), carbon dioxide (CO₂), glucose (C₆H₁₂O₆), acetic acid/vinegar (CH₃COOH), methanol (CH₃OH), and ethanol (C₂H₅OH)
Review and Assessment (time: 5 minutes)
The teacher will provide a molecule that s/he wants the students to create and explain how they modeled it in a short summary either aloud or written. The students may work individually or in pairs. The summary will include how many elements and the number of atoms are needed to make the molecule and how they determined how to create the molecule.

The teacher will have the students create molecules created in Practice and Application or other common molecules, such as salt (NaCl), propane (C₃H₈), and silica tetrahedron (SiO₄).

Lesson 5
Dehydration Synthesis and Hydrolysis

Goal
The students will describe the process of dehydration synthesis and the important role it plays in creating macromolecules by turning monomers into polymers.

Do Now (time: 7 minutes)
As students come into class, the teacher will have the students build molecules similar to the ones created the day before.

Hook (time: 5 minutes)
The teacher will explain to the students that they will be using the computer to complete a lab through an online Gizmo. The teacher may use an example of another Gizmo to show the students what a Gizmo is.

Presentation (time: 15 minutes)
The teacher will present the ideas of dehydration synthesis and hydrolysis.

Note: Dehydration synthesis is the process through which monomers join together through losing water to create a polymer. Hydrolysis is the process of breaking apart a polymer by using water. A teacher-created PowerPoint may help students understand the process.

Practice and Application (time: 21 minutes)
Students will use the Gizmo “Dehydration Synthesis Lab” on the ExploreLearning website.

A study guide for the lab is found in ExploreLearning. This lab may be completed by students individually, in groups, or as a class.

See: www.explorelearning.com

Review and Assessment (time: 7 minutes)
Students will need to complete the lab assessment provided by ExploreLearning, which looks at the processes of dehydration synthesis and hydrolysis. The teacher should allow this time for the students to ask questions and quietly finish their work and reflect on the lab.
Lesson 6

Carbon Compounds and Macromolecules

**Goal**
The students will make a connection between macromolecules and food choices, laying the foundation for understanding how these molecules are used in the body.

**Do Now** (time: 5 minutes)
Working independently or as a group, students will read an article on 2015 USDA Dietary Guidelines.


**Hook** (time: 5 minutes)
The teacher should ask each student to highlight one new thing she or he learned from the article and share it with the class.

**Presentation** (time: 15 minutes)
Biomolecules:
The teacher should present information on Nutrition Facts labels (listing of proteins, carbohydrates, fats, vitamins, minerals, etc.) in oral and visual forms.
Activate students’ prior knowledge through brainstorming:
- What are each of these components?

**Practice and Application** (time: 20 minutes)
Students will research each of the biomolecules listed on a food label (fats, carbohydrates, proteins), write their chemical formulas, draw their structural formulas, and build them with a ball-and-stick molecular modeling kit or paper and tape.

**Review and Assessment** (time: 5 minutes)
The teacher will have students examine the chemical formulas carefully and ask:
- What do the formulas have in common?

Students will complete a turn and talk and write their responses on chart paper or the board.

The students’ responses should include C, H, and O. The teacher will review the different responses with the class and highlight what the class found.
Lesson 7

Sugar in Plants

Goal
Students will explain the molecular composition of carbohydrates and how to identify carbohydrates, especially starches.

Do Now (time: 5 minutes)
Students should respond to this prompt in writing or orally to a partner:
Why do people cut out carbs from their diets?

Hook (time: 5 minutes)
The teacher should start a class discussion about what a carbohydrate is and why people would try to limit their carbohydrates in their diets. The students should list items that have carbohydrates.

Presentation (time: 20 minutes)
The teacher will explain the different types of carbohydrates (monosaccharides, disaccharides, polysaccharides, fructose, sucrose, lactose, glucose) and their molecular compositions. During discussion, the teacher will distinguish between polymers and monomers.

To help students organize their thinking, students will complete the Macromolecule Graphic Organizer (included in the Supplement on p. 4.6.2), which they will use throughout the unit.

The teacher should make sure to describe what a starch is, a polysaccharide that functions as a carbohydrate store.

Practice and Application (time: 20 minutes)
Note: Please check with the program and obtain permission to use chemicals prior to any experiment.

Students will learn how an iodine solution is used to determine the presence of starches. The teacher should provide different options for students to test whether starches are present in common foods.

Options for food for testing with iodine include:
bread, apple (cut thinly), lunch meat, potato (cut thinly), and pineapple

Students may work on the Starch Lab in the Supplement on p. 4.6.3 individually, in groups, or as observers of a teacher demonstration. Each sample tested will produce a blue-black color if starch is present.

Review and Assessment (time: 5 minutes)
Students should keep track of the results during the lab and write a summary of what they learned during the lab.

Extension
The teacher could provide different food examples and students could try to hypothesize if the foods have starch. The students would then have to support their reasoning.
Lesson 8

Proteins

Goal
Students will describe the structure and function of proteins in a living thing and, on a smaller scale, in an individual cell.

Do Now (time: 5 minutes)
Students will respond to the following prompt in writing or drawing:
Where have you heard the word protein before?

Hook (time: 5 minutes)
The teacher should show the video of the Taco Bell protein commercial. Students will then brainstorm as a class why protein is important and what foods contain protein.
SEE: www.youtube.com/watch?v=ReLGpe17TLc

Presentation (time: 15 minutes)
The teacher will make a short presentation on proteins to the class, including information from Miller and Levine Biology, pp. 48-53. The teacher may read the information with the class from the textbook or create a PowerPoint from the text to help students understand concepts such as:
- The structure and function of proteins
- Foods that contain a great deal of protein
- Enzymes and chemical reactions and energy

Practice and Application (time: 25 minutes)
Students will create a poster, using paper and markers or Microsoft Publisher, to describe the function and importance of proteins in the body or in a cell.

Review and Assessment (time: 5 minutes)
Exit Ticket: Students will fill out the protein row in the Macromolecule Graphic Organizer found in the Supplement on p. 4.6.2.

Extension
The teacher could introduce Fold It to the students and provide the article “Gamers Succeed Where Scientists Fail” for the students to read and discuss.

If the teacher and students have time, the class could try different levels of Fold It on an ENO Board.
SEE: http://fold.it/portal
Lesson 9

Enzymes Lab

**Goal**
Students will explain how an enzyme increases the speed of chemical reactions and how the different shapes of proteins may alter the protein’s effectiveness.

**Do Now** (time: 5 minutes)
Students will respond to the following prompt in writing or drawing:

Does cooking food change it?

**Hook** (time: 5 minutes)
The teacher will ask the students to discuss what they wrote and have them share out their thoughts about fats to the class.

**Presentation** (time: 10 minutes)
Students should read by themselves or as a group pp. 50-53 of the Miller and Levine *Biology* textbook.

As students read, they should complete a note-taking template and give examples of enzymes to the class.

**Practice and Application** (time: 25 minutes)
The teacher should demonstrate one or both of the following labs or allow students to complete the lab themselves. (Please check with the program before any experiment for permission to use any chemicals.)

1. Catalase Lab—Supplement p. 4.6.4
2. Denaturation Lab—Supplement p. 4.6.5

**Review and Assessment** (time: 10 minutes)
Students should keep track of the results during the lab and write a summary of what they learned using the lab data.

**Extension**
Students could write about or discuss the following prompt:

Looking at your Do Now, do you stick with your answer or change your answer? Explain why.
Lesson 10

Lipids

**Goal**
Students will explain the importance of lipids/fats in our cells. They will also be able to identify foods with a high lipid content in order to make healthy choices in their diets.

**Do Now** (time: 4 minutes)
Students should respond to the following prompt in writing or drawing:
Name two benefits from and two problems with eating fats.

**Hook** (time: 3 minutes)
The teacher should ask the students to discuss what they wrote and have them share out their thoughts about fats to the class.

**Presentation** (time: 18 minutes)
The teacher should present a brief introduction to lipids. The teacher could have the students read the information on lipids on p. 47 from the Miller and Levine *Biology* textbook. During the presentation, the teacher should focus on lipids' role in the cell and the body, the different types of fats, the structure of the lipids, (e.g., fatty acid or triglyceride), and the process of reading a food label to determine the amount of lipids in a food item.

**Practice and Application** (time: 25 minutes)
The teacher will introduce the “Fat Lab” (found in the Supplement on p. 4.6.6) and support students as they complete the steps.

Students will complete a lab report for the experiment.
The students will answer the questions at the end in partners, individually, or to the group either orally or written down on their paper.
The students will then read the food’s nutrition information and chart as a group the amount of fat in each serving.

**Review and Assessment** (time: 5 minutes)
Students will complete the row for lipids on the Macromolecule Graphic Organizer on p. 4.6.2.
Lesson 11

Eating Macromolecules

**Goal**
Students will apply their knowledge of macromolecules to determine if the diet options promoted in medical communities or media are beneficial to personal or cell health.

**Do Now (time: 5 minutes)**
Students will respond to the following prompt in writing or drawing:
How has this unit changed how you eat?

**Hook (time: 5 minutes)**
The class will share out their answers. The teacher will then brainstorm with the students to name as many diets as possible and write them on chart paper or the board.

**Presentation (time: 10 minutes)**
To remind students that they eat many different macromolecules, they can choose between two different Label the Bucket activities:

1. The first activity requires the teacher to provide students with pictures of different foods and another sheet for the students to place each food in the macromolecule column—Lipids, Carbohydrates, and Proteins—where it belongs. The teacher could increase difficulty by providing foods that may straddle two categories, such as cake or meatloaf. Students need to justify their decisions. A sample sort is seen below:

<table>
<thead>
<tr>
<th>CARBOHYDRATES</th>
<th>LIPIDS</th>
<th>PROTEINS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thai noodles</td>
<td>Crisco</td>
<td>Sunflower seeds</td>
</tr>
<tr>
<td>Apple</td>
<td>Butter</td>
<td>Turkey</td>
</tr>
<tr>
<td>Banana</td>
<td>Olive oil</td>
<td>Soy</td>
</tr>
<tr>
<td>Whole wheat bread</td>
<td>Salad dressing</td>
<td>Hamburger</td>
</tr>
<tr>
<td>Kale</td>
<td>Corn oil</td>
<td>Walnuts</td>
</tr>
<tr>
<td>Potatoes</td>
<td>Margarine</td>
<td>Eggs</td>
</tr>
<tr>
<td>Cake</td>
<td></td>
<td>Salmon</td>
</tr>
</tbody>
</table>

Trick ones: peanut butter, cheese, avocado, cake icing

2. The second activity allows students to move around the classroom in teams to sort different balls with food labels on them into the correct bins. The challenge could be timed, or students could be required to go up one at a time to place a ball in a bin. As above, students need to justify their choices.
**Practice and Application** (time: 15 minutes)

Next, students will work independently or in groups to read one of three articles. After reading, the students should determine the key ideas and present the article to the class.

**SEE:** “School cafeteria favorites could disappear as food rules take hold”
https://newsela.com/articles/lunch-standards/id/3951/

“Fast-food companies feed millennial generation’s healthy appetites”
https://newsela.com/articles/Fastfood-millennials/id/4712/

“PRO/CON: Should parents support the new school meal standards?”
https://newsela.com/articles/healthylunch-procon/id/5197/

**Review and Assessment** (time: 20 minutes)

At this time, the teacher will share the Summative Assessment with the students to prepare the students for future tasks. Thinking about health and food choices, the students will fill in a graphic organizer as the teacher discusses several diet plans, such as:

- Atkins
- South Beach
- Mediterranean
- Paleo
- Gluten-Free
- DASH—Dietary Approaches to Stop Hypertension
- SAD—Standard American Diet

Students should decide whether each diet is healthy for the body or cells and explain their reasoning.

In addition, students can answer:

What eating plan from today would you choose for yourself? Why?

**Extension**

Students who have finished their work may create a persuasive letter encouraging the program director to adopt a particular diet plan for all the students.

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**Lesson 12**

**Nucleic Acid**

**Goal**
Students will model the structure of a nucleotide and explain how it is the backbone of the DNA double-helix.

**Do Now** (time: 5 minutes)
Students should draw a DNA strand.

**Hook** (time: 5 minutes)
The teacher will play the DNA Song and ask students to summarize its message.

**SEE:** www.youtube.com/watch?v=ckZEds5taX4
Presentation (time: 15 minutes)
Students will use either open or closed two-column notes highlighting the components, function, and importance of nucleic acids. The teacher should refer to the Miller and Levine Biology textbook, pp. 48-49. To demonstrate their understanding, the students should fill in the last section of the Macromolecule Graphic Organizer located in the Supplement on p. 4.6.2.

Practice and Application (time: 20 minutes)
Students will complete a DNA Origami Activity to create a DNA model using a hands-on approach. A template for the activity is found at the second link below.

www.dnai.org/teacherguide/pdf/ori_bw.pdf

Review and Assessment (time: 10 minutes)
Students will draw and label a singular nucleotide, the monomer of nucleic acid, with a phosphate, deoxyribose sugar molecule, and a nitrogenous base, which is found at the bottom of the instructions for the DNA Origami Activity. Some students may expand their work and create DNA strands emphasizing the double helix structure and chains of nucleotides.

Extension
Students could watch the student produced video about Rosalind Franklin and her impact on the scientific community in discovering the double helix structure, “Rosalind Franklin vs. Watson and Crick: Science History Rap Battle.”

SEE: www.youtube.com/watch?v=35FwmiPE9tI

Lesson 13
Determine the Macromolecule

Goal
Students will explain the importance of scientific investigations to discover elements and molecules, while reviewing major concepts in the unit about the different macromolecules.

Do Now (time: 5 minutes)
Students will respond to the following prompt in writing or drawing:

If I gave you an unknown food substance, how could you find out what it was without tasting it?

Hook (time: 5 minutes)
The teacher should have the students share their answers and discuss why scientists have to develop tests to determine substances.

Presentation (time: 10 minutes)
Teacher will review with the students the Macromolecule Graphic Organizer (Supplement p. 4.6.2) they have been working on throughout the unit. The students will share their responses with a partner or the
class. The teacher will then discuss how scientists investigate unknown substances. The teacher should also review the carbohydrate, lipid, and enzyme tests and how they work, especially for the benefit of new students in the program. Students who have already learned about these tests could serve as experts for their peers.

**Practice and Application** (time: 25 minutes)
The teacher should provide students with a “mystery” food, and students will need to determine which macromolecule family it belongs to. Gelatin could be a possible mystery food. (Please check with the program before any experiment for permission to use any chemicals.) Students will use the Carbohydrate Test (iodine), the Lipid Test (paper bag), or the Enzyme Test (hydrogen peroxide).

Labs for tests are found in the Supplement on pp. 4.6.3-4.6.6.

**Review and Assessment** (time: 10 minutes)
Students will record the results of their experiments and write a rationale for their conclusion.

CULMINATING LESSON

*Includes the Performance Task, i.e., Summative Assessment—measuring the achievement of learning objectives*

**Lesson 14**

Performance Task (2 Days)

**Goal**
Students will complete the Performance Assessment, Comparing Two Diets, which directly relates to their mastery of the unit standards and demonstrates their understanding of the unit.

**Do Now** (time: 5 minutes)
The teacher should post the standard for the unit on the board. Students should write down how they could demonstrate their mastery of the standard.

**Hook** (time: 5 minutes)
The teacher should lead a discussion of the Do Now and ask students to brainstorm reasons why it is important to complete a Performance Task to end the unit.

**Presentation** (time: 20 minutes)
The teacher will provide the students with an overview of the Performance Task and provide the students with a copy of the rubric (see Supplement p. 4.6.7) outlining the expectations and an example for the students. The students may edit or add to the rubric as a class to increase ownership to the assessment.
The students will compare different kinds of diets and their allowances of carbohydrates, lipids, and proteins. The students could research the information online from *U.S. News “Best Diet Rankings,”* or the teacher could print out examples of different diets. The students will then create a persuasive argument about which is healthier. The argument must include an explanation of what the macromolecules are composed of and their function in the human body. The teacher should scaffold the task by encouraging students to use a table or graphic organizer to compare diets, to develop clear claims, and to cite evidence in their responses.

SEE: “U.S. News Best Diet Rankings”
http://health.usnews.com/best-diet

**Practice and Application** *(time: 50 minutes over 2 days)*
Students will work on the Performance Task in class with teacher supervision. The teacher should be prepared to differentiate to address students’ abilities and length of time present during the unit.

If a student has an idea for a more personalized assessment that addresses the standards, the teacher may permit the student to use that approach.

Students will submit an Exit Ticket at the end of Day 1 summarizing their progress and noting any questions or concerns, and at the teacher will provide specific feedback and support at the start of Day 2.

**Review and Assessment** *(time: 30 minutes)*
Students will present their projects to the class or to the teacher, depending on the student’s preference, and receive feedback based on the rubric on p. 4.6.7. The teacher should highlight the work that students put into their research, argument, and presentation.

**Extension**
At the end of the class, the students could reflect on the unit using these possible questions:

1. I learned about …
2. Knowing this information now will help me in the future because …
3. I really liked learning about …
4. I would have learned better if …
5. When you teach this in the future, I would change …
6. The best part of these lessons was …
7. The worst part of these lessons was …
POST-UNIT REFLECTION

On meeting the Learning and Language objectives
Future Ready Connections
The presentation and practice and the application sections of Lesson 2 focus on the periodic table of elements and how these elements are the building blocks of all matter. Teachers can make connections to Future Ready skills and EYF by asking students to consider: What are the building blocks for specific skills and abilities? What are the building blocks for effective communication, accountability, and initiative? What are the basic elements for success? For happiness? Teachers can have students make a periodic table of elements that combine to create a happy, productive, and successful life. Students will likely list elements such as determination, honesty, follow-through, hard work, compassion, etc. Encourage students to see how different situations require a combination of different elements just like different forms of matter are built from different elements.

Lesson 13 emphasizes critical thinking and problem solving by asking students to determine a “mystery food” by applying their knowledge from the previous lessons.

This lesson provides an opportunity for teachers to evaluate students on their Future Ready skills, specifically initiative and accountability. Students will need to be responsible for their own planning and will be accountable for discovering the answer and explaining how they came to their conclusion. Teachers can expand on this lesson by asking students to consider how they problem-solve in their personal lives and in professional environments. What do they do when they have to figure out a problem at work? What tools or resources can they use?

Transfer Goals Connections
The Transfer Goal for this unit focuses on how students will apply their understanding of macromolecules, carbohydrates, lipids, and proteins to make healthy dietary choices. Making healthy choices is a fundamental aspect of the EYF curriculum and teachers are encouraged to make connections to the physical health, mental health, and effective budgeting lessons in the EYF curriculum. Making positive mental health decisions can affect, and is often affected by, our diet. Teachers can encourage youth to reflect on times when their mental health impacted their diet in positive or negative ways and when their diet impacted their mental health. Ask students to consider times when they eat a lot of junk food or sugar and what that does to their energy level, mood, and ability to focus. Have students consider what they do when they are stressed—do they avoid food or indulge too much? Students should make connections between how their physical health and mental health are linked and what this can do to their performance in school or at a job or how it can impact their relationships. Teachers can also make connections to financial budgeting by expanding Lesson 2, which has students select a four-course meal that will be the healthiest for their bodies. Teachers can introduce a specific budget to this activity and have students balance choosing a healthy meal and not exceeding their budget. This will encourage youth to consider the challenges in balancing priorities and necessities.
PYD / CRP Connections

This unit reflects Culturally Responsive Practice and Positive Youth Development by providing opportunities for critical thinking and independent discovery, activating prior knowledge (Do Now prompts and Hooks), and for making personal connections to the content. In the Performance Task, youth have the option to not only pick a specific diet to research for their presentation, but also have the opportunity to edit or add to the rubric and help determine how the task will be evaluated and assessed. Encouraging youth to actively participate in how they will be assessed allows for a sense of ownership, empowerment, and accountability. Youth are also not simply reporting out for the Performance Task, but are creating an argument, which encourages youth voice and active participation in understanding the topic fully. The lessons are also flexible and allow for students to work and discover in different ways (independently, with a partner, as a class, and with different mediums and activities), which respects their individual needs and abilities.

Lesson 3 and Career Exploration Connections

Teachers are encouraged to expand the Hook for this lesson which has students watch a video and answer questions, including the question: What career shown in the video would you be interested in? Classes can use MassCIS to complete research on the career field and specific jobs from the video and report their findings. Students can also analyze these roles and determine what Future Ready skills these jobs require and how these skills could likely be demonstrated. For example, one aspect of a researcher’s job is to report his/her findings which requires strong communication skills. The researcher would demonstrate this skill by writing reports and articles and getting them published.
Creating a Healthy, Enjoyable Meal  
Lesson 2

**DIRECTIONS:** Create a healthy, enjoyable meal with three to five items from the menu.

<table>
<thead>
<tr>
<th>Items from the menu</th>
<th>Calories</th>
<th>Fats</th>
<th>Carbohydrates</th>
<th>Proteins</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
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<tr>
<td>3.</td>
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</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**QUESTIONS:**

1. Which item had the most fat/lipids?

2. Which item had the most carbohydrates?

3. Which item had the most protein?

4. What surprised you during this exercise?

5. How do you think you did creating a healthy meal?

6. What elements do you think carbohydrates, proteins, and fats are made of?

7. What do you want to learn about most during this unit focused on lipids, carbohydrates, proteins, and nucleic acids?
The Macromolecule Graphic Organizer
Lessons 7, 8, 10 and 12

DIRECTIONS: Enter the correct information into the appropriate area at appropriate times throughout the unit.

<table>
<thead>
<tr>
<th>Macromolecule</th>
<th>Monomer</th>
<th>Polymer</th>
<th>Also Known As ...</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lipids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proteins</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nucleic Acids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Starch Lab: Carbohydrate Test
Lesson 7

DIRECTIONS: Follow the lab procedure.

Foods that the students may use for the lab:
Bread, apple (cut thinly), lunch meat, potato (cut thinly), and pineapple

Differences between starch and carbohydrate

SEE: www.livestrong.com/article/415993-differences-between-starches-and-carbs

“Starches are one of the three main types of carbohydrates. They fall under the category of complex carbohydrates, along with fiber, and are differentiated from the carbs known as ‘simple sugars’ by their structural composition. Good starches are a healthy part of your diet and can be enjoyed by just about everyone. But some starches come from refined carbohydrates and add little nutritive value to your diet.”

Steps and Questions:

1. Which substance or substances do you expect to test positive for starch?

2. To test for starch you will use iodine as an indicator. In the presence of starch, iodine will change color from yellow-brown to blue-black.

3. Add 5 drops of iodine solution to each container. Stir the contents of each container.

4. In the data table below, record the color of the iodine solutions. Put a plus next to those samples testing positive for starch and a minus for those testing negative.

<table>
<thead>
<tr>
<th>SUBSTANCE</th>
<th>STARCH PRESENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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5. Why do we test for starch?

6. Conclusion (after the lab): Which substances have starch? Was your hypothesis correct? What will you take away from this lab?

Catalase Lab: Enzyme Test
Lesson 9

DIRECTIONS: Follow the lab procedure.

Purpose of Lab:
1. Illustrate lock and key model for enzymes.
2. Inform students that hydrogen peroxide is H₂O₂.

Steps:
1. To prepare, cut up pieces of chicken liver in chunks or use raw potatoes.
2. Using test tubes or small graduated cylinders, fill the containers with 15mL of hydrogen peroxide.
3. Place a paper towel underneath to reduce spills or a mess.
4. Put the liver or potatoes in the hydrogen peroxide and have students describe or draw the reaction.
5. Students must explain why they think it happened.
6. Students should make the connection that the liver’s or potato’s enzymes (catalase) caused the hydrogen peroxide to break up into water and oxygen gas.

   The chemical equation for this reaction is: 2 H₂O₂ → 2 H₂O + O₂.
Denaturation Lab: Enzyme Test
Lesson 9

DIRECTIONS: Follow the lab procedure.

Purpose of Lab:
1. Illustrate lock and key model for enzymes.
2. Inform students that hydrogen peroxide is H₂O₂.

Steps:
Students will use cooked and raw carrots to see if cooking changes the enzymes found in the carrots.

1. Using two test tubes or small graduated cylinders for each student, fill the containers with 15mL of hydrogen peroxide.
2. Place a paper towel underneath to reduce spills or a mess.
3. Put the raw carrot in the hydrogen peroxide and have students describe or draw the reaction.
4. Put the cooked carrot in the hydrogen peroxide, and the students will describe or draw that reaction.

After the experiment, students must explain what they think happened and why. They should identify reasons for the different reactions in the lab. The teacher can help the students understand that cooking foods at high temperatures alters the proteins’ formation and structure.
The Fat Lab: Lipid Test
Lesson 10

DIRECTIONS: Follow the lab procedure.

Foods that the students may use for the lab:
Butter, doughnut, cake, nuts (if no students with nut allergies are present), olive oil, fish oil, corn oil,
shortening, hamburger, and potato chips

What are indicators?
An indicator is a substance that changes color in the presence of a particular type of molecule.

Testing for lipids
1. If a food that contains lipids is put on brown paper, it will leave a spot that lets light through.
   To test for lipids, divide a piece of a brown paper bag into 5 sections.
   Label the sections with the foods you will be using in the test.

2. In each section, rub a small amount of the substance on to the brown paper.
   With a paper towel, rub off any excess that may stick to the paper.

3. Set the paper aside until the spots appear dry—about 10 to 15 minutes.
   While you are waiting, answer questions 4 and 5.

4. Which substance or substances do you expect to test positive for lipids?

5. What is the purpose of testing water for lipids?

6. Why do we test for lipids?

7. Conclusion (after the lab): Which substances have lipids?
   Was your hypothesis correct? What will you take away from this lab?

**Summative Assessment: Comparing Two Diets**  
**Lesson 14**

**DIRECTIONS:** Compare two different kinds of diets and their allowance of carbohydrates, lipids, and proteins. Create a persuasive argument through PowerPoint, writing, or posters about which diet is healthier. The argument must include what the macromolecules are composed of and their function in the human body.

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<th>NEEDS</th>
<th>WHAT THE PRODUCT HAS</th>
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<td>Uses one argument tool</td>
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Human Impact on the Environment

TOPIC SEASON: Ecology—Food Web, Cycles, and Trophic Levels

This unit is designed for use in long-term programs. Sections may be adapted to short-term settings.

Unit Designers: E. White and K. Webster

Introduction

There can hardly be a more important goal in science education today than teaching an understanding of ecology and the human impact upon the environment. If we as a species don’t make changes in the ways that we interact with the world around us, there won’t be an ecosystem that supports our needs. Students must learn how to analyze data and interpret findings about human impact on the world in order to become informed citizens who can use their scientific knowledge to solve real-world environmental problems. Students will learn that their choices can affect the world around them and that they have opportunities to make a difference. They will be engaged in learning through relevant topics and by having choices of topics to research. They will also develop career skills in analyzing data and problem solving.

The Human Impact on the Environment unit is designed to come first in the six-week Ecology season and take at least four weeks to complete (perhaps more because of professional development days and the Columbus and Veteran’s Day holidays.) To follow up on this unit, teachers should consider diving deeper into local ecological issues to stress the relevance of the season’s Emphasized Standards. Other units could focus on investigations of environmental problems in the area and include opportunities to bring in guest speakers or, if possible, to take a field trip or virtual field trip to an important local ecological site. Students could explore the Quabbin Reservoir’s creation, Woburn’s toxic waste issue, or Falmouth’s investigation on their own wind turbines.

SEE: video.wgby.org/video/2365046325
www.wgbh.org/wcai/turbine.cfm

This unit focuses on all three of the Ecology season’s Emphasized Standards. HS-LS2-1 focuses on carrying capacity, the concept that the number of organisms an ecosystem can maintain is based on the resources available. An ecosystem with a small amount of water, an abiotic factor, would not be able to maintain a large herd of antelope or a large school of freshwater fish, which are two biotic factors. Through analyzing data about resources and population sizes, this unit will allow students to see this connection and use that understanding to think about environmental factors and their impacts in their neighborhoods or other communities locally and globally.

HS-LS2-4 focuses on the cycles that occur in the environment. It is important to stress that lower trophic level organisms, such as grass or small animals, must be in abundance to support higher trophic level organisms, such as lions or hawks, due to the loss of energy at each level. The unit provides lessons focusing on the cycles of elements.

HS-LS2-7 concerns human behaviors and how they have affected the environment. Students will be provided with examples of human impacts, such as pollution, and their consequences. Throughout the unit, the teacher
should reference local environmental issues and possible actions to encourage positive change in the ecosystem, such as riding a bicycle instead of driving a car. Prior knowledge that students need for this unit includes, from the Chemistry of Life season, an understanding of the importance of carbon, hydrogen, oxygen, phosphorous, sulfur, and nitrogen in the cycles of nutrients. Math skills such as looking at data sets, graphing, and analyzing data are also required. However, if the students do not possess these skills, the teacher might utilize technology to help analyze the data or use group work to support the needed skills. The unit may present challenges for some students surrounding global thinking and communication skills. They may struggle with the breadth of the topic, wondering, “How can my small choices make an impact on the entire world?” As students write arguments, the teacher should support them by providing graphic organizers and assistive technology to capture their thoughts. Scientific readings and vocabulary will need class review and practice.

The unit provides various differentiation options and multiple means of engagement, representation, and action and expression. The teacher can engage the students through real-life examples and student interest in a topic that is prevalent in the news and in other contents. In addition, the teacher can provide the students with lessons filled with varied texts, video selections, and technology. For action and expression, the students should have ample choices to demonstrate their understanding through different forms of writing or speech.

By implementing this unit, teachers can guide their students to think about the ecosystem and evaluate their personal impact on Earth. Through the lessons and concepts highlighted, students will demonstrate their knowledge of the standards while practicing Future Ready skills.

For short-term adaptation ideas for this unit, see p. 4.7.3 on the right.
### Overview
The unit focuses on how human behaviors cause changes in the environment. Learning how biotic and abiotic factors affect the carrying capacity of an ecosystem allows students to hypothesize how human actions or natural catastrophes could have resulted in an unbalanced environment. The students could link the ramifications of these events in altered relationships found in food webs and chains. In addition, the unit stresses the importance of energy flowing through all levels in the environment starting from the sun and diminishing as it moves through each trophic level. While analyzing human behaviors, students will apply their knowledge of ecology to creating solutions to stop further destruction of the environment. Throughout the unit, many students will reflect on their personal choices and how they result in environmental change for better or worse.

### Desired Results
The Knows, Understands, and Do’s for the unit are correlated to the standards, especially energy/food relations, abiotic interactions, and human impacts on environment. In a short-term program, the teacher should consider providing the students with various supports as the lessons focus on the chosen KUDs; however, the teacher should keep work posted in the classroom to reference past ideas in the unit and show connections among the main three KUDs. For the focus on vocabulary and transitional words, a word wall would greatly help those students who are joining the class. The teacher could utilize daily review of the vocabulary and provide Do Nows and Exit Tickets practicing the application of transition words in writing and explicitly acknowledging them in various text forms the students are reading in class.

### Assessment Evidence
At the end of the unit, the Summative Assessment asks students to create a presentation to encourage elected officials to make changes by implementing a solution the student has created to solve an environmental problem. In longer-term programs, the student would know about different problems and factors and possible ways to correct them. For students who were not present throughout the unit, the teacher could provide an article to the class that states a problem and provides various solutions to correct it. The students would then have to judge which solution is the best and justify in their presentation to the elected official why it is the most reasonable action. Throughout the unit, the Formative Assessments help provide connections to the Summative Assessment. However, for short-term students, the Formative Assessments provide opportunities to assess what the students have learned in the stand-alone lessons. In Lesson 4, the use of the Gizmo lab activity allows teachers to look at how the students are able to interpret data and determine how small changes in a food chain can affect the entire ecosystem. Also, in Lesson 9, students will create a PowerPoint allowing for a Summative Assessment comparing and contrasting human and natural impacts on succession.

### Learning Plan
With a unit lasting four weeks, it may be difficult to complete all the lessons with the number of days taken up with trainings and events. For short-term programs, it may be easier to condense a few lessons or remove lessons that have connections later in the unit.

**Lessons 5 and 6**: Cycles of Matter could be shortened into one lesson by providing an overview of the cycles and labeling of the diagrams without pulling apart each cycle so closely.

**Lesson 7**: Climate could be removed from the lesson sequence. The idea of climate change is addressed in Lesson 13: Humans’ Effect on the Environment.

**Lessons 10 and 11**: Population/Human Population could be intertwined in one lesson with students completing the population chart looking at animals and applying the impacts of the human population on the ecosystem.

If the unit needs to be completed early, Lesson 15: Resource Use and Data Analysis could be removed and the ideas could be connected to Lesson 13: Humans’ Effect on the Environment.
Emphasized Standards (High School Level)

HS-LS2-1: Analyze data sets to support explanations that biotic and abiotic factors affect ecosystem carrying capacity.

Clarification Statements:
- Examples of biotic factors could include relationships among individuals (e.g., feeding relationships, symbioses, competition) and disease.
- Examples of abiotic factors could include climate and weather conditions, natural disasters, and availability of resources.
- Example data sets can be derived from simulations or historical data.

HS-LS2-4: Use a mathematical model to describe the transfer of energy from one trophic level to another. Explain how the inefficiency of energy transfer between trophic levels affects the relative number of organisms that can be supported at each trophic level and necessitates a constant input of energy from sunlight or inorganic compounds from the environment.

Clarification Statements:
- The model should illustrate the “10% rule” of energy transfer and show approximate amounts of available energy at each trophic level in an ecosystem (up to five trophic levels).

HS-LS2-7: Analyze direct and indirect effects of human activities on biodiversity and ecosystem health, specifically habitat fragmentation, introduction of non-native or invasive species, overharvesting, pollution, and climate change. Evaluate and refine a solution for reducing the impacts of human activities on biodiversity and ecosystem health.

Clarification Statements:
- Examples of solutions can include captive breeding programs, habitat restoration, pollution mitigation, energy conservation, and ecotourism.

Essential Questions (Open-ended questions that lead to deeper thinking and understanding)

How does the environment affect living things? How do living things affect each other? How do you impact the health of an ecosystem? Why do structures, like buildings or business models, require more support at the bottom than at the top?

For Empower Your Future Connections, see pp. 4.9.1 to 4.9.2
Learning and Language Objectives

By the end of the unit:

- **Students should know...**
  - Vocabulary:
    - abiotic, biotic, cycling of materials, ecology, ecosystem, species, energy pyramid, food chain, food web, trophic level, autotrophic, decomposer, environment, heterotrophic, denitrification

- **understand...**
  - Biotic and abiotic factors contribute to how an ecosystem operates.
  - Energy is continuously added and lost in an ecosystem, but elements are recycled.
  - The flow of materials through the ecosystem creates a homeostatic environment interacting with living species.
  - Humans have a cause-and-effect relationship with the environment; thus students’ decisions have an impact on their ecosystem.

- **and be able to...**
  - Explain biotic and abiotic factors that impact the human environment or our ecosystem using Tier II and Tier III ecology-specific terminology.
  - Use mathematical models of stored energy in biomass to describe the transfer of energy from one trophic level to another.
  - Construct and revise an explanation based on evidence for the cycling of matter and the flow of energy in aerobic and anaerobic conditions.
  - Create a persuasive presentation that resolves an environmental problem caused by human activities.

**Transfer Goals** *(How will students apply their learning to other content and contexts?)*

Students will apply their understanding of how an individual’s decisions have an impact on the environment to make informed decisions in their own lives, and apply their understanding of collecting, organizing, and modeling data to draw conclusions and to predict future outcomes.

Students will gather, evaluate, and synthesize evidence to support arguments to effect change, and will convey their thoughts and ideas by oral, written, and nonverbal standard communication skills.
Assessment Evidence
Quality questions raised and tasks designed to meet the needs of all learners

Performance Task and Summative Assessment (see pp. 4.8.29 to 4.8.31)
Aligning with Massachusetts standards
Using the GRASPS format, the students’ task will be to write or create presentations to elected officials explaining their solutions to environmental issues. The goal is for students to argue their positions through data and facts using their knowledge about cycles of biotic and abiotic factors, interdependent relationships in ecosystems, and the impact of humans on the environment.

Pre-Assessment (see p. 4.8.8)
Discovering student prior knowledge and experience
The teacher will ask the students to rank seven environmental issues and decide the order of importance to their own lives. The teacher will bring the class together to hear the students’ ideas. After the discussion, the students will write down why and how they chose their most and least important environmental issues.
Possible issues: human population growth, deforestation, invasive species, increasing nitrogen output, climate change, ozone depletion, water pollution

Formative Assessments (see pp. 4.8.12, 4.8.15)
Monitoring student progress through the unit
Creation and identifying and labeling of cycle diagrams for water, carbon, and nitrogen
Community Interaction Stations Activity
Student assessments provided by Pearson Biology website or curriculum CDs/DVDs through the unit’s
• Lesson Grabbers
• Workbook Editable Templates
• Data Analysis Activities
See: www.pearsonsuccessnet.com
Gizmo Food Web Activity
Lab sheets for The Effect of Fertilizer on Algae
Water Pollution Activity (see www.rivanna-stormwater.org/bacteria.pdf)
Oral surveys, discussions, journaling, student notes, group discussion notes, Exit Tickets, and Do Nows

For Empower Your Future Connections, see pp. 4.9.1 to 4.9.2
Multiple Means of Engagement

Throughout the unit, the students will be provided with various activities to recruit and retain their interest. The students will be analyzing authentic problems and data while they complete numerous tasks in the unit. Moreover, the content affects their daily lives and living conditions, which may increase their level of engagement. In one lesson, students will be able to use a song or poem to demonstrate their knowledge. Throughout the lessons, teachers will be providing goals and objectives for the students to meet, which will be guided by the teacher’s consistent feedback from Do Now activities, Formative Assessments, and class discussions. Most importantly, teachers will be able to provide options for individual choice in assignments, such as the topic of the Performance Assessment.

Multiple Means of Representation

During the unit, students will have information presented to them in several modalities. Teachers are encouraged to use pictures, diagrams, graphs, videos, text, PowerPoint, and scaffolded notes. One lesson encourages students to utilize the computer to work with a Gizmo to manipulate data and observe the outcomes. Throughout the unit, the teacher should provide support with vocabulary and ensure that students have access to the key terms visually and auditorily. Students will also experience the impact fertilization can have on algae by completing a real-world experiment and tracking changes through observation.

Multiple Means of Action and Expression

Throughout the lessons, the students will be given a multitude of options to express what they are learning. Students will have assistive technologies, such as a NEO or an AlphaSmart, to respond to answers. Also, students will be able to use the computer to complete a PowerPoint or design flyers; they may use Word features as well. Students will be able to demonstrate their learning through written words; discussion; or creating graphs, drawings, or diagrams for their answers. While learning about the cycles, students will be able to use rap or poetry to show mastery of objectives. Students will also be able to display their learning through movement, such as the “Water Cycle Shuffle” or while they are moving from station to station during another lesson. Throughout the unit, the teacher should provide levels of support for positive practice and performance to foster learning.
Literacy and Numeracy
Across Content Areas

Reading
Through the unit, the students will be reading nonfiction text from the textbook and informational websites. The students will be reading the information to gain understanding and to scaffold their knowledge base of the material being explained in class. With a central focus on determining central ideas and citing textual evidence, students will be involved in activities of researching topics while reading various articles and choosing evidence that supports their claim in their summative project. In addition, students will also be reading to provide feedback on other peer’s work.

Writing
The students will be utilizing writing to display their knowledge of the information and will help visual learners to process the factual knowledge. Students will be writing their conclusions to labs and to explorations of the content. The writing will help teachers to assess the students’ skills to complete the assignments and meet the standard. The unit’s writing includes an array of formal and informal formats focusing on the argumentative style. The students will work on persuading a political official to adopt a solution to an environmental problem.

Speaking and Listening
Students will learn the processes for engaging in a range of academic conversations using multiple perspectives and effective questioning while participating in both small and whole group discussions throughout the unit. They will share ideas orally, communicate about relevant topics, and participate collaboratively in lessons using appropriate terminology. During the final Performance Task, students will give speeches to an appropriate audience.

Language
Within the unit, the students will be exposed to various formats of academic language. During the lessons, the teacher can scaffold the language through modeling, turn and talks, and class discussion about the content. In addition, students will learn and utilize Tier II and Tier III academic vocabulary dealing with ecological factors and cycles or biotic and abiotic factors. The students will be faced with determining denotations of words with multiple meanings, like *cycle*, which could be described as a Tier II and a Tier III word.

Providing students with opportunities to present to the class will allow practice using Standard English conventions. In addition, students will be responding in class with simple and complex sentences. The teacher should encourage full responses during answers and will model formal English usage when possible. In addition, students will work with standard English capitalization, spelling, and punctuation conventions.

Numeracy
Through this unit, students will be working with numbers in equations and interpreting data in virtual simulations. Students will need to understand equations and basic computations dealing with relationships within the environment and human impact factors. Students will be interpreting data from the graphs and other representations of numeric data to decipher the scientific evidence to claims being made by different researchers and special interest groups.
Resources (in order of appearance by type)

Print

Websites


“Morning Lesson with Mufasa.” *The Lion King*. Walt Disney Studios. 2011. www.youtube.com/watch?v=bW7PITaawfQ.


“Food Chain Song.” Mr. Parr. 2013. www.youtube.com/watch?v=iWfEn8J5xKM.


Materials (some located in the Supplement)

Templates/Graphic Organizers:
- Top-Down Energy Producers’ Chart (p. 4.10.1)
- The Energy Pyramid (p. 4.10.2)
- Community Interactions Template (p. 4.10.3)
- Ecology Performance Assessment (p. 4.10.4)
- Photosynthesis, Carbon Cycle, Nitrogen Cycle, Phosphorus Cycle, Hydrologic (Water) Cycle—student created
Outline of Lessons
Introductory, Instructional, and Culminating tasks and activities
to support achievement of learning objectives

INTRODUCTORY LESSON
Stimulate interest, assess prior knowledge, connect to new information

**Note:** Teachers should vet all videos included in this unit according to program standards and create templates or graphic organizers for students to monitor their comprehension of the material.

Lesson 1
Introduction into Ecology

**Goal**
Students will identify living and nonliving things, explain abiotic and biotic factors, and how they relate to different global environments.

**Do Now** (time: 5 minutes)
Students will draw or complete a freewrite answering:

What is alive in this classroom environment?

**Hook** (time: 20 minutes)
(Pre-Assessment for the unit) The teacher will ask the students to rank seven environmental issues and decide the order of importance to their own lives. The teacher brings the class together to hear the students’ ideas. After the discussion, the students will indicate in writing why and how they chose their first and last issue. Possible Issues:

- human population growth
- deforestation (cutting down trees)
- invasive species (one animal/plant dominating)
- increasing nitrogen output (fertilizer getting in water)
- climate change (temperatures unseasonal)
- ozone depletion (hole in ozone layer)
- water pollution

Besides introducing the concept of ecology for the lesson, the teacher should spend time laying out the unit and connecting it to the broader aspects of the biology curriculum, such as discovering how living things strive to create homeostasis, or balance, within their systems and how life reacts or attempts to readjust to sudden changes.

**Presentation** (time: 15 minutes)
The teacher will facilitate a classroom discussion referring back to the Do Now (what is alive in this classroom environment) and students will respond by sharing their answers aloud. Students should name as many living things as possible in the classroom. The list should include insects, bacteria, and other microorganisms. The teacher will explain the difference between abiotic (physical and chemical) and biotic (living) factors in the environment and ensure students know that without abiotic factors nearly all life on Earth would not survive. Use CO₂ as an example of an abiotic factor:

Without CO₂ plants could not perform photosynthesis and produce the oxygen animals need to breathe.
Practice and Application (time: 10 minutes)
The teacher should post pictures of different environments around the globe and ask students to name the abiotic and biotic factors in each. Push students to explain how those abiotic factors work to help organisms survive. (Some examples: oxygen is needed for animals to live, soil provides nutrients for plants to grow, light is needed for most plants to grow.)

Review and Assessment (time: 5 minutes)
Students will complete this Exit Ticket:

List 3 biotic and 3 abiotic factors in a desert.
Add for higher level thinking: Is time an abiotic factor? Cite evidence to support your claim. (The answer is yes; physical and chemical properties make up abiotic factors, and time is physical.)

Extension
Students may draw an environment they are familiar with and list the biotic and abiotic factors on the back of the picture. Inform the students that they may have their picture displayed or used as a sample in class.

INSTRUCTIONAL LESSONS
Build upon background knowledge, make meaning of content, incorporate ongoing Formative Assessments

Lesson 2
Energy Producers and Consumers 1
Note: PowerPoint and graphic organizer available on Google Drive in the Science Supplement Folder.

Goal
Students will explain how energy is obtained by living things in a system that creates interconnected relationships for food.

Do Now (time: 5 minutes)
Students will write down five abiotic and five biotic factors in the environment.

Hook (time: 10 minutes)
Students will watch a clip from The Lion King, then write or discuss:
How does Mufasa’s explanation of the “Circle of Life” describe the relationships between species?

SEE: The Lion King “Morning Lesson With Mufasa”
www.youtube.com/watch?v=bW7PlTaawfQ

Presentation (time: 25 minutes)
Student will read as a class or individually Section 3.2, “Energy, Producers, and Consumers,” from Miller and Levine Biology (pp. 69-72). Use the top-down chart or two-column chart to synthesize information from the text. Students may complete the chart, located on p. 4.10.1 of the Supplement, on their own
or as a class. Heterotrophs/consumers can be split into several groups:

- herbivores, omnivores, scavengers, carnivores, decomposers, and detrivores

The teacher will then explain that there are two ways organisms obtain food. Those organisms are either autotrophic/producers (make their own food using solar energy) or heterotrophic (consume other organisms for food).

**Practice and Application** (time: 25 minutes)

The teacher will assign the students an organism category to research and make a small poster about it. The students will be required to include on their poster:

- Name of the category
- Three characteristics of the category
- An explanation about how the living things in this category obtain energy
- Four examples of living things in the category
- Three visual representations (drawn or printed pictures)

**Review and Assessment** (time: 5 minutes)

Without their notes, students will list examples of producers and different forms of consumers.

**Extension**

Teachers may be able to plant seeds to grow within their classroom if permitted. This may be done with a formal flower pot or a Styrofoam cup with dirt. The students should make the connection that the seeds will need the energy from the sun to grow through the process of photosynthesis. The teacher could complete the experiment by having two pots; one that will have access to sunlight and one that will be placed in a drawer or dark spot of the classroom. The students will then compare the growth of both plants.

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**Lesson 3**

**Energy Producers and Consumers 2**

*Note:* A PowerPoint presentation is available on Google Drive in the Science Supplement Folder.

**Goal**

Students will explain pyramids of energy and calculate energy loss at each trophic level through data sets.

**Key Ideas**

- Consumers and producers are placed on different levels of a pyramid of energy and separated into four groups: primary producers (photosynthetic organisms), primary consumers, secondary consumers, and tertiary consumers.
- Most energy is converted to heat and leaves the pyramid, going back into nature.
Only 10% of the energy from the previous level moves to the next level.

Energy transfer affects the number of individuals at particular levels (i.e., there are fewer predators at the top because there is less energy to compete for and unsuccessful competitors die).

**Do Now** (time: 5 minutes)
The students will list in order the organisms and abiotic factors that exist on Earth by either the population or the amount of energy (total mass):
- May include light or chemical energy (as holding the largest amount of energy)
- Producers: trees, grasses, vegetables
- Consumers: rabbits, snake, lions

**Hook** (time: 10 minutes)
The teacher will prompt the students to share their answers with the class. As the students are sharing, the teacher should be writing their answers down on the board placing them in a pyramid without drawing the shape on the board. After the discussion, the teacher will draw the pyramid on the board.

**Presentation** (time: 20 minutes)
The teacher introduces the Pyramid of Energy to students by utilizing the PowerPoint presentation (Google Drive) and template. In the PowerPoint, there will be explanations on how to calculate energy transfers between trophic levels. From the Pyramid of Energy, students will reason why the top levels have less biomass than lower levels (due to less energy to be shared). An energy pyramid template is on p. 4.10.2 in the Supplement.

**Practice and Application** (time: 15 minutes)
Students will mathematically calculate the energy transfers between trophic levels using data sets. The teacher should scaffold the math problems by providing detailed notes and calculators to students. By dividing the higher level's energy by the lower level's energy (in kCal), they will calculate that there is roughly a 10% transfer.

**Review and Assessment** (time: 5 minutes)
As an Exit Ticket, students will explain how Earth would change if there were more secondary consumers than producers.

**Note:** This Exit Ticket serves as a Pre-Assessment for the next lesson.

**Extension**
In Miller and Levine’s *Biology*, p. 78, students could answer this question:

2b. Draw an energy pyramid for a five-step food chain. If 100 percent of the energy is available at the first trophic level, what percentage of that energy is available at the highest trophic level?
Lesson 4

Energy Flow

Goal
Students will decipher and explain the energy flow through an environment looking at numerical or pictorial representations.

Do Now (time: 5 minutes)
The teacher will share the students’ responses from the Exit Ticket from the previous day about what would happen if there were more secondary consumers than producers, revisit the question, and reflect on the answers with the class.

Hook (time: 10 minutes)
Students will play a customized rock, paper, and scissors game that shows hierarchy and consumption. Have losers be eliminated by being “eaten.” Once a winner is announced, lead students to respond with what will happen to the winners eventually if they don’t eat. Instructions for Rock, Paper, and Scissors are at the site listed below.


Presentation (time: 10 minutes)
The teacher will ask students what they observed in this simple and familiar game. The game should help students understand that there isn’t a “best move,” as there is not a best organism in communities or ecosystems. Students will begin to understand the dependent relationships in the ecosystem. The teacher should show examples to the class to remind them how food webs and food chains show the flow of energy. To pique students’ interest, the teacher may play “Food Chain Song” by Mr. Parr.

See: www.youtube.com/watch?v=iWfEn8J5xKM

Practice and Application (time: 25 minutes)
Students will independently or as a class explore the Food Chain Gizmo Food Web Activity below.


Note: The accompanying template for this activity on Gizmo may be used as a Formative Assessment. Students will be able to look at data to discover a cause and effect system.

Review and Assessment (time: 5 minutes)
Students will share their findings with the class about the Gizmo. The class will be asked to provide at least three of their own questions about the Gizmo or the scientific information.

Extension
Students may be able to complete an owl pellet lab, dissecting the owl’s prey and taping down the bones to draw a food web or chain to show the process. If students are unable to complete the lab physically, they could complete the lab online.

Lesson 5

Cycles of Matter 1

Goal
Students will list and explain the four parts of the water cycle: precipitation (rain, snow), evaporation, condensation, and transpiration (from plants), and list and explain the processes at work in the carbon cycle: biological, geological, chemical, and human.

Key Ideas
Water (Hydrologic) Cycle
- Water is one the most important molecules on earth.
- Liquid water distinguishes Earth from neighboring planets.
- Water travels massive distances as vapor across the globe.

Carbon Cycle
- Carbon is the building block of life on this planet.
  Every living organism is made out of carbon-based molecules.
- Carbon is found in large reservoirs: plants, the ocean, ice in glaciers, and fossil fuels.
- Humans are affecting the carbon cycle and thus the Earth by burning fossil fuels.

Do Now (time: 5 minutes)
Students will name 10 abiotic factors and list their importance to life. They should be as specific as possible.

Note: Students may not be able to get up to 10 on their own, or they may have partial answers. Water and carbon-based compounds should be on their lists.

Hook (time: 10 minutes)
The teacher uses Lesson Grabber 3.4 “It’s Raining, It’s Pouring” from the Pearson CD or on Biology.com.

Presentation (time: 20 minutes)
The class will read from the Biology textbook (pp. 79-83) individually or as a class, and complete the Lesson 3.4 (“Cycles of Matter”) template found on the Pearson website or CD up to the Nitrogen Cycle.

For kinesthetic learners and for fun: The teacher may lead the class in the “Water Cycle Shuffle” as a way to get the students moving. This activity can be completed sitting down or standing up.

1. “Evaporation” (As this is being said, raise hands to over the head.)
2. “Condensation” (With hands over the head, sway the body back and forth keeping the hands up.)
3. “Precipitation” (Bring hands down to the sides while moving fingers.)
4. “This is how you do the Water Cycle Shuffle.”
   (Students can shuffle in a circle if standing up, or students can give “jazz hands.”)

Practice and Application (time: 15 minutes)
Students will copy and label their own diagrams of the water and carbon cycles. Students’ diagrams can be detailed with color and other images such as trees.
Review and Assessment (time: 5 minutes)
As an Exit Ticket, students should work in pairs to compose explanations of the water cycle and/or carbon cycle as the teacher walks around and listens to their conversations.

Extension
Students could create a movement activity similar to the “Water Cycle Shuffle” to represent the carbon cycle.

Lesson 6
Cycles of Matter 2

Goal
Students will explain the importance of and the processes involved in the nitrogen and phosphorus cycles, including the impacts of human activity.

Key Ideas

Nitrogen Cycle
- Nitrogen is necessary to make amino acids and nucleotides, which are critical to protein form and function.
- Nitrogen exists as N2, NO3-, and NO2.
- The process of converting nitrates into nitrogen gas is called denitrification.
- Humans add nitrogen to the biosphere by using fertilizer, which runs off into the ground and surface water.

Phosphorus Cycle
- This cycle doesn’t involve the atmosphere but affects Earth’s crust.
- Phosphorus is essential to DNA and RNA function.
- Dissolved phosphates are immediately assimilated back into organisms.
- Rocks and sediment release phosphorus as they break down.

Do Now (time: 5 minutes)
Students will complete a quick drawing of the water or carbon cycle by using a real photo to trace the movement of water or carbon.

SEE: http://oceanenergy.epri.com/images/streamenergy.jpg

Hook (time: 5 minutes)
The teacher will introduce phosphate and nitrogen. The students will be asked to find and identify the elements on the periodic table. The class will discuss the properties of the elements in relation to their position on the table.
Presentation (time: 25 minutes)
The teacher will present the video “Nitrogen and phosphorus cycles: Always recycle!”

Note: The teacher should watch the video before screening and create guided notes for students to follow along. If the video is not available, the class may read from the Biology textbook (pp. 84-86) and complete the Lesson 3.4 Cycles of Matter template found on the Pearson website or CD from the prior day.


Practice and Application (time: 15 minutes)
The teacher will explain that the students will write a rap or a poem for one of the nutrient cycles. For support, the teacher can play the quick video “The Water Cycle Rap,” which is a rap about the water cycle. Students can write their raps or poems individually, in pairs, or as a group.

SEE: www.youtube.com/watch?v=i3NeMVbXXU

Review and Assessment (time: 5 minutes)
Before leaving, students share their work with the teacher or with the class.

Extension
Lab: The Effect of Fertilizer on Algae
1. From the Pearson website or CD, make copies for the lab “The Effect of Fertilizer on Algae.”
2. Obtain needed materials or permission to use materials from list that follows.

Materials
- 2 test tubes
- glass-marking pencil
- test tube rack
- 2 dropper pipettes
- algae culture
- 25-mL graduated cylinder
- spring water
- fertilizer
- 2 cotton balls
- grow light—outside light

3. Complete the directions from the lab sheets.
4. Use the student’s lab sheet as a Formative Assessment to prepare them for the final product.

Lesson 7
Climate

Goal
Students will gain background information on the climate and explain the “Greenhouse Effect.”

Key Ideas
Climate is the average weather conditions (temperature and precipitation) over time.

Helpful distinction: Climate determines the clothes you buy in your environment; weather determines what clothes you wear on a certain day.
• Sunlight and solar energy have a huge effect on climate.
• Curvature of the earth results in different parts getting more or less intense solar energy.
• Differences in distribution create three distinct climate zones: tropical, temperate, and polar.
• Temperature differences in the heat from the tropics and the cool air from the poles create wind and ocean currents. Wind and currents interact to produce climate.
• Deep ocean currents are caused by very cold water sinking near the North and South Poles. This water can rise in warmer regions (upwelling).

Do Now (time: 5 minutes)
Students will answer:
What is our climate?
Depending on students’ knowledge, they might confuse climate with weather. If they do, ask students what weather is.

Hook (time: 5 minutes)
After looking over their answers, the teacher and students will participate in a brainstorming session that focuses on the factors that determine climate in a region.

Presentation (time: 25 minutes)
Read aloud the material from the Miller and Levine Biology textbook (pp. 96-98) or use the Pearson website or CD to obtain an editable PowerPoint: Lesson Overview 4.1, Climate. During the reading or PowerPoint, students may complete the accompanying templates provided by the website or CD.

Practice and Application (time: 15 minutes)
After the presentation, students will complete the Climate Zone template (from the Pearson editable PowerPoint) and draw and label with details the Greenhouse Effect.

Review and Assessment (time: 5 minutes)
As an Exit Ticket students will respond to this question:
Is the Greenhouse Effect good or bad for Earth’s creatures?
Response options should include a writing prompt, class discussion, class debate, or Think-Pair-Share.
Note: The Greenhouse Effect is good and bad. Pollution intensifies the Greenhouse Effect, making it much warmer on the surface than normal. This can cause a host of problems. At the same time, the Greenhouse Effect occurs naturally and keeps enough heat to make Earth hospitable.

Extension
Students may explore A Student’s Guide to Climate Change on the Environmental Protection Agency (EPA) website. This student guide provides insights into the scientific evidence for climate change and allows students to see the processes, tools, and activities of career scientists.

SEE: www.epa.gov/climatestudents/scientists/index.html
Lesson 8

Community Interactions

Goal
Students will explain how organisms interact with each other in a symbiotic manner.

Key Ideas

- Habitat: The general place or environment where an organism lives
- Niche: What an organism does and how it interacts with the environment
- Interactions between organisms: Prey/predator, competition, symbiosis
- Symbiosis: A close relationship of two individuals from different species living together
- Types of symbiosis: Mutualism (both benefit), commensalism (one benefits and the other is fine), parasitism (one benefits and one suffers)

Do Now (time: 5 minutes)
Students will complete the Lesson Grabber 4.2 “Fitting In” from the Pearson CD or on Biology.com.

Hook (time: 5 minutes)
The teacher shows a picture of a crocodile with an Egyptian plover cleaning its teeth. Ask students if they would be willing to climb into a killer whale’s mouth and do the same.

SEE: www.wolaver.org/animals/crocodile-plover.htm

Presentation (time: 15 minutes)
The teacher explains habitat, niche, interaction, and symbiosis to students.

Habitat example:
The “California fog belt,” a specific Pacific Coast environment, is the habitat for the redwood forest. The redwood forest canopy in turn creates a habitat for epiphytes (plants that grow on trees).

Niche example:
The redwood canopy epiphytes occupy the niche of producers for a host of animals that live in the redwood canopy.

Interactions (use these terms to classify relationships in nature):
- Competition: e.g., monkeys compete for trees with the best fruit
- Predation: e.g., lions prey on gazelles or deer prey on grass
- Symbiosis: commensalism, mutualism, and parasitism

For each interaction and relationship come up with an analogy from our own world. It can be an example from a television show, a movie, a book, something from another class, news, etc.

EXAMPLE

Competition: In Twilight Edward and Jacob were not from the same species but they competed for the same resource—Bella.
As the teacher explains the information, the students should complete the chart.
A copy of this chart for class distribution is located on p. 4.10.3 of the Supplement.

**Practice and Application** (time: 25 minutes)

1. Guess the relationship:
   a. Lichen and tree (Mutualism)
   b. Dogs and heartworms (Parasitism)
   c. Barnacles on a whale (Commensalism)

2. STATION ACTIVITY: Post pictures around the room of the following relationships (pictures may be obtained through a Google search) and have students list the relationship at each station.
   a. Ants/caterpillar/plant—mutualism
   b. Fish and sea lamprey—parasitism
   c. Lion and zebra—mutualism, predation
   d. Pinworms and humans—parasitism
   e. Pseudoscorpions and beetles—commensalism
   f. Goby fish and shrimp—mutualism
   g. Tubeworms and bacteria—mutualism
   h. Whale and barnacles—commensalism
   i. Ticks and animals—parasitism
   j. Imperial shrimp and sea cucumbers—commensalism
STATION 1
The caterpillars have nectar organs, which the ants drink from, and the acacia tolerates the feeding caterpillars. The ants appear to provide some protection for both plant and caterpillar.

STATION 2
The sea lamprey is a species native to the Atlantic Ocean that has been introduced into the Great Lakes where its population growth has gotten out of control. The lamprey attaches itself to the body of a native fish, such as a trout and drains the fish's body fluids for nutrition.

STATION 3
The fastest lions are able to catch food and eat, so they survive and reproduce, and gradually, faster lions make up more and more of the population. The fastest zebras are able to escape the lions, so they survive and reproduce, and gradually, faster zebras make up more and more of the population. An important thing to realize is that as both organisms become faster to adapt to their environments, their relationship remains the same: because they are both getting faster, neither gets faster in relation to the other.

STATION 4
Pinworms are extremely common intestinal parasites. It’s hard to avoid pinworm infestation; their eggs are often airborne. Once pinworms are snugly ensconced inside the human body, they crawl outside the anus at night, causing severe itching, and then lay their eggs on bedding or sleep wear.

STATION 5
A few species of pseudoscorpions disperse by concealing themselves under the wing covers of large beetles such as the cerambycid beetle shown below. The pseudoscorpions gain the advantage of being dispersed over wide areas while simultaneously being protected from predators. The beetle is unharmed.

STATION 6
The Goby fish, sometimes lives with a shrimp. The shrimp digs and cleans up a burrow in the sand in which both the shrimp and the Goby fish live. The shrimp is almost blind, leaving it vulnerable to predators when above ground. In case of danger the Goby fish touches the shrimp with its tail to warn it. When that happens, both the shrimp and Goby fish quickly retract into the burrow.

STATION 7
Tubeworms and bacteria live together at hydrothermal vents and cold seeps. This is a symbiosis where the worm completely loses its digestive tract and is solely reliant on their internal symbionts (the bacteria) for nutrition. The bacteria oxidize either hydrogen sulfide or methane, which the host supplies to them. These worms were discovered in the late 1980s at the hydrothermal vents near the Galapagos Islands and have since been found at deep-sea hydrothermal vents and cold seeps in all of the world’s oceans.

STATION 8
Barnacles lodge themselves on to living organisms to live their adult lives. Barnacles are sedentary, highly modified crustaceans resembling cone-like pyramids. Barnacles live by using long, feathering appendages to sweep the surrounding water for small, free-floating organisms. The critical resource for barnacles is a place to stay. Barnacles attach to rocks, ships, shells, whales, and just about anywhere else they can gain a foothold. The barnacle gains a place to live and, presumably, the rock, ship, shells, etc. are not harmed by the presence of the barnacles. These organisms (like whales) carry them to environments in which nutrients are readily available.
STATION 9
Ticks attach to animals (like dogs, cats, or humans) and suck their blood for nutrition. Ticks attach to animals by inserting their mouthparts into the skin. Many ticks also produce a sticky, glue-like substance that helps them to remain attached. After attaching to the skin, ticks begin feeding on the animal’s blood. The places where ticks attach can become red and irritated. Ticks can also cause diseases such as Lyme disease or Rocky Mountain fever.

STATION 10
Imperial shrimps hitch a ride on a large area of potential food by their host with only a minimal expenditure of energy on their part. They can be observed getting off their host cucumber to feed in productive areas, and back on for a ride to the next spot! The Imperial shrimp also rides on large nudibranchs such as genus Dendrodoris, which although slow moving, afford the shrimp with protection by virtue of their toxic chemical secretions and warning colors.

Review and Assessment (time: 5 minutes)
1. Describe two important ways that organisms interact.
2. What are the different symbiotic relationships organisms can have?
3. Provide an example of one type of symbiotic relationship and explain.

Extension
The teacher may have note cards for each of the symbiotic vocabulary words and examples, definitions, or pictures for each word. The students could match terms and examples or play a game of memory trying to match the terms and definitions.

Lesson 9
Succession

Goal
Students will explain how ecosystems adapt from a disturbance and the differences between a human disturbance and a natural disturbance.

Key Ideas
Succession never ends.

- Ecological succession: a series of gradual changes that occur in a community following a disturbance
- Primary succession: when organisms populate a space for the first time (this takes a long time—thousands to millions of years)
- Pioneer species: the first species to populate an area during succession
- Secondary succession: changes to a community that occur after a small disturbance

Do Now (time: 5 minutes)
Students will complete a free write about a time they were in the middle of a disaster, like a Nor’easter, tornado, flood, etc. They should be encouraged to explain their personal experiences. If students have
not been in a disaster, the they can imagine what a disaster would be like based on their own background knowledge or what they have observed in the media, in order to complete the free write.

**Hook** (time: 5 minutes)
Students will complete the Lesson Grabber for Section 4.3 on the Pearson CD, which asks students to think about natural and man-made disasters.

**Presentation** (time: 20 minutes)
Students will complete two-column notes as they watch the video “Ecological Succession: Change is Good.” For differentiation, one side of the notes page could be in a closed-note format (partially filled in), and the other side could be blank. The link to the video is below. Discuss the information found in the video and help students sort through their notes.


**Practice and Application** (time: 20 minutes)
Students will research and create a five-slide PowerPoint about an ecosystem where primary or secondary succession took place. The PowerPoint must include:

1. A title slide with the name of the disturbance
2. A slide describing the events of the disturbance
3. A slide explaining why the disturbance had either primary or secondary succession
4. A slide explaining if it has reached its “climax community”
5. A slide describing what humans could do to improve this ecosystem

**Review and Assessment** (time: 5 minutes)
QUESTIONS ▶
1. What type of succession might occur after an asteroid hits Earth?
2. What kinds of conditions might prevent a community from returning to its pre-disturbance state?
3. True or False: Succession after a disturbance event will reach an ending point.

**Extension**
The teacher may choose to read an article to the students about personal preparedness in a disaster, or the students may use the internet to research the government’s tools about being prepared and create their own personal plans.

SEE:  www.ready.gov/make-a-plan

**Lesson 10**

Population Growth

**Goal**
Students will determine why scientists focus on statistics to determine the population’s impact on the environment and the environment’s impact on the population.
Key Ideas

- **Population density**: measure of a population per unit area or volume area
- **Limiting factors**: conditions that limit the growth or development of an organism or population
- **Carrying capacity**: the largest number of individuals of a population that a given environment can support
- **Exponential growth**: a growth pattern in which the individuals in a population reproduce at a constant rate
- **Logistic growth**: a growth pattern in which a population’s growth rate slows or stops, following a period of exponential growth
- **Growth rate formula**: \( r \) (rate of growth) = \( \frac{\text{Births} - \text{Deaths}}{\text{N (population)}} \)

**Example**: 200 births - 100 deaths / 1,000 population = 10% growth rate

**Do Now** (time: 5 minutes)

The teacher will create for the students a hypothetical situation in which all the trees in the neighborhood were being infected by a disease. The students will brainstorm all the organisms that would be affected by this occurrence.

**Hook** (time: 5 minutes)

The students will review their answers as a class. The teacher will highlight ideas about populations diminishing or leaving the area. The students will be introduced to the idea of populations and why scientists care.

**Presentation** (time: 15 minutes)

Students will watch the video “Population Ecology: The Texas Mosquito Mystery.” The teacher should provide note taking support to help students understand the context. If the video is not working, the class may read pp. 130-135 from the Biology textbook and complete Lesson 5.1, “How Populations Grow,” using templates found on the Pearson website or CD.

**Data Set 1: Rabbit Population Growth**

<table>
<thead>
<tr>
<th>Generations</th>
<th>Number of Rabbits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>105</td>
</tr>
<tr>
<td>25</td>
<td>1,000</td>
</tr>
<tr>
<td>37</td>
<td>1,600</td>
</tr>
<tr>
<td>55</td>
<td>2,400</td>
</tr>
<tr>
<td>72</td>
<td>3,350</td>
</tr>
<tr>
<td>86</td>
<td>8,000</td>
</tr>
<tr>
<td>100</td>
<td>13,150</td>
</tr>
</tbody>
</table>

**RELATED ACTIVITY FOR DATA SET 1**

FOR DATA SET 1 FOLLOWS ON THE NEXT PAGE.
Questions for class analysis (Data Set 1):
1. Discuss the results of your graph. What trends do you see?
2. What type of growth does this population exhibit? How can you tell?
3. Did this population reach carrying capacity? Why or why not? If so, indicate WHEN the population reaches carrying capacity and indicate the maximum number of individuals that can be supported.
4. What factors are responsible for this type of growth pattern?
5. If predators like foxes and cats, which often prey on rabbits, were introduced into this environment during the 10th generation, what would happen to the population growth? Explain AND sketch your answer on a separate sheet of paper.

Review and Assessment (time: 15 minutes)

Data Set 2: Fruit Fly Population Growth

<table>
<thead>
<tr>
<th>Fruit Fly Population Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>35</td>
</tr>
<tr>
<td>40</td>
</tr>
</tbody>
</table>

Analysis questions for independent work (Data Set 2):
1. Discuss the results of your graph. What trends do you see?
2. What type of growth does this population exhibit? How can you tell?
3. Did this population reach carrying capacity? Why or why not? If so, indicate when the population reaches carrying capacity and indicate the maximum number of individuals that can be supported.
4. What factors are responsible for this type of growth pattern?
5. What factors would allow this population to exhibit the other type of growth pattern (hint: what things need to be present in the environment?).
6. Do you think the same limiting factors are present in both the fruit fly and rabbit habitats? Explain and give examples to support your claim.

Extension
1. Describe logistic growth and provide an example outside of population statistics of logistic growth.
2. A few European gypsy moths (invasive species of moth in Massachusetts with no natural predators) were accidentally released from a lab near Boston. Describe what might happen to the population over the next several years.
Review and Assessment (time: 5 minutes)
Enter Ticket: Are zoos a form of preservation or a threat to biodiversity?

Extension
Students may find out more information about zoos and ideas about conservation and maintaining biodiversity. Students should discuss whether “Why Zoos Matter” is a biased source.

SEE: www.stlzoo.org/about/whyzoosmatter

Lesson 13
How Humans Affect the Environment

Goal
Students will explain how biodiversity affects the stability of Earth’s ecosystem and why high biodiversity is extremely important, and cite evidence that humans are impacting the biodiversity at an alarming rate and causing changes.

Key Ideas
- Pollution is any substance in an unnatural place and concentration in the environment.
- Carbon increases the greenhouse gas effect.
- Nitrogen and phosphorus can create dead zones in marine ecosystems and are the main ingredients in fertilizers.
- Cyanide dissolves metals trapped in rocks which can leak into the groundwater supply.
- Mercury, a by-product of coal-fired power plants, leaks into groundwater to affect marine life and acts as a neurotoxin in humans.
- Sulfur dioxide and nitrogen dioxide are released by burning fossil fuels and causes acid rain.
- Endocrine disruptors are chemicals that can interfere with the endocrine (or hormone) system in animals.

Do Now (time: 5 minutes)
Students will write or draw their responses to the question:
Do humans affect the environment? How?

Hook (time: 15 minutes)
Students will read together or on their own the Newsela article “Rare butterflies’ habitats designated ‘no spray’ zones in South Florida.”
The teacher should ask questions or encourage peer conversation about the article. Also, if there is time, the students may complete the quiz that accompanies the article.

SEE: newsela.com/articles/mosquito-butterflies/id/11330

Presentation (time: 15 minutes)
The teacher should present the video “5 Human Impacts on the Environment”:

Lesson 11

Human Population Growth

Goal
Students will determine why the human population has increased exponentially and how human population growth will impact the environment.

Key Ideas:
Quantity v. Quality (r v. K Selection)

- **r-selected species**: species that exhibit rapid population growth.  
  EXAMPLE: Mosquitos
- **K-selected species**: species that live closer to their carrying capacity.  
  EXAMPLE: Elephants

- There is a spectrum between the two that most organisms occupy.
- Humans have been able to avoid the limits of carrying capacity and raise it.
- The human population growth rate is dropping, particularly in industrialized countries.

Do Now (time: 5 minutes)
Students will create a written list of what might contribute to limiting a species population size.  
(Competition, predation, parasitism and disease, unusual weather, natural disaster)

Hook (time: 10 minutes)
After discussing the Do Now, as a class, students will brainstorm ideas that contribute to the growth of a population.

The teacher should show a human population graph and ask what students think will happen to the population based on what we know about populations (p.143 in the Miller and Levine *Biology* textbook).

Presentation (time: 25 minutes)
The teacher will present the video below, having watched it before screening and created guided notes for students to follow along.


The class may also read pp. 142-145 from the *Biology* textbook and complete Lesson 5.3, Human Population Growth, using templates found on the Pearson website or CD.

Practice and Application (time: 10 minutes)
Students should answer the questions below to summarize what they have learned.

1. Are humans r-selected species or K-selected species? Explain your answer.
2. What is happening to the population growth rate?
3. What are some of the reasons the population growth rate is dropping, particularly in industrialized countries?

Review and Assessment (time: 5 minutes)
Students should complete a 3-2-1 (three facts they learned, two questions they have, and one main idea from the lesson) as an Exit Ticket.
Extension

The class or select students may read “China formally eases one-child policy.” Students could write a summary on how that would impact future population growth.


Lesson 12

Biodiversity

Goal

Students will explain that the ecosystem is an interconnected system where all living and nonliving things play a role.

Key Idea

Biodiversity is important to maintain equilibrium throughout the world and to avoid extinction.

Do Now (time: 5 minutes)

Students will write or draw their answers to this question:

What does a balanced environment look like?

Hook (time: 5 minutes)

Students will share their Do Nows and discuss the question:

What benefits do you think come from biodiversity?

Presentation (time: 20 minutes)

The teacher should read the material from the Miller and Levine Biology textbook, pp. 166-172, or present the editable Power Point CD “Lesson Overview 6.3 Biodiversity.”

During the reading or PowerPoint, students will complete the accompanying template provided by the website or CD.

Practice and Application (time: 20 minutes)

The teacher can choose which data activity students will work on. The options are working from “Analyzing Data: Saving the Golden Lion Tamarin” (p. 172 in the Miller and Levine Biology textbook) or “Lab B: Data Analysis Activities: Saving the Golden Lion Tamarin” from the Pearson website or CD.

The teacher may review answers with the class or collect the assignment as a Formative Assessment.

Students should also answer the questions below:

1. Does it matter if a species becomes extinct?
2. Is this a healthy place? What is the evidence?
3. How are living and nonliving things interconnected?
4. How does an ecosystem respond to change?
5. How have humans affected the environment?
6. How do we come to know the natural world and our place in it?
Students will copy the notes below on how humans are affecting the environment.

Five ways humans are affecting the environment:

- **Desertification**: lower land productivity caused by overfarming, overgrazing, seasonal drought, and climate change: the spread of dry unproductive land
- **Deforestation**: the destruction of forests
- **Global warming**: the gradual warming of the Earth by increased CO2 by humans
- **Nonnative species**: introducing organisms from one environment to another; the invasive species usually out-competes the native species
- **Overharvesting**: by removing species by hunting or harvesting, biodiversity decreases

**Practice and Application** (time: 15 minutes)

Students will be assigned case studies from the Miller and Levine Biology textbook (pp. 175-179). Due to their differing lengths, teacher should differentiate for each student’s appropriate skill level.

Students will read the case studies and summarize:

1. What is the problem?
2. What research/data is found?
3. What is the suggested changed behavior?
4. Describe what the graphs provided in the case studies represent.

**Review and Assessment** (time: 5 minutes)

As an Exit Ticket, students will write how humans have changed the environment. The students should cite specific examples from the video and lesson and also list three ways humans can help maintain Earth’s health.

**Extension**

Students may research cities’ plans to combat devastation and potential city flooding caused by global warming. Possible cities to research include Boston, New York City, and Philadelphia.

**Lesson 14**

**Water Pollution Activity**

**Goal**

Students will learn the importance of scientific investigation, while focusing on human impact on groundwater.

**SEE**: www.rivanna-stormwater.org/bacteria.pdf

**Note**: This lesson requires copies and materials prepared before the start of the lesson. Go to the website listed. It contains the lesson plan, classroom materials, and handouts.

**Do Now** (time: 5 minutes)

Students will list the five ways humans are impacting the environment from the previous lesson.
Hook (time: 5 minutes)
The students will receive clue cards or victim cards to help. They will be told not to share their information with the class until their turn.

Presentation (time: 10 minutes)
The teacher will describe cholera to the students and the 1854 London cholera outbreak. The students’ job is to discover how people were being infected in the area by examining the victim and clue cards.

Practice and Application (time: 25 minutes)
The teacher should track the information on a large posterboard or through the ELMO document projector. The students will copy the other students’ information from their cards as they present them to the class. The teacher should ask students to provide hypotheses throughout the process.

Review and Assessment (time: 10 minutes)
Students will respond to the following questions provided in the lesson:
1. How did cholera get into the water used by the people who lived on Broad Street?
2. Why are we unlikely to contract cholera living in North America?
3. What are the symptoms of cholera?
To achieve higher-order thinking appropriate for high school, the teacher may provide additional questions to challenge the students.

Lesson 15
Resource Use and Data Analysis

Goal
Students will track data and analyze how daily human activities impact the environment.

Do Now (time: 5 minutes)
Students will write down how much their family or friends are driving on the road during the week. The class will share their answers and find a final total.

Hook (time: 5 minutes)
The class will have a discussion about which cars are the best for the environment. The teacher should ask if the students know anyone with a hybrid or low-emissions car and what they think about them.

Presentation (time: 10 minutes)
The teacher will explain that the class will be completing a data analysis on vehicle emissions and provide a modeled example to be completed as a class.

Practice and Application (time: 25 minutes)
The teacher can choose what activity students work on with this data. The options are working from the Biology textbook, p. 164, “American Air Pollution Trends,” or Lab B: Data Analysis Activities: “Vehicle Emission Trends.”
**Review and Assessment** (time: 10 minutes)

Students will share their findings with the class. The class will brainstorm other ideas to help make their daily activities environmentally friendly.

**Extension**

If time/permission permits, screen *An Inconvenient Truth* and modify questions from this study guide:

SEE:  [www.nwf.org/pdf/Eco-schools/AITInTheClassroom7_08.pdf](http://www.nwf.org/pdf/Eco-schools/AITInTheClassroom7_08.pdf)

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**CULMINATING LESSONS**

*Includes the Performance Task, i.e., Summative Assessment—measuring the achievement of learning objectives*

**Lesson 16**

**Introduction of the Performance Assessment and Research Topic** (2 days)

**Goal**

Students will understand the Performance Task, interpret the rubric, and research the topic. A template for this lesson is located in the Supplement on p. 4.10.4.

**Do Now** (time: 5 minutes)

Students will brainstorm a list of environmental issues that have biotic and abiotic factors.

**Hook** (time: 15 minutes)

The teacher will read an article with the students concerning an environmental issue that was challenged by locals within the community. A possible reading for the class would be the synopsis of a trial in Woburn, Massachusetts, about toxic chemicals leaking into the water supply named *Anderson v. W.R. Grace*. Students should circle the transition words used in the article and discuss the effect of the transitions in the article.


**Presentation** (time: 25 minutes)

The teacher will share with the class the assessment task and tell students that their goal is to find an environmental issue that they care about and to try to convince lawmakers to make changes in order to help the environment. After explaining the task and possible products that students can create, the teacher should lead a discussion of the criteria for success. The teacher can share a premade rubric with the students or create a rubric with students so that students have ownership of their assessment. The teacher should stress that students should use past learning, assignments, and the textbook to support their arguments in their products. The teacher should review annotation skills so that students can read and take notes on their texts.
Practice and Application (time: 55 minutes)
On Day 1, students will begin researching or reading about their issues. They will use their textbook and internet resources that they find or resources that are provided by their teacher. Students should take notes or annotate the texts. On Day 2, students will spend most of the class completing the reading/annotating/note-taking process.

Review and Assessment (time: 10 minutes)
As an Exit Ticket the students list three important facts that they want to include in their final products. The teacher should review these immediately to ensure that students are collecting appropriate data.

Extension
The students can watch a clip from the making the movie A Civil Action, which is based on the Woburn trial.

SEE:  www.youtube.com/watch?v=T7AJLHOnti8

Lesson 17
Preparing the Final Product (2 days)

Goal
Students will compile their research into a product.

Do Now (time: 10 minutes)
Students will brainstorm and discuss their ideas about these questions:

How do we persuade people? What does it take to make someone listen to what we have to say?

Hook (time: 10 minutes)
The teacher will remind students of the goals of the unit and explain how these goals should be incorporated into their final products.

Presentation (time: 15 minutes)
The teacher should brainstorm possible products with the students. Students could present their information in the form of a letter, a speech, a public service announcement, a poster, or in a variety of other formats. The teacher must decide what formats are appropriate for the classroom.

Practice and Application (time: 70 minutes)
Students will spend the remainder of Day 1 and most of Day 2 creating their final products. The teacher will monitor and guide students throughout the process.

Review and Assessment (time: 5 minutes)
Students will use the rubric provided or created in Lesson 16 as a means of self-assessment.
Lesson 18

Presentations

**Goal**
Students will present their final products effectively to an audience of their peers.

**Do Now (time: 5 minutes)**
What do effective presenters do? Students will list five things that make presentations interesting.

**Hook (time: 5 minutes)**
As a class, students will create a presentation rubric/checklist using the criteria that students brainstormed.

**Presentation (time: 5 minutes)**
The teacher should review effective presentation techniques with the class and model what the criteria should look like in a presentation (e.g., eye contact, good posture, clear speaking voice).

**Practice and Application (time: 30 minutes)**
Students will practice their presentations with partners. When they are ready, they will present them to the class.

**Review and Assessment (time: 10 minutes)**
Classmates should provide feedback to the presenters after each presentation. Students can use the 3, 2, 1 format. They should list THREE things they learned from the presentation, TWO things that the presenter did well during the presentation, and ONE thing that the presenter can improve upon. The teacher should review the feedback before giving it to the presenters.

**Extension**
Students may continue their research by focusing on an environmental issue that could be impacting their local communities.
POST–UNIT REFLECTION

On meeting the Learning and Language objectives

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

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__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
Connections to Empower Your Future
UNIT: Human Impact on the Environment

Future Ready, CYP, and PYD Connections
This unit reflects Culturally Responsive Practice and Positive Youth Development by providing multiple opportunities for choice in products (Lesson 6, Performance Task), by allowing for independent opinions about environmental issues (Lesson 1, Lesson 7, Lesson 12), and by asking youth to make personal connections to the material (Lesson 8, Performance Task). Teachers can further utilize these positive practices by asking students to reflect on how these topics may affect their personal and professional lives in the future and encourage students to become active participants in the discussion about how to address environmental issues. For example, teachers can ask youth to consider what will happen if they want to study ocean life in the future but pollution is endangering many of the species they want to study. If youth cannot solve this problem, what considerations should they have about a future career in ocean life research?

This unit is also connected with Future Ready skills. Youth have many opportunities to strengthen their communication skills through group discussions, partner work, and a presentation for the Performance Task. Youth must also take the initiative to complete research and make personal connections to the material. The Performance Task and the Exit Tickets are good opportunities to evaluate students on their accountability for completing tasks and actively engaging in critical thinking.

Teachers are encouraged to use the Future Ready Rubric to evaluate students and are encouraged to support students as they self-evaluate their demonstration of Future Ready skills.

Essential Questions Connections
Teachers can make connections between the Essential Questions and EYF curriculum by focusing on two of the Essential Questions: How do living things affect each other? How do you impact the health of an ecosystem? Ask students to reflect on how people impact each other and their personal and professional environments much like how different factors in nature (such as biotic and abiotic factors) affect each other. Classes can build upon this idea by discussing how an individual’s behavior, appearance, attitude, and actions can greatly impact his or her personal, academic, and professional relationships and experiences. Consider connecting this concept to:

• How one’s attire can impact a job interview
• How positive beliefs impact one’s performance and relationships
• How one’s attitude at work can impact his/her relationship with a supervisor or team

Lesson 7 asks youth to determine the difference between climate and weather and uses the example of climate determining the clothes you buy in your environment while weather determines the clothes you wear on a certain day. Consider making a connection to students’ everyday clothes (environment) and their interview or work clothes (weather) and how they need to dress appropriately for different situations. Lesson 8 focuses on types of interactions and relationships between organisms (competition, symbiosis, commensalism, etc.), which provides an opportune moment to discuss personal and professional relationships that students will need to navigate. These human interactions likely share qualities found in symbiotic interactions (such as a mutual relationship where both organisms benefit).
Transfer Goal Connections

Future Ready topics and the EYF curriculum align strongly with the Transfer Goals which state that students will support arguments with evidence, make predictions, and apply their understanding of how decisions have an impact on the environment and on others. The transfer goals connect the ability to identify and analyze how actions in nature impact the environment with understanding how our decisions and actions impact our environments and relationships in our personal lives. Teachers should emphasize this connection and the underlying skills needed to analyze and understand these impacts and relationships (such as identifying, analyzing, reflecting, evaluating, predicting, and tracing). The transfer goals also connect with Future Ready skills and the EYF curriculum by having youth draw conclusions and predict outcomes based on research and evidence. EYF classes conduct research on careers, complete values and skills inventories, and estimate personal budgets in order to draw conclusions and predict which careers will align with their interests, values, and desires.

Lessons 3 and 4 Connections

Lessons 3 and 4 focus on the impact of having more secondary consumers than producers. Teachers can use this concept of producers, consumers, and energy transfer to discuss the concept of budgeting. The underlying concept in the producer and consumer relationship is balance of resources, which connects with the concept of balancing a budget or planning on how much to spend on necessities like rent. This concept of balancing resources also connects to more abstract concepts such as anticipating the impact of investing time or energy into developing a particular skill or aligning one’s choices to specific values or interests. For example, teachers can encourage students to think about the benefit of taking time and money (resources) to learn to speak French when they have no plan to travel or work in a French speaking country. Teachers can also have students reflect on what would happen if someone pursued a low salary career but highly valued making a lot of money.

Lesson 10 Connections

Lesson 10 has youth analyze the population’s impact on the environment and the environment’s impact on the population. Teachers can make a Future Ready or EYF connection to this concept by discussing labor market trends and how the labor market impacts education and the availability of jobs. Use the MassCIS site to search for a specific occupation, review the Employment and Outlook section at the bottom of the page, and then discuss with youth how changes in the labor market could impact this job. For example: The MassCIS site lists that 149 motorcycle mechanics work in Massachusetts. The overall employment is small, the 10-year growth of this career field is slow (2.7%) and the annual openings average is only 3. Discuss with students what would happen if the labor market improved and more people were employed and made more money. What would happen if the labor market worsens, unemployment increases, and people have less money to spend on leisure items?

For Technical Assistance with Empower Your Future connections and lessons, please request support by submitting a Coaching Request ticket using the Coaching Feature on TeachPoint.
Top-Down Energy Producers’ Chart
Lesson 2

DIRECTIONS: Complete this chart based on information from pp. 69-72 in Miller and Levine’s Biology textbook.

ALL Living Things

Autotrophs - a.k.a. Producers
Definition: __________________________
______________________________
______________________________
Example: _________________________

Heterotrophs - a.k.a. Consumers
Definition: __________________________
______________________________
______________________________
Example: _________________________

Carnivores
Definition: __________________________
______________________________
______________________________
Example: _________________________

Omnivores
Definition: __________________________
______________________________
______________________________
Example: _________________________

Herbivores
Definition: __________________________
______________________________
Example: _________________________

Scavengers
Definition: __________________________
______________________________
______________________________
Example: _________________________

Decomposers
Definition: __________________________
______________________________
______________________________
Example: _________________________
The Energy Pyramid
Lesson 3

DIRECTIONS: Enter the correct information into the appropriate area on the Energy Pyramid Template. Labels should include trophic levels, organisms, and heat and energy transfer. Be prepared to explain how this template demonstrates energy flows between different levels of organisms.
# Community Interaction Template

**Lesson 8**

**DIRECTIONS:** Complete the chart.

<table>
<thead>
<tr>
<th>RELATIONSHIP</th>
<th>DEFINITION</th>
<th>EXAMPLE</th>
<th>ANALOGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction &gt; Predation</td>
<td>Organism consumes another organism</td>
<td>Lion eats gazelle</td>
<td>T-Rex eats people in <em>Jurassic Park</em></td>
</tr>
<tr>
<td>Interaction &gt; Competition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interaction &gt; Symbiosis Parasitism</td>
<td>One organism thrives while the other is weakened</td>
<td>Ticks and mammals</td>
<td>Spiderman and the Venom “symbiote”</td>
</tr>
<tr>
<td>Interaction &gt; Symbiosis Mutualism</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interaction &gt; Symbiosis Commensalism</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**

**Habitat example**

The “California fog belt,” a specific Pacific Coast environment, is the habitat for the redwood forest. The redwood forest canopy in turn creates a habitat for epiphytes (plants that grow on trees).

**Niche example**

The redwood canopy epiphytes occupy the niche of producers for a host of animals that live in the redwood canopy.

**Interactions**

Use these terms to classify relationships in nature:

- **Competition:** e.g., monkeys compete for trees with the best fruit
- **Predation:** e.g., lions prey on gazelles or deer prey on grass
- **Symbiosis:** commensalism, mutualism, and parasitism

**Analogy**

Competition, predation, and symbiosis:

For each interaction and relationship come up with an analogy from our own world. It can be an example from a television show, a movie, a book, something from another class, news, etc.

EXAMPLE: Competition In *Twilight*: Edward and Jacob were not from the same species but they competed for the same resource—Bella.
Ecology Performance Assessment (Using G.R.A.S.P.*
Lesson 16

NAME: ____________________________
DATE: ____________________________

GOAL
Your goal is to persuade your elected officials to use your solution to an environmental problem. You must use data and facts to convince your officials.

ROLE
You are a concerned citizen and resident of the area. You have been asked to create a product to persuade lawmakers to use your solution.

AUDIENCE
The target audience are the lawmakers in your area.

SITUATION
Something harmful is happening to the environment in your town. You want to stop this from happening.

PRODUCT, PERFORMANCE, AND PURPOSE
You need to develop a product so that lawmakers will be informed and convinced of your position. This could take the form of a speech, PowerPoint presentation, letter, poster, or public service announcement.

STANDARDS AND CRITERIA FOR SUCCESS
Your product must meet the following standards:

1. 1-3 diagrams
2. 1-3 charts
3. 1-3 descriptions

You MUST SYNTHESIZE data and explain how the data relates to biotic and abiotic factors that affect the ecosystem. Also, your project should include how elements cycle in the environment and could impact the organisms in each trophic level. Lastly, you should describe how human activities impact the health of the environment.

You MUST PRESENT a solution to the problem. The solution must be supported with data. You MUST ALSO USE AT LEAST THREE TRANSITION WORDS in your presentation.

*G.R.A.S.P. was adapted from Jay McTighe and Grant Wiggins’ Understanding by Design Professional Development Workbook
Introduction

We live in an exciting time for DNA research, as technological advances are allowing scientists to discover ways to manipulate the genetic code of a cell. Likely, in our students’ lifetimes, they will see a revolution in DNA research and discoveries that will force them, as medical consumers, to make clinical choices about their health as it relates to DNA manipulation. In order for this generation of students to make informed decisions, they need to understand the basic components of DNA and understand how DNA functions within the cell. This unit will equip students with the knowledge to understand how DNA determines the function and structure of all living things. Through studying the processes of transcription and translation, students will also understand the importance of following a step-by-step process and will learn to relay that process to others in a clear and concise way. Knowing how to follow directions and to clearly explain those directions to another person will be a crucial skill that will allow students to be successful in their future careers.

The DNA: What’s the Point? unit is designed to come first in the six-week Cell Biology season and will take about two weeks to complete. After completing this unit of study, teachers could expand upon the unit by exploring DNA technology and newsworthy topics such as CRISPR (gene editing) technology, reproductive cloning, and the first death that was recently attributed directly to gene therapy. These current events shine a light some of the ethical questions that arise when scientific advancements occur and will allow students to engage in critical thinking about these topics. Allowing students to think critically about how these issues could affect them and their world will ensure engagement and deeper thinking about the topics in this unit.

This unit focuses on the first of this season’s Emphasized Standards, HS-LS1-1 addresses a fundamental aspect of cell biology—DNA is a molecule present in all living things. With a relatively simple four-letter code (A, T, C, G) denoting the nucleotides Adenine, Thymine, Cytosine, and Guanine, DNA determines the structure and function of all living things. Taking the code from DNA and ultimately manufacturing proteins is explained by the elegant process of transcription and translation, which students will explore in detail through this unit. Students will study and understand the four classes of proteins that regulate and carry out the essential functions of life: enzymes, structural proteins, hormones, and antibodies. Hands-on activities, videos, discussions, and readings will

“Likely, in our students’ lifetimes, they will see a revolution in DNA research...”
reinforce these concepts and will allow students to explain this process to others. Parts of this unit will be important for students to remember as they move into the next season on Genetics and Heredity, which also deals with the structure of DNA.

Since the processes of transcription and translation are molecular processes and are abstract, they can be intimidating for students to understand. It will be critical for teachers to physically model the processes in order for students to understand what they are learning about. In order to be successful in this unit, students must also have a clear understanding of the organelles of a cell and their functions. This can be difficult for students to remember, so teachers should use as many visuals as possible.

For long-term adaptation ideas for this unit, see p. 4.11.3 on the right.
### Unit Title

**DNA: What’s the Point?**

Adapting This Short-Term Unit for Long-Term Programs

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>DNA: What’s the Point?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overview</strong></td>
<td>During this unit, students will be furthering their understanding of DNA and RNA and how they help create proteins to be used in the body. In Standard <strong>HS-LS1-1</strong>, the students will obtain an overview of the transcription and translation process and recognize the four classes of proteins and their functions. In long-term settings, it may be helpful to provide a variety of opportunities to work with the translation and transcription process. Also, in <strong>Lesson 4</strong>, students may need support while learning about how genetic disorders are caused by a mutation during protein synthesis, as this may affect someone they know.</td>
</tr>
<tr>
<td><strong>Desired Results</strong></td>
<td>The KUDs are broken down by lessons in this unit. However, the four classes of proteins are in one <strong>Know</strong>, and it may be helpful to separate study of the proteins into four lessons for deeper understanding of the function of each protein. In the <strong>Do</strong> related to genetic disorders and explaining the cause of mutations, a teacher may take students’ presenting on a genetic mutation further by asking them to generate and research ideas to help people living with these mutations.</td>
</tr>
<tr>
<td><strong>Assessment Evidence</strong></td>
<td>If <strong>Lesson 3</strong> is separated into four classes, the Formative Assessment for each class could be a meme for each protein. The class could then hold a competition to determine which one should be posted in the classroom or hallway. For the Summative Assessment, the student could also complete a three-dimensional model of transcription and translation by utilizing their skills from the DNA origami. The students could add this visual assessment to their narrative of the process.</td>
</tr>
<tr>
<td><strong>Learning Plan</strong></td>
<td>In <strong>Lesson 2</strong>, it may be helpful for students to complete the <strong>ExploreLearning</strong> Gizmo on RNA and Protein Synthesis (<a href="https://www.explorelearning.com/index.cfm?method=cResource">https://www.explorelearning.com/index.cfm?method=cResource</a> dspDetail&amp;ResourceID=442). Completing the Gizmo by themselves or as a class with the teacher controlling the computer or the students using an interactive whiteboard will help the students to view the process and review base pairings. Also, <strong>Lesson 4</strong> may provide an opportunity (after approval by the program and coordinators) to have a speaker come to the program to discuss a personal experience or scientific work with mutation. This opportunity could open a deeper conversation about the science and make the issue more personal for the student. The teacher could also share a video about an infant’s struggle with cystic fibrosis (<a href="http://yhoo.it/2bW1ISj">http://yhoo.it/2bW1ISj</a>).</td>
</tr>
</tbody>
</table>
Emphasized Standards (High School Level)

HS-LS1-1: Construct a model of transcription and translation to explain the roles of DNA and RNA that code for proteins that regulate and carry out essential functions of life.

Clarification Statements:
- Proteins that regulate and carry out essential functions of life include enzymes (speed up chemical reactions), structural proteins (provide structure and enable movement), and hormones and receptors (send and receive signals).
- The model should show the double-stranded structure of DNA, including genes as part of DNA’s transcribed strand, with complementary bases on the non-transcribed strand.

State Assessment Boundary:
- Specific names of proteins or specific steps of transcription and translation are not expected in state assessment.
- Cell structures included in transcription and translation will be limited to nucleus, nuclear membrane, and ribosomes for state assessment.

Essential Questions (Open-ended questions that lead to deeper thinking and understanding)

What is the purpose of DNA?

Transfer Goals (How will students apply their learning to other content and contexts?)

Students will follow and explain complicated sequences of events.

Students will explain why failing to follow a specific set of instructions can result in unforeseen consequences.
Multiple Means of Engagement

Current events and historical readings about scientific discoveries, as well as internet research of recent and past discoveries about the progress of science and medicine as they relate to our knowledge and development of treatments for diseases, can help students see the importance of the topic. Some of the unit work can and should be done in pairs and small heterogeneous cooperative learning groups, fostering interaction. Providing information in a variety of audio/visual forms can also spur interest.

Multiple Means of Representation

The ways in which information is displayed should vary, including size of text, images, graphs, tables, or other visual content. Information should be chunked into smaller elements, and the complexity of questions can be adjusted based on prior knowledge and competency. The teacher should emphasize key elements in text and diagrams, and should provide many opportunities for review and practice. Students will be able to read the textbook and other related materials, watch videos, listen to teacher instruction, act out processes, and work with manipulatives in order to achieve objectives. Learning objectives may be changed as needed for particular students.

Multiple Means of Action and Expression

Students will be given high- and low-tech options to create representations of the processes of transcription and translation through text, speech, drawing, illustration, comics, storyboards, design, film, music, visual art, sculpture, or video. For the Performance Task, students will be provided with as much choice as possible in the level of challenge, type of high- and low-tech tools used, color, design and layout of graphics, and sequencing and timing, and they will have the opportunity to deliver a presentation to the class. Evaluative emphasis should be placed on process, effort, and improvement. Formative Assessments should be designed to invite personal response, self-evaluation, and reflection. Accommodations intended to enhance learning abilities, provide access to the general curriculum, and provide opportunities to demonstrate knowledge and skills will be necessary for students with applicable Individualized Education Programs (IEPs) and could benefit all learners.
### Learning and Language Objectives

By the end of the unit:

KUDs are essential components in planning units and lessons. They provide the standards-based targets for instruction and are linked to assessment.

<table>
<thead>
<tr>
<th>Students should know...</th>
<th>understand...</th>
<th>and be able to...</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transcription:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• nucleus</td>
<td>The “instructions” contained in DNA must leave the nucleus on an mRNA molecule.</td>
<td>Illustrate the process of transcription using appropriate vocabulary and visuals.</td>
</tr>
<tr>
<td>• nuclear pore</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• DNA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• messenger RNA (mRNA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Translation:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• ribosome</td>
<td>The instructions on mRNA are specific for individual amino acids and are used to create amino acid chains (proteins).</td>
<td>Explain the process of translation and decode the genetic code into amino acid sequences.</td>
</tr>
<tr>
<td>• ribosomal RNA (rRNA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• transfer RNA (tRNA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• codon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• anticodon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• amino acid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• protein</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Classes of proteins:</strong></td>
<td>Different classes of proteins regulate and carry out the essential functions of life.</td>
<td>Compare and contrast the structures and functions of each class of protein.</td>
</tr>
<tr>
<td>• enzymes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• structural</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• hormones</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• antibodies</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Genetic mutations and diseases</strong></td>
<td>Genetic mutations and diseases are caused by errors in transcription and/or translation.</td>
<td>Explain how an error leads to a mutation or disease.</td>
</tr>
</tbody>
</table>
Assessment Evidence
Quality questions raised and tasks designed to meet the needs of all learners

Performance Task and Summative Assessment (see pp. 4.12.12-4.12.13)
Aligning with Massachusetts standards

Students will tell the story of protein synthesis using the appropriate vocabulary for the “characters” in their narrative. The conflict of the story will be an interruption of the process of protein synthesis. The conclusion of the story will resolve the conflict with either a happy or tragic ending. The story may be in the form of a narrative, comic strip, play, video, board game, etc.

Goal: To create a story that explains the processes of transcription and translation
Role: An author
Audience: Students who have not yet learned about transcription and translation
Situation: You are introducing students to the processes of transcription and translation in a user-friendly format
Product: A narrative/graphic novel/etc. that illustrates the processes of transcription and translation and shows the results of an error in the process
Standards: Correct vocabulary and accurate information, story flow

Pre-Assessments (see pp. 4.12.7-4.12.8)
Discovering student prior knowledge and experience

Labeling cell structures
Building and explaining a DNA molecule and its parts

Formative Assessments (see pp. 4.12.9 to 4.12.11)
Monitoring student progress through the unit

Exit Ticket on transcription and translation (Lesson 2)
Meme of protein classes (Lesson 3, see p. 4.14.2)
Circulating and checking in with students
Class discussions

For Empower Your Future Connections, see pp. 4.13.1 to 4.13.2
Literacy and Numeracy Across Content Areas

Reading
Students will be reading informational websites and an online excerpt of literary nonfiction. The students will be reading the information to gain understanding and to scaffold their knowledge base of the material being explained in class.

Writing
The students will be utilizing writing to display their knowledge of the information and to help them process the factual knowledge. Students will be writing about protein synthesis. The writing will help teachers to assess the students’ skills to complete the assignments and meet the standard. The unit’s writing will include an array of formal and informal formats focusing on the narrative style.

Speaking and Listening
Throughout the unit, there are ample opportunities for students to speak in the class. Students will be speaking in presentations to the class or the teacher for their meme presentations, Summative Assessment, and through other opportunities for students to explain their understanding of the concepts.

Listening will occur with a number of audio options. The teacher should be delivering the information through direct instruction, short videos, and computer simulations with sound. Students will be expected to listen and respond to their classmates’ presentations. Students will provide acknowledgment of through responding to questions or adding their own extensions to the materials.

Language
Within the unit, the students will be exposed to various formats of academic language. During the lessons, the teacher should scaffold the language through modeling, turn and talks, and class discussion about the content. In addition, students will learn and utilize Tier II and Tier III academic vocabulary dealing with protein synthesis. The students will be faced with determining denotations of words with multiple meanings, like transcription and translation, which could be described as both Tier III and Tier II words.

Providing students with opportunities to present to the class and to each other will allow practice using Standard English conventions. In addition, students will be responding in class with simple and complex sentences.

The teacher should encourage full responses during question and answer sessions and will model conventions using formal English when possible. In addition, teachers will encourage that students’ written work contains standard capitalization, spelling, and punctuation.

Numeracy
Students will be expected to compile numeric data when they research genetic diseases during Lesson 4. They might need to interpret graphs and data when they research the disease.
Resources (in order of appearance by type)

Print

(with accompanying CD or web resource). Ch. 13 (pp. 360-376) RNA and Protein Synthesis


Websites


Videos on Protein Synthesis:

“Protein Synthesis and the Lean, Mean Ribosome Machines.” Amoeba Sisters. 2014.  
www.youtube.com/watch?v=h5mJbP23Bu0.

www.youtube.com/watch?v=GieZ3pk9YVo.

www.youtube.com/watch?v=_POdWsii7AI&list=PLwL0Myd7Dk1HK8gH2XlafNgQJD1dMX2aW.

http://learn.genetics.utah.edu/content/molecules/transcribe/.

www.youtube.com/watch?v=XUn64HY5bug.


http://learn.genetics.utah.edu/content/molecules/proteintypes/.


Materials

Cell Structure Review (p. 4.14.1)  
Meme (p. 4.14.2)  
DNA Origami instructions and template:  
Outline of Lessons
Introductory, Instructional, and Culminating tasks and activities to support achievement of learning objectives

INTRODUCTORY LESSON
Stimulate interest, assess prior knowledge, connect to new information

Lesson 1
Cell and DNA Structure

Goal
The student will clarify prior knowledge about cell and DNA structure.

Do Now (time: 5 minutes)
Students will respond in writing or another form:

What do you know about cells and what controls them? Discuss your thoughts with a partner.

Hook (time: 10 minutes)
The teacher should pass out a diagram of a cell with a word bank. (Word bank can be found in the Answer Key below.) Students should reflect on what they learned earlier in the Cell Biology unit to label the parts and indicate their functions. They can work with a partner if they are having difficulty completing the diagram. Students should complete the diagram by labeling the cell parts that they know first, then by using process of elimination to complete the rest to the best of their ability. The teacher can monitor students to ensure that questions are answered as students are working. The teacher can also provide resources to aid the students, as appropriate to their setting: textbook, computers, or cell models/posters. A cell diagram is located in the Supplement pages.

Answer Key for the cell diagram on p. 4.14.1:


Presentation (time: 20 minutes)
The teacher will project a picture of a cell and review the cell parts and functions. Students should check their own diagrams and make corrections. The teacher will then say that for this particular unit, the class will focus in on the nucleus and ribosomes. The teacher will ask the students what the connection is between the nucleus and the ribosomes. Many students should remember that ribosomes are where proteins are made, but they might not understand the connection between the nucleus and ribosomes. The teacher should point out that the nucleus contains DNA in the form of chromosomes. The chromosomes contain active regions called genes, and genes code for proteins. The teacher should also review the structure of DNA and discuss genetic mutations.
Practice and Application (time: 15 minutes)

Students will construct a DNA molecule by following the instructions on the following websites:

SEE: “DNA Origami instructions and template”
www.dnai.org/teacherguide/pdf/ori_bw.pdf
www.dnai.org/teacherguide/pdf/origami_inst.pdf
www.dnai.org/teacherguide/guide.html

Students will see the double helix structure and that the strands are complementary so that A and T are bonded and that C and G are bonded. (A=Adenine, T=Thymine, C=Cytosine, G=Guanine.)

Review and Assessment (time: 5 minutes)

Students will turn to a partner. Using their models, they should explain to their partner the structure of DNA and each part’s function. They should reflect on prior knowledge that helped them perform this task. If students are unable to correctly explain each part’s function, they should determine what they do not know so that they can review with a partner or the teacher to clarify their thinking.

INSTRUCTIONAL LESSONS

Build upon background knowledge, make meaning of content, incorporate ongoing Formative Assessments

Lesson 2

Transcription and Translation (2 Days)

Goal

The student will model how the DNA message must be transferred accurately through RNA.

Do Now (time: 10 minutes)

Students will respond to these questions in writing or another form:

What does it mean to transcribe? To translate?
What careers involve these actions? Why are they important?

Note: The point of this Do Now is to get students thinking about the vocabulary and the meaning of the words transcribe and translate as they relate to science and other disciplines.

Hook (time: 20 minutes)

Students will play a game of telephone. The intent is to show students the importance of accurately relaying a message or instructions. The teacher should start the game by saying something related to the unit, such as reading standard HS-LS-1:

“Genes are regions in the DNA that code for proteins, which carry out the essential functions of life” (or a complicated sentence of his/her choice)

After one round, the teacher leads a discussion about how the message changed and why it matters, emphasizing the importance of a clear and accurate message. The teacher should refer back to the “Do
Now” activity and discuss why accuracy counts in careers that involve transcribing and translating. The teacher should make sure that the students are aware that if this were to happen in a DNA message, an abnormal protein could be formed. This could lead to catastrophic or minor effects in a living system.

**Discussion:**

What is the point of DNA? How does it relate to the game we just played?

Students will probably mention that DNA is a genetic code or that it is our “instructions.” The teacher should prompt students to explain what that means.

**Presentation** (time: 25 minutes)

Students will act out and demonstrate the processes of transcription and translation, resulting in the formation of a protein. The teacher should review the following Amoeba Sisters videos so that they can demonstrate the processes of transcription and translation. These videos are meant as supplementary information for the teacher. If the teacher chooses to show the students these videos, then s/he should watch the videos to prepare for the student viewing. The teacher should make a note template for the students to fill out as they are watching the videos:

SEE:  [www.youtube.com/watch?v=h5mJbP23Buo](www.youtube.com/watch?v=h5mJbP23Buo)
SEE:  [www.youtube.com/watch?v=GieZ3pk9YVo](www.youtube.com/watch?v=GieZ3pk9YVo)
SEE:  [www.youtube.com/watch?v=_POdWsi7AI&list=PLwL0Myd7Dk1HK8gH2XlafNgQJD1dMX2aW](www.youtube.com/watch?v=_POdWsi7AI&list=PLwL0Myd7Dk1HK8gH2XlafNgQJD1dMX2aW)

The teacher should explain that a difference between RNA and DNA is that RNA uses U (uracil) instead of T (thymine) so the complementary pairing in RNA would be A-U instead of A-T.

**Practice and Application** (time: 45 minutes)

On Day 2, students will be given manipulatives to create the process of protein synthesis. Students should also use an online interactive simulation, “Transcribe and Translate a Gene”:

SEE:  [learn.genetics.utah.edu/content/molecules/transcribe](learn.genetics.utah.edu/content/molecules/transcribe)

**Review and Assessment** (time: 10 minutes)

Exit Ticket: Students will explain three differences between transcription and translation.

**Extension**

Teachers could extend the discussion of translation to include careers that involve interpreters instead of translators and discuss the difference.

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**Lesson 3**

Classes of Proteins

**Goal**

Students will explain the four classes of proteins and their importance.
Do Now (time: 5 minutes)
Students will respond to this prompt in writing or another form:

List five things that you know about proteins. Compare your list with another student’s list.

Hook (time: 5 minutes)
The teacher will show students a meme that illustrates the importance of enzymes and asks:

Based on this meme, what do you think enzymes do?

A meme for class use has been provided and is located on p. 4.14.2 in the Supplement. The teacher may also choose to design a different meme to illustrate the property of enzymes from the website below.

SEE:  imgflip.com/memegenerator

Note: Students should understand that enzymes are a class of protein. Enzymes help to speed up biochemical reactions. Without them, the chemistry that keeps us alive would not happen fast enough for us to stay alive. The teacher needs to explicitly teach this information to students in the presentation below. See “Enzymes and ... Pac-Man?” for background knowledge.

SEE:  www.youtube.com/watch?v=XUn64HY5bug

Presentation (time: 10 minutes)
The teacher will explain all four classes of proteins (enzymes, structural proteins, hormones, antibodies) and their functions. There are many YouTube videos that explain proteins if the teacher wishes to show one. The four classes of proteins must be taught according to the Massachusetts STE standards, but this information is not included in the Pearson Biology textbook.

SEE:  “What are proteins and what do they do?”
ghr.nlm.nih.gov/handbook/howgeneswork/protein

“Role of Proteins in the Body”

Practice and Application (time: 20 minutes)
After learning about types of proteins, each student will create a meme for one of them that explains the protein’s function. If students have access to computers, they may use the Memeful website to create their memes.

SEE:  memeful.com/generator

However, it should be noted that meme websites often contain inappropriate content, so online activity must be closely supervised. An alternative is that the teacher can print out several base photos from the Memeful website, and the students can create the top and bottom captions.

Students may use this lesson on “Types of Proteins” as a resource.

SEE:  learn.genetics.utah.edu/content/molecules/proteintypes

Review and Assessment (time: 15 minutes)
Students will present their memes to the class. Students will comment on how well each presenter represents the function of the protein through the meme with a brief explanation.
Lesson 4

Genetic Disorders (2 Days)

Goal
Students will explain a real-life problem that can occur as a result of a genetic disorder.

Do Now (time: 5 minutes)
Students will respond to this question in writing or another form:
What genetic disorders do you know of? Discuss.

Hook (time: 10 minutes)
What can a problem in protein synthesis result in? The teacher will show slides and lead a discussion of diseases that are caused by genetic mutations. The teacher should download the slideshow onto his/her computer for easy access.

See:  [Link]

Presentation (time: 10 minutes)
The teacher will review mutations and why they occur. The teacher should explicitly make the connection to protein synthesis and then present the assignment of reading about a particular gene mutation and the effects that it has on people.

Practice and Application (time: 70 minutes)
On Day 1, students will conduct online research about a specific mutation and take notes. On Day 2, they will create a product (e.g., brochure, poster, comic strip, etc.) that explains the disease, including:

• What causes it?
• What are the symptoms?
• What are the treatments?
• What is the prevalence?
• What other determining factors exist? (e.g., genetics, ethnicity, geography)

Examples of websites students could explore include Huntington’s Disease Society of America or Cystic Fibrosis Foundation.

See:  [Links]

Note: Be aware that there is a difference between genetic and chromosomal diseases. Down Syndrome results from an extra copy of an entire normal chromosome, number 21. There is nothing genetically wrong with this chromosome as there would be with genetic mutations. Students should research genetic mutations so that they understand the process of transcription and translation and how this can result in a mutation. Therefore, they must research genetic diseases, not chromosomal ones.

For Empower Your Future Connections, see pp. 4.13.1 to 4.13.2
**Review and Assessment** (time: 15 minutes)
Students will present their products to the class, answer questions, and receive feedback.

**Extension**
This lesson leads into the next unit on genetics and heredity. The teacher could also extend this lesson by talking about careers related to genetic disorders.

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**CULMINATING LESSON**

*Includes the Performance Task, i.e., Summative Assessment—measuring the achievement of learning objectives*

### Lesson 5

**Transcription and Translation Narrative** (4 days)

**Goal**
Students will create narratives that apply the processes of transcription and translation.

**Do Now** (time: 10 minutes)
Students will respond to this question in writing or another form:

- What do all good stories contain? Brainstorm and discuss.

**Hook** (time: 15 minutes)
The teacher will read to the class the excerpt from *The Sports Gene* on the website listed below. The teacher should pose the question:

- What makes this engaging?

Students will discuss elements of good storytelling and how writers of literary nonfiction write differently from and similarly to writers of fiction.

(The excerpt is accessed by clicking on the “read an excerpt” button.)

**Presentation** (time: 30 minutes)
The teacher will assign the performance assessment and create a rubric with the class. The rubric should contain elements of good storytelling, but also ensure that the story is factually accurate and uses the vocabulary from this unit appropriately. The story may be in the form of a narrative, comic strip, play, video, board game, etc. The teacher and students can use the website [rubistar.com](http://rubistar.com) to create the rubric. Categories on the rubric should include accurate use of vocabulary, accurate information about protein synthesis, visuals that correspond with the story, and elements of a story (characters, conflict, resolution).

**Performance Assessment**
Students will tell the story of protein synthesis using the appropriate vocabulary for the “characters” in their narrative. The conflict of the story will be an interruption of the process of protein synthesis.
The conclusion of the story will resolve the conflict with either a happy or tragic ending. The story may be in the form of a narrative, comic strip, play, video, board game, etc.

**Goal:** To create a story that explains the processes of transcription and translation

**Role:** An author

**Audience:** Students who have not yet learned about transcription and translation

**Situation:** You are introducing students to the processes of transcription and translation in a user-friendly format

**Product:** A narrative/graphic novel/etc. that illustrates the processes of transcription and translation and shows the results of an error in the process

**Standards:** Correct vocabulary and accurate information; story flow

### Practice and Application (time: 110 minutes)

On Days 2 and 3, students should create their narratives. The teacher should circulate and ensure that students are meeting the requirements. Students should submit partial drafts for teacher comments at the end of class on Day 2.

Students can brainstorm for this narrative by folding a piece of paper into four quarters. Students should consider characters, conflict, setting, and resolution, and they will brainstorm one in each box.

1. Characters may include RNA, DNA, enzymes, and ribosomes.
2. Settings may include within a nucleus or within cytoplasm.
3. The conflict will be some type of mutation: insertion, deletion, frameshift.
4. Depending on the mutation, the resolution could be neutral (no effect on the organism), negative (a disease), or positive (resistance to infection).

### Review and Assessment (time: 55 minutes)

On Day 4, students will rehearse their presentations with a partner. Then students will share their stories and get feedback from the class. Students will use the rubric to score their classmates’ stories. The teacher should review the comments before handing them back to the presenters.

### Extension

Teachers should make explicit connections between what was taught in this unit and the next unit on Genetics and Heredity. This unit is critical prior knowledge for students to understand main concepts in the next unit.
POST–UNIT REFLECTION

On meeting the Learning and Language objectives

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Connections to Empower Your Future
UNIT: DNA—What’s the Point?

Future Ready Connections

This unit allows youth to exercise their Future Ready skills. Youth have many opportunities to strengthen their communication skills through group discussions, partner work, and a presentation of the protein meme in Lesson 3. Youth can also be evaluated for initiative and self-direction as they conduct research about genetic disorders in Lesson 4. Teachers should reflect on whether or not youth stay on task without prompting and if they push themselves to create a detailed final product instead of only addressing the minimum required information. The product for Lesson 4 and the Performance Task (a narrative retelling of the process of protein synthesis) and the Exit Tickets are good opportunities to evaluate students on their accountability for completing tasks aligned to the rubric and if they are actively engaging in critical thinking.

Teachers are encouraged to use the Future Ready Rubric to evaluate students and are encouraged to support students as they self-evaluate their demonstration of Future Ready skills.

Essential Question Connections

The Essential Question for this unit is “What is the purpose of DNA?” To answer this question, students must analyze a complicated sequence of events and the roles of different elements related to DNA, such as proteins, polypeptides, and enzymes.

To connect this Essential Question to the concept of future planning and goal setting, classes may consider how one idea, action, or moment affects or leads to another. Consider asking youth to brainstorm which present or future actions, experiences, and relationships may combine to lead them down a path to a future career or a decision. Prompt youth to consider education and certification milestones, entry level jobs, influential mentors or supervisors, mid-level jobs, and other personal, academic, and professional experiences that will build on each other and combine to lead to a final professional goal. If it is challenging to map toward the future, have youth pick a future goal and then trace the important connecting experiences back to their present situation and actions.

Performance Task and PYD/CRP Connections

The Performance Task, which asks students to tell the story of protein synthesis and the processes of transcription and translation, empowers youth by allowing them to decide on a final product and to use a variety of different skills—reading, writing, critical thinking, and creativity—to complete the project. This task exemplifies culturally responsive practice because students can craft their project so that it is relevant to their interests and skills, and so it both reflects and helps build their academic and personal identities. For example, youth with artistic talent may choose to create a graphic novel while youth with linguistic talent may choose to write a traditional narrative.

Encourage students to reflect on their EYF skills inventories and values clusters and identify if they are using them in this project. Consider encouraging students to strengthen skills they already have or to challenge themselves to develop new skills by completing a final product outside of their typical comfort zone. This is a great opportunity to emphasize Positive Youth...
Development by encouraging students to take risks, utilize their best skills, deepen relationships with peers and teachers, and actively engage in decisions about their education and assessments. By encouraging youth to take ownership over their developing skills, teachers can reinforce the idea of taking ownership over one’s education and advancement of personal, professional, and academic goals.

Transfer Goal and Goal Setting Connections

The Transfer Goals for this unit state that students will follow and explain a complicated sequence of events and explain why failing to follow a set of instructions may result in unforeseen, and likely negative, consequences. Teachers can explain that much like having to identify and explain a complicated sequence of events to understand cell biology and the role of DNA, a person setting goals needs to identify, establish, and follow a complicated sequence of events in his/her own life in order to set and attain short term and long term goals. The process of identifying how you will reach your goals (setting goals, mapping progress, reflecting on growth, setting transitional goals, etc.) utilizes the same underlying skills—planning, anticipating, analyzing—as tracing and explaining the process of transcription and translation.

Consider making a connection to Future Ready discussion topics and EYF classes about how our own lives follow a sequence of events that can be identified and analyzed, but unlike in biology we have control over much of that sequence because we can choose our actions, responses, and decisions. This connection also reflects Culturally Responsive Practice because teachers are encouraging youth to make personal connections with the content and to reflect on their own actions and decisions.

Career Exploration Connections

Consider expanding Lesson 4: Genetic Disorders by making connections to EYF lesson plans that address career research, career clusters, and goal setting. Lesson 4 asks students to research a specific mutation and create a product that explains the disorder. Teachers can expand this project by having students research information about careers that are related to the research and treatment of this disorder (medical researcher, chemist, toxicologist, physician, physical therapist, nurse, laboratory technician, etc.). Youth may even identify a specific individual in the medical field and trace his/her career path.

For Technical Assistance with Empower Your Future connections and lessons, please request support by submitting a Coaching Request ticket using the Coaching Feature on TeachPoint.
Cell Structure Review
Lesson 1

DIRECTIONS: Label each part of the cell, indicated by number, from the choices listed in the Word Bank. Students should be prepared to discuss the function of each part.

WORD BANK: Centriole, Cytoskeleton, Cytosol, Golgi apparatus (or “Golgi body”), Lysosome, Mitochondrion, Nucleolus, Nucleus, Ribosome, Rough endoplasmic reticulum, Smooth endoplasmic reticulum, Vesicle, Vacuole

An answer key is located on p. 4.12.7 in Lesson 1 of this unit.
Adapted from: https://commons.wikimedia.org/wiki/File:Biological_cell.svg (includes annotated image and links to definitions).
Memes
Lesson 3

A meme is an idea, behavior, or style that spreads from person to person within a culture. (Wikipedia)

A variety of meme generators are available on the Internet for the easy production of memes.

SEE:  https://imgflip.com/memegenerator
     http://imgur.com/memegen
     http://memeful.com/generator?ref=9gag
     http://www.imagechef.com/meme-maker
Inheritance: Implications and Applications

TOPIC SEASON: Genetics and Heredity

This unit is designed for use in short-term programs. The unit may be adapted for long-term settings.

Unit Designers: H. Lee and K. Miele

Introduction

Most students are probably aware that some of the things that they do throughout their lives can have a positive or negative impact on their health, but they might not be aware of the fact that the things that they do during their lifetimes can affect their future children, too. This unit explores how traits are passed on from parents to offspring, how the things we do and decisions we make can affect future generations, and how traits can be beneficial or detrimental depending on the environment in which a person is living. Despite the temptation to classify traits as either beneficial or detrimental, students will learn that we simply cannot do that since our environment and other factors determine how traits affect our lives. Students should be engaged in this unit by exploring how the decisions they make today could affect their future lives and the lives of any children they may have.

The Inheritance: Implications and Applications unit is designed to come last in the six week Genetics and Heredity season and will take about two weeks to complete. Before beginning the study of this section of the season, students should have an understanding of the structure of DNA, be able to explain why there is a variability of traits in living organisms, and be able to explain how mutations occur. After completing this unit of study, teachers could further delve into the study of diseases discussed in the unit. Students can research information on other infectious diseases and explore how they relate to epigenetics. Inviting a speaker from a local board of health or from an infectious disease hospital to educate students about local disease concerns and careers related to health, disease, and epidemiology might be a good way to wrap up this season before beginning the next season on Evolution and Biodiversity.

This unit focuses on one of this season's Emphasized Standards. HS-LS3-4 (MA), focuses on the need for students to be able to illustrate how the environment exerts selective pressure to favor a disease phenotype and explain the significance and mechanism of epigenetics and how gene expression is affected. Students will explore how one trait could be beneficial if a person were living in one environment, but harmful if that same person were living in a different environment. To fully understand the differences, students will conduct research about diseases in specific environments and create presentations that display their findings.

“Students will explore how one trait could be beneficial if a person were living in one environment, but harmful if that same person were living in a different environment.”
In order to be successful in this unit of study, students will need to have a basic understanding of DNA and genetics, which should be reviewed at the start of the unit. Students will also need a basic understanding of how to conduct research in order to successfully complete the Performance Task. Teachers will need to ensure that students understand how to find credible sources if students are conducting research on their own. Lessons have been included in this unit to help students with this background knowledge, but the teacher will need to adjust the lessons and depth of background knowledge review based on the students’ needs in his or her classroom.

Teachers should pre-teach necessary vocabulary to ensure understanding of those terms. Students might also become anxious when discussing how decisions we make, particularly those that affect our bodies, affect our immediate and long-term health and the health of future children. Teachers should be sensitive to this when discussing how traits can be passed from parents to children.

For long-term adaptation ideas for this unit, see p. 4.15.3 on the right.
## Overview
In this unit, the students are focusing on epigenetics, building on their understanding of genetics and passing on traits while acknowledging environmental factors, especially focusing on the connection of malaria and sickle cell anemia. The long-term program teacher may want to address more deeply the Clarification Statements of the standard, such as discovering more about alleles and their role with proteins or the role of the environment in expressed traits in an individual can include the likelihood of developing inherited diseases.

## Desired Results
The first Do could be expanded by having students look at various types of environmental factors and population health data and try to determine correlations between the two. The second KUD focuses on epigenetics. Teachers may expand on the Do by having students apply epigenetics to their own health choices.

## Assessment Evidence
The Summative Assessment of the project focusing on malaria may be extended to give students additional time to find connections and compare reports. Infographics may be used to help students understand what is presented to them and how to convey information. To provide more practice and application to the students, a teacher may decide to complete the malaria project as a class activity before using another example for the students to work through individually.

## Learning Plan
The learning plan has only seven lessons with the final project being worked on starting in Lesson 3. During Lesson 1, a teacher may also choose to use Hexagonal Thinking to track students’ understanding of the topics and vocabulary words (https://therelevanteducator.wordpress.com/2015/05/10/hexagon-thinking/).

While discussing epigenetics in Lesson 2, the teacher could create a sorting activity for the students to see different health behaviors that could impact offspring. As an assessment for this activity, the teacher might ask the students to create a letter to their great-great-grandchildren explaining how they had to change or continue a behavior to improve future generations’ health while explaining epigenetics in the letter.
Emphasized Standards *(High School Level)*

**HS-LS3-4(MA):** Use scientific information to illustrate that many traits of individuals, and the presence of specific alleles in a population, are due to interactions of genetic factors and environmental factors.

**Clarification Statements:**

- Examples of genetic factors include the presence of multiple alleles for one gene and multiple genes influencing a trait.
- An example of the role of the environment in expressed traits in an individual can include the likelihood of developing inherited diseases (e.g., heart disease, cancer) in relation to exposure to environmental toxins and lifestyle; an example in populations can include the maintenance of the allele for sickle-cell anemia in high frequency in malaria-affected regions because it confers partial resistance to malaria.

**State Assessment Boundary:**

- Hardy-Weinberg calculations are not expected in state assessment.

**Essential Questions** *(Open-ended questions that lead to deeper thinking and understanding)*

How can events in life affect what genes are passed on to children?
How do your genetics affect your health?
How can where we live impact our health?

**Transfer Goals** *(How will students apply their learning to other content and contexts?)*

Students will apply their understanding to draw appropriate and logical conclusions from multiple sources of evidence.

Students will use facts, images, and data to explain what they have learned to another person.
Learning and Language Objectives

By the end of the unit:

- **Vocabulary:**
  - Homozygous, heterozygous, dominant, recessive, allele, genotype, phenotype, amino acid, protein

- **Vocabulary:**
  - Gene expression, methylation, epigenetics, epigenome

KUDs are essential components in planning units and lessons. They provide the standards-based targets for instruction and are linked to assessment.

<table>
<thead>
<tr>
<th>Students should know...</th>
<th>understand...</th>
<th>and be able to...</th>
</tr>
</thead>
</table>
| **Vocabulary:**
  - Homozygous, heterozygous, dominant, recessive, allele, genotype, phenotype, amino acid, protein |
  - There may be positive and negative implications of a disease genotype. |
  - Demonstrate that sickle cell trait is advantageous in malaria-prone areas of the world. |
| **Vocabulary:**
  - Gene expression, methylation, epigenetics, epigenome |
  - Epigenetic factors (such as environment or stress) can alter gene expression. |
  - Explain why epigenetics can be a significant factor in people’s health. |
Assessment Evidence

Quality questions raised and tasks designed to meet the needs of all learners

Performance Task and Summative Assessment (see pp. 4.16.15 to 4.16.16)

Aligning with Massachusetts standards

Malaria Project

**Goal:** Educate your audience about malaria: who can get it and who can’t get it

**Role:** You are a public health officer/epidemiologist

**Audience:** Everyone in the town who is worried about contracting malaria

**Situation:** Imagine that mosquitoes in America can carry malaria

**Product:** Create infographics (using www.easel.ly or by hand) that show how the disease got here, how it spreads, who can get it, and who can’t get it

**Standards:** Sufficient, accurate research that explains who can contract the disease, how it’s transmitted, and where it came from

Pre-Assessment (see p. 4.16.7)

Discovering student prior knowledge and experience

Concept mapping

Formative Assessments

Monitoring student progress through the unit

- Brainstorming/KWL chart (KWL Chart located in the Supplement on p. 4.18.1)
- Do-now journal entries
- Reflection on epigenetics and how it affects students’ lives
- Explanatory paragraph using vocabulary
Access for All

Considering principles of Universal Design for Learning (UDL), Positive Youth Development/Culturally Responsive Practice (PYD/CRP), differentiation, technology integration, arts integration, and accommodations and modifications.

Multiple Means of Engagement

Current information about epigenetic research is included, as is internet research about the progression of the theories of inheritance. Some of the unit work can and should be done in pairs and small heterogeneous cooperative learning groups, fostering interaction. Information and real-world examples in a variety of audiovisual forms can be found in the unit to engage youth learning objectives.

Multiple Means of Representation

The way in which information is displayed should vary, including size of text, images, graphs, tables or other visual content. Information should be chunked into smaller elements, and complexity of questions can be adjusted based on prior knowledge competency. Students will be able to read the Pearson Biology textbook (Chapter 12) and other related materials, watch and analyze videos, and listen to teacher instruction in order to achieve objectives. If lessons are planned considering materials, methods, and assessment to meet the needs of all the students, learning objectives need not be changed for particular students. Modifications to adjust the unit content may be necessary for students with mandated specially designed instruction described in their Individualized Education Programs (IEPs).

Multiple Means of Action and Expression

Reading and writing tasks may be scaffolded and/or adapted to provide access to all differentiated content according to students’ needs. Concept mapping with Inspiration or drawings by hand, checklists, sticky notes, and mnemonic strategies can help students better understand and demonstrate comprehension of the material. Students can respond to the text not only through writing, but also through art. For all Performance Tasks, students will be provided with as much choice as possible in the level of challenge, type of high- and low-tech tools used, color, design and layout of graphics, and sequencing and timing. Evaluative emphasis should be placed on process, effort, and improvement. Formative Assessments should be designed to invite personal response, self-evaluation, and reflection. For the Summative Assessment, students will have the opportunity to present to the class. Accommodations intended to enhance learning abilities, provide access to the general curriculum, and provide opportunities to demonstrate knowledge and skills on all Performance Tasks may be necessary for students with applicable Individualized Education Programs (IEPs) and could benefit all learners.
Literacy and Numeracy Across Content Areas

Reading
Throughout the unit, the students will be reading nonfiction text from the textbook, online articles, and informational websites, with e-readers or other assistive technologies as appropriate. The students will be reading the information to gain understanding and to scaffold their knowledge base of the material being explained in class.

Writing
The students will be utilizing writing to display their understanding and to help them process factual knowledge. Students will be writing about how epigenetics affects their lives. The writing (which make take a variety of forms) will help teachers to assess the students’ skills to complete the assignments and meet the standard. The unit’s writing will include an array of formal and informal formats focusing on the informational style.

Speaking and Listening
Throughout the unit, there are ample opportunities for students to speak in the class. Students will be speaking to the class or the teacher for their presentations, Summative Assessment, and through other opportunities to explain their understanding of the concepts.

The teacher will be delivering some information through direct instruction. Students will be expected to listen and respond to their classmates’ presentations. Students will provide acknowledgement of comprehension through responding to questions or adding their own extensions to the materials.

Language
Within the unit, the students will be exposed to various formats of academic language. During the lessons, the teacher will scaffold the language through modeling, turn and talks, and class discussion about the content. In addition, students will learn and utilize academic vocabulary dealing with genetics.

Providing students with opportunities to present to the class and to each other will allow practice using Standard English conventions. In addition, students will be responding in class with simple and complex sentences. The teacher will encourage full responses during question and answer sessions and will model conventions using formal English when possible. In addition, teachers will ensure that students’ written work contains standard capitalization, spelling, and punctuation.

Numeracy
Students will interpret graphs and data regarding the number of people affected by malaria around the world. Lesson 3 includes a link to a graph from the World Health Organization that the teacher can show students about the rates of malaria from 2010-2015. Students can read and interpret this graph to see trends in cases of malaria. They will also use numeracy skills when they conduct research for the performance assessments. They will likely find charts, graphs, and data tables that they need to interpret correctly in order to relay accurate information in their infographics.
Resources (in order of appearance by type)

Print
(with accompanying CD or web resource).

Websites
“Concept map example.” University of Missouri-Kansas City. 2016.


www.pbs.org/wgbh/evolution/library/02/3/l_023_01.html.


www.youtube.com/watch?v=kp1bZEUgqVI.

“The Ghost in your Genes.” BBC Worldwide. BBC. 2016. (Content may be blocked--may need to search)
www.youtube.com/watch?v=toRIkRa1fYU. (5 parts)


www.youtube.com/watch?v=M4boKud1MRk.

www.nhlbi.nih.gov/health/health-topics/topics/sca.

www.mayoclinic.org/diseases-conditions/sickle-cell-anemia/basics/definition/con-20019348.

www.cdc.gov/malaria/about/index.html.

www.who.int/mediacentre/factsheets/fs094/en/.

www.who.int/gho/malaria/epidemic/cases/en/.

www.rollbackmalaria.org/microsites/annualreport2012/. (scroll down)


http://rubistar.4teachers.org.

http://zapatopi.net/treeoctopus/.
Websites (continued)


Materials
KWL Chart (p. 4.18.1)

Outline of Lessons
Introductory, Instructional, and Culminating tasks and activities to support achievement of learning objectives

INTRODUCTORY LESSON
Stimulate interest, assess prior knowledge, connect to new information

Lesson 1
DNA Review

Goal
Students will review the terminology that they learned in the DNA unit and earlier in the genetics unit and connect it to the genetics standard for this unit.

Do Now (time: 5 minutes)
Students will respond to the following question in writing or drawing: What is the relationship among chromosomes, genes, DNA, and traits? Students should try to use all four words in one sentence or diagram.

Hook (time: 5 minutes)
The teacher will write the following sentence on the board: DNA is organized into chromosomes, which have segments called genes that are responsible for traits. Students will read the sentence and compare it to the sentence or diagram that they created.

Presentation (time: 10 minutes)
The teacher will explain the sentence written on the board, ask the students to take notes, and clarify vocabulary. The teacher will define the terms DNA, chromosomes, genes, and traits, and explain the connections among the terms. The teacher will remind students that DNA is found in structures called chromosomes (humans have 23 pairs within each cell nucleus). Chromosomes have active regions called...
genes (20,000-30,000 in the human genome). These genes code for our traits and determine things such as hair color, eye color, height, hereditary diseases, etc. If the teacher needs support understanding these terms, s/he should refer to pp. 336-353 in the Biology textbook. Sections can also be assigned to students if they lack the background knowledge to understand these terms. The teacher should vary the way s/he displays information. Illustrations/pictures, charts, and models giving similar information may be shown.

**Practice and Application** (time: 25 minutes)
Students will create a simple concept map using the following terms:
- chromosomes
- genes
- DNA
- traits
- homozygous
- heterozygous
- dominant
- recessive
- allele
- genotype
- phenotype
- amino acid
- protein

The students should have learned these terms already; here they are activating their prior knowledge. The teacher may show an example of a concept map about a topic already covered in class, such as this example below.

**SEE:** l.web.umkc.edu/likinsl/concept_mapping_assignment_1.htm.

The teacher will explain that simply putting words into boxes is not enough to show that they understand the relationships among concepts. Students must include the connecting words that show an understanding of the relationships between concepts.

**Review and Assessment** (time: 10 minutes)
Students will share their concept maps. The maps are unlikely to be identical, but different versions can still be valid. The teacher will discuss with the class the different ways that students created these maps and ask students to explain how they were thinking about the relationships among these terms. Students will receive peer and teacher feedback on the accuracy of their maps.
misconceptions as they arise. (For example, a woman’s swimming a great deal during pregnancy will not cause her child to become a strong swimmer.)

**Hook** (time: 5 minutes)
The teacher will pose the question:
What would you say if someone told you that if we cut off the tails of two mice, their babies would be born without tails? Discuss.
The teacher will tell students that the babies will not be born tailless, but this thought was an old theory of evolution.

**Presentation** (time: 15 minutes)
The teacher will introduce Lamarck’s theory of acquired characteristics and discuss the implications of the theory. He believed that the characteristics that an organism acquired during its life would be passed on to its offspring. For example, he believed if you swam every day during your pregnancy, your child would love swimming and be a good swimmer.

SEE: “Jean Baptiste Lamarck”
www.pbs.org/wgbh/evolution/library/02/3/l_023_01.html

The teacher will explain that new take on this theory is epigenetics. Students can take notes or also perform a jigsaw reading.

SEE: “A Comeback for Lamarckian Evolution?”

**Practice and Application** (time: 20 minutes)
Students will perform internet research on epigenetics and share it with their teacher (or read materials provided by the teacher) and take two-column notes on what they learn and how it applies to their own lives. For example, students could begin with the following article:

SEE: kidshealth.org/parent/medical/genetic/about-epigenetics.html

**Review and Assessment** (time: 10 minutes)
Students will write a reflection on or discuss in pairs how their new knowledge about epigenetics might change their behavior. The teacher might ask students to think about these questions:

What do you do now that could affect your health (or what do you see other people doing that affects their health)? How could changing your behaviors change your health for the better (or how should other people change their behaviors to change their health for the better)?

**Extension**
While this is a relatively new theory of inheritance, there is a lot of information about it that students might find interesting and relevant to their own lives.

Any of the following videos could be useful:

SEE: “Epigentics” (Video is 9 minutes and 28 seconds.)
www.youtube.com/watch?v=kp1bZEUgqVI (The teacher can ask students to think about how what we do impacts the extent to which our genes are expressed.)
Lesson 3
Can the Same Trait Be Beneficial and Detrimental? (2 Days)

Goal
Students will explain how the same trait can be beneficial or detrimental depending on the individual’s environment.

Do Now (time: 5 minutes)
The teacher will put a picture of a white rabbit on the board or screen. Students will look at the picture and write down what they know about the organism. (It’s white, it’s a rabbit, it is covered with fur, etc.)

Hook (time: 5 minutes)
The teacher will then put up pictures of three different environments: a snow-covered forest, a desert, and a tropical rain forest. How well will this animal survive in each environment? The class will discuss how the same trait can be beneficial or detrimental in each environment.

Presentation (time: 55 minutes over 2 days)
The teacher will put the terms sickle cell anemia and malaria on the board. Students will come up to the board and write any words that they associate with these terms or raise their hands to share their words. The teacher might need to prompt with questions to get a sufficient number of ideas on the board, such as:

- How do you get it?
- Where could you get it?
- Why do you get it?
- Who gets it?
(or perhaps use a word wall)

Once enough words are written on the board, the teacher will have students fill out a modified KWL chart by putting words/connections that they know and can explain to someone in one column, words/connections that they have heard or think they know in the next, and words/connections that they do not know in the last column. See p. 4.18.1.

The teacher will ask students to share out some items from their charts. Things that the students know about these diseases will most likely be negative (you’ll die, you’ll pass these diseases on to your children, etc.).

For Empower Your Future Connections, see pp. 4.17.1 to 4.17.2
Students are unlikely to understand the connection between sickle cell disease and malaria. The teacher will explain that sickle cell comes in two forms: sickle cell disease and sickle cell trait. (Individuals with sickle cell trait have one gene and do not have any medical problems associated with sickle cell disease. However, they can pass the gene on to their children. Those with sickle cell disease inherit two genes from their parents and do have symptoms.) Traits are not always beneficial or detrimental; it depends on the environment that the individual is in. Sickle cell trait actually protects people against malaria; thus the trait is common in malaria-infested areas. The teacher will be sure to use appropriate vocabulary (chromosomes, genes, DNA, traits, homozygous, heterozygous, dominant, recessive, allele, genotype, phenotype) when explaining the idea and scaffold student note-taking by writing key ideas on the board, projecting them on the screen, and/or placing them on a word wall. This information will serve as background knowledge for the students before they begin their research. The teacher will provide as many vocabulary supports, multimedia representations, and teacher-created materials as is appropriate to the needs of students in the classroom.

At the end of Day 1 of the lesson, students will submit Exit Tickets with questions they have about the concepts or the vocabulary. At the start of Day 2, the teacher will review these points on the Exit Tickets.

Additional knowledge base for the teacher:

SEE: “World Health Organization: Number of Malaria Cases”
www.who.int/gho/malaria/epidemic/cases/en
“What is Sickle Cell Disease?”
www.nhlbi.nih.gov/health/health-topics/topics/sca
“Sickle Cell Anemia”
www.mayoclinic.org/diseases-conditions/sickle-cell-anemia/basics/definition/con-20019348
“About Malaria”
www.cdc.gov/malaria/about/index.html
“Protective Effect of Sickle Cell Trait Against Malaria”
www.cdc.gov/malaria/about/biology/sickle_cell.html
“Malaria”
www.who.int/mediacentre/factsheets/fs094/en

Practice and Application (time: 30 minutes)
The students will set up a two-column chart. On one side of the chart, they will list the misconceptions/lack of knowledge that they had about sickle cell and malaria. On the other side of the chart, they will add what they learned and how their misconceptions have been addressed and corrected.

Then, the students will use the appropriate vocabulary to explain the connection between sickle cell trait and malaria. The students will then show their newfound knowledge in written, oral, graphic organizer, and/or illustration format in order to solidify their understanding.

Review and Assessment (time: 15 minutes)
Students will trade their written explanations with a partner. The partner will comment on whether or not the information is correct and complete and easy to understand. The partner will do a 3, 2, 1 giving feedback to the author to assess whether the author completed the task as assigned:
What are three things your partner learned about sickle cell and malaria? What are two misconceptions/limited understandings that s/he had that are now understood? What is one connection s/he made between sickle cell trait and malaria?

While the partner is doing this, s/he will comment on whether the connection is correct based on his or her own understanding. When the partners turn this work in to the teacher, the teacher can check for understanding for both partners at once.

**Extension**

This article discusses why climate change could affect the snowshoe hare population. It ties in nicely with the Do Now activity.

SEE: “Climate Change May Be Deadly For Snowshoe Hares”

www.sciencenews.org/blog/wild-things/climate-change-may-be-deadly-snowshoe-hares

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**CULMINATING LESSONS**

Includes the Performance Task, i.e., Summative Assessment—measuring the achievement of learning objectives

**Lesson 4**

Introduction to Final Project

**Goal**

Students will explain why diseases live in certain environments and populations (epidemiology). Students will explain the expectations for the Performance Task.

**Do Now** (time: 5 minutes)

Students will respond to the following question in writing or by discussing with a classmate: Why do people study disease? Students will share their ideas with the class.

**Hook** (time: 10 minutes)

The teacher will show a map of malaria distribution throughout the world and ask: “What do you notice about the map?” The teacher will lead the class in discussion about what might explain the differences in incidence of malaria. (The teacher will also have a map of Africa so that students can identify the countries on the map.)

SEE: www.rollbackmalaria.org/microsites/annualreport2012 (scroll down for map)

**Presentation** (time: 10 minutes)

The teacher will present the final project to the class. Students will research what an epidemiologist does and the relationship between epidemiology and public health. Students will need to be sure to explain the genetics behind who can and can’t contract malaria. Students will then research malaria and create a presentation that follows the scenario below.
Goal: Educate your audience about malaria, who can get it, and who can’t get it

Role: You are a public health officer/epidemiologist

Audience: Everyone in the town who is worried about contracting malaria

Situation: Imagine that mosquitoes in America can carry malaria

Product: Create infographics (using http://www.easel.ly or by hand) that show how the disease got here, how it spreads, who can get it, and who can’t get it

Standards: Sufficient, accurate research that explains who can contract the disease, how it’s transmitted, and where it came from

Practice and Application (time: 20 minutes)
The teacher will lead students in a discussion of how they will be assessed on this final project. The teacher will also ask students to brainstorm what visual elements a perfect product would contain, and the teacher and students will co-create a rubric that will assess the completed project and presentation. Scientific accuracy, proper vocabulary, and satisfying each of the requirements will be included on the rubric. It will also specify that the product will graphically engage the audience and contain data from reputable sources that supports students’ claims. Students will also discuss what criteria should be on the rubric for the presentation of the infographic. For the presentation, students will be able to explain the product to an audience in clear and accurate language. The teacher will also ask students to think about things good presenters or speakers do. Students should note that good presenters make eye contact, speak clearly, don’t read everything from notes, and aren’t monotone.

Review and Assessment (time: 10 minutes)
Students will work with the teacher to create the rubric based on the criteria they brainstormed. Point values should be assigned to each category based on importance. (For example, eye contact shouldn’t be 50 points while scientific accuracy is 5 points.) A website like Rubistar might help teachers create this rubric with the class.

Lesson 5

Introduction to Research (2 Days)

Goal
Students will evaluate websites to determine if they are credible and use credible sources to conduct research for their final projects.

Do Now (time: 5 minutes)
The students will respond to the following question in writing or discuss with a classmate:

What makes you believe someone’s statements? What makes you think someone is lying or uninformed?
**Hook** (time: 15 minutes)
The teacher will choose a website that appears to be legitimate science, but isn’t, such as the one below at zapatopi.net. Students will examine the website, determine whether or not they think it is credible, and explain why.

SEE:  http://zapatopi.net/treeoctopus

**Presentation** (time: 10 minutes)
The teacher will then lead the class in a discussion of how to determine whether a website is credible and unbiased. She or he can provide students with these suggestions from the University of Wisconsin Green Bay.

SEE:  https://uknowit.uwgb.edu/page.php?id=30276

**Author:** Information on the internet with a listed author is one indication of a credible site. The fact that the author is willing to stand behind the information presented (and in some cases, include his or her contact information) is a good indication that the information is reliable.

**Date:** The date of any research information is important, including information found on the internet. By including a date, the website allows readers to make decisions about whether that information is recent enough for their purposes.

**Sources:** Credible websites, like books and scholarly articles, should cite the source of the information presented.

**Domain:** Some domains such as .com, .org, and .net can be purchased and used by any individual. However, the domain .edu is reserved for colleges and universities, while .gov denotes a government website. These two are usually credible sources for information (though occasionally a university will assign a .edu address to each of its students for personal use, in which case use caution when citing). Be careful with the domain .org, because .org is usually used by non-profit organizations, which may have an agenda of persuasion rather than education.

**Site Design:** This can be very subjective, but a well-designed site can be an indication of more reliable information. Good design helps make information more easily accessible.

**Writing Style:** Poor spelling and grammar are an indication that the site may not be credible. In an effort to make the information presented easy to understand, credible sites watch writing style closely.

Of course, there may be some reliable websites that do not include all these qualities. If you are unsure whether the site you’re using is credible, verify the information you find there with another source you know to be reliable, such as an encyclopedia or a book on the subject. The kind of websites you use for research can also depend on the topic you are investigating. In some cases it may be appropriate to use information from a company or non-profit organization’s website, such as when writing an industry or company overview.
**Practice and Application** (time: 75 minutes over 2 days)

Students will conduct research that answers the questions posed in the prompt and take notes from and document their sources. When students are conducting their research, they will likely come across graphs and data tables/charts that they need to interpret. The teacher might need to help students interpret the data that they are seeing in their research. At the end of the first day’s work, students will submit Exit Tickets summarizing their progress and listing any questions or concerns they have. At the start of the second day, the teacher will provide individual feedback and support as appropriate.

**Note:** Be sure that students are understanding through their research how people with the sickle cell trait have a resistance to malaria. Despite a high prevalence of malaria in some areas of Africa, many people living there have the sickle cell trait and do not die of malaria.

**Review and Assessment** (time: 5 minutes)

Students will write down any questions that they have (especially if they know that they need information that they couldn't find) and three interesting facts that they learned. The teacher will review these before the next class.

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**Lesson 6**

**Creating the Infographic (2 Days)**

**Goal**

Students will create their infographics, paying attention to the rubric criteria.

**Do Now** (time: 10 minutes)

Students will review the criteria on the rubric that they created to remind themselves what they need to include in their infographics in order to effectively communicate their data. They should take this time to clarify any questions they have.

**Hook** (time: 10 minutes)

The teacher will show students an example of an infographic and ask them:

- How does this infographic communicate an idea without the use of many words?
- What is it communicating? How is it using graphics to communicate the message?

Teachers can use the following infographic or any other infographic from www.easel.ly.


**Presentation** (time: 20 minutes)

The teacher will introduce students to the website www.easel.ly. If students have access to computers, they can create their infographics on this website. If they do not have access to computers, students will have to create them using posterboard and markers, images from magazines, etc. The teacher will show students a bad example of an infographic.


This will be used to illustrate how too many words on a page makes the message difficult to read.
The teacher will remind students of how easy it was to understand the message in the Hook because the creator of the infographic used graphics to depict the message. The teacher can show other good examples of infographics.


The teacher should lead the class in a quick discussion about what makes a good infographic so that students understand how to create theirs. If the teacher wants a list of tips to use with students, s/he can find it at:

SEE: www.easel.ly/blog/top-tips-from-experts-on-what-makes-a-great-infographic

**Practice and Application** (time: 60 minutes over 2 days)

Students will create their infographics. The teacher will circulate throughout the room to check in with students and answer any questions. The teacher will remind students that the graphics they are using need to show/support the data that they researched. The goal of this assignment isn’t just to make an eye-catching poster, but to convey a message and information. At the end of the first day’s work, students will submit Exit Tickets summarizing their progress and listing any questions or concerns they have. At the start of the second day, the teacher will provide individual feedback and support as appropriate.

**Review and Assessment** (time: 10 minutes)

Students will use the rubric that they created during Lesson 4 to make sure that they have met the criteria on the rubric for the infographic.

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**Lesson 7**

**Presentations** (1 day or more, depending on class size)

**Goal**

Students will present their infographics in a logical, coherent manner.

**Do Now** (time: 5 minutes)

Students will review and highlight the criteria on the rubric for the presentation of the infographic (eye contact, speaking clearly, etc.).

**Hook** (time: 5 minutes)

Students will take this time to ask any last-minute questions they have before their presentations.

**Presentation** (time: 10 minutes)

The teacher will give a mock presentation for the students. S/he will hold a piece of paper and read from it in a monotonous voice without making eye contact. This should make students realize that this is what they should not do in their presentations. The teacher will then ask students why his/her presentation wasn’t effective. The students will then generate a list of positive behaviors that make a presentation effective.

**Practice and Application** (time: 15 minutes)

Students will practice their presentations. Teachers should build in enough time to allow students to
practice with partners before presenting to the entire class. While students are practicing, the teacher will circulate throughout the room and offer suggestions to students to improve their presentations.

**Review and Assessment** (time: 20 minutes)
Students will present their infographics. Teachers and peers will assess the presentations based on the class-created rubric. They will give presenters feedback on their presentations. The timing of this activity may vary due to class size.

**Extension**
The teacher will introduce students to other mosquito-borne diseases such as Eastern equine encephalitis, Japanese encephalitis, La Crosse encephalitis, St. Louis encephalitis, West Nile virus, Western equine encephalitis, dengue fever, malaria, Rift Valley fever, Chikungunya, Zika virus, and yellow fever.

**POST–UNIT REFLECTION**
On meeting the Learning and Language objectives

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Connections to Empower Your Future
UNIT: Inheritance—Implications and Applications

Future Ready and Performance Task Connections

The Performance Task provides an excellent opportunity for teachers to expand on career exploration and goal setting skills. In Lesson 4, students will begin their projects by researching what an epidemiologist does and how his/her work connects with public health services and topics. Teachers can consider expanding this lesson after the completion of the Performance Task or in connection to it by having students research other careers that are involved in public health services and disease management. Students can research jobs such as: pharmacists, registered nurses, phlebotomists, medical assistants, genetic counselors, etc. Youth will find useful information on the MassCIS website.

Students will also actively participate in the development of the rubric to assess their Performance Tasks which allows them to develop Future Ready skills and benefit from Culturally Responsive Practice and Positive Youth Development. Allowing youth to participate in the development of the assessment tool encourages youth voice and ownership over the assignment and their own learning. By creating the rubric, youth must identify what it means to have effective communication in their presentations, how they will be held accountable, and what they must do to demonstrate initiative, follow-through and self-direction.

By identifying how the Future Ready skills will be evaluated, students will have already started demonstrating those skills.

Essential Questions and PYD/CRP Connections

The Essential Questions in this unit ask students to consider: How can events in life affect what genes are passed on to children? How do your genetics affect your health? and, How can where we live impact our health? These questions require students to understand the role of DNA and genetics and the impact of environmental factors on an individual’s mental and physical health.

Teachers can make a direct connection between the impact of environmental factors and EYF lessons that address healthy dietary choices. There are also many EYF lessons that address mental strength and resiliency and how a person can cope with stress and maintain a positive outlook. Teachers can make the connection between how our environments affect our health just like our genetics do. These connections demonstrate Culturally Responsive Practice and Positive Youth Development because youth will be making personal connections with the scientific concepts and will reflect on how their family history and personal choices will impact their futures.

Teachers may also consider discussing elements of the Possible Selves Theory and how our future possible selves are able to be changed and improved upon with thoughtful effort and reflection. Be sure to emphasize that neither our environment nor our genetics can predict exactly what our lives will be like and that it is important to actively cultivate a healthy environment, a positive image of ourselves, and to be aware of mental and physical health issues that may arise due to our family history and genetics.

Teachers can also have youth discuss what they will do with this knowledge about genetics and if they feel that genetics pre-determines someone’s life and abilities. Does having information about family history and your genetics limit you or give you an advantage? Ask students: What can a person could do to proactively address information they learned about their own genetics and
family history? If someone knows she is likely to develop diabetes because of her family’s genetic traits, what can she do? (The person can exercise and eat a healthy diet low in sugars and carbs.) If he knows his family has a history of anxiety or depression, what can he do before he even knows if he will suffer from depression? (The person can practice meditation, seek counseling, develop coping strategies, etc.) Encourage youth to see that there are many things an individual can do to preemptively address possible genetic concerns. Emphasize the positive aspects of genetics and how knowing genetic traits can be a benefit. Consider asking youth what they could do with the knowledge that their family has a history of being good multi-taskers with excellent eyesight. What can you do with that information? Who would benefit from having these traits? (Air Force pilots are known for having and needing these traits.) Show students that while genetics plays a large role in our lives, we are empowered to act on information, prepare for different situations, and emphasize the positive.

**Lesson 3 Connections**

In Lesson 3, students will explain how the same trait can be beneficial or detrimental depending on the individual’s environment. Teachers can expand on this concept by asking youth to consider what personality traits or behaviors can be both positive and negative depending on the situation. For example, teachers can ask youth to reflect on how being outspoken or opinionated may be positive or negative depending on the circumstances and who is involved. Ask youth to think about how being outspoken could be beneficial in the workplace. How could it be detrimental? Encourage students to consider many personality and behavior traits and discuss when those traits are and are not useful in their personal, academic, and professional lives. Students can also reflect on how certain traits in their cultures, families, or peer groups are encouraged and discouraged. Ask students to reflect on how this makes them feel and what challenges arise when they have to code switch for different situations.

**Lesson 5 Connections**

Lesson 5 asks youth to evaluate websites to determine if they are credible resources. Youth must evaluate these websites on their communication and representation of information to see if the information is clear, concise, unbiased, and credible. Teachers can expand on this lesson by asking youth to consider other times when they will have to evaluate information to see if it is credible. Consider asking youth to discuss concerns about banking advertisements, making large purchases such as a house or car, evaluating politicians’ messages, and identifying scams. Emphasize to students that they will have to be savvy consumers of information and goods and will need to take the initiative to do their research and think critically.

“...it is important to actively cultivate a healthy environment, a positive image of ourselves...”
**Modified KWL Chart**

Lesson 3

**TOPIC: Sickle Cell and Malaria**

<table>
<thead>
<tr>
<th>WHAT I KNOW AND CAN EXPLAIN</th>
<th>WHAT I HAVE HEARD OF OR THINK I KNOW</th>
<th>WHAT I DON’T KNOW YET</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
**Evidence for Evolution**

**TOPIC SEASON:** Evolution and Biodiversity

This unit is designed for use in short-term programs. Sections may be adapted for long-term settings.

Unit Designers: H. Lee and K. Miele

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**Introduction**

As evolutionary biologist Richard Dawkins said, “You can’t even begin to understand biology, you can’t understand life, unless you understand what it’s all there for, how it arose—and that means evolution.” Since the study of biology concerns the study of all living things, it is imperative that students understand why there is so much diversity in our world and how organisms evolve. This unit allows students to explore the various lines of evidence for evolution and to explore how scientists use the scientific process to gather data, analyze evidence, and make claims. Students will be engaged in the scientific process by compiling multiple sources of evidence that support the process of evolution and by engaging in a debate that proves the process of evolution. Students will find that they can follow this same process in other aspects of their lives in order to draw conclusions based on valid reasoning and evidence.

The Evidence for Evolution unit is designed to come first in the six-week Evolution and Biodiversity season and will take about three weeks to complete. After completing this unit of study, teachers should delve into the study of biodiversity and explore why populations of living things change over time. Students can also explore how changes in environmental conditions can affect populations and can cause the extinction of a species. Students should understand how humans are impacting other species and what they can do to make sure that species do not become extinct because of human actions. If possible, teachers should consider taking students on a field trip to a natural history museum (e.g., the Beneski Museum of Natural History at Amherst College).

This unit focuses on the first of this season’s Emphasized Standards. **HS-LS4-1** addresses the need for students to be able to communicate the multiple lines of evidence that support the process of evolution. Students will be looking at biogeographical, fossil, structural, and genetic and molecular evidence for evolution. In order to understand these multiple lines of evidence, students will be engaged in hands-on activities that show them how scientists discovered and used these lines of evidence for evolution. Videos, discussions, and readings will reinforce these concepts.

This unit pairs well with the ELA emphasis on argumentative writing. Students will spend time evaluating the evidence for evolution and determining whether or not evidence presented by scientists is
valid and persuasive. They also will explore arguments presented by creationism and examine whether or not there is scientific evidence to support this theory. Students will use the evidence that they gather throughout the unit to support the theory of evolution in a debate-like format.

Prior knowledge that students need for this unit includes a basic understanding of the scientific process and how scientists use evidence to make claims. A basic understanding of DNA from the unit on heredity will help students understand genetic evidence for evolution.

The unit may present challenges for some students and teachers. Students and teachers might come into the science classroom with religious beliefs about how living things came to be. Teachers should be sensitive to this issue and explain to students that in the science classroom, students should think like scientists in terms of looking at claims, evidence, and reasoning. Teachers should explain clearly that they are not asking students to renounce their beliefs, but are asking students to think about the scientific process when studying evolution.

For **long-term adaptation ideas for this unit**, see p. 4.19.3 on the right.
## Evidence for Evolution
Adapting This Short-Term Unit for Long-Term Programs

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Evidence for Evolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overview</td>
<td>Throughout this unit, the focus is on helping students meet the standard and supporting them in developing the ability to complete the Performance Task. Standard HS-LS4-1 focuses on students’ being able to communicate the evidence to support the theory of evolution. Although this is a controversial topic in society, the unit allows the students to examine the scientific facts and understand the inquiry processes that led to the theory. Since this is a shorter unit, teachers in long-term programs may find opportunities to delve more deeply into the lessons with additional supporting documentation for the students.</td>
</tr>
<tr>
<td>Desired Results</td>
<td>With one KUD in the unit, the Know is essential for the students to be able to effectively complete the Do. In the Know, it may help to break apart Lesson 5 into two days focusing on the molecular biology on day one and the genetics on day two. As a class is going through each part of the Know, it would be helpful for the students to create posters for each of the sets of evidence. It may support students to be able to discuss why evolution is based on scientific evidence.</td>
</tr>
<tr>
<td>Assessment Evidence</td>
<td>The culminating lessons may last five days. During that time, it could be helpful to have students work towards a goal of presenting their work to an authentic audience. Students could take an extra class to present their work to the entire program. Many staff and directors are aware of the debate about evolution that may take place outside of class. Having the students share their work with everyone may bring a fresh approach to the conversation, and the focus would be on supporting the youths to share their work and hone their presentation skills.</td>
</tr>
<tr>
<td>Learning Plan</td>
<td>For extra support and activities in this unit, Lesson 2 may be an opportunity to involve Earth Science students as well. Discussing the continental drift theory in more detail allows for a deeper conversation about evidence supporting the theory, which the worksheet helps to scaffold. Students may then complete a research project on Alfred Wegener and his unlikely journey into developing a scientific concept. Moreover, in Lesson 4, teachers may add an activity for kinesthetic learners. If permitted in the program, students could create clay models of two animals’ homologous structure and compare the similarities and differences. The activity would allow students to go deeper into the science of comparative anatomy and gain a new skill of working with scale models as well.</td>
</tr>
</tbody>
</table>
Emphasized Standards *(High School Level)*  
**HS-LS4-1:** Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence, including molecular, anatomical and developmental similarities inherited from a common ancestor (homologies), seen through fossils and documented laboratory and field observations.

*Clarification Statements:*
- Examples of evidence can include the work of Margulis on endosymbiosis, examination of genomes, and analyses of vestigial or skeletal structures.

**Essential Questions** *(Open-ended questions that lead to deeper thinking and understanding)*

- How do we know that living things have changed over time, and how do we communicate that information?
- How do we use evidence to support or refute an argument?
- How can newly found evidence affect previously drawn conclusions?

**Transfer Goals** *(How will students apply their learning to other content and contexts?)*

- Students will use their understanding of the evidence for evolution to draw appropriate and logical conclusions from multiple sources of evidence on other topics.
- Students will use facts to arrive at an informed conclusion.
- Students will effectively communicate ideas supported by multiple forms of evidence.
Learning and Language Objectives

By the end of the unit:

<table>
<thead>
<tr>
<th>Students should know...</th>
<th>understand...</th>
<th>and be able to...</th>
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</thead>
<tbody>
<tr>
<td>Evidence that supports evolution:</td>
<td>A wide variety of evidence exists to support evolution.</td>
<td>Argue how each type of evidence for evolution is grounded in science and supports evolution.</td>
</tr>
<tr>
<td>• geographic distribution (biogeography)</td>
<td>It is essential to use facts to support arguments and decision making.</td>
<td>Analyze and evaluate evidence to construct an argument.</td>
</tr>
<tr>
<td>• fossils</td>
<td>Theories are dynamic and constantly changing based on new information.</td>
<td>Synthesize information.</td>
</tr>
<tr>
<td>• homologous structures</td>
<td></td>
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<tr>
<td>• vestigial structures</td>
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<td></td>
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<tr>
<td>• embryology</td>
<td></td>
<td></td>
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<tr>
<td>• genetics (DNA)</td>
<td></td>
<td></td>
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<tr>
<td>• molecular biology (homologous molecules)</td>
<td></td>
<td></td>
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</tbody>
</table>
Assessment Evidence

Quality questions raised and tasks
designed to meet the needs of all learners

Performance Task and Summative Assessment (see pp. 4.20.14-4.20.16)

Aligning with Massachusetts standards

After studying the various lines of evidence supporting evolutionary theory, evaluate contradictory claims. Craft a response using evidence from this unit. The response may take the form of an argumentative paper, audio response, blog post, podcast, comic strip, etc.

**Goal:** To rebut the arguments of someone who does not believe in evolution

**Role:** A scientist who has evaluated the evidence for evolution and is certain of its validity

**Audience:** Anyone who has visited www.icr.org/life-science and is now confused

**Situation:** You’ve just visited a website that says evolution is a fraud. You are enraged and want to set the record straight.

**SEE:** www.icr.org/life-science

**Product:** Argumentative paper, audio response, blog post, comic strip, podcast, etc.

**Standards:** Sufficient evidence to prove that the process of evolution exists

Pre-Assessment (see p. 4.20.7-4.20.8)

Discovering student prior knowledge and experience

Anticipation Guide for Evolution
(An anticipation guide for evolution is located on p. 4.22.1 of the Supplement.)

Formative Assessments (see pp. 4.20.7-4.20.12)

Monitoring student progress through the unit

- Exit Ticket (Lesson 1)
- “Analyzing Evidence” graphic organizer and Exit Ticket (Lesson 2)
- Mystery Bone graphic organizer and presentation (Lesson 3)
- Exit Ticket (Lesson 4)
- Molecular Homology Questions 1-4 in Lesson 16.4 (p. 470) of Miller and Levine Biology textbook (Lesson 5)
- T-Chart (Lesson 6)
- Circulating and checking in with students and class discussions

For Empower Your Future Connections, see pp. 4.21.1 to 4.21.2
Access for All
Considering principles of Universal Design for Learning (UDL), Positive Youth Development/Culturally Responsive Practice (PYD/CRP), differentiation, technology integration, arts integration, and accommodations and modifications

Multiple Means of Engagement
Current events and historical readings about evolutionary evidence are included, as is internet research of recent and past discoveries about the progression of evolutionary theory as new technologies are developed. Some of the unit work can and should be done in pairs and small heterogeneous cooperative learning groups, fostering interaction. Providing information in a variety of audiovisual forms can also spur interest.

Multiple Means of Representation
The way in which information is displayed should vary, including size of text, images, graphs, tables, or other visual content. Information should be chunked into smaller elements, and complexity of questions can be adjusted based on prior knowledge and competency. Students will be able to read the textbook and other related materials, watch videos, listen to teacher instruction, and work with manipulatives in order to achieve objectives. Learning objectives may be changed as needed for particular students. Modifications intended to adjust the unit or content may be necessary for students with mandated specially designed instruction described in their Individualized Education Programs (IEPs).

Multiple Means of Action and Expression
Reading and writing tasks may be scaffolded and/or adapted to provide access to all differentiated content according to students’ needs. Concept mapping with Inspiration or drawings by hand, checklists, sticky notes, and mnemonic strategies can help students better understand and demonstrate comprehension of the material. Students can respond to the text not only through writing, but also through art. For all Performance Tasks, students will be provided with as much choice as possible in the level of challenge, type of high- and low-tech tools used, color, design and layout of graphics, and sequencing and timing. Evaluative emphasis should be placed on process, effort, and improvement. Formative Assessments should be designed to invite personal response, self-evaluation, and reflection. For the Summative Assessment, students will have the opportunity to present to the class. Adaptations intended to enhance learning abilities, provide access to the general curriculum, and provide opportunities to demonstrate knowledge and skills on all Performance Tasks will be necessary for students with applicable Individualized Education Programs (IEPs) and could benefit all learners.
Literacy and Numeracy Across Content Areas

Reading
Throughout the unit, the students will be reading nonfiction text from the textbook, online articles, and informational websites. The students will be reading the information to gain understanding and to scaffold their knowledge base of the material being explained in class.

Writing
The students will be utilizing writing to display their knowledge of the information and to help them process the factual knowledge. Students will be writing about evidence for evolution. The writing will help teachers to assess the students’ skills to complete the assignments and meet the standard. The unit’s writing will include an array of formal and informal formats focusing on the argumentative style.

Speaking and Listening
Throughout the unit, there are ample opportunities for students to speak in the class. Students will be speaking to the class or the teacher for their Mystery Bone presentations in Lesson 3, Summative Assessment, and through other opportunities to explain their understanding of the concepts.

Listening will occur with a number of audio options. The teacher should deliver the information through direct instruction, short videos, and computer simulations with sound. Students will be expected to listen and respond to their classmates’ presentations. Students will provide acknowledgment of comprehension through responding to questions or adding their own extensions to the materials.

Language
Within the unit, the students will be exposed to various formats of academic language. During the lessons, the teacher may scaffold the language through modeling, turn and talks, and class discussion about the content. In addition, students will learn and utilize Tier II and Tier III academic vocabulary dealing with evolution evidence. The students will be faced with determining denotations of words with multiple meanings, like evolution, which could be described as a Tier III and Tier II word.

Providing students with opportunities to present to the class and to each other will allow practice using Standard English conventions. In addition, students will be responding in class with simple and complex sentences. The teacher should encourage full responses during question and answer sessions and will model conventions using formal English when possible. In addition, teachers will encourage that students’ written work contains standard capitalization, spelling, and punctuation.

Numeracy
Students will be expected to interpret numeric data in Lesson 5 when they look at chromosome counts of various organisms.
Resources (in order of appearance by type)

Print


Websites


“Evidence of Evolution.” www.youtube.com/watch?v=cC8k2Sb1oQ8.


“Image of vestigial structures”. N.P. 2016. i.ytimg.com/vi/C0T3QcN6MRU/maxresdefault.jpg.


**Websites (continued)**


**Materials**

Anticipation Guide for Evolution (p. 4.22.1)

Continental Drift cutouts: SEE: earthref.org/ERDA/download:1541/. (p. 2)

Analyzing evidence worksheet: SEE: earthref.org/ERDA/download:1541/. (p. 3)

Mystery Bones Activity: SEE: mjksciteachingideas.com/pdf/MysteryBones.pdf

**Outline of Lessons**

Introductory, Instructional, and Culminating tasks and activities to support achievement of learning objectives

**INTRODUCTORY LESSON**

*Stimulate interest, assess prior knowledge, connect to new information*

**Lesson 1**

Introduction to Evolution (2 Days)

**Goal**

Students will develop interest in the upcoming unit and learn necessary vocabulary.

**Do Now** (time: 10 minutes)

On Day One the teacher asks students to respond to this question in writing or another form:

What has evolved in your lifetime?

As a class, students will discuss the meaning of *evolution* and how it applies to the things in their life that have evolved. Students may refer to technology, fashion, or music.

**Hook** (time: 15 minutes)

*Note:* Before handing out the Anticipation Guide to students, the teacher should address the potential conflict of beliefs that this unit presents. Some students might have firm religious beliefs that do not
Coincide with the study of evolution. The teacher needs to be sensitive to this; however, s/he should stress that this is a science classroom and we are studying this unit in relation to scientific evidence. We must think like a scientist, and scientists gather evidence and reason from that evidence. The teacher should allow for time to address student concerns.

Students will fill out the “Before Studying” column of the Anticipation Guide in the Supplement on p. 4.22.1. The teacher will then lead a discussion about the statements on the Anticipation Guide. This could be a sensitive topic, so the teacher should carefully monitor the conversation, and the Anticipation Guide should be modified if it is deemed necessary. Students will fill out the “After Studying” column in Lesson 6. The Anticipation Guide in the Supplement is based on one from the website below.

See:  
departments.jordandistrict.org/curriculum/science/secondary/archive/biology/b0502/Evolutionanticipationguide.doc

Presentation (time: 30 minutes)

Students will watch one of the following videos, which give background information on evidence for evolution. The teacher should stop the video periodically in order to discuss and clarify what is being said as students take notes. Students will learn that evidence for evolution comes from many disciplines and each source of evidence complements and supports the others.

See:  
“What is the Evidence for Evolution?”
www.youtube.com/watch?v=lIEoO5KdPvg

“Evidence of Evolution”
www.youtube.com/watch?v=cC8k2Sb1oQ8

At the end of Day 1, the teacher and students should compile a list of the types of evidence for evolution.

Practice and Application (time: 30 minutes)

On Day 2, the teacher should list the following topics on the board:

- geographic distribution (biogeography)
- fossils
- homologous structures
- vestigial structures
- embryology
- genetics (DNA)
- molecular biology (homologous molecules)

Working in pairs, students will try to figure out what each of the topics means and how each is connected to evolution. Students will have access to dictionaries, the textbook, and, if possible, the internet as resources. Each pair of students will create a chart summarizing the types of evidence for evolution.

Review and Assessment (time: 25 minutes)

Students will present their charts to the class, and the teacher may review the topics and clear up any misconceptions. This activity may be structured as development of a class anchor chart, created with student input.

Exit Ticket: Students will explain how two of these lines of evidence support evolution.
INSTRUCTIONAL LESSONS

Build upon background knowledge, make meaning of content, incorporate ongoing Formative Assessments

Lesson 2

Biogeographical Evidence for Evolution

Goal
Students will understand and explain biogeographical evidence for evolution.

Do Now (time: 5 minutes)
Students will respond to this question in writing or speaking to a partner:
What are some of the sources of evidence that we discussed last class?
Attempt to define “biogeography” by deconstructing the word based on what you know about root words. Share your thoughts with a partner.

Hook (time: 5 minutes)
The teacher will provide students with cutouts of the continents and ask students to think of them as a puzzle and attempt to put them together in an attempt to understand why similar fossils are found on different continents even though an ocean separates the continents. Find the cutouts at the website below.

See: https://earthref.org/ERDA/download:1541

Presentation (time: 10 minutes)
The teacher will explain that there are multiple lines of evidence that support the process of evolution. Each day for the following few days, the class will focus on one or two lines of evidence. The teacher should show one of the following videos that explains biogeography as evidence for evolution. The teacher should be explicit about making the connection between the video and the activity they just completed.

See: “Biogeographical Evidence for Evolution”
www.youtube.com/watch?v=0QgNETHv1vk
“Evidence of Evolution”
www.youtube.com/watch?v=cC8k25b1oQ8 (3:00-5:10) (same as second video in Lesson 1)

Students can also reference the Pearson Biology textbook, Lesson 16.4.

Practice and Application (time: 20 minutes)
In order for students to understand the importance of Continental Drift and biogeography as a form of evidence, students should complete the activity “Analyzing Evidence” on the website below. The purpose of this activity is for students to understand what evidence is and how it should be used to support an argument.

See: https://earthref.org/ERDA/download:1541

Review and Assessment (time: 15 minutes)
The teacher will review the activity with the class, being sure to focus on and discuss in detail what evidence is and how we analyze its validity. This will be essential for the Summative Assessment. Exit Ticket: Students will list and explain two of the most compelling pieces of biogeographical evidence that support evolution.

Note: Students will hold on to these Exit Tickets so that they can use them for their Summative Assessment.
Extension
The teacher can extend the lesson on continental drift by reading “The Really Big One” and “How to Stay Safe When the Big One Comes,” as a means of connecting the lesson to earth and space science standards. The articles discuss the possibility of a very large and destructive earthquake in the United States.

SEE: www.newyorker.com/magazine/2015/07/20/the-really-big-one
www.newyorker.com/tech/elements/how-to-stay-safe-when-the-big-one-comes

Lesson 3
Fossil Evidence for Evolution (2 Days)

Goal
Students will understand and explain fossil evidence for evolution.

Do Now (time: 10 minutes)
Students will respond to these questions in writing or another form:

What do you know about fossils? How they are formed, and what do they tell you?

Turn to a partner and share what you wrote.

Hook (time: 10 minutes)
The teacher will take images from the following website, being careful not to show students the text surrounding the images, and ask students to determine what each fossil is. The teacher could ask what organism or part of an organism each picture shows.

SEE: http://mentalfloss.com/article/64093/8-types-imaginary-creatures-discovered-fossils

Presentation (time: 10 minutes)
After students guess what each picture represents, the teacher explains that fossil evidence shows the evolution of modern species from extinct ancestors. The teacher can show clips from the following videos (from Lesson 1) to explain this line of evidence. Students can also reference the Miller and Levine Biology textbook, Lesson 16.4.

SEE: www.youtube.com/watch?v=lIEoO5KdPvg (5:01-7:15)
www.youtube.com/watch?v=cC8k2Sb1oQ8 (5:15-6:02)

Practice and Application (time: 50 minutes)
Working in pairs, students will attempt to put together mystery fossil bones to create an organism. This activity illustrates the process of taking fossils and drawing on prior knowledge about the morphology and function of certain bones. Using that prior knowledge, students will assemble an organism. It is important for the teacher to address (mis)identifications of bones and how prior knowledge may influence it. It also illustrates that scientific conclusions are changeable depending on the evidence at hand and the background knowledge of the person drawing the conclusions. The similarities between modern skeletons and fossil remains allow us to infer function from form.

SEE: mjksciteachingideas.com/pdf/MysteryBones.pdf
Note: This activity involves students’ using scissors. If scissors are not allowed, the teacher should cut out the mystery fossils ahead of time and place them in envelopes for students.

On Day 1, students should cut out the fossil bones, work on assembling them, and glue them to a large sheet of paper. On Day 2, they should sketch the animal on the lab sheet and answer the summary questions.

**Review and Assessment** (time: 30 minutes)

Students will present and explain their conclusions. The teacher should ask students questions about each bone and what it tells us about the organism. Then the teacher should distribute the sheet “The Mystery Revealed” and encourage students to evaluate their own responses.

**Extension**

Teachers could extend the activity to include information about the latest thinking about feathered dinosaurs and their relationship to birds.


Teachers could also extend the activity to talk about the process of fossilization and what conditions need to be present for fossilization.

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### Lesson 4

#### Structural Evidence for Evolution (2 Days)

**Goal**

Students will understand and explain how homologous and vestigial structures and embryology provide evidence for evolution.

**Do Now** (time: 15 minutes)

Students will look at the picture in the website below that compares bone structures in a human, cat, whale, and bat. Students should respond to the following questions in writing or another form:

- What do you notice? What similarities and differences do you see?
- How does each limb function in each organism?

The teacher should then discuss these questions with the class.

SEE: www.bio.miami.edu/dana/pix/homologous.jpg

**Hook** (time: 10 minutes)

The teacher will show students the following picture (website below) that depicts vestigial structures. The class will discuss what these structures tell us about evolution and the relationship between organisms

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For **Empower Your Future Connections**, see pp. 4.21.1 to 4.21.2
that have fully functioning versions of these structures and organisms that have vestigial versions? The teacher should define *vestigial* for students.

SEE: i.ytimg.com/vi/C0T3QcN6MfU/maxresdefault.jpg

**Presentation** (time: 30 minutes)
The teacher will explain *homologous* and *analogous* structures and distinguish between them. Then, the teacher can show one of the following videos (from Lesson 1).

SEE: “What is the Evidence for Evolution”
www.youtube.com/watch?v=llEoO5KdPvB (0:00 - 3:56)

“Evidence of Evolution”
www.youtube.com/watch?v=cC8k2Sb1oQ8 (6:05-7:00)

Using comparative embryology, the teacher should discuss differences and similarities of embryos during different stages of development and what that shows about relatedness. Then the teacher should show and discuss the following picture that depicts embryos at different stages.

SEE: “Comparative Anatomy: Embryology”
image.slidesharecdn.com/comparativeanatomy-091126195652-phpapp02/95/compareTo2-28-728.jpg

Students can also reference the Pearson **Biology** textbook, Lesson 16.4.

**Practice and Application** (time: 30 minutes)
On Day 2, the teacher will review the content from Day 1 then lead the class through the interactive website about homology and analogy listed below. The students will notice that there are many similarities among the structures presented in the website. The students will also use a graphic organizer to note the similarities in structure among organisms.

They will see that homologous structures are evidence that organisms have common ancestors. They will realize that not all homologies are obvious, but upon close inspection, students will be able to see the homologous structures presented in the website.

The teacher will make sure that students understand the difference between homologous structures and analogous structures. They should know that analogous structures have similar functions, but they were not inherited from a common ancestor, and they evolved separately. The students should be able to use their knowledge from the presentation to explain what is presented in each segment of the website.

SEE: “Understanding Evolution: Test Your Understanding”
evolution.berkeley.edu/evolibrary/article/similarity_ms_01 (stop at p. 08)

**Review and Assessment** (time: 25 minutes)
Students will read the background information on the following website and answer the question. The question asks students to examine two animals: the sugar glider and flying squirrel. Based on their knowledge of homologous and analogous structures, students will be able to answer the question.

SEE: “Understanding Evolution: Test Your Understanding”
evolution.berkeley.edu/evolibrary/article/0_0_0/similarity_ms_09
In writing and drawing, students will explain their responses and what the evidence tells us about the relationship between these organisms. Students should present their explanations to the class.

**Extension**

Explain Ernst Haeckel’s phrase “ontogeny recapitulates phylogeny” and the reasons that it has largely been discredited. The students or teacher should Google this phrase to find discussions about its validity. Background information can be found at the website below.

SEE: embryo.asu.edu/pages/ernst-haeckels-biogenetic-law-1866

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**Lesson 5**

Genetic and Molecular Evidence for Evolution

**Goal**

Students will understand and explain how genetics and molecular biology provide evidence for evolution.

**Do Now** (time: 5 minutes)

Students will respond to the following question in writing or another form:

Based on your knowledge of genetics from the previous unit, explain the following in terms of how they relate to all living things: DNA, chromosomes, inheritance.

Students will compare their answers with a partner.

**Hook** (time: 8 minutes)

The teacher will remind students that humans, like all living things, contain DNA. Human DNA is distributed into 46 chromosomes.

In light of evolution, how many chromosomes would students expect other organisms to have? Students should think about what characteristics might be related to the number of chromosomes.

After a discussion, provide students with a list of organisms and the number of chromosomes each organism has.

What conclusions can they draw? What surprises them?

Students often expect that the number of chromosomes is related to the perceived complexity of the organism. In fact, the number of chromosomes is highly variable.

SEE: en.wikipedia.org/wiki/List_of_organisms_by_chromosome_count

**Presentation** (time: 7 minutes)

The teacher should show one of the following videos (from Lesson 1) to provide students with the factual information surrounding DNA as another line of evolutionary evidence. Students can also reference the Miller and Levine *Biology* textbook, Lesson 16.4.

SEE: www.youtube.com/watch?v=IlEoO5KdPvg (7:17-8:59)

www.youtube.com/watch?v=c8k2Sb1oQ8 (7:05-9:15)

**Practice and Application** (time: 25 minutes)

Students should read the article “This Picture Has Creationists Terrified.” The picture discussed in the
article shows side-by-side comparisons of chromosomes for humans, chimpanzees, gorillas, and orangutans. The article discusses the similarities among the chromosomes, arguing that this is evidence of evolution.

Students should discuss whether or not Chris Mooney’s argument is compelling.

SEE:  www.motherjones.com/politics/2014/01/bill-nye-creationism-evolution

Review and Assessment (time: 10 minutes)

Students should answer the Molecular Homology Questions 1-4 in Lesson 16.4 (p. 470) of the Biology textbook.

Extension

Students can research, or teachers may research and share with the students, the development of evolutionary evidence and thought as new technologies are developed. Students can and teachers may also research how many genes are in a particular genome (set of DNA) since genes are the functional components of DNA. After research is performed, a determination whether there is a correlation between complexity of an organism and number of genes may be made.

CULMINATING LESSONS

Includes the Performance Task, i.e., Summative Assessment—measuring the achievement of learning objectives

Lesson 6

Gathering Evidence (2 days)

Goal

Students will gather evidence in preparation for the Performance Assessment.

Do Now (time: 5 minutes)

Students should go back to their anticipation guides from Lesson 1 (Supplement p. 4.22.1) and fill out the “After Studying” column on the right. They should discuss why any of their answers changed or remained the same.

Hook (time: 15 minutes)

Students will read the article “Probing Question: Why is teaching evolution still controversial?”

SEE:  news.psu.edu/story/314026/2014/06/06/research/probing-question-why-teaching-evolution-still controversial

Note: The teacher should remember that evolution may be an uncomfortable topic for some students due to their religious beliefs, even though it is not controversial in the scientific community. The teacher should stress that the Performance Assessment focuses on understanding and presenting the scientific evidence for evolution.

Presentation (time: 20 minutes)

The teacher will present the Performance Assessment to the students:

After studying the various lines of evidence supporting evolutionary theory, evaluate contradictory
claims. Craft a response using evidence from this unit. The response may take the form of an argumentative paper, audio response, blog post, podcast, comic strip, etc.

The teacher will then create a rubric with the class. The rubric should contain topics such as accurate scientific evidence, proper vocabulary, and logical conclusions. With the class, teachers can create this rubric using an online tool like rubistar.4teachers.org.

Regardless of the format of presentation, all projects should include the rubric topics.

**Practice and Application** (time: 65 minutes)

Beginning on Day 1 and continuing on Day 2, students should watch as a class the videos on the following website, which argue for creationism instead of evolution. There are many videos and related articles on this site. The teacher should select an appropriate number of videos to watch depending on time and program constraints. The teacher may include an article or two.

Students should take notes on a T-Chart of the evidence that is presented in the videos. After watching the videos, they should evaluate whether or not the evidence presented is valid. They should refer to their textbook and other resources to refute the arguments presented in favor of creationism. They should complete the second column of the T-Chart with their researched evidence.

SEE: www.icr.org/life-science

The teacher should check in with students as they are researching and filling out the T-Chart. The teacher should push the students to make sure that the evidence is complete and valid.

**Review and Assessment** (time: 5 minutes)

Students will submit their completed T-Charts with a brief self-assessment indicating what points they feel confident about and what they have concerns about. The teacher can respond to these concerns the next day.

**Extension**

Students can watch the PBS special, *Intelligent Design on Trial*.

SEE: www.pbs.org/wgbh/nova/evolution/intelligent-design-trial.html

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**Lesson 7**

**Creating an Argument (3 days)**

**Goal**

Students will create a final product that utilizes research to explain how the process of evolution is supported by multiple lines of evidence.

**Do Now** (time: 5 minutes)

Students should write on note cards any clarifying questions that they have about the project so far. The teacher should collect cards and review them so that questions can be answered.
**Hook** (time: 5 minutes)
Each student can share one piece of unexpected information that they found during the previous lesson.

**Presentation** (time: 10 minutes)
The teacher will remind students of the rubric and explains what is expected, then discuss different formats that the presentation may take. The teacher should list these on the board for students to refer to when deciding how they want to present their information.

**Practice and Application** (time: 90 minutes)
On Day 1, using the T-Charts that they filled out during the previous lesson, students should decide what form their final products will take and plan them accordingly.
On Day 2, students should craft their products with teacher check-in, support, and review of drafts, as appropriate.

**Review and Assessment** (time: 55 minutes)
On Day 3, students will rehearse their presentations with partners before presenting them to the class. When students present their projects, their classmates should give them feedback by scoring them on the rubric. The teacher should clarify what the peer assessment should look like.

**Extension**
Students can read selections from “In Defense of Evolution,” a conversation with Ken Miller, one of the authors of their textbook. Students can reflect on how they grew/changed/evolved in their thought process throughout the unit.

**POST–UNIT REFLECTION**
*On meeting the Learning and Language objectives*
Connections to Empower Your Future
UNIT: Evidence for Evolution

Future Ready Connections
Teachers are encouraged to use the Future Ready Rubric to evaluate students’ growth and are encouraged to have students self-evaluate their progress using the Future Ready Rubric. Youth have many opportunities to strengthen their communication and listening skills through group discussions, partner work, teacher presentations, videos, and their own presentations in Lesson 7. Youth can also be evaluated for initiative and self-direction as they complete the mystery fossil bones activity (Lesson 3), use interactive websites (Lesson 4), read articles independently (Lesson 5), and take notes on a T-Chart (Lesson 6). Teachers should reflect on whether or not youth stay on task without prompting and if they push themselves to thoroughly complete the activity, answer their own questions, and create a detailed final product instead of only addressing the minimum required information. The independent student activities, the Performance Task (rebuttering the arguments of someone who does not believe in evolution), and the Exit Tickets are good opportunities to evaluate students on their accountability for completing tasks and if they are actively engaging in critical thinking.

Essential Questions Connections
The Essential Question for this unit addresses how we know that living things have changed over time, which connects to the fundamental concept that people can and do change. Teachers can ask students to discuss:

- How can you tell that you have changed over time? This question will prompt youth to identify their positive growth and milestones in their professional, personal, and academic lives. If youth struggle to identify changes, start with concrete examples like physical changes that come with aging and then transition to abstract concepts such as maturity, decision making skills, and other academic, personal, and professional skills. Lesson 1 also includes a Do Now that prompts students to consider: What has evolved in your lifetime? This provides a concrete introduction to the concept of change in our personal lives over time. Additional prompting from the teacher can encourage students to identify not only how they have changed but why they have changed over time.

- Teachers should also consider asking “How do I know that change is possible?” in order to focus on positive thinking and goal setting. Teachers can use examples of role models who faced adversity or obstacles but overcame them and changed into a stronger more successful person. Asking youth about the life story of one of their favorite artists, writers, or athletes will likely reveal that they know that change can happen.

Emphasized Standards and Transfer Goal Connections
The Emphasized Standard and Transfer Goals for this unit focus on testing theories and drawing appropriate and logical conclusions based on observations, evidence, and facts.

Teachers can make EYF and Future Ready connections to the standard and transfer goals by emphasizing that when we make decisions in our personal and professional lives we must also observe and use what we have learned (evidence and facts) to inform those decisions. For example, if a youth wants to pick a career field that interests him/her then s/he will need to observe and gather facts and evidence about what jobs in that
career field are like in order to make a well-informed decision. Teachers should emphasize that all well-thought out theories and decisions—personal, academic, or professional—are based on gathering information and reflecting on original opinions and theories and adjusting as necessary.

Performance Task, PYD/CRP Connections

The Performance Task allows youth to respond to the prompt in a variety of media (such as a blog post, comic strip, debate, written response, etc.) which gives youth the opportunity to challenge themselves by completing the project using less developed skills or by emphasizing their strengths by showcasing a strong skill. Teachers should encourage students to make connections between the type of project they are going to complete and the skills that the project will develop or require. Teachers may want to encourage youth to select a project that will allow them to develop skills that are essential to their career interests.

Lesson 6 includes a Do Now (Students must go back to their anticipation guides from Lesson 1 and fill out the “After studying the evidence for evolution” column on the right) that reflects culturally responsive practice by encouraging students to return to their anticipation guide and identify their beliefs before and after studying evolution and encouraging them to reflect on how and why their understanding may have changed.

Lesson 4 Connections

Lesson 4 discusses how homologous and vestigial structures provide evidence for evolution and has youth explore how different animals and organisms that seem completely different actually have some characteristics in common. Teachers can connect this concept to future planning and goal setting by asking youth: How do you define success? What does success look like to you? Who do you know that is successful? Why do you think this person is successful? What qualities does this person have? These questions will help youth identify positive and negative actions, decisions, and traits that influence a person’s success.

The teacher, perhaps with the help of youth, may also list famous people who are successful and ask youth to identify what these people have in common. An example of this could be listing famous actors, musicians, and writers that youth would likely know and then generating a list of qualities such as hard-working, communicates effectively, respectful, reliable, self-directed, attended college, creative, follows through, etc. Teachers should consider having youth develop a rubric that evaluates success and then have students use it to evaluate both themselves and the famous people used as examples.

For Technical Assistance with Empower Your Future connections and lessons, please request support by submitting a Coaching Request ticket using the Coaching Feature on TeachPoint.
## Anticipation Guide for Evolution

### Lesson 1

**DIRECTIONS:** Complete “Before Studying” for Lesson 1 and “After Studying” for Lesson 6.

<table>
<thead>
<tr>
<th>BEFORE STUDYING</th>
<th>STATEMENT</th>
<th>AFTER STUDYING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agree</td>
<td>Disagree</td>
<td>Agree</td>
</tr>
<tr>
<td>Evolution is a theory and does not have evidence that supports it.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evolution is a scientific theory that religious people cannot accept.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evolution states that humans are the descendants of monkeys.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If evolution were true, organisms would still be changing today.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evolution is not an important part of the study of biology and can be ignored without losing an understanding of biology.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modern study of genetics does not support the theory of evolution.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charles Darwin based the original ideas on observations he made of the natural world.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other theories of the development of life on Earth have a scientific basis.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The fossil record has missing “links” which cannot be explained by science.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Introduction

There may be no other unit in biology that directly relates more to our students’ everyday lives than the study of our anatomy and physiology. Understanding how our bodies work is essential to understanding how the things we do affect us; it helps us understand how we can make good decisions that will allow our bodies to function properly and helps us to become informed medical consumers. Through this unit, students will also explore how our behavior, particularly as it relates to taking antibiotics, creates an evolutionary pressure that may result in infections that are largely untreatable. Furthermore, students will learn that in science, much as in life, systems and events are interconnected and need to be explored through those connections, not in isolation.

The Amazing You: More Than Just Parts is designed to address all three of the major standards for this season and will take about three weeks to complete. There are multiple opportunities for extension activities in this unit, such as discussing body systems not covered in this model unit, or looking at the different types of food that we eat and how our digestive system uses them to provide us with the energy needed for survival. Students could explore how the foods that they eat or the exercises that they do affect their body systems. Teachers could also consider inviting a school nurse or other health professional from the community into the classroom to talk about their careers and how this unit relates to their day-to-day work.

This unit focuses on all three of this season’s Emphasized Standards. HS-LS1-2 requires that students be able to illustrate and explain that the systems in our bodies work together or carry out the essential functions of life. HS-LS1-3 requires students to be able to provide evidence that feedback mechanisms within our bodies work to maintain homeostasis. HS-LS4-4, the focus standard for the Summative Assessment in this unit, asks students to be able to research and communicate information about viral and bacterial adaptations that allows the virus or bacterium to survive in a wide variety of environments. Besides researching a type of drug-resistant infection for the Performance Assessment, students will be asked to consider how the infection they researched affects the body systems that they studied in the beginning of this unit, with an understanding that since the systems are interconnected, an infection that might seem to affect only one system likely affects others as well. In order to

“However, in order for students to truly understand how our bodies function, they need to understand that the systems are interconnected and do not work in isolation.”
deeply understand each of these standards, students will be engaged in on-line interactive activities that show them how the organs in each body system work. Videos, lab activities, discussions, and readings will reinforce other concepts.

In order for students to understand how viruses and bacteria adapt and evolve, prior knowledge about evolution will be helpful for students to have. Understanding that each body system has a function of its own, but also works with other systems, might be difficult for students to conceptualize since it is easier to think of each system in isolation. However, in order for students to truly understand how our bodies function, they need to understand that the systems are interconnected and do not work in isolation. In order to be successful with the Summative Assessment, students should also be familiar with how to conduct online research; if they are not, the teacher will have to spend some time exploring credible websites with students.

The unit may present challenges for some students and teachers. Teachers must be comfortable talking with students about body parts and functions, especially if the teacher decides to teach the reproductive system in this unit.

For short-term adaptation ideas for this unit, see p. 4.23.3 on the right.
The Amazing You: More Than Just Parts
Adapting This Long-Term Unit for Short-Term Programs

Overview
This unit focuses on human anatomy and physiology while examining specialized systems, like the cardiovascular, respiratory, and digestive systems, and how they interact with each other to maintain homeostasis. Throughout the unit, the students will be learning the functions of certain body systems and how each system contributes to the organism’s overall health. The students will apply their knowledge of bacteria and viruses to explain how the body reacts to fight infections and diseases. In short-term programs, the unit can be divided into mini-units focused on the various body systems.

Desired Results
The KUDs in this unit align nicely with the standards being assessed. Although this unit is written for a long-term program, the teacher and students in short-term programs should be able to utilize the same knowledge and skills. Each of the Do’s requires a higher-order thinking skill and will allow a student in a short-term program to accomplish a piece of the standard being assessed. Asking students to illustrate and explain organ functions and interactions with other systems is taken from standard HS-LS1-2. Teachers should try to use the KUDs to monitor students’ abilities and scientific knowledge.

Assessment Evidence
Throughout the unit, the lessons provide opportunities to assess students in correlation with the standards.
In Lessons 5, 6, and 7, students are asked to model how the organs work together and illustrate the process.
Lesson 8 has students diagram the feedback loop to maintain homeostasis. These assessments may be broken into chunks for students in a short-term programs.
The Summative Assessment, Lesson 11, may be differentiated for the students by offering the information to students rather than requiring research on the computer. This will save time for a short-term student who may have missed the earlier lesson on reliable websites. The teacher should look for articles and information that allow students to see the connections to the unit and the assessment.

Learning Plan
To streamline the 11 lessons in the unit, each lesson could be shortened by eliminating a short activity or combining it with other activities to make the connections to the key understandings and goals.
Lessons 5 and 6 focus on gathering data and modeling how systems interact. A short-term program teacher may look to combine the activities to connect circulatory and respiratory graphing and data collection into one lesson.
For Lesson 9, teachers may want to set the criteria for the Summative Assessment rubric. If many students will not be there when completing the assessment, it may save time to complete the rubric and gather student voice by asking if anything should be removed or added.
Lastly, in Lesson 11, the teacher may shorten the assignment to two days by providing the information and having students determine if it is from a reliable site. Also, the teacher may use a premade book with flaps to have a student fill in the needed information for the assessment.
**Emphasized Standards** *(High School Level)*

**Note:** This unit focuses primarily on Standards HS-LS1-2 and HS-LS-4-4 with Standard HS-LS-1-3 taught in a single lesson. Since this unit focuses on human anatomy, it addresses only the parts the standards that pertain to human beings.

**HS-LS1-2:** Develop and use a model to illustrate the key functions of animal body systems, including (a) food digestion, nutrient uptake, and transport through the body; (b) exchange of oxygen and carbon dioxide; (c) removal of wastes; and (d) regulation of body processes.

**Clarification Statements:**

- Emphasis is on the primary function of the following body systems (and structures): digestive (mouth, stomach, small intestine [villi], large intestine, pancreas), respiratory (lungs [alveoli], diaphragm), circulatory (heart, veins, arteries, capillaries), excretory (kidneys, liver, skin), and nervous (neurons, brain, spinal cord).

**State Assessment Boundary:**

- Chemical reactions in cells, details of particular structures (such as the structure of the neuron), or the identification of specific proteins in cells are not expected in state assessment.

**HS-LS1-3:** Provide evidence that homeostasis maintains internal body conditions through both body-wide feedback mechanisms and small-scale cellular processes.

**Clarification Statements:**

- Feedback mechanisms include the promotion of a stimulus through positive feedback (e.g., injured tissues releasing chemicals in blood that activate platelets to facilitate blood clotting), and the inhibition of stimulus through negative feedback (e.g., insulin reducing high blood glucose to normal levels).
- Cellular processes include (a) passive transport and active transport of materials across the cell membrane to maintain specific concentrations of water and other nutrients in the cell and (b) the role of lysosomes in recycling wastes, macromolecules, and cell parts into monomers.

**State Assessment Boundary:**

- Interactions at the molecular level (for example, how insulin is produced) are not expected in state assessment.
Emphasized Standards (continued)

**HS-LS4-4:** Research and communicate information about key features of viruses and bacteria to explain their ability to adapt and reproduce in a wide variety of environments.

**Clarification Statements:**
- Key features include high rate of mutations and the speed of reproduction which produces many generations with high variability in a short time, allowing for rapid adaptation.

**State Assessment Boundary:**
- Specific types of viral reproduction (e.g., lytic and lysogenic) are not expected in state assessment.

Essential Questions (Open-ended questions that lead to deeper thinking and understanding)

How does the human body work?
How do the body systems work together to maintain good health?
How does the body regulate itself?
Why do living things “get sick”? 

Transfer Goals (How will students apply their learning to other content and contexts?)

Students will apply their understanding of the interactions of body systems to make better choices regarding their health and be informed medical consumers/patients.

Students will evaluate how interaction and interconnection are evident in all aspects of their lives. Just as our body systems interact and are interconnected, nothing works in isolation.

Students will evaluate how positive and negative feedback affect our bodies and will apply their understanding of feedback mechanisms to their everyday lives in order to evaluate how they respond to feedback that they receive and how that can affect choices that they make.
### Learning and Language Objectives

By the end of the unit:

- **Vocabulary:** Interaction, nutrient; circulatory, digestive, respiratory, skeletal, muscular, and nervous systems
  - The structures within and the functions of each system

- **Vocabulary:** Positive feedback, negative feedback, equilibrium, homeostasis
  - The systems are constantly monitoring and adjusting as a result of internal and external environmental changes.

- **Vocabulary:** Virus, bacteria, evolution, adaptation, antibiotic resistance
  - The speed of reproduction of a virus or bacterium can allow for many generations in a short time, resulting in rapid adaptation.

**KUDs are essential components in planning units and lessons. They provide the standards-based targets for instruction and are linked to assessment.**

<table>
<thead>
<tr>
<th>Students should know...</th>
<th>understand...</th>
<th>and be able to...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary: Interaction, nutrient; circulatory, digestive, respiratory, skeletal, muscular, and nervous systems</td>
<td>Systems do not work in isolation; they are deeply interconnected with each other.</td>
<td>Illustrate and explain the functions of the organs within each system.</td>
</tr>
<tr>
<td>Vocabulary: Positive feedback, negative feedback, equilibrium, homeostasis</td>
<td>The systems are constantly monitoring and adjusting as a result of internal and external environmental changes.</td>
<td>Compare and contrast the two feedback systems.</td>
</tr>
<tr>
<td>Vocabulary: Virus, bacteria, evolution, adaptation, antibiotic resistance</td>
<td>The speed of reproduction of a virus or bacterium can allow for many generations in a short time, resulting in rapid adaptation.</td>
<td>Analyze what happens to other systems and to the human body when one system isn’t functioning correctly (i.e., disease). Research and communicate information about viruses and disease.</td>
</tr>
</tbody>
</table>
Assessment Evidence

Quality questions raised and tasks designed to meet the needs of all learners

Performance Task and Summative Assessment (see pp. 4.24.24-4.24.29)

Aligning with Massachusetts standards

Students will research an antibiotic-resistant infection, explain how that disease evolved, what the symptoms are, how it progresses, and what the treatment is. They should also explore alternative treatments. Students will have to explain how this disease impacts one or more of the body systems. They will create a flipbook or an accordion book to showcase their findings.

Note: This Summative Assessment is introduced to students in Lesson 9. This is the Summative Assessment for standards HS-LS1-2 and HS-LS-4-4.

Students will complete the body temperature regulation handout with a partner. They should use the textbook as a resource to fill in any information that they are unsure of. The teacher might also give students some key phrases such as “blood vessels,” “shivering,” “sweat,” “heat loss,” etc. and tell students that these words should show up in the diagram. (See handouts.)

The completed flowchart can be found here:

SEE:  https://cnx.org/contents/BP24ZReh@7/Homeostasis

The teacher will then ask students:

How is a feedback loop at play when you are exercising?

Students should write and draw their answers, explaining the feedback process.

When a person is exercising, her/his muscles need a certain amount of oxygen to function. In order to meet the increased oxygen demand, the person has to bring in more oxygen, and the body has to move that oxygen from the lungs to the working cells. This has to continue until the need gets met.

Note: This Summative Assessment is introduced to students in Lesson 8. This standard HS-LS1-3 is taught in only one lesson. The Summative Assessment for this standard is included in the lesson plan.

Pre-Assessment (see p. 4.26.1)

Discovering student prior knowledge and experience

Organ Systems Word Sort (see p. 4.26.1)

Formative Assessments (see pp. 4.24.10-4.24.13)

Monitoring student progress through the unit

Interactive activities that illustrate the names of and functions of organs within each system, two-column notes for organ systems, feedback mechanism diagram, graphs of respiratory rate and heart rate with conclusions, and “Why Do Athletes Have Lower Heart Rates” writing and connections.
Multiple Means of Engagement

Students should be engaged in this unit by learning about how the things that they do affect their bodies and organ systems. Some of the unit work can and should be done in pairs and small heterogeneous cooperative learning groups, fostering interaction. Providing information in a variety of audiovisual forms can also spur interest. There are many videos included in this unit that can be used at the teacher’s discretion; all videos do not need to be used in order for students to be engaged in the learning. The video on David Blaine’s ability to hold his breath for an extended amount of time and the excerpt from Superbug will engage students and encourage them to learn more about the topics under discussion. Students can also use technology and online resources to interact with material and be engaged in their learning through interactive websites.

Multiple Means of Representation

The way in which information is displayed should vary, including size of text, images, graphs, tables, or other visual content. Teachers should make decisions about how many videos to include in their instruction and be sure to vary the way that they are presenting information to students. Information should be chunked into smaller elements, and complexity of questions can be adjusted based on prior knowledge competency. Students will be able to read the Miller and Levine Biology textbook (Unit 8), excerpts from books and other related materials (such as the Superbug excerpt), watch videos, use interactive websites that allow them to engage in the organs and functions of the body systems, and listen to teacher instruction in order to achieve objectives. Learning objectives may be changed as needed for particular students. Modifications to adjust the unit or content will be necessary for students with mandated specially designed instruction described in their Individualized Education Programs (IEPs).

Multiple Means of Action and Expression

Reading and writing tasks may be scaffolded and/or modified to provide access to all differentiated content according to students’ needs. Students should be reminded how to annotate a text effectively and should be shown how to use two-column notes effectively. To ensure that students have other options for taking notes, students might make flowcharts or illustrations to show their understanding. Concept mapping with Inspiration or drawings by hand, checklists, sticky notes, and mnemonic strategies can help students better understand and demonstrate comprehension of the material. Students can respond to the text not only through writing, but also through art. For all Performance Tasks, students will be provided with as much choice as possible in the level of challenge, type of high- and low-tech tools used, color, design and layout of graphics, and sequencing and timing. For the main Summative Assessment in this unit, students can create flipbooks, or, if available, use technology such as Prezi or PowerPoint to show their learning. They will be able to present this to their classmates. Evaluative emphasis should be placed on process, effort, and improvement. Formative Assessments should be designed to invite personal response, self-evaluation, and reflection. The Formative Assessments in this unit range from using technology to show their understanding.
to creating graphs and explaining their understanding in writing. Accommodations to enhance learning abilities, provide access to the general curriculum, and provide opportunities to demonstrate knowledge and skills on all Performance Tasks will be necessary for students with applicable Individualized Education Programs (IEPs) and could benefit all learners.

**Literacy and Numeracy**  
**Across Content Areas**

**Reading**

Throughout the unit, the students will be reading nonfiction text from the textbook, online articles, excerpts from a non-fiction book *Superbug*, and informational websites. The students will be reading the information to gain understanding and to scaffold their knowledge base of the material being explained in class. To help students engage with the material, teachers should show students close reading strategies, such as annotation.

**Writing**

The students will be utilizing writing to display their knowledge of the information and to help them process the factual knowledge. Students will be writing about how the body systems work and about how antibiotic resistant infections can affect their lives. The writing will help teachers to assess the students’ skills to complete the assignments and meet the standard. The unit’s writing will include an array of formal and informal formats focusing on the informational style.

**Speaking and Listening**

Throughout the unit, there are ample opportunities for students to speak in the class. Students will be speaking in presentations to the class or the teacher for their Summative Assessment presentations and through other opportunities to explain their understanding of the concepts.

The teacher will be delivering some information through direct instruction. To help students listen carefully, they should be provided with note-taking strategies, such as two-column notes. Students will be expected to listen and respond to their classmates’ presentations and to peer evaluate them using a rubric. Students will provide acknowledgment of comprehension through responding to questions or adding their own extensions to the materials.

**Language**

Within the unit, the students will be exposed to various formats of academic language. During the lessons, the teacher will scaffold the language through modeling, turn and talks, and class discussion about the content. In addition, students will learn and utilize academic vocabulary dealing with anatomy.

Providing students with opportunities to present to the class and to each other will allow practice using Standard English conventions. In addition, students will be responding in class with simple and complex sentences. The teacher will encourage full responses during question and answer sessions and will model conventions using formal English when possible. In addition, teachers will encourage that students’ written work contains standard capitalization, spelling, and punctuation.
Numeracy

In Lessons 5, 6, and 7, students will be collecting and analyzing numerical data about heart rate and respiratory rate. Students can use the data they collect about respiratory and heart rates to calculate a class average, calculate an average for males, an average for females, etc. Students will create data tables that show their resting respiratory and heart rates as well as their respiratory and heart rates after exercising. Students will use an Excel spreadsheet and these data tables to create graphs of their classmates' heart rates and respiratory rates.

Resources (in order of appearance by type)

Print


Websites


“Impact of Healthy Food 2 of 2.” Natural Ovens Bakery, Inc. 2009. www.youtube.com/watch?v=KWYPjppBSgQ.


“Five Minute Calming Meditation.” The Honest Guys. 2014. www.youtube.com/watch?v=i50ZAs7v9es.


ANATOMY AND PHYSIOLOGY: The Amazing You

Websites (continued)


Materials (Location: Teacher-created or in the Supplement)

Organ System Word Sort. (p. 4.26.1)

Body Temperature Regulation. (p. 4.26.2)

Rubric generator.

SEE: rubistar.4teachers.org

Outline of Lessons

Introductory, Instructional, and Culminating tasks and activities to support achievement of learning objectives

INTRODUCTORY LESSON

Stimulate interest, assess prior knowledge, connect to new information

Lesson 1

Introduction to Anatomy

Goal
The student will develop interest in the upcoming unit and draw on prior knowledge of the human body.

Do Now (time: 5 minutes)
The student will write or discuss with a partner three facts and three questions about the human body. After this, the students should share what they thought about with the entire class. The teacher can make a list of questions on the board. If technology is available, students can use Padlet or Socrative to share their answers with the class. The teacher will project student responses.
Hook (time: 10 minutes)
The teacher will ask the class if anyone knows the answer to any questions that were posed by their classmates. Students should draw on any prior knowledge that they have to attempt to answer the questions. If there are not many students in the program, the teacher might project questions of his/her own to ask the students to answer by drawing on any prior knowledge that they have.

Presentation (time: 15 minutes)
The teacher will pose the question to the class:

What are you made of?

Students will name organs, body parts, or cells. Students might know that there are body systems, but they might not know the names of them. As students are brainstorming, the teacher should record what students are saying on the board. After a long list is brainstormed, the teacher should tell students that their goal is to organize everything they thought of. The teacher will lead students in a discussion of the fact that there are levels of organization within the human body.

From top down: **Organism** (the human body), **organ systems** (respiratory, cardiovascular, digestive, etc.), **organs** (liver, heart, stomach, etc.), **tissue** (muscle, nerve, connective), **cells**. The teacher shouldn’t go into specifics about what is in each system. The students will draw on prior knowledge to try to figure this out themselves in the practice and application part of this lesson.

Practice and Application (time: 20 minutes)
The teacher will hand students cards with terms on them. (See Organ Systems Word Sort in the Supplement on p. 4.26.1) With a partner or small group, students will have to attempt to categorize the words on the cards. For example, students should see the term Organ System and put the terms respiratory, cardiovascular, and digestive under that term. Then, students should realize that the heart is an organ within the cardiovascular system, etc. until all cards are in a category.

Review and Assessment (time: 5 minutes)
The students should share their word sorts with the class. The teacher will correct any problems or misconceptions.

**INSTRUCTIONAL LESSONS**
*Build upon background knowledge, make meaning of content, incorporate ongoing Formative Assessments*

Lesson 2

Circulatory System

Goal
Students will illustrate and explain the parts and functions of the circulatory system.

Do Now (time: 5 minutes)
Students will respond to the following question in writing or by talking to a partner:

What do you know about the circulatory system? Students should share their answers with the class.
Hook (time: 10 minutes)
The teacher should ask students the following questions and facilitate a brief discussion:
- Does our heart rate remain the same throughout the day?
- What might cause it to change?
- Is your heart rate the same as the heart rate of the person sitting next to you?
- What might your heart rate tell you?

Presentation (time: 10 minutes)
The teacher will describe the function of each of the major structures of the circulatory system. Students should take two-column notes while the teacher is explaining the structures. The left column should list the structures and the right column should explain the functions.

Students and/or teachers can use the Biology textbook (pp. 948-953) and other available resources to define the function.

The following short videos can be used to supplement instruction.

SEE: “The Heart, part 1”
www.youtube.com/watch?v=X9ZZ6tcxArI

SEE: “The Heart, part 2”
www.youtube.com/watch?v=FLBMwcvOaEo

SEE: “Blood Vessels, part 1”
www.youtube.com/watch?v=v43ej5lCeBo

SEE: “Blood Vessels, part 2”
www.youtube.com/watch?v=ZVklPwGAL

Practice and Application (time: 10 minutes)
Once students know each of the structures in the system, they should attempt to label them in a diagram of the human body. If computers are available for students, they can use the following interactive website. While labeling the parts, each student should work with a partner and take turns labeling a part and explaining what it does. If computers aren’t available, teachers can print out an unlabeled diagram and have students label each structure and explain what each structure does.

SEE: “Circulation Station”

Review and Assessment (time: 20 minutes)
Students should read the article, “Why do Athletes Have a Lower Heart Rate?” and explain its connections in writing to what they just learned about the circulatory system. While students are reading the text, they should highlight anything that relates to what they learned in class. They should make notes in the margins that allow them to show the connections that they are making. The teacher should model how to highlight important information and make a connection by reading the beginning of the article with the class and doing a “think-aloud” that models how to think about the connection and how to mark it on the article. After reading and writing, students should share their responses.

SEE: “Why do Athletes have a Lower Heart Rate?”
www.livestrong.com/article/385209-why-do-athletes-have-a-lower-heart-rate
Lesson 3

Respiratory System

Goal
Students will illustrate and explain the parts and functions of the respiratory system.

Do Now (time: 5 minutes)
The teacher should project an online stopwatch and ask students to hold their breath for as long as they can. After they do this, the teacher should ask students:

How were you feeling before you had to breathe? What might account for the differences between how long you and a classmate could hold your breath?

SEE: “Stopwatch”
www.timeanddate.com/stopwatch

Hook (time: 20 minutes)
The teacher should show students the following TED Talk and ask students to think about how what it describes is possible. While students are watching the video, they should be taking notes on how it is possible for someone to hold his breath for 17 minutes when they were only able to hold their breath for ____ seconds. (The teacher should get the average amount of time students are able to hold their breath from the Do Now activity.) At the end of the video, students should write two questions that they have about the respiratory system. The teacher will want to address those questions during the presentation time.

SEE: “David Blaine: How I Held My Breath for 17 Minutes”
www.ted.com/talks/david_blaine_how_i_held_my_breath_for_17_min?language=en

Note: As of 2012, the record for breath holding is 22 minutes and 22 seconds.

Presentation (time: 10 minutes)
The teacher will describe the function of each of the major structures of the respiratory system. Students should take two-column notes while the teacher is explaining the structure. The left column should list the structures and the right column should explain the functions.

Students and/or teachers can use the Miller and Levine Biology textbook (pp. 963-969) and other available resources to define the function.

The videos below can be used to supplement instruction.

SEE: “Respiratory System, part 1”
www.youtube.com/watch?v=bHZsvBdUC2I

“Respiratory System, part 2”
www.youtube.com/watch?v=Cqt4LjHnMEA

Practice and Application (time: 10 minutes)
Once students know each of the structures in the system, they should attempt to label them in a diagram of the human body. If computers are available for students, they can use the following interactive website. While labeling the parts, each student should work with a partner and take turns labeling a part and
explaining what it does. If computers aren't available, teachers can print out an unlabeled diagram and have students label each structure and explain what each structure does.

**SEE:** “Lung Animation”
www.kscience.co.uk/animations/lungs.swf

**Review and Assessment** (time: 10 minutes)
After learning about the circulatory and respiratory systems, the students will write or draw a response making a connection between them. (The David Blaine video will help them make this connection.) Students should be able to show in drawing or in writing that the circulatory and respiratory systems are connected because the circulatory system needs oxygen from the lungs to pump blood around the body and the respiratory system supplies the oxygen by getting oxygen from the air we breathe into our bloodstream. Students should share their responses with the class; the teacher should address any misconceptions.

## Lesson 4

### Digestive System

**Goal**
Students will illustrate and explain the parts and functions of the digestive system.

**Do Now** (time: 5 minutes)
Students will respond to the following question in writing or by talking to a partner:

Why do we eat?

Students should share their responses with the class.

**Hook** (time: 5 minutes)
The teacher should ask:

What do we get from the food that we eat?

Lead the class in a discussion about the energy and nutrients that we get from food. We only get this energy and nutrients because the digestive system breaks down the food into absorbable molecules.

**Presentation** (time: 15 minutes)
The teacher will describe the function of each of the major structures of the digestive system. Students should take two-column notes while the teacher is explaining the system. The left column should list the structures and the right column should explain the functions. If the teacher does not want to have students take two-column notes, s/he might ask students to create a flowchart that attempts to show the structures, their functions, and how they are connected.

Students and/or teachers can use the Biology textbook (pp. 875-881) and other available resources to define the function. These short videos can be used to supplement instruction, if desired.

**SEE:** “Digestive System, part 1”
www.youtube.com/watch?v=yIoTRGfcMqM
“Digestive System, part 2”
www.youtube.com/watch?v=pqgcE1aXGME
“Digestive System, part 3”
www.youtube.com/watch?v=jGme7BRkpuQ

**Practice and Application** (time: 10 minutes)

Once students know each of the structures in the system, they should attempt to label them in a diagram of the human body. If computers are available for students, they can use the following interactive website. While labeling the parts, each student should work with a partner and take turns labeling a part and explaining what it does. If computers aren’t available, teachers can print out an unlabeled diagram and have students label each structure and explain what each structure does.

SEE: “The Digestive System: Put the Digestive System back together”

**Review and Assessment** (time: 20 minutes)

Students should think about and explain in writing and illustrations how what they just learned about the digestive system connects to the circulatory system. They should be realizing now that all of these systems are interconnected and do not work in isolation. The teacher should make sure that students understand that food gets broken down into nutrients by the digestive system; the circulatory system then circulates those nutrients throughout the body. In order to get students to show this in drawing for writing, the teacher can ask students:

- How are the digestive system and circulatory system connected?
- What does the digestive system do to food?
- What does the circulatory system do once the digestive system is done digesting food?

**Note:** The extension activities for this lesson can be used to further students’ understanding of the digestive system and how our body uses the food that we eat.

**Extension**

Much of the conventional wisdom about diet and exercise is probably wrong. Students could explore these videos to learn more about dieting and exercising.

SEE: “Eat, Fast, and Live Longer”

“The Truth About Exercise”
vimeo.com/51836895

Students could also explore relationships between food and behavior.

SEE: “Impact of Healthy Food Part 1”
www.youtube.com/watch?v=OYG4V_hogzI
“Impact of Healthy Food Part 2”
www.youtube.com/watch?v=KWYPjpjBSgQ

The teacher might also want to show clips of the movie *Supersize Me* and *Food Inc.*
Lesson 5

Respiratory and Cardiovascular Systems Data Collection

**Goal**
Students will collect data on the respiratory system and cardiovascular systems. (They will more deeply understand the connection between the two systems after these next three lessons.)

**Do Now** (time: 5 minutes)
The student will write or discuss with a partner:
- What information might a doctor or nurse collect from a patient? What tools do they use to do this?
- What kind of information can you gather about your body without special tools?

Students will share their thoughts with the class.

**Hook** (time: 5 minutes)
The teacher will ask students:
- Why is it important for us to know these things about our bodies?

S/he will lead students in a discussion about how doctors use heart rate, oxygen saturation, blood pressure, and temperature as indications of health and to be able to understand and track changes in our bodies.

**Presentation** (time: 5 minutes)
In the “Do Now,” one of the students probably mentioned that people can feel their heartbeat or pulse.
The teacher should ask students:
- How do you figure out your heart rate?

Using the picture, show students how to find their radial pulse.

**Practice and Application** (time: 30 minutes)
Note: Students might have a difficult time finding their pulse, so this activity might take some time for students to complete. They should do each activity with a partner, if possible. The partner should use a timer while the other student keeps track of his/her pulse and breathing rate. Each student might want to do these activities twice to be sure of an accurate pulse and breathing rate. If the teacher would like to try a meditation activity with the students to get them to relax and rest as much as possible, s/he could do this first. A video that guides students through meditation can be found below.

**For Empower Your Future Connections, see pp. 4.25.1 to 4.25.2**
Heart Rate

- sit calmly for 30-60 seconds
- find your radial pulse
- take your radial pulse for 60 seconds (or 30 seconds and multiply by 2)
- record your pulse in BPM (beats per minute)

Note: A normal resting heart rate for adults ranges from 60 to 100 beats a minute. Generally, a lower heart rate at rest implies more efficient heart function and better cardiovascular fitness. For example, a well-trained athlete might have a normal resting heart rate closer to 40-60 beats a minute.
(From Mayo Clinic)

Breathing Rate

- sit calmly for 30-60 seconds
- record your relaxed breathing rate for 60 seconds (or 30 seconds and multiply by two)
- record your respiratory rate in BPM (breaths per minute)

Note: The typical respiratory rate for a healthy adult at rest is 12–16 breaths per minute.
(From Johns Hopkins)

Review and Assessment (time: 10 minutes)

The teacher will ask the class:

What do these numbers tell you about what is happening in your body?

Students should write their answers on notecards and pass them in before leaving. The teacher should review these notecards and use the responses to start the next class.

Extension

The teacher can do breathing exercises with students to show them the benefit of meditation, relaxation, and mindfulness. If students take their heart rates at the end of an extended meditation session, they will probably find that their heart rates and breathing are slower. They can explore how yogis can control their body functions.

Lesson 6

Respiratory and Cardiovascular Systems Data Analysis

Goal

Students will chart and analyze data from Lesson 5 to develop deeper understanding of the respiratory and cardiovascular systems.

Do Now (time: 5 minutes)

The teacher will show students a graph of an average person’s body temperature throughout the day. The teacher will ask students:

What is this graph telling you? Students will share their answers with the class.

SEE: “Biological Rhythms”

cnx.org/contents/tefy7E6c@6/What-Is-Consciousness
Hook (time: 5 minutes)
The teacher should ask:

What associations or conclusions can you draw about your activity and your temperature?

Teachers can use sentence frames such as:

When you are ____________________________, your body temperature is __________________________.
(When you are sleeping, your body temperature is decreasing.)

As you move throughout your day, your body temperature __________________________.
(As you move throughout your day, your body temperature increases.)

Presentation (time: 15 minutes)
The teacher will tell students that they will draw two bar graphs. One will show the class data for heart rate. The other will show the class data for respiratory rate. The teacher will explain how to make a graph and data table.

The teacher should make sure that the scale used on the y-axis is appropriate for the number of students in the class. The two graphs below show the same data, but since the y-axis range has changed from 0-8 to 0-100, the graph appears different.
**Practice and Application** (time: 25 minutes)

The students will create class data tables and graphs for respiratory rate and heart rate. To do this, they can use graph paper or, if available, computers. Teachers can show students how to input data into Excel and then create graphs based on that data. Students should make notes about what they notice in the charts.

For example:

What does the average heart rate seem to be?

Students can calculate a class average, an average by age, etc. The teacher can expand this lesson to include more mathematical problems in this way.

Does a person's heart rate seem to correlate with his respiratory rate in any way?

What might the correlation be?

**Note:** Students will see in the next lesson that heart rate and respiratory rate will both increase with exercise in order to meet the increased need for oxygen and fuel. Right now, they might notice that generally, the better physical condition someone is in, the more efficiently their organs work, so it would be reasonable to see a lower starting rate for both heart rate and respiratory rate in these students.

**Review and Assessment** (time: 5 minutes)

Students should share their graphs and conclusions with the class. Since everyone is graphing the same data, all graphs should looks similar. Students should correct any problems.

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**Lesson 7**

**Respiratory and Cardiovascular System Experiment (2 Days)**

**Goal**

Students will collect, graph, and analyze data to understand how exercise affects heart rate and breathing rate.

**Do Now** (time: 5 minutes)

The teacher should ask students to find their radial pulse and then walk rapidly around the room for 15 seconds, then find their pulse again. If the teacher is uncomfortable having students do this, students can rapidly circle their arms, jog in place, raise their arms rapidly over their heads and down again as if they are lifting weights, etc. The goal here is to have students notice that their heart rate increases with activity, so any movement that will raise the students’ heart rates will achieve this goal.

**Hook** (time: 5 minutes)

The teacher should ask students what happened and why. (They should realize that their heart rates increased.) The point of this qualitative opening activity is to make students aware of what they will find in the lab. Students will quantify what they realized in this quick activity.

**Presentation** (time: 45 minutes)

**Note:** To save time, the teacher might decide to divide the class into two groups. One group could collect data on how exercise affects heart rate and the other group could collect data on how exercise affects respiration.
The teacher will tell students that they will perform some exercises in the class and collect data on how the exercises affect heart rate and respiration.

The students will create a data table that looks like the example below.
As the activities that follow are performed, students will record the results in the data table.

<table>
<thead>
<tr>
<th></th>
<th>Starting Rate</th>
<th>Exercise Rate</th>
<th>Rest 1</th>
<th>Rest 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Students will take their starting heart and respiration rates after sitting calmly for 60 seconds.
(Starting Rate)

Students will then do some mild exercise for 60 seconds.
(running in place, jumping jacks, pushups, other exercises as deemed appropriate by the teacher)

Students will then be paired off.

When teacher says STOP, the exerciser will record her/his own heart rate.
(for 60 seconds)

While s/he is doing this, her/his partner will observe the exerciser's respiration rate and record data.
(Exercise Rate)

The students will rest for two minutes and record pulse and breathing again with a partner’s help.
(Rest 1)

Students will rest again for two minutes, and record pulse and breathing again with a partner’s help.
(Rest 2)

At the end of Day 1, the teacher should wrap up class with a closing activity such as an Exit Ticket. Students can write down one thing that they learned or a question that they have. Teachers should begin the next class by reviewing what was achieved the previous day.

**Practice and Application** (time: 35 minutes)
On Day 2, students will take the data from their charts (a completed chart will look similar to the example below) and create line graphs that show the correlation between heart rate and respiration rate.

<table>
<thead>
<tr>
<th></th>
<th>Starting Rate</th>
<th>Exercise Rate</th>
<th>Rest 1</th>
<th>Rest 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate</td>
<td>66</td>
<td>122</td>
<td>80</td>
<td>66</td>
</tr>
<tr>
<td>Respiration</td>
<td>15</td>
<td>36</td>
<td>18</td>
<td>15</td>
</tr>
</tbody>
</table>

The teacher might need to show students how to create a double line graph. It will look similar to the example that follows on the next page (p. 4.24.20).
Lesson 7: Practice and Application—related graphic

The information from the completed data chart example on the preceding page is depicted at right as a double line graph.

Review and Assessment (time: 20 minutes)

Students should look at their charts and draw conclusions. The teacher should ask students:

What happened here? What exactly had to happen in your body to do the activity?

Students will draw a diagram or make a flowchart to illustrate the process, or they may write a paragraph that explains what happened. When students are done drawing or writing, the teacher should ask students to share their conclusions, and the teacher should correct any misconceptions or question students’ thinking to get them to draw accurate conclusions.

The conversation that teachers will have with students should include the following information:

• The brain had to tell muscles to contract.
• As muscles contracted, they needed more fuel and oxygen (to burn that fuel) so the heart rate sped up.
• Blood delivered more oxygen and glucose for muscles to use in cell respiration (creating ATP).
• Muscles created carbon dioxide as a waste product of cell respiration; it was removed by blood and brought to the lungs to be released.
• Blood also cleared lactic acid building up in the muscles.
• All of this continues while there is increased activity (increased demand) and decreases during the resting phase.
Lesson 8

Feedback and Homeostasis

Goal
Students will explain how the body maintains homeostasis by using negative and positive feedback loops.

Do Now (time: 5 minutes)
Students will complete a quick write or diagram on the following prompts:
  What is the function of a thermostat? How does it work?

Note: If students do not know what a thermostat is, the teacher can show students a picture of one and explain its function in a home. A thermostat regulates the temperature of a home or room by turning on heat when the temperature drops too low or by turning on air conditioning when the temperature becomes too high.

Hook (time: 5 minutes)
The teacher should lead a brief follow-up discussion using the following questions:
  How does your body's thermostat work? How does your body react to being too hot?
  How does your body react to being too cold?

Presentation (time: 20 minutes)
The teacher will present various types of feedback loops to students.

The teacher can present these feedback loops to students in the form of an "educated guessing" game before explaining each feedback loop to students. The teacher could divide the class into two groups and pose questions to the students.

For example, the teacher might say:
  When a person is hungry and doesn’t have food to eat, what do you think our bodies do to keep us alive?

Students can discuss their thoughts with their group before answering the question. Students might make the educated guess that our metabolism slows down. The teacher will need to add more detail to student responses, but the students probably know more about our body’s responses, and therefore, feedback loops, than they realize. The teacher can draw on student’s prior knowledge first (probably with body temperature and metabolism since they have experienced being hot/cold and hungry), before asking them to “guess” about other feedback mechanisms.

Some notes for the teacher are provided below. These notes come from the following websites:

SEE: “Examples of Negative Feedback”
examples.yourdictionary.com/examples-of-negative-feedback.html

“Homeostasis: Positive and Negative Feedback Mechanisms”
anatomyandphysiologyi.com/homeostasis-positivenegative-feedback-mechanisms
Negative Feedback Mechanisms

Here are examples of negative biological feedback in humans:

- **Body temperature:** The hypothalamus of a human responds to temperature fluctuations and responds accordingly. If the temperature drops, the body shivers to bring up the temperature, and if it is too warm, the body will sweat to cool down through evaporation.

- **Metabolism:** When a human is hungry, metabolism slows down to conserve energy and allow the human to continue living with less food.

- **Blood sugar:** When blood sugar rises, insulin sends a signal to the liver, muscles, and other cells to store the excess glucose. Some is stored as body fat and some as glycogen in the liver and muscles.

- **Production of red blood cells (erythropoiesis):** A decrease in oxygen is detected by the kidneys and they secrete erythropoietin. This hormone stimulates the production of red blood cells.

Positive Feedback Mechanisms

A positive feedback mechanism is the exact opposite of a negative feedback mechanism. With negative feedback, the output reduces the original effect of the stimulus. In a positive feedback system, the output enhances the original stimulus.

- **Childbirth:** During labor, a hormone called oxytocin is released that intensifies and speeds up contractions. The increase in contractions causes more oxytocin to be released and the cycle goes on until the baby is born. The birth ends the release of oxytocin and ends the positive feedback mechanism.

- **Blood clotting:** Once a vessel is damaged, platelets start to cling to the injured site and release chemicals that attract more platelets. The platelets continue to pile up and release chemicals until a clot is formed.

Summary: positive feedback mechanisms enhance the original stimulus, and negative feedback mechanisms inhibit it.

Practice and Application (time: 15 minutes)

Students will complete the body temperature regulation organizer located on p. 4.26.2 in the Supplement with a partner. They will use the textbook as a resource to fill in any information that they are unsure of. The teacher might also give students some key phrases such as “blood vessels,” “shivering,” “sweat,” “heat loss,” etc. and tell students that these words should show up in the diagram.

*The Answer Key* for the organizer is provided in the illustration on next page (p. 4.24.23).

Review and Assessment (time: 10 minutes)

The teacher will ask students:

How is a feedback loop in play when you are exercising?

Students will write and draw their answers, explaining the feedback process.

(When a person is exercising, his or her muscles need a certain amount of oxygen to function. In order to meet the increased oxygen demand, the person has to bring in more oxygen, and the body has to move that oxygen from the lungs to the working cells. This has to continue until the need gets met.)
Lesson 8: Practice and Application—Answer Key

Body temperature FALLS

Blood vessels constrict so that heat is conserved. Sweat glands do not secrete fluid. Shivering (involuntary contraction of muscles) generates heat, which warms the body.

Body temperature RISES

Blood vessels dilate so that heat is lost to the environment. Sweat glands secrete fluid. As the fluid evaporates, heat is lost from the body.

Normal Body Temperature

Heat is retained

Heat is lost to the environment

The Body Temperature Regulation Organizer can be found in the Supplement on p. 4.26.2.
CULMINATING LESSONS

Includes the Performance Task, i.e., Summative Assessment—measuring the achievement of learning objectives

Lesson 9

Superbugs: Evolution and Disease (2 Days)

Goal
Students will draw their prior knowledge of evolution to explain the connection between evolution and disease. Students will explain the expectations of the Summative Assessment.

Do Now (time: 5 minutes)
Students should answer the following question in writing or with a partner:

Knowing what you know from yesterday’s lesson on homeostasis, how does disease affect homeostasis?

Hook (time: 5 minutes)
The teacher should lead a discussion of this topic:

Why do you think doctors often prescribe medications in 10-day doses? Why do they stress that you should complete all 10 days of the medication even if you are feeling better after five days?

Note: Even if a person is feeling better after five days, any resistant (“stronger”) bacteria that have not yet been killed by the antibiotic would still be lingering. If the person were to stop taking the antibiotic, resistant bacteria would reproduce and maintain the infection. Ten days gives the antibiotic enough time to kill more of the remaining resistant bacteria, at which time our own immune system will be able to deal with it.

Presentation (time: 70 minutes)
The teacher should give students the following excerpt (or a portion) of Superbug.

Note: This is quite a long excerpt, but Maryn McKenna is a great storyteller and her writing style is extremely engaging. The teacher will probably need to read it in sections, perhaps having students read aloud. Take the time to address any vocabulary students are having difficulty with. It may be useful to preview the vocabulary used in the portion selected for reading. It’s important to set the context for this emerging infection, (i.e., why do we care?) and the first chapter does that very well. It is also an opportunity to develop students’ reading skills for nonfiction texts, as recommended by the Common Core standards.

After reading the excerpt, the teacher should lead a discussion about how superbugs evolve and adapt in a relatively short amount of time.

The teacher will then explain to students that they will research an antibiotic-resistant infection, explain how that disease evolved, what the symptoms are, how it progresses, the treatment for it and long-term effects. They should also explore alternative treatments. Students will have to explain how this disease impacts one or more of the body systems. Stress that connections to the body systems should be made within the sections explaining the symptoms, progression, and long-term effects. Students should be
explicit about what body systems are affected and the consequences of the infection on that system, e.g. Zika virus (currently no vaccine) will cause a rash (integumentary system—skin) and joint pain (skeletal system) and in pregnant women, can lead to microcephaly (nervous system, abnormally small brains and often associated with developmental delays).

Students will create a flipbook or an accordion book to showcase their findings. (If the teacher would like to give students more options, students could do this same activity using Prezi or PowerPoint.) The teacher should have a sample flipbook or accordion book to show students. Directions for making the books can be found at:

SEE: “How to make flip-books”
www.makingbooks.com/stepbook.pdf
“How to make accordion books”
www.makingbooks.com/accordion.pdf

Note: his portion of the lesson will span two days. On Day 1, the teacher will need to decide how to wrap up the learning activity, depending on how far the reading and instruction have progressed. Students might complete a 3, 2, 1 activity in which they write down three interesting things they learned from reading Superbug, two questions that they have about the reading, and one new vocabulary word that they learned. The teacher should begin the next day’s lesson by reviewing the reading and answering questions that arose from the previous day’s Exit Ticket.

Possible superbugs for students to research can be found at:

SEE: www.everydayhealth.com/pictures/scary-drug-resistant-infections

Practice and Application (time: 20 minutes)
The teacher will lead students in a discussion of how they will be assessed on this final project. The teacher can also ask students to brainstorm what elements a perfect product would contain, and the teacher and students should co-create a rubric that will assess the completed project and presentation. Scientific accuracy, proper vocabulary, and satisfying each of the requirements should be included on the rubric. It should also specify that the product should graphically engage the audience and contain data from reputable sources that answers students’ questions. Students will discuss what criteria should be on the rubric for the presentation of the flipbook or accordion book. The teacher may also lead the class in a discussion of what research questions to ask. For example:

How did the disease evolve? What are the symptoms? How does it progress? What is the treatment?

Students might want to research more questions, so more questions could be added to the assessment and therefore, the rubric. For the presentation, students should be able to explain the product to an audience in clear and accurate language.

Review and Assessment (time: 10 minutes)
Students will work with the teacher to create the rubric based on the criteria they brainstormed. Point values should be assigned to each category based on importance. (For example, visual appeal shouldn’t be 50 points while scientific accuracy is 5 points.) The website below might help teachers create this rubric with the class.

SEE: rubistar.4teachers.org
Lesson 10
Superbug Research (2 Days)

Goal
Students will find and take notes on scientifically accurate information on the internet that addresses their research questions.

Do Now (time: 5 minutes)
The students will respond to the following question in writing or through discussion with a classmate:

Do you believe everything that you read on the internet? Why or why not?

Hook (time: 15 minutes)
Note: If students were not in the classroom during the Inheritance: Implications and Applications unit when students learned to conduct research, the teacher should teach the following background knowledge necessary to do accurate research. If students were present, a shorter review could be used than the one that follows.

The teacher should choose a website that appears to be legitimate science, but isn’t, like the example below. Students should examine the website, determine whether or not they think it is credible, and explain why.

SEE: zapatopi.net/treeoctopus

Presentation (time: 10 minutes)
The teacher should lead the class in a discussion of how to determine whether a website is credible and unbiased. S/he can provide students with these suggestions from the University of Wisconsin Green Bay:

SEE: https://uknowit.uwgb.edu/page.php?id=30276

Author: Information on the internet with a listed author is one indication of a credible site. The fact that the author is willing to stand behind the information presented (and in some cases, include his or her contact information) is a good indication that the information is reliable.

Date: The date of any research information is important, including information found on the internet. By including a date, the website allows readers to make decisions about whether that information is recent enough for their purposes.

Sources: Credible websites, like books and scholarly articles, should cite the source of the information presented.

Domain: Some domains such as .com, .org, and .net can be purchased and used by any individual. However, the domain .edu is reserved for colleges and universities, while .gov denotes a government website. These two are usually credible sources for information (though occasionally a university will assign a .edu address to each of its students for personal use, in which case use caution when citing). Be careful with the domain .org, because .org is usually used by non-profit organizations, which may have an agenda of persuasion rather than education.
Site Design: This can be very subjective, but a well-designed site can be an indication of more reliable information. Good design helps make information more easily accessible.

Writing Style: Poor spelling and grammar are an indication that the site may not be credible. In an effort to make the information presented easy to understand, credible sites watch writing style closely.

Of course, there may be some reliable websites that do not include all these qualities. If you are unsure whether the site you’re using is credible, verify the information you find there with another source you know to be reliable, such as an encyclopedia or a book on the subject. The kind of websites you use for research can also depend on the topic you are investigating. In some cases it may be appropriate to use information from a company or non-profit organization’s website, such as when writing an industry or company overview.

Practice and Application (time: 75 minutes)

Students will conduct research that answers the questions posed in the prompt. The teacher should create a graphic organizer for students to use that will guide students through the research process and will help them address each strand of the rubric that the class created. As students are conducting their research, the teacher should ask students to list the sources that they are using to answer their research questions. This way, the teacher can check in with students to make sure that they are finding their information from credible sources. If the teacher notices that a student’s sources are not credible, it should be addressed immediately so that the student doesn’t include that information in his final project.

Here is a list of possible infections for students to research:

SEE: www.everydayhealth.com/pictures/scary-drug-resistant-infections

Note: Be sure that students are understanding through their research how antibiotic-resistant infections evolve and how the infection affects the body system(s). This Performance Task asks students to make a connection between standard HS-LS1-9(MA) and HS-LS1-2. The teacher should be monitoring the work and checking in with each student to help guide research.

LESSON TIPS:
This lesson will take place over two days. Students likely will be in the middle of their research when Day 1 of this lesson ends. The teacher should wrap up class by asking students if they have any questions or by asking them to list interesting information that they found. The teacher will want to begin the next class by reviewing the expectations of the lesson and allowing students to continue with their research.

Review and Assessment (time: 5 minutes)

Students will write down any questions that they have (especially if they know that they need information that they couldn’t find) and three interesting facts that they learned. The teacher should review these before the next class.
Lesson 11

Superbug Publications and Presentations (3 Days)

Goal

Students will create their flipbooks or accordion books and present them to the class.

Do Now (time: 5 minutes)

Students will do a “whip around” in which each student rapidly shares one interesting fact that s/he learned about the infection s/he is researching. (If there are not enough students in the classroom to perform this activity, the student can write down one interesting fact that s/he learned and wants to include in the book s/he is creating.)

Hook (time: 10 minutes)

The teacher shows students an example of a flipbook or accordion book and explains how to create a flipbook or accordion book using the following websites.

SEE: “How to make flip-books”
www.makingbooks.com/stepbook.pdf
“How to make accordion books”
www.makingbooks.com/accordion.pdf
“Making books” (general bookmaking information)
www.makingbooks.com/step.shtml

Presentation (time: 5 minutes)

The teacher should review the rubric with students and discuss the expectations set forth in the assignment.

Practice and Application (time: 90 minutes)

The students will create their books. After students are done researching their topics, they should think about how they are going to organize the information that they found. They might decide to organize the information into a “Question and Answer” format, where questions are visible to the viewer and when the page is lifted, an answer is shown. For example, a question on the flipbook might say, “Which body systems are affected by this superbug?” When the page is lifted, an explanation of which systems are affected is there. The teacher should brainstorm other ways to organize the researched information into the books.

Regardless of how they choose to organize their information, students should make drafts of their books before they make their final copies. The teacher should check each student’s draft to make sure that each student is including all of the relevant information to meet the standards of this unit. If a student is not meeting the requirements, the teacher should direct the student to the class-generated rubric so that the student can do a self-assessment of what might be missing. The teacher should circulate throughout the room to check in with students and answer any questions. The teacher should remind students that the graphics they are using need to show/support the data that they researched. The goal of this assignment isn't just to make an eye-catching book, but to convey a message and information.
When students think that they have finished the project, they should use the rubric that they created to make sure that they have met the criteria on the rubric.

**Note:** Since this lesson is taking place over three days, the teacher will want to make sure that each day’s lesson includes a wrap-up activity, perhaps asking students what their plans are for the following day and to list what they accomplished during that day’s lesson. The teacher will want to start each day by reviewing expectations and answering any questions that students have.

**Review and Assessment** (time: 55 minutes)

Students will practice presenting their work with a partner. The partner will use the rubric to give feedback to the presenter. The presenter will have ample time to fix anything that needs to be addressed before presenting the project to the class. The teacher should make sure that enough time is given for this process.

**Note:** Time will need to be adjusted depending on the number of students in the class, but the teacher should allow for plenty of time for practice and revision.

After students have time to practice their presentations, they will present to the class. Students will have time at the end of each presentation to ask any clarifying questions of the presenter. Students should score each presenter based on the class-generated rubric. The teacher should collect these peer assessments and review them before giving them to each presenter.

After looking at the peer assessments and teacher assessment, each student should complete a reflection on what they learned, what they did well, and what they could have improved upon if they had to do this project again.

**Extension**

Frontline documentary: *Hunting the Nightmare Bacteria.*

**SEE:** www.pbs.org/wgbh/frontline/film/hunting-the-nightmare-bacteria
POST–UNIT REFLECTION

On meeting the Learning and Language objectives
Connections to Empower Your Future
UNIT: The Amazing You—More Than Just Parts

Future Ready Connections

This unit provides many opportunities to help youth improve and be assessed on Future Ready skills. Youth have many opportunities to strengthen their communication skills through group discussions, partner work, and a presentation for the Performance Task (create flipbooks and present on a specific antibiotic-resistant infection). Youth must also take the initiative to complete research, complete the practice and application activities that require labeling of system's structures, and make personal connections to the material. Students are encouraged throughout the unit to work together to make discoveries and answer each other's questions which encourages youth to be accountable to themselves and each other for their knowledge and success. The Performance Task and practice and application activities are good opportunities to evaluate students on their accountability for completing tasks thoroughly and actively engaging in critical thinking and reflection. The practice and application activities in Lessons 6 and 7 are especially useful for assessing productivity because youth must analyze data and generate graphs.

Teachers should emphasize that the activities help develop important Future Ready skills (such as the ability to analyze and interpret data, synthesize and summarize information, and visually represent data) that will carry over to future experiences and jobs.

Teachers are encouraged to use the Future Ready Rubric to evaluate students and are encouraged to support students as they self-evaluate their demonstration of Future Ready skills.

Emphasized Standards

Standard HS-LS1-3 requires that youth be able to provide evidence that feedback mechanisms promote or inhibit activities through positive and negative feedback in order to maintain homeostasis in an organism.

Lesson 8 specifically addresses this standard and teachers can connect this concept to Future Ready experiences and EYF lessons by discussing how in our personal relationships, academic settings, and professional lives we receive feedback and must know how to accept it and respond to it. Teachers should consider asking youth: How do you like to receive feedback or constructive criticism from someone? How do you use that feedback to make positive changes? What if you disagree with that feedback? What is an example of positive and negative reinforcement?

Essential Questions and Transfer Goal Connections

The Essential Questions from this unit address the following: How does the human body work? How do the body systems work together to maintain good health? How does the body regulate itself? Why do living things “get sick”?

These questions address the idea that humans are adaptable and resilient and use many resources and techniques to maintain a healthy body and mind. This ties into EYF lessons that discuss both physical health (through diet and exercise) and mental health (through optimism, coping strategies, using appropriate support systems and utilizing resources). Teachers can ask students to discuss: How do you maintain good physical and mental health? How do you regulate your emotions and physical health when you are under stress?

Teachers can also make EYF and Future Ready skills connections to the following Transfer Goal:
Students will evaluate how interaction and interconnection are evident in all aspects of their lives. Just as our body systems interact and are interconnected; nothing works in isolation.

The Essential Questions and the Transfer Goal emphasize that multiple systems and elements play a role in maintaining a healthy mind and body, which ties into the concept that our lives are also built from multiple systems and elements (personal, academic, and professional) that interact and build on each other. Just like the systems in the human body, our personal, academic, and professional worlds must work together in order to support the development of a successful and happy life. When one system is weakened or stressed, then the other systems are affected as well and must react to help regain control and stability. For example, if we are struggling in our academic system, then that can affect our personal system (stress, anxiety, impact on relationships), and potentially affect our professional system (goal setting, skill building, and attainment of goals). Teachers can ask students to reflect on how these three systems in their lives interact and what they can do when one system is not functioning properly and is putting strain on the other systems. What can they do? How can they regain homeostasis in their lives by getting these systems to work together effectively?

**PYD/CRP Connections**

This unit reflects Culturally Responsive Practice and Positive Youth Development by providing opportunities for academic exploration, activating prior knowledge (Do Now prompts and Hooks), and self-reflection. In the Performance Task, youth have the option to not only pick a topic for their presentation, but also to determine how the task will be evaluated and assessed (developing a rubric and expectations).

**Encouraging youth to actively participate in how they will be assessed allows for a sense of ownership, empowerment, and accountability.** The activities throughout the unit also encourage youth to make personal connections to the material by reflecting on the changes in their own bodies when they stress one of their systems. Youth can also reflect on how their cultures (home, friends, etc.) encourage or discourage certain reactions to receiving constructive feedback.

**Lesson 5 Connections**

Lesson 5’s Hook encourages students to understand that it is important for people to identify their baseline so that they can monitor for change. This concept of tracking information and monitoring for change or growth ties into both Future Ready skill assessment and EYF lessons. Just as we must monitor for changes in the body, we must also monitor for changes in behavior, ability, and understanding to promote healthy and consistent growth and progress. Teachers can have students self-assess several times over an extended time period (whole unit, several weeks, etc.) using the Future Ready Rubric and help them track this information like data doctors would collect. How have they changed? What does this mean? Many EYF lessons focus on goal setting and documenting personal information (MassCIS self-evaluations, values clusters, skills inventories) which students can revisit, track, and analyze like data. Students should reflect on what any changes may mean and what next steps are needed to act on this new data.
## Organ System Word Sort

### Lesson 1

**DIRECTIONS:** Cut out all boxes and give to students. Have students re-arrange cards into categories/systems.

<table>
<thead>
<tr>
<th>Organ Systems</th>
<th>Larynx</th>
<th>Capillaries</th>
<th>Salivary glands</th>
<th>Rectum/Anus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory</td>
<td>Trachea</td>
<td>Bronchi</td>
<td>Lungs</td>
<td>Large Intestine (colon)</td>
</tr>
<tr>
<td>Digestive</td>
<td>Mouth</td>
<td>Esophagus</td>
<td>Stomach</td>
<td>Small Intestine</td>
</tr>
<tr>
<td>Circulatory</td>
<td>Heart</td>
<td>Arteries</td>
<td>Veins</td>
<td>Blood</td>
</tr>
</tbody>
</table>
Body Temperature Regulation

Lesson 8

**DIRECTIONS:** Complete the body temperature regulation organizer.

The answers for blank boxes are on p. 4.24.23.

Adapted from a diagram found at: https://cnx.org/contents/04fdb865-17a1-43d8-bb33-36f821ddd119@7."
# Chapter 5: Chemistry

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<td>Supplement</td>
<td>5.6.1</td>
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<td>Reaction Rates and Equilibrium—Season Introduction/Adaptation ....</td>
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<tr>
<td>UNIT PLAN</td>
<td>Why and How Chemicals React</td>
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<tr>
<td>Empower Your Future</td>
<td>5.9.1</td>
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<tr>
<td>Supplement</td>
<td>5.10.1</td>
</tr>
</tbody>
</table>
Introduction to Chemistry
Does a subject as complex as Chemistry have to be difficult to teach?

Introduction
Chemistry Teacher’s first day of school (enthusiastically, and with a smile): “Who likes chemistry!”

The inevitable response: Collective groan, some grumbling, and a few well-recycled anecdotes that include explosions.

Chemistry Teacher’s follow up question: “What is chemistry?”

Wait for it: “Complicated formulas that never balance”; “bubbling test tubes”; “old guys with wacky goggles.”

Chemistry Teacher shakes her head at the wearisome stereotypes and soldiers on: “What is chemistry—really? Have you ever seen chemistry happen?”

Suddenly the floor is looking very interesting to the former experts; however, the class clown has an idea. “I saw chemistry once—my mom spilled some bleach and now the cat’s tail is white!” Chuckles, elbows, winks from peers. Ha ha, what a jokester, but a way in ...

“So, tell me more about your cat’s tail.”

“Well, my mom was pouring bleach into that little cap and I bumped her …”

Others in the class are not going to miss this opportunity:
“I use bleach in my hair!”
“Gramma says bleach is the only thing to clean floors with.”
“My friend’s boyfriend’s uncle almost died mixing bleach and ammonia.”
“Freshman year we learned about coral bleaching!”
“Is that really bleach tied to the stems of my prom corsage?”
“Okay, class. Is bleach a chemical? How do you know? Can anyone summarize what we learned about bleach? So … what is chemistry? Why do you think we are studying it?”

Even when students do not acknowledge it, they know more about chemistry than they think or are willing to admit. It is important to “set the hook” and delve into what they have been exposed to by television, the internet, and former well-intentioned students. Once there is buy-in, misconceptions can be clarified, and a rich discussion on the benefits of studying the sciences can commence.

As demonstrated above, chemistry is part of our everyday existence—all day, every day. So, what is it? According to Dictionary.com, chemistry is the science that deals with the composition and properties of substances and various forms of matter. What does that have to do with living the life of a productive citizen? Do students really need to study it? That exact concern was fielded by the Washington Post when a Maryland father wrote in that his son had no interest in taking chemistry, but it was a mandated part of the curriculum. “Students shouldn’t have to take chemistry if they don’t want to,” was the father’s perspective.

Mandated interest seems something of an oxymoron, but let’s investigate.

“… chemistry is part of our everyday existence—all day, every day.”
In the household, chemical reactions can be seen in cooking, crafts, cleaning, and medicines. As for careers, technology is exploding at a staggering rate. Workers who have the ability to solve problems, understand systems, and create new products will have tremendous advantage over those “who had no interest.” Industry leaders and environmental scientists, but also chefs and painters—each of them will use advanced technologies pulled from the minds of students who studied subjects like 3-D bioprinting, genomics, nanotechnology, and chemistry.

**Chemistry Course Content**

3-D bioprinting and nanotechnology may seem esoteric in a discussion about mandated high school courses, but they foreshadows a future that will be more complex, challenging, and connected. The Commonwealth of Massachusetts has recognized that reading, writing, and thinking skills are changing as more of the world has access to the internet, chat rooms, mobile apps, and computer programs. It is no longer satisfactory for teachers to lecture, assign conventional writing tasks, and rely on evaluations that test rote memory. Observing, researching, computing, and analyzing are the operative words used repeatedly in the Next Generation Science Standards (NGSS). In the effort to help students become future-ready and to align with Science, Technology, Engineering, and Mathematics (STEM) goals, Massachusetts has raised the bar in science education. The pedagogical approach to creating successful students has shifted away from passive learning to active, sustained engagement and creation of authentic products. This shift will produce not just better science students—more grounded in scientific concepts and methods—but also more engaged students. *Those experiments maybe seem a tiny bit cool. (But, moles, really?)*

About those moles: Even with the shifts in science education, there are too many topics to “cover” adequately in a single year of high school chemistry. Which ones should be emphasized? In preparing the scope and sequence for this Chemistry course, the
INTRODUCTION TO CHEMISTRY

Reaction Rates and Equilibrium will integrate Le Châtelier’s principle into chemical systems. Students will recognize the importance of equilibrium in natural systems, including the human body.

This season includes units on collision theory and Le Châtelier’s principle.

Acids and Bases will investigate the influences acids and bases have on the body and the environment. Students will apply this understanding to problems ranging from health to gardening.

This season includes units on the specifics of pH and neutralization reactions.

Oxidation/Reduction Reactions will prompt research on the properties of electrons. Students will analyze and design substances that can produce electricity.

This season includes units on reaction models and electron transfer.

Teaching Chemistry in DYS Schools

Does a subject as complex as chemistry have to be difficult to teach? The core knowledge of the subject can seem as obscure as it is ubiquitous and as minute as it is expansive. Like matter, it takes different forms. However, mixing up what students bring to the class, introducing new ideas and concepts, and adding some “How did you do that?” moments is enough to get a reaction and foster engagement.

The two exemplar chemistry units in this Guide showcase techniques that will allow students to acquire skills necessary to compete in the 21st century global economy. The lessons have been designed to fulfill the ideals of NGSS: think critically, use technology, work collaboratively, and communicate effectively.

For example:

- Discuss: how ammonia is important to your health
- Predict: the impact of using alternatives to fossil fuels in making electricity
- Design: show Le Châtelier’s principle using an Alka-Seltzer reaction
- Collaborate: work with a partner to create an original chemistry game to review key concepts
- Present: design a poster showing ratios or a PowerPoint demonstrating reaction rates
- Use technology: Experiment with Gizmos to balance equations or research atomic orbitals.

With respect to the diversity in the DYS community, multiple paths to success have been provided. The lessons incorporate Universal Design for Learning (UDL) principles and include differentiated assignments for youth who may have been frustrated by repetitious and mechanical instruction or who expect failure. Here, concepts are presented in small, meaningful chunks that work progressively toward a cumulative appreciation for problems using the periodic properties of elements, the six seasons of Chemistry will lead students to discoveries that will build the confidence needed to succeed in the modern science classroom.
“It is no longer satisfactory for teachers to lecture, assign conventional writing tasks, and rely on evaluations that test rote memory.”

the vocabulary, theories, and experiments supporting the science and scientists of chemistry. In addition, units have been organized to complement Massachusetts’ Literacy, Mathematics, Earth and Space Science, Biology, Physics, and Technology/Engineering standards. Providing students with a comprehensive science education and incorporating challenges with opportunities to shine is the intent of the exemplar units and lessons.

Additional Information

Many students may require additional background information and supplementary materials. Although the exemplar units provide many websites to support learning, the teacher may find additional material online that is appropriate for particular students. These include Gizmos at ExploreLearning.com, Kahn Academy, and Bozeman Science, all of which are accessible in DYS classrooms.

In addition, there are many print materials that can supplement the Chemistry textbook. Dr. Birdley Teaches Science graphic texts, all by Nevin Katz (Incentive Publications) are very accessible. These books should be in all programs, and they can be used both to introduce and to supplement the chemistry units. Another graphic text that may be worth purchasing for the program is called The Cartoon Guide to Chemistry by Larry Gonick. It covers material that is a little more complex, but will probably be appreciated by students of a more literary bent.

There are a number of products by Theodore Gray that are wonderful for visual and kinesthetic learners, and they all emphasize how elements are used in everyday life to create products we all use. See the Works Cited section for product details.

works Cited


Reading the Chemistry Scope and Sequence Chart

The amount of information contained in the Scope and Sequence on the following pages may seem overwhelming at first. The best way to study it is to read across from left to right. The keys in both the left and right hand columns below on this page offer guidance on how to properly access the Scope and Sequence Chart on pp. 5.2.2 to 5.2.5.

The Scope and Sequence is COLOR-CODED. Each color is important, and its meaning is described in detail in the key in the LEFT column below. The key in the RIGHT hand column below is information you will see in the first column in the Scope and Sequence. This key lists out the chemistry topics (seasons) and the approximate timeframe in which they may be taught during the academic year.

Emphasized Standards listed with an asterisk (*) in the Scope and Sequence are utilized in units in this Guide.

### Scope and Sequence Chart Key

- **The GREEN columns provide the focus for each season. This focus includes the title, timeframe, Essential Questions, and Emphasized Standards.**
- **The BLUE column indicates the Pearson Chemistry textbook sections that apply to the topic and timeframe.**
- **The GOLD column indicates the ELA and Math standards that are connected or could be connected to the Topic/Season indicated.**
- **The RED column indicates other science disciplines that are connected to the Topic/Season indicated.**
- **The PURPLE column indicates possible Performance Tasks which can be used during the Topic/Season indicated.**
- **The GRAY row across the bottom indicates Crosscutting Science Concepts that should be emphasized throughout the entire subject year.**

### Chemistry Topics (Seasons)

<table>
<thead>
<tr>
<th>Topic/Season</th>
<th>Timeframe</th>
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<tbody>
<tr>
<td>The Physical Nature of Matter</td>
<td>SEPTEMBER TO MID-OCTOBER</td>
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<tr>
<td>Atomic Structure and Periodic Table Trends</td>
<td>MID-OCTOBER TO NOVEMBER</td>
</tr>
<tr>
<td>Chemical Reactions: Bonding and Balancing</td>
<td>DECEMBER TO JANUARY</td>
</tr>
<tr>
<td>Reaction Rates and Equilibrium</td>
<td>FEBRUARY TO MARCH</td>
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<tr>
<td>Acids and Bases</td>
<td>APRIL TO MID-MAY</td>
</tr>
<tr>
<td>Oxidation/Reduction Reactions</td>
<td>MID-MAY TO JUNE</td>
</tr>
</tbody>
</table>
### Chemistry Topics

<table>
<thead>
<tr>
<th>Period</th>
<th>Topic</th>
<th>Essential Questions</th>
<th>Emphasized Standards</th>
<th>Pearson Chemistry Textbook Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>September to November</td>
<td>The Physical Nature of Matter</td>
<td>How do we put chemicals to work for us? How do we classify matter, and why does it matter? Why does sugar dissolve in water, but oil and water don’t mix? How do attractions between atoms and molecules become unique chemical properties? How are substances identified?</td>
<td>HS-PS1-11(MA). Design strategies to identify and separate the components of a mixture based on relevant chemical and physical properties. HS-PS2-7(MA). Construct a model to explain how ions dissolve in polar solvents (particularly water). Analyze and compare solubility and conductivity data to determine the extent to which different ionic species dissolve.</td>
<td>Chapter 2: 34-47 (chemicals and compounds)</td>
</tr>
<tr>
<td>Mid-October to November</td>
<td>Atomic Structure and Periodic Table Trends</td>
<td>How can the periodic table be used to predict the properties of elements, including as yet undiscovered elements? Why is atomic number better than atomic mass for organizing elements? Why does size increase from top to bottom, but decrease from left to right? Why do electrons affect the shape of a molecule?</td>
<td>HS-PS1-1. Use the periodic table as a model to predict the relative properties of main group elements, including ionization energy and relative sizes of atoms and ions, based on the patterns of electrons in the outermost energy level of each element. Use the patterns of valence electron configurations, core charge, and Coulomb’s law to explain and predict general trends in ionization energies, relative sizes of atoms and ions, and reactivity of pure elements. HS-PS1-2. Use the periodic table model to predict and design simple reactions that result in two main classes of binary compounds, ionic and molecular. Develop an explanation based on given observational data and the electronegativity model about the relative strengths of ionic or covalent bonds. HS-PS1-3. Cite evidence to relate physical properties of substances at the bulk scale to spatial arrangements, movement, and strength of electrostatic forces among ions, small molecules, or regions of large molecules in the substances. Make arguments to account for how compositional and structural differences in molecules result in different types of intermolecular or intramolecular interactions.</td>
<td>Chapter 6: 158-185 (periodic table) Chapters 7 and 8: 192-253 (ionic and covalent bonding)</td>
</tr>
<tr>
<td>December to January</td>
<td>Chemical Reactions: Bonding and Balancing</td>
<td>How are chemical bonds similar to the relationships between people? How do you know a chemical reaction is occurring? Why do some atoms form chemical bonds to form stable compounds while others do not? When are two atoms likely to form a double or triple bond? Why are recipes important in science? What happens if we don’t use cooking ingredients in the right proportion?</td>
<td>HS-PS1-4. Develop a model to illustrate the energy transferred during an exothermic or endothermic chemical reaction based on the bond energy difference between bonds broken (absorption of energy) and bonds formed (release of energy). *HS-PS1-7. Use mathematical representations and provide experimental evidence to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. Use the mole concept and proportional relationships to predict the quantities (masses or moles) of specific reactants or products. HS-PS2-6. Communicate scientific and technical information about the molecular-level structures of polymers, ionic compounds, acids and bases, and metals to justify why these are useful in the functioning of designed materials. HS-PS3-4b. Provide evidence from informational text or available data to illustrate that the transfer of energy during a chemical reaction in a closed system involves changes in energy dispersal (enthalpy change) and heat content (entropy change) while assuming the overall energy in the system is conserved.</td>
<td>Chapter 11: 344-373 (chemical reactions) Chapter 12: 382-418 (stoichiometry) Chapter 17: 554-577 (heat and energy)</td>
</tr>
</tbody>
</table>

### Cross-Cutting Concepts

<table>
<thead>
<tr>
<th>Patterns</th>
<th>Cause and Effect</th>
<th>Scale, Proportion, and Quantity</th>
<th>Systems and System Models</th>
</tr>
</thead>
</table>
### Chapter Contents

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<tr>
<th>Connections to Literacy and Math Standards</th>
<th>Connections to Other Science Disciplines</th>
<th>Performance Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELA Season 1 standards:</td>
<td>Earth and Space Science:</td>
<td>Give detailed instructions about how to separate a mixture you make.</td>
</tr>
<tr>
<td>W1. Write arguments</td>
<td>Similarities and/or differences of terrestrial and extraterrestrial compounds</td>
<td>Determine what properties you would use to separate two or more substances, and explain why you chose a particular process for separation. (Pearson Chemistry 41)</td>
</tr>
<tr>
<td>R1. Cite textual evidence</td>
<td>Biology:</td>
<td>Make flashcards for the major elements and use them to create molecules (Pearson Chemistry 45)</td>
</tr>
<tr>
<td>Related Math standards:</td>
<td>Properties of carbon as a building block of organisms</td>
<td></td>
</tr>
<tr>
<td>G-CO.12. Make formal geometric constructions with a variety of tools and methods</td>
<td>Physics, Technology/Engineering:</td>
<td></td>
</tr>
<tr>
<td>A-CED. Create equations that describe relationships</td>
<td>Functionality and environmental impacts of plastics, glass, and aluminum as beverage containers</td>
<td></td>
</tr>
<tr>
<td>S.ID.1. Summarize and interpret data</td>
<td>Biology:</td>
<td></td>
</tr>
<tr>
<td>ELA Season 1 standards:</td>
<td>Impact of free radicals on aging and health</td>
<td></td>
</tr>
<tr>
<td>R2. Determine central ideas</td>
<td>Physics:</td>
<td>Create a board game about atomic structure vocabulary and concepts that follows the rules of periodic trends.</td>
</tr>
<tr>
<td>Related Math standards:</td>
<td>Physical laws followed by carbon, hydrogen, and oxygen atoms</td>
<td></td>
</tr>
<tr>
<td>N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems</td>
<td>Technology/Engineering:</td>
<td></td>
</tr>
<tr>
<td>S.ID.1. Summarize and interpret data</td>
<td>Modeling of polar molecule and connections to polarity in other fields (e.g., politics)</td>
<td></td>
</tr>
<tr>
<td>F.LE.1a,b,c. Construct and compare models to solve problems</td>
<td>Biology:</td>
<td></td>
</tr>
<tr>
<td>Earth and Space Science, Physics:</td>
<td>Comparison of calorie consumption in space and on earth</td>
<td></td>
</tr>
<tr>
<td>Structure and Function</td>
<td>Relationship of metabolism to chemical reactions in the cell</td>
<td></td>
</tr>
<tr>
<td>Stability and Change</td>
<td>Chemical fire extinguishers</td>
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<tr>
<td>Energy and Matter</td>
<td>Use knowledge of stoichiometry to calculate and report on the carbon emissions of different fuels burned to create electricity.</td>
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<tr>
<td>Conservation of energy and matter, energy lost as heat thermochemistry, transfer of energy through changes of matter</td>
<td>Identify chemical reactions in foods—fried eggs, soda, bread dough. (Pearson Chemistry 355). Develop a model showing the energy transfer in the food reactions (heating food, carbonation, yeast fermentation).</td>
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<tr>
<td>Structure and Function</td>
<td>Write an essay about being an unbalanced equation (being the limiting reagent). Explain the situation from a reactant’s point of view.</td>
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<td>Basic principles of atomic structure and how it affects function</td>
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### Chapter Contents

**SCIENCE | Chemistry, Chapter 5**

#### SCOPE AND SEQUENCE

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<td><strong>Reaction Rates and Equilibrium</strong></td>
<td>What happens if plants don’t get enough sunlight and water? Why is it important, in chemistry and in life, for things to balance? How is the balance in chemical systems like homeostasis? Why and how do outside forces affect chemical reactions? How can we control chemical reaction rates in the kitchen, in our cars, or at work?</td>
<td><em>HS-PS1-5</em>. Construct an explanation based on collision theory for why varying conditions influence the rate of a chemical reaction or a dissolving process. Design and test ways to alter various conditions to influence (slow down or accelerate) rates of processes (chemical reactions or dissolving) as they occur. <em>HS-PS1-6</em>. Design ways to control the extent of a reaction at equilibrium (relative amount of products to reactants) by altering various conditions using Le Châtelier’s principle. Make arguments based on collision theory to account for how altering conditions would affect the forward and reverse rates of the reaction until a new equilibrium is established. HS-PS2-6. Communicate scientific and technical information about the molecular-level structures of polymers, ionic compounds, acids and bases, and metals to justify why these are useful in the functioning of designed materials. HS-PS2-8(MA). Use kinetic molecular theory to compare the strengths of electrostatic forces and the prevalence of interactions that occur between molecules in solids, liquids, and gases. Use the combined gas law to determine changes in pressure, volume, and temperature in gases.</td>
<td>Chapter 18: 594-620 (rates of reaction)</td>
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<tr>
<td><strong>Acids and Bases</strong></td>
<td>What are the essential components of acids and bases that make them similar and different? Why is it important to monitor pH? Why is acid rain a concern for us? How does the strength of an acid or base determine its impact on a reaction?</td>
<td>HS-PS1-9(MA). Relate the strength of an aqueous acidic or basic solution to the extent of an acid or base reacting with water as measured by the hydronium ion concentration (pH) of the solution. Make arguments about the relative strengths of two acids or bases with similar structure and composition.</td>
<td>Chapter 19: 644-676 (acids and bases)</td>
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<td><strong>Oxidation/Reduction Reactions</strong></td>
<td>How can electrochemistry work for us? What properties of electrons can you assume from an oxidation-reduction reaction? Does your body rust or corrode? Could there be life without reduction or oxidation reactions?</td>
<td>HS-PS1-10(MA). Use an oxidation-reduction reaction model to predict products of reactions given the reactants, and to communicate the reaction models using a representation that shows electron transfer (redox). Use oxidation numbers to account for how electrons are redistributed in redox processes used in devices that generate electricity or systems that prevent corrosion.</td>
<td>Chapters 20: 690-715 (reduction and oxidation)</td>
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### Cross-Cutting Concepts

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### ELA Season 3 standards:
- W2. Write explanatory texts
- R9. Compare related texts

### Related Math standards:
- N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems
- A-CED. Create equations that describe relationships
- S.ID.1. Summarize and interpret data
- A-SSE.1.a. Interpret parts of an expression, such as terms, factors, and coefficients

### Earth and Space Science, Physics:
- Global warming and/or the hole in ozone layer

### Biology:
- Diet and metabolism

### Technology/Engineering:
- Adjustments needed to make recipes work at high altitudes (measurements, baking times, baking temperatures)

### ELA Season 4 standards:
- W7. Conduct research
- R8. Evaluate arguments

### Related Math standards:
- N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems
- A-CED. Create equations that describe relationships
- S.ID.1. Summarize and interpret data
- A-SSE.1.a. Interpret parts of an expression, such as terms, factors, and coefficients

### Earth and Space Science, Physics:
- Soil acidity and plant growth

### Biology:
- What role do acids and bases have on the optimum functioning of enzymes?

### Technology/Engineering:
- Technological remedies to save the plants and animals in an acidified lake

### ELA Season 5 standards:
- W6. Use technology to write
- R4. Interpret words/phrases

### Related Math standards:
- A-CED. Create equations that describe relationships
- S.ID.1. Summarize and interpret data
- A-SSE.1.a. Interpret parts of an expression, such as terms, factors, and coefficients

### Earth and Space Science, Physics:
- Life without photosynthesis in ecosystems based entirely on chemosynthetic organisms

### Biology:
- Photosynthesis and cellular respiration

### Technology/Engineering:
- Rust-inhibiting compounds

### Performance Assessment
- Create a portfolio of completed and new work that summarizes and applies their learning in the unit, including an introduction, experiment, and presentation.
- Using an endothermic and exothermic reaction, discuss how the reactants and products are measured.
- Demonstrate Le Châtelier’s principle by opening a warm, room temperature, and ice cold soda.
- Practice combination, combustion, single and double replacement, and decomposition on the Chemical Equations Student Exploration Gizmo. Then apply scientific method to determine how scientists know how much of each substance to mix. Summarize why it is useful to use moles.
- Research the importance of a proper pH level in soil, water, or human blood. Create an informational flyer or PowerPoint to teach someone how to monitor and adjust pH for plant, water, or human health and safety. Write an argument that humans have adapted to acid rain. Using a cookbook, summarize acid/base reactions seen in many recipes. Use as many sections of the cookbook as possible.
- Complete a Gizmo exploration to measure the quantity of a known solution needed to neutralize an acid or base of unknown concentration. Calculate the unknown concentration. Read and interpret titration curves.
- Build a model of a car with paper. Using classroom items, find ways to cause corrosion in the car. Now find classroom items that could have saved the car from corrosion. Observe the differences between the two. Discuss whether temperature would make an impact on the amount of corrosion observed. Observe and discuss the browning of an apple. In an essay, explain what technology a store manager could use to keep all produce safe from ripening and discoloration.
Balancing Chemical Equations

TOPIC SEASON: Chemical Reactions—Bonding and Balancing

This unit is designed for use in long-term programs.
Sections may be adapted to short-term settings.

Unit Designers: H. Hay and M. McMahon Chappell

Introduction

The Balancing Chemical Equations unit focuses on two key concepts important in science and in everyday life: ratios and conservation. It is important for students to recognize that ratios are part of the natural universe in which they live. They rule the production of chemicals all around us. It is also important for students to know that nothing ever really disappears—it only changes form—but that food, water, air, and other resources can be spoiled, wasted, and corrupted if we don’t take care of them, create products in the right proportions, and recycle. Having a greater awareness of conservation on the molecular level will help students develop understandings that will allow them to be better stewards of the environment.

Many students are interested in culinary arts, and this unit will enhance their understanding of the processes of cooking and thus could help them to advance their careers. Other students are interested in construction and automotive mechanics. These fields can be used as analogies for chemical reactions. Every building needs doors, windows, walls, beams, and flooring; and these elements are used in different ratios depending on the desired attributes of the finished construction, just as certain combinations of chemicals will yield particular products. Every car needs one engine, four wheels, etc., in order for it to run—and chemical reactions that occur in the engine are dependent on precise ratios of fuel and air.

The Balancing Chemical Equations unit is designed to come toward the end of the seven-week Chemical Reactions season and take at least four weeks to complete (perhaps more because of the holiday break, open houses, and Martin Luther King Day). Prior to this unit on stoichiometry, students should study chemical bonding, including energy transfer during exothermic and endothermic reactions. After this unit, students may continue their study of stoichiometry by solving problems pertaining to limiting reagents and percent yield. There are tutorials on the Pearson website and instruction in Chapter 12 of the Pearson Chemistry book, as well as practice problem sets on websites in the resource section of the exemplar unit.

This unit addresses one of the two Emphasized Standards in the Chemical Reactions season. HS-PS1-7 focuses on how scientific knowledge about chemical reactions can help predict how much of a product a chemical reaction will yield, given finite amounts of reactants. Mass is conserved, even though molecular composition may
change, since atoms are neither created nor destroyed. This concept is crucial to understanding what happens during cooking and how everyday products are created in factories. Cooking, eating, and using manufactured products are activities we engage in all day every day, yet we don’t often think about how the final product was created. This unit allows students to see the importance of conservation, a concept they learned about in Biology, on a molecular level. This will be most apparent to them when they complete the Performance Task asking them which fossil fuel they would choose to minimize CO₂ emissions.

Prior knowledge that students need for this unit includes atomic structure, what coefficients and subscripts mean, the names of common elements, and how to work with ratios. The unit includes hooks and introductory lessons that review the names of common elements and how to find them on the periodic table as well as a lesson to review ratios. Teachers may have to spend some time on coefficients and subscripts if students do not understand them. Using manipulatives and having an interactive periodic table projected on the whiteboard if possible may also be helpful for the beginning lessons in this unit. Summarizing units on posters, word walls, and graphic organizers will assist new students entering the classroom.

The math in the unit will be challenging to some students because many have difficulty with fractions and proportions. The concept of moles and Avogadro’s Number may seem very abstract and hard to grasp. The unit includes a number of resources for differentiation, including websites with problems for differing levels of ability; interactive Gizmos from ExploreLearning.com, which may be teacher-directed or independent activities; choices of videos, teacher demonstrations, or hands-on labs; graphic organizers for vocabulary words and molecular mass calculations; manipulatives to help balance equations; and posters with key concepts and formulas.

For short-term adaptation ideas for this unit, see p. 5.3.3 on the right
### Balancing Chemical Equations

**Adapting This Long-Term Unit for Short-Term Programs**

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Chemical Reactions: Balancing Chemical Equations</th>
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<tr>
<td>Overview</td>
<td>The Balancing Chemical Equations unit focuses on students’ utilizing stoichiometry to demonstrate their understanding of fundamental chemical laws. Throughout the unit, the students are applying their understanding of ratios and ideas of conservation to chemical reactions and chemical yields. The lessons include charts to help students learn new vocabulary (and to help new students catch up with their peers) and activities for students to practice balancing equations and to produce evidence to represent their knowledge of the material.</td>
</tr>
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</table>

| Desired Results | The standard of this unit, HS-PS1-7, requires that students be able to use math to represent the law of conservation of matter and provide evidence to support it. In addition, students should be able to predict the amount of reactants and products using proportional relationships and the mole concept. For short-term programs, it is essential that the students are able to identify parts of a chemical equation and understand that nothing is lost or gained during a reaction. While the teacher plans to accomplish the KUDs in the unit, it may be helpful to stress the importance of the Law of Conservation of Mass and how it ties into stoichiometry in each lesson while focusing on that Know. In the Do’s, it is vital that students are able to predict the quantities of reactants and products, which is highlighted in the standard; therefore, throughout the unit, the teacher must provide valuable and regular practice of the concept. With students entering and leaving the program, teachers should have students completing a few problems every day to practice calculating the moles and masses in chemical reactions. It may be helpful to do this as a class or to have a student who has been in the program throughout the unit to lead the group through the problems. |

| Assessment Evidence | During this unit, there are many assessments to help provide data on students’ understanding. In short-term programs, teachers should try to utilize the Formative Assessments listed throughout the unit, like the suggested ExploreLearning Gizmo practice, chemical equation problems, written summaries, and lab hand-outs. However, the unit’s Summative Assessment in Lesson 12 may last too long for a short-term program, especially with students joining at the end. The plan suggests that the summative last three class periods. A teacher may use differentiation to support the students who were in the program longer. It may benefit some students to shorten the Summative Assessment by providing only two types of fuel for the students to compare and contrast in the graphic organizer labeled “Electricity Production Stoichiometry Calculation Sheet” found in the Supplement. A brand new student may need all the information completed for him or her in the graphic organizer. The presentation of the Summative Assessment should still be shared with the class; however, for new students, teachers may want to make it more informal according to students’ comfort with the material. |

| Learning Plan | With the complexity of the unit, it will be important to focus on the student supports to meet their learning needs. At times, the teacher may need to slow the lessons down to aid the students’ understanding. In addition, while teaching the lessons, the teacher should keep the vocabulary activity from Lesson 2 posted during the unit as an anchor chart for newer students and as a reminder for the older students. In Lesson 11, the unit has students creating a game for two class periods. A teacher may want to shorten that activity by eliminating a day for creation and turn the individual assignment into a class project to produce the game. The teacher could choose the game format ahead of time or have students vote. The students would be responsible for creating problems to use in the game. The teacher could have each class create a game and challenge other classes to play the various games. |
Emphasized Standards (High School Level)

**HS-PS1-7:** Use mathematical representations and provide experimental evidence to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. Use the mole concept and proportional relationships to evaluate the quantities (masses or moles) of specific reactants needed in order to obtain a specific amount of product.

Clarification Statements:
- Mathematical representations include balanced chemical equations that represent the laws of conservation of mass and constant composition (definite proportions), mass-to-mass stoichiometry, and calculations of percent yield.
- Evaluations may involve mass-to-mass stoichiometry and atom economy comparisons, but only for single-step reactions that do not involve complexes.

Essential Questions (Open-ended questions that lead to deeper thinking and understanding)

Why are recipes important in science?
What happens if we don’t use cooking ingredients in the right proportion?
What happens if plants don’t get enough sunlight and water?
Why is it important, in chemistry and in life, for things to balance?

Transfer Goals (How will students apply their learning to other content and contexts?)

Students will explain how specific proportions of elements and compounds are used to make everyday products such as cakes and cookies, cleaning products, and paint for art projects.
Students will explain how the energy sources they consume impact the world around them.
Students will create presentations to express their opinion to others, using evidence and reasoning to support their claims.
### Learning and Language Objectives

By the end of the unit:

<table>
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<th>Students should know...</th>
<th>understand...</th>
<th>and be able to...</th>
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<tr>
<td><strong>Tier III Vocabulary:</strong> stoichiometry, reactant, product, mole, reaction, constant, mole ratio, algebraic equations</td>
<td>Law of Conservation of Mass means that the mass of the products equals the mass of the reactants. Stoichiometry is a branch of chemistry that involves using relationships between reactants and/or products in a chemical reaction to determine desired quantitative data (UC Davis Chemwiki). Stoichiometry demonstrates the Law of Conservation of Mass. When a chemical equation is balanced, the number of moles of each element of reactants is equal to the number of moles of each element in products, even after the resulting chemical changes. Avogadro’s number (6.02 x 10²³) is used to represent particles in one mole of a substance.</td>
<td>Identify and apply the use of vocabulary terms in class discussions and writing.</td>
</tr>
<tr>
<td><strong>Tier II Vocabulary:</strong> measurement, balance, evaluate, progress, progression, ratio</td>
<td>Algebraic operations used to balance equations. Technological tools needed to produce a game and create a presentation.</td>
<td>Chemicals balance equations by balancing the moles of reactants and products. Mole ratios are derived from the coefficients of a balanced chemical equation. Balancing equations is a multi-step process: analysis of known and unknown quantities, calculation to solve for the unknown, and evaluation of the answer. Moles are used as a conversion factor.</td>
</tr>
<tr>
<td><strong>Algebraic operations used to balance equations</strong></td>
<td><strong>Chemists balance equations by balancing the moles of reactants and products.</strong> Mole ratios are derived from the coefficients of a balanced chemical equation. Balancing equations is a multi-step process: analysis of known and unknown quantities, calculation to solve for the unknown, and evaluation of the answer. Moles are used as a conversion factor.</td>
<td>Calculate moles in reactants and products. Calculate the mass of reactants and products. Apply the Law of Conservation of Mass to solve a chemical equation. Predict quantities of reactants and products. Produce a board game to demonstrate concepts and vocabulary. Create a presentation to argue in favor of a particular type of fuel to generate electricity.</td>
</tr>
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</table>
Assessment Evidence
Quality questions raised and tasks designed to meet the needs of all learners

Performance Task and Summative Assessment (see pp. 5.4.23 to 5.4.26) Aligning with Massachusetts standards

Working individually or as a group, students will use their knowledge of stoichiometry to calculate and report on the carbon emissions of different fuels burned to create electricity as outlined in the following scenario:

Goal: To analyze, evaluate, and report on the environmental impact of burning different kinds of fuels in a proposed power plant

Role: A city or county engineer with expertise in carbon emission

Audience: City or county policy makers who will decide on the type of power plant to be built

Situation: The city or county needs a new power plant to meet electricity demand, and several types have been proposed, including those that burn fossil fuels (coal, oil, and natural gas). The policy makers must decide whether to approve one of these types or to seek alternatives such as biofuel (wood). Ongoing carbon emissions will be an important consideration.

SEE: www.icr.org/life-science

Product: A report and oral presentation explaining the environmental impact of each option, including stoichiometric equations showing the amounts of CO$_2$ produced by each type of fuel, and an evidence-based recommendation to the policy makers

Standards: Completeness and accuracy of stoichiometric equations, clarity of explanations, support for final recommendation, organization and correctness of report materials, and coherence of oral presentation

Pre-Assessments
Discovering student prior knowledge and experience

Assess knowledge of ratios, chemistry subscripts (number and property), Avogadro’s number, and ability to balance an equation. Here are some suggestions:

- Start a word wall for Tier III words on the first lesson and continue with this process throughout the unit, using the flashcards for classification, writing for understanding, concentration games, etc. Students may also use Quizlet online to learn and review vocabulary.
- Ask students to brainstorm for five minutes about what balance means.
- Create a periodic table scavenger hunt to activate prior knowledge of vocabulary (e.g., find the element with the atomic number 75, find the element with the chemical symbol Zn, find the element that has 19 electrons, find the element with an atomic mass of 12.011, find the element that has 45 protons, find an element that is a noble gas, find an element that is a metal, find an element that is a solid at room temperature, find the lightest element, find two elements that share a letter in their chemical symbols).
• Give cards to each person with random elements and s/he writes the number of atoms in a mole and the molecular and molar mass of the element.

Formative Assessments
Monitoring student progress through the unit

Using a graphic organizer from Dr. Birdley’s Chemistry (pp. 16-18 in Elements, Compounds, and Mixtures), and a periodic table, students will calculate the molecular mass of various molecules and compounds.

Students will complete problem sets independently, using variables for the parts of tricycles to determine the number of each part needed to create a certain number of tricycles.

Students will solve a variety of problems, both individually and in whole group, that require them to balance equations, with an understanding of conservation of mass.

Students will practice “Balancing Equations and Stoichiometry” with ExploreLearning Gizmos. Students will discover the importance of conservation of mass and the relationship between molecular mass and molar mass. They will convert molecular mass to molar mass and solve stoichiometry problems.

Students will play a card game to determine the difference between atoms, molecules, mass, and moles by matching the quantitative relationship to a balanced equation.

Students will use a summary model to create a summary for the formation of a compound. They will write about the significance of the chemical reaction and the role that compound plays in their world.

Students will analyze, calculate, and evaluate equations, using a given quantity to find an unknown reactant or product by using ratios. Problems will be taken from the book and/or online resources.

Students will participate in labs that require them to predict, observe, analyze, conclude, and share their results.

Students will create a game to review and practice unit vocabulary.
Access for All
Considering principles of Universal Design for Learning (UDL), Positive Youth Development/Culturally Responsive Practice (PYD/CRP), differentiation, technology integration, arts integration, and accommodations and modifications

Note: Throughout the unit, opportunities are provided for interactive learning that is linked to student experiences with food and products they use on a daily basis, such as bicycles, cars and household energy.

Multiple Means of Engagement
Throughout the unit plan, the student will be provided with as many choices as possible in order to recruit and sustain engagement. For example, the teacher will encourage and support students in setting their own personal, academic, and behavioral goals. The teacher will use many strategies to guide students, including reminders, guides, rubrics, checklists, and prompts among other things that focus on self-regulatory goals. Student tasks will be varied, allowing for active participation, exploration, and experimentation. The teacher will provide differentiated models, scaffolds, and feedback, as well as content material that is culturally relevant and responsive to student’s backgrounds. Most important is that teachers design assignments and tasks with authentic outcomes, and that are purposeful and convey meaning to real audiences. For instance, students will create a game to teach others about stoichiometry. They will also do a presentation based upon a real-life GRASPS scenario. Throughout the unit, they will be engaged by participating in activities that relate to their own experience with food (making sandwiches) and studying the production of products like bicycles. There are also interactive Gizmos from ExploreLearning.com and videos for visual and kinesthetic learners.

Multiple Means of Representation
Throughout the unit, the teacher will provide information/material in several modalities such as diagrams, vocabulary notebooks, word walls, posters, charts with formulas for calculations, models, videos, and audio for text. The teacher will also demonstrate concepts through hands-on activities. The teacher will make use of Gizmos as well as videos to show students how to use stoichiometry. The teacher will also do labs with vinegar and baking soda to show a chemical reaction.

Multiple Means of Action and Expression
In reading and writing activities students will be provided options for demonstrating what they know and can do. Students will have access to assistive technology and multiple media including text, videos, illustrations, charts, and visual art if necessary. In composing or writing activities, the teacher will provide students with multiple options. For example, students will have access to word processors with grammar checks, word prediction, and spell checkers. Students will be provided with algebra review, scaffolding, manipulatives, and calculators as need to succeed with the math calculations involved in this unit. Students will complete projects by making PowerPoint or Scratch presentations, acting as a city engineer. Students will define words and create charts, as well as draw illustrations for classroom posters. The teacher will scaffold writing or composing activities using tools such as concept maps, outlining tools, or graphic organizers. Students may need sentence starters and story webs to complete writing or composing tasks. The teacher will also break down long-term goals into short-term reachable goals.
Literacy and Numeracy
Across Content Areas

Reading
Students will read from the Pearson Chemistry textbook: Lessons 12.1, 12.2, Gizmo worksheets and computer simulations, and will also read word walls, peer-created games and presentations and interactive activities.

Writing
Students will give written responses to textbook, teacher-created, and Gizmo lesson questions. Students will organize information using two-column notes, top-down webs, and brainstorming activities. Students will also create games or presentations that require labeling and generation of questions and answers. In addition, students will write lab reports and complete Exit Tickets.

Speaking and Listening
Students will participate in discussions throughout the unit and speak and listen to other students during the Pre-Assessment interactive activities.

Students may do Gizmo Formative Assessments in whole group or in pairs, where discussion will be part of the lesson.

The final Performance Assessment will involve presenting and responding to information.

Language
Students will think critically using the vocabulary presented in this unit.

Students will improve their understanding of words that may have multiple meanings. There will be some discussion about various meanings of words such as mole, reaction, and constant that may mean something very different in daily conversation than they do in chemistry.

There can also be links made between ratios and products, both math words. Students will discuss the origin of science vocabulary. For example, stoichiometry comes from the combination of Greek words stoicheion, meaning “element,” and metron, meaning “to measure.”

Students will also expand their vocabulary and be able to apply it to understand the lesson by using the above-referenced strategies, as well as a word wall and repetition throughout the unit.

Numeracy
Students will use knowledge of ratios and algebraic equations to balance equations and complete stoichiometry problems and compare and contrast math and chemistry vocabulary.
Resources (in order of appearance by type)

Print

Websites
www.youtube.com/watch?v=o5LT_wfl98w.

“Burger Boost: McDonald’s quietly changes the size of its quarter pounder.” *NBCnews*. 2015.

http://tinyurl.com/q9cspod.

“Proportions.” *4bp Blogspot*.
http://4.bp.blogspot.com/-R5txcqfZRRQ/UHdYF8tWKYI/AAAAAAAACs/qY2ftmuRAXQ/s320Ratio+Example.png.


www.youtube.com/watch?v=_B73SturDoM.

http://tinyurl.com/m9wevcu.


“Bozeman Science Mole Conversions.” *Bozeman Science*.
www.bozemanscience.com/mole-conversions.

“Gram/Mole/Volume Conversions.” *Science Geek*.

www.youtube.com/watch?v=FtzDgMbuC8M.


“Stoichiometry Review.” *Science Geek*. Mr. Allen.
www.sciencegeek.net/Chemistry/taters/Unit4Stoichiometry_B.htm.
“Image of Power Plant.”

www.healthgrades.com/conditions/elevated-blood-ammonia-level.


www.youtube.com/watch?v=lW7SUBw_aAA.

www.scienceiscool.org/stoichiometry.


Materials
Paper, pencils, textbooks, student computers and/or teacher laptop and projector, whiteboard and markers, poster and markers as indicated for assessments, index cards and a word wall for vocabulary instruction throughout the unit

Cupcake Recipe (p. 5.6.1)
Words With Multiple Meanings (p. 5.6.2)
Table: Finding Molecular Mass (p. 5.6.3)
Game Planning Template (p. 5.6.4)
Game Rubric (p. 5.6.5)
Using Chemistry to Evaluate Power Plan Options (p. 5.6.6)
Electricity Production Stoichiometry Calculation Student Organizer and Answer Sheet (pp. 5.6.7 to 5.6.8)
Outline of Lessons
Introductory, Instructional, and Culminating tasks and activities
to support achievement of learning objectives

INTRODUCTORY LESSONS
Stimulate interest, assess prior knowledge, connect to new information

Lesson 1
Balance, Ratios, and Algebraic Equations

Goal
Students will activate prior knowledge of ratios and algebra, especially balancing equations, as well as Tier II vocabulary that applies to lesson concepts (reaction, product, proportion, etc.).

Note: Balancing chemical equations, or stoichiometry, is the same process as balancing algebraic equations.

Do Now (time: 10 minutes)
Each student should get a copy of the cupcake recipe. This recipe is located on p. 5.6.1 of the Supplement to this unit.
Students should identify the following:
- reactants (flour, salt, baking powder, butter, sugar, eggs, milk), products (cupcakes),
- and energy source (heat)
The class will then discuss the difference between reactants and products and the role energy plays in the chemical reaction. These terms should be used to begin a unit word wall.

Hook (time: 5 minutes)
Once the concepts of reactants and products are reviewed, ratios and proportions can be addressed. Students will come up with a solution for the following problem:
- Only one egg is available.
- Discuss whether the solutions offered take into account the proportion of ingredients.

Presentation (time: 10 minutes)
The teacher will provide an introduction to the unit, noting the connections between balancing chemical reaction equations and everyday activities such as adjusting recipes, as well as their similarity to algebraic equations.

Note: The extension for this lesson includes some algebraic equations that could be used at this point for review and reinforcement of the concept of balance. The introduction should also include a brief preview of the final Performance Task, which will involve calculating the carbon emissions of different kinds of fuel.

For Empower Your Future Connections, see pp. 5.5.1 to 5.5.2
**Practice and Application** (time: 20 minutes)

Students will design posters that demonstrate balanced equations, ratios, and proportions based on everyday activities such as making sandwiches. The activity should begin with a teacher-led example on the board, such as an equation for making a ham-and-cheese sandwich:

\[
2 \text{ slices of bread} + 2 \text{ slices of ham} + 1 \text{ slice of cheese} = 1 \text{ ham-and-cheese sandwich}
\]

Working in pairs with teacher guidance, students will then calculate how many sandwiches can be created from one loaf of bread (16 slices), one package of ham (12 slices), and one package of cheese (8 slices), and create a new balanced equation (note that there will be leftover ingredients):

\[
12 \text{ slices of bread} + 12 \text{ slices of ham} + 6 \text{ slices of cheese} = 6 \text{ ham-and-cheese sandwiches}
\]

After this group work, students will design their own posters with balanced equations (using pictures as well as numbers and words) showing how to make other products (e.g., a beaded necklace with a particular color pattern, a hot fudge sundae, or a skateboard). As the students complete their equations, the teacher can ask them to create new equations given a particular amount of one or more reactants (ingredients) or a specific number of products.

**Review and Assessment** (time: 10 minutes)

Students will present their posters and give and receive feedback on the accuracy of the equations and the clarity of the format. During the process, the teacher should help them clarify any misconceptions and add terms to the word wall as appropriate.

**Extension**

Use the following tiered equations for review or remediation on what it means for an algebraic equation to be balanced. Students should solve for \( x \). Problems can be adjusted to skill level. Discuss the solutions.

\[
\begin{align*}
x &= 85 + 9 \\
13 + 17 &= x \\
100 - x &= 49 \\
x - 16 &= 26 \\
x/120 &= 3 \\
11/x &= 4 \\
3^5 &= x \\
x &= 15^2 
\end{align*}
\]
Lesson 2

Terms with Multiple Meanings

Goal
Students will review, practice, and explain Tier II and Tier III words that they will encounter in this unit.

Do Now (time: 10 minutes)
Students will fill in the “Words with Multiple Meanings” chart with what they know. This chart is located on p. 5.6.2 of the Supplement for this unit.

Hook (time: 10 minutes)
The teacher will ask students to share and discuss their responses to the daily usage portion of the chart and encourage them to formulate a definition for each word, charting their answers on the board. The teacher can then ask what answers students have to the math and chemistry usage portions and follow the same process, passing over for the time being any terms that are unknown to the group.

Presentation (time: 10 minutes)
The teacher will provide examples of math and chemistry uses of the terms in the chart, again prompting students to generate definitions. The teacher will also point out the similarities and differences of the words’ meanings in the three contexts.

Practice and Application (time: 15 minutes)
The teacher will assign students the task of creating informative and visually attractive posters to illustrate the chemistry meanings of the words in the chart. Students may work in teams if they wish. One possibility is that the table could be copied to student computers to allow for digital design, and then printed and mounted on construction paper.

Note: For a review of ratios use the first link; for Proportions, use the second link.

Review and Assessment (time: 10 minutes)
Students will evaluate their own or peers’ posters using the following questions:

1. Would someone who didn’t know the meaning of the terms be able to figure them out based upon the sentences you wrote?
2. Are they clear and context-rich?

Students will then make any needed revisions. The finished posters will serve as anchor charts for the unit and the terms placed on the word wall.
Lesson 3

Molecular Mass and Molar Mass

Goal
Students will calculate molecular mass and convert it to molar mass.

Do Now (time: 5 minutes)
Students will respond to the following questions in a brief discussion:

1. What is the ratio of hydrogen to oxygen in a molecule of water? (2:1)
2. What is the ratio of carbon to oxygen in carbon dioxide? (1:2)
3. What other compounds use ratios? (Examples: NH₃—ammonia; CH₄—natural gas)
4. Why do you think that atoms always have to be in the same ratio to make a particular compound?

Hook (time: 10 minutes)
Students will demonstrate their understanding of how to use the periodic table to find elements that make up compounds. They will do a periodic table scavenger hunt, during which they will search for elements on the table using hints from the teacher (e.g., find the element with the atomic number 75, find the element with the chemical symbol Zn, find the element that has 19 electrons, find the element with an atomic mass of 12.011, find the element that has 45 protons, find an element that is a metal, find an element that is a solid at room temperature, find the lightest element, find two elements that share a letter in their chemical symbols).

Note: The molar mass of elements is found by looking at the atomic mass of the element on the periodic table. For example, if you want to find the molar mass of carbon, you would find the atomic mass of carbon on the periodic table, and this is equal to the molar mass in grams per mole. So, in our example, carbon has a molar mass of 12.011 grams per mole.

Presentation (time: 15 minutes)
The teacher and students work together to find the molecular mass of the compounds CO₂, O₂, H₂O, NH₃ using the table on p. 5.6.3 in the Supplement for this unit. The teacher may also create tables on the board to demonstrate as the students create their own tables (one for each compound). Student tables will be monitored to assess understanding, and results will be reviewed.

Practice and Application (time: 20 minutes)
Students will complete mini-comics in Elements, Compounds, and Mixtures, pp. 16-18, to find the molecular mass of up to 14 compounds (number depending on student ability), using a table to organize the data as necessary. This activity may take longer, depending upon students’ backgrounds and their understanding of the periodic table.

Review and Assessment (time: 5 minutes)
The teacher will lead a discussion of the results.

Which compound was the heaviest and which the lightest? Are metals heavier than gases?
The teacher will introduce the term molar mass, which is the same as molecular mass, but we use grams instead of atomic mass units (AMUs) as the unit.
### Lesson 4

**Balancing Equations**

**Goal**
Students will demonstrate how to balance equations and explain how the process is similar to following a recipe.

**Materials include:**
- baking soda, vinegar, plastic beakers, and triple-beam scale if lab is performed;
- otherwise, demonstration with laptop and projector

**Do Now** (time: 5 minutes)
Students do a quick write or brainstorm:
Define the words *reactants* and *products* in your own words. Think of something you like to bake, build, or create, such as cookies, woodworking projects, or bracelets. List the ingredients you would need to make a finished product.

**Hook** (time: 5 minutes)
The teacher leads a discussion about how the materials students listed and the finished products are similar to reactants and products in chemistry. The discussion should include these inquiry questions:
- Is anything lost or gained? How do things change?
- Can products be taken apart again to individual ingredients?

**Presentation** (time: 10-15 minutes)
The teacher will explain and prove the Law of Conservation of Mass by using vinegar and baking soda reactants to make a product and comparing the mass of the reactants to that of product by weighing them on a triple-beam or digital scale to show that mass has been conserved. The following video about conservation can serve as a demonstration of the lab, either to model it before doing the experiment, or to take the place of the experiment:

SEE: “Lab of Conservation of Mass”
tinyurl.com/pv5b9z6)

**Practice and Application** (time: 20-25 minutes)
The students will read pp. 384-385 in the *Pearson Chemistry* book, using everyday equations to make tricycles. (Supplement with Kinetic Art: Interpreting a Balanced Chemical Equation, from *Pearson Chemistry* supplementary online animations). The teacher may scaffold the use of a balanced equation as a recipe. Students will then complete a problem independently, using variables for the parts of the tricycles to determine the number of each part needed to create a certain number of tricycles. They will be able to discern that input equals output even though the product may look a lot different than the individual parts did.

SEE: www.successnetplus.com
Review and Assessment (time: 10 minutes)
The teacher will lead a discussion of the results of the calculations, and students will show notebook or board work to explain their thinking, either at their desks or in front of the class. Students should consider the connection between the experiment with baking soda and vinegar and the production of tricycles:

How are they similar and how different?

Note: Some students may be aware that one is a physical change and one is a chemical change, but they should all be able to see that there is a product that is created from the reactants. No mass was lost, and nothing was gained.

Extension
Students may also write equations that give recipes for making skateboards or other products of their own choosing and create word problems for other students to solve.

ADDITIONAL PRACTICE WITH BALANCING EQUATIONS AS NECESSARY.
Students should have learned this in a previous lesson but may need reinforcement. This extension may add one or more days of practice to this lesson:

SEE: “A beginners guide to balancing equations”
www.youtube.com/watch?v=_B735turDoM
“Balancing Chemical Equations 1”
tinyurl.com/m9wevcu
“Balancing Chemical Equations” (easy and gets progressively more difficult)
www.sciencegeek.net/Chemistry/taters/EquationBalancing.htm
“Balancing Chemical Equations” (a PhET interactive)
phet.colorado.edu/sims/html/balancing-chemical-equations/latest/balancing-chemical-equations

Lesson 5

Balancing Equations Using Moles (2 days)

Goal
Students will explain why it is important to convert to moles when doing a stoichiometry problem to prove that an equation is balanced.

Do Now (time: 10 minutes)
Students will complete the following as a quick write or partner activity:

Add 1 + 3. Does 1 N₂ + 3 H₂ = 4 NH₃? If not, why not? (Check to make sure students understand subscripts. There are 2 nitrogen atoms and 6 hydrogen atoms on the reactant side and 4 nitrogen atoms and 12 hydrogen atoms on the product side. We have to count atoms, not just add the coefficients.) How many ammonia molecules do we produce from the 2 reactant molecules? (Students should discover the need to have the same number of atoms on the reactant and product sides if they could not answer the initial question and explain.)
Note: If they don’t realize that the equation doesn’t balance or can’t explain why, students should work with manipulatives or math models to discover the imbalance).

**Hook** (time: 10 minutes)

Each student chooses a teacher-made card with a diagram of a common molecule like glucose or methane and counts out how many of each atom would be needed to make the molecule. (The teacher could demonstrate with a molecule of water.) The teacher will lead a discussion of how businesses must determine how many reactants they need to produce particular products, just as molecules must be made from a particular number of atoms. See the link below for a methane molecule model.

**SEE:** [https://cnx.org/contents/QhGQhr4x@5/Biological-Molecules](https://cnx.org/contents/QhGQhr4x@5/Biological-Molecules)

**Presentation** (time: 45-60 minutes)

The teacher introduces the concept of mole with a video if internet presentation is feasible.

**SEE:** [www.bozemanscience.com/mole-conversions](http://www.bozemanscience.com/mole-conversions)

The teacher will reinforce the video with the following activity:

The students write Avogadro’s number in their notebooks with this definition: “Avogadro’s number (6.022 ×10²³) is the number of atoms or molecules in a mole of a substance.” (This number is based on the number of carbon atoms in 12 grams of carbon 12.) Students then write mole and define it as follows:

- Mole is a chemical mass unit, defined to be 6.022 ×10²³ atoms or molecules.
- The mass of a mole is the same as the gram formula mass of a substance.

The teacher will write the terms and definitions on large cards for the word wall.

The teacher will also provide and explain these examples:

- 1 mole of carbon has 6.022 ×10²³ atoms and weighs 12.011 grams (from periodic table)
- 1 mole of NH₃ has 6.022 ×10²³ molecules and weighs approximately 17 grams (14.007 grams + 3 x 1.008 grams)

Students will create an additional example using a compound of their own choosing to demonstrate understanding.

On Day 2, students will read pp. 386-387 in **Pearson Chemistry**, with teacher think-aloud and scaffolding to introduce stoichiometry as a form of bookkeeping. The teacher can create a top-down web or other graphic organizer to summarize what units can be used to create a balanced equation: atoms, molecules, moles, mass, and volume. The class should discuss which ones might be most useful and work through the sample problem on p. 388, interpreting a balanced chemical equation. With teacher guidance, students should look up molecular mass on the periodic table, convert to molar mass, then multiply that by the respective coefficients to prove a balanced equation. For instance, 2 H₂O₂ → 2 H₂O and O₂ is a reaction that shows hydrogen peroxide being broken into water and oxygen. H₂ x 2 would be 2 diatomic hydrogen molecules multiplied by 2. Since the atomic weight is 1, 4 hydrogens would have a molar mass of 4 grams. Oxygen has a molar mass of 16, so 4 oxygens (2 diatomic oxygen molecules) would be 64 grams. Thus the reactants have a molar mass of 68 and the products have a molar mass of 68 because there are 4 hydrogen atoms and 4 oxygen atoms on each side, even though the types of molecules are different. (This reaction can be demonstrated by putting a piece of raw potato in a 15 ml solution of hydrogen peroxide. Students will see oxygen foaming.)
Practice and Application (time: 15-20 minutes)

Working in pairs or with the teacher, students will balance an equation showing the production of glucose from carbon dioxide and water:

Given that the formula for a glucose molecule is \( \text{C}_6\text{H}_{12}\text{O}_6 \), how many carbon dioxide molecules and water molecules do we need to make one molecule of glucose, and what do we do with the extra oxygen? How is this reaction similar to the one we just saw? How is it different? Calculate the molar mass of glucose.

Review and Assessment (time: 15-20 minutes)

Students will balance an equation independently:

This is the equation for the reaction of baking soda and vinegar: \( \text{NaHCO}_3 \) (sodium bicarbonate or baking soda) + \( \text{HC}_2\text{H}_3\text{O}_2 \) (acetic acid or vinegar) \( \rightarrow \) \( \text{NaC}_2\text{H}_3\text{O}_2 \) + \( \text{H}_2\text{O} \) + \( \text{CO}_2 \) (sodium acetate, water and carbon dioxide).

What causes the bubbles when we add vinegar to baking soda, and how do the atoms get rearranged in the product? Calculate the molar mass of each reactant and product.

Is the reactant mass equal to the product mass?

After performing the calculations, students should compare results, and the teacher should help clarify any misunderstandings.

Extension

Apply concepts by balancing and interpreting additional equations on p. 389 of Pearson Chemistry or from supplementary activities. Website suggestion:

SEE: www.sciencegeek.net/Chemistry/taters/Unit4GramMoleVolume.htm

Lesson 6

Stoichiometry Practice (2 Days)

Goal

Students will summarize and explain information derived from balanced chemical equations (atoms, molecules, multiples of molecules, moles, and grams).

Do Now (time: 10 minutes)

Students will balance an equation for the formation of 2 moles of ammonia by following the model previously used to prove that the number of grams on the reactant and product sides are the same.

Solution:

\[
\text{N}_2 + 3 \text{H}_2 = 2 \text{NH}_3
\]

\[
(14 \times 2) + (3 \times [1 \times 2]) = 2 \times (14 + [1 \times 3]) = 34
\]

Hook (time: 20 minutes)

Ammonia is used extensively in the production of a wide range of food and beverages, and the human body naturally produces ammonia every day. Students will review selected information from the following websites and reflect upon how ammonia enters and leaves their bodies and why a proper balance is critical.
for their health. They will discuss why it is important for our body’s ammonia level to be at equilibrium to maintain homeostasis.

SEE: www.beefproducts.com/Ammonia-EssentialForLife.pdf
SEE: www.healthgrades.com/conditions/elevated-blood-ammonia-level

Presentation (time: 25 minutes)
The teacher will review the Do Now activity and interpret for students the summary of information provided in the balanced chemical equation for the formation of ammonia on p. 389 of Pearson Chemistry. This includes balancing based upon atoms, molecules, a multiple of molecules that are in the same ratio, Avogadro’s number, moles, mass, and volume (22.4 L per mole assuming standard temperature and pressure).

Practice and Application (time: 40 minutes)
On Day 2, working as a group, students will use the summary model example on p. 389 (reactants and products expressed as atoms, molecules, multiples of molecules, moles, and grams) to create on a poster a summary for the formation of carbon dioxide (CO₂) and water (H₂O) from methane (CH₄) and oxygen (O₂).

Note: Combustion of methane is a multiple-step reaction, with the net result being CH₄ + 2 O₂ → CO₂ + 2 H₂O (Wikipedia), which is all the students will focus on. After creating a graphic, students will write several sentences about the significance of this reaction, reflecting upon the benefits and the potential detriments of greenhouse gases that result from using methane as a fuel source.

Review and Assessment (time: 15 minutes)
Students will explain what they have done on the poster and write an Exit Ticket about what they have learned about the different ways (atoms, molecules, moles, grams, Avogadro’s number, multiples of any of them in the same proportion) to balance equations.

Extension
Websites for additional explanation and practice:
SEE: “Stoichiometry Made Easy: The Magic Number Method”
www.youtube.com/watch?v=FrzDgMbuC8M
“Practice Problems”
dl.clackamas.edu/ch104-03/practice.htm

Lesson 7
Conservation of Matter (2 Days)

Goal
Students will explain how and why conservation of matter demands that chemical equations are balanced. They will interpret chemical formulas and balance a wide variety of chemical equations. They will state the relationship between molecular mass and molar mass. They will determine the masses of reactants and products in a chemical reaction. The ExploreLearning website contains an exercise.
SEE: “Explore Learning Gizmo on Balancing Equations”

Materials, if lab is performed, include a candle, lighter, triple-beam balance, jar to put over the candle to extinguish it. Alternative demonstration can be done with a laptop and projector.

**Do Now** (time: 10 minutes)
Students complete the prior knowledge questions on the Gizmo student exploration sheets, included in the Balancing Equations Gizmo.

**Hook** (time: 10-20 minutes)
To demonstrate conservation of matter, the teacher may conduct the following demonstration with probing questions for students:

Place a large candle on a triple-beam balance and carefully measure its mass so that the balance is balanced. Light the candle and wait for about one minute. As students are waiting, ask them to hypothesize what will happen.

Then they can respond to these questions:

What happens to the mass of the candle, and how can you tell? Where did the missing mass go?

Blow out the candle, and invert a large jar over the candle. Rebalance the candle and jar, then remove the jar, light the candle, and replace the jar. The candle should burn for several seconds before running out of air and burning out.

What happens this time? Why doesn’t the mass of the candle/jar change now?

An alternative demonstration can be found at the following website.
SEE: www.youtube.com/watch?v=IW7SUBw_aAA

**Presentation** (time: 20 minutes)
The teacher will do the Gizmo exploration with a laptop and projector as a teacher-led activity using discussion questions from the teacher guide to guide instruction.

**Practice and Application** (time: 50-60 minutes)
Beginning on Day 1 and continuing on Day 2, students will complete the questions on the Stoichiometry Gizmo activities with teacher and peer assistance as needed.

**Review and Assessment** (time: 10 minutes)
Students will write what they have learned how and why conservation of matter demands that chemical equations are balanced, as well as questions they still have about what they have learned.

**Extension**
Web resources are listed in the Gizmo for further explanation or reteaching.

For **Empower Your Future Connections**, see pp. 5.5.1 to 5.5.2
Lesson 8

Mole Ratios (2 Days)

Goal
Students will use mole ratios to determine an unknown product or reactant.

Do Now (time: 5 minutes)
Students will look at a photo of chemical industrial plant, speculate on what is produced there, and explain why stoichiometry is important in the production process.

Hook (time: 10 minutes)
Students will write three ratios for the production of ammonia, relating nitrogen to hydrogen moles, ammonia to nitrogen moles, and ammonia to hydrogen moles: \( \text{N}_2 \) reacts with 3 \( \text{H}_2 \) to create 2 \( \text{NH}_3 \), so:

What is the ratio of \( \text{N}_2 \) to \( \text{H}_2 \) (1:3) and the ratio of the product to each reactant (2:1 and 2:3 respectively)?

Students should also respond to this question:

How do you think ratios could help you to find an unknown reactant or product?

Presentation (time: 40 minutes)
The teachers will introduce the topic calculating moles using ratios with the Khan Academy video below. The teacher should reinforce the video with a reading and think-aloud from pp. 390-391 of Pearson Chemistry, focusing on how to calculate the moles of a product using ratios when one reactant is known.

Practice and Application (time: 45 minutes)
On Day 2, students will analyze, calculate, and evaluate equations, using a given quantity to find an unknown reactant or product by using ratios. The teacher will provide guided practice using the sample practice problem on p. 391: \( \text{Fe}_2\text{O}_3 \) (solid) + 3 \( \text{CO} \) (gas) → 2 \( \text{Fe} \) (solid) + 3 \( \text{CO}_2 \) (gas). Ask how many moles of \( \text{Fe} \) will be produced if there are 1.8 moles of \( \text{Fe}_2\text{O}_3 \).

Solution:

Relating the coefficients of the balanced equation to the number of moles given yields this proportion:

\[
\frac{1 \text{ Fe}_2\text{O}_3}{1.8 \text{ moles}} = \frac{2 \text{ Fe}}{x \text{ moles}}.
\]

Cross multiply to solve for \( x \) to get 3.6 moles of \( \text{Fe} \).

Students will work on similar problems independently, numbers 11 and 12, on p. 391 of Pearson Chemistry, with teacher and peer assistance as necessary, using their preferred method of calculation.

Suggestions for further problem solving: Review problems from Pearson Chemistry on p. 411 (numbers 45, 47 and 49) or the online resource Science Geeks on Stoichiometry:

See: www.sciencegeek.net/Chemistry/taters/Unit4Stoichiometry_B.htm
Review and Assessment (time: 10 minutes)
Exit Ticket: Students will explain what a mole is and when to use the word. They will also explain what a coefficient reveals about a chemical reaction.

Lesson 9
Mass and Moles

Goal
Students will calculate the mass of a product using stoichiometric equations and explain the process.

Do Now (time: 5 minutes)
Students will solve the following stoichiometry problem to review how to calculate the moles of a product. The teacher will go through the problem, step by step, asking students to anticipate each step. The following problem was adapted from a Stoichiometry problem on the web.

SEE:  www.scienceiscool.org/stoichiometry/answer1.html

Stoichiometry problem:
Oxygen gas can be produced by decomposing potassium chlorate using the reaction below. If 138.6 g of KClO₃ is heated and decomposes completely, what mass of oxygen gas is produced?

\[
\text{KClO}_3 (s) \rightarrow \text{KCl} (s) + \text{O}_2 (g) \quad \text{[unbalanced]}
\]

Answer:
1. Balance your equation first.
\[
2 \text{ KClO}_3 (s) \rightarrow 2 \text{ KCl} (s) + 3 \text{ O}_2 (g) \quad \text{[balanced]}
\]
2. Convert from grams to moles using molar mass.
To get moles from grams of potassium chlorate, divide by the molar mass of KClO₃ = 122.55 g/mol:
\[
138.6 \text{ g KClO}_3 \times (1 \text{ mol} / 122.55 \text{ g}) = 1.131 \text{ mol KClO}_3
\]
3. Use ratios to find the moles of the reactant or product you need to find.
Since KClO₃ is the only reactant, it is the limiting reagent. You use the moles of KClO₃ if you have to calculate how many moles of oxygen gas (the product you're trying to find) are being produced.
Use your mole ratios from your balanced equation:
\[
1.131 \text{ mol KClO}_3 \times (3 \text{ mol O}_2 / 2 \text{ mol KClO}_3) = 1.696 \text{ mol O}_2 \text{ produced}
\]
4. Convert from moles back to grams of the new substance using that substance's molar mass.
To get grams from moles of oxygen (O₂), multiply by its molar mass = 32 g/mol.
\[
1.696 \text{ mol O}_2 \times (32 \text{ g} / 1 \text{ mol}) = 54.286 \text{ g O}_2 \text{ produced}
\]
Hook (time: 5 minutes)
The teacher will ask students to discuss this question:
Why would astronauts need to know what the cloud composition is on planets they want travel to? How could chemistry help them to find out the concentration of ammonia, compared to plain nitrogen (N₂), which we find in Earth's atmosphere?

Presentation (time: 20 minutes)
The teacher will lead a read-aloud of pp. 392-393 of Pearson Chemistry and ask students if they think that there is a law of “conservation of moles” and give reasons for their opinions. The teacher will provide copies of the pages to the students as reference so they can write notes about what they understand and what they still have questions about in the margins. The teacher will then work with students to solve the sample problems in the margin on p. 393 to reinforce that mass is conserved but there can be more or fewer moles on the product side than on the reactant side (looking at the coefficients).

The class should then focus on calculating the mass of a product. The teacher may scaffold the three-step process to convert given mass to wanted mass. Students should write out the formula in their notebooks and apply it to solve the sample problem on p. 393. (This can be displayed with a projector in white board mode from the Pearson Successnet website. There are also good models of this equation on slide 18 of Chapter 12.2 PowerPoint on Pearson Successnet or on p. 394 of the Pearson Chemistry book) In the formula below, “a mol G” represents the given quantity and “b mol W” represents the unknown quantity that you want to find.

\[
\text{Mass of G (given) x 1 mol G} \rightarrow \text{mol G x b mol W} \rightarrow \text{mol W x mass W} \rightarrow \text{Mass W (wanted)}
\]

Practice and Application (time: 20 minutes)
Students will solve this problem on p. 393 of Pearson Chemistry, with peer and teacher assistance as needed.

\[
\text{Calcium carbide + water} \rightarrow \text{Acetylene (gas) + calcium hydroxide}
\]

\[
\text{CaC}_2 + 2 \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_2 + \text{Ca(OH)}_2
\]

Given 5 g of CaC₂, how much C₂H₂ will be produced?

Solution:

\[
\frac{5\text{g CaC}_2 \times 1 \text{ mol CaC}_2}{64\text{g CaC}_2 (\text{molar mass of 1 Ca and 2 C})} \times \frac{1 \text{ mol C}_2\text{H}_2}{1 \text{ mol CaC}_2} = \frac{26\text{g C}_2\text{H}_2 (\text{molar mass of 2 C and 2 H})}{5/64 \times 26/1 = 130/64 = 2.03 \text{g C}_2\text{H}_2}
\]

Review and Assessment (time: 5 minutes)
Exit Ticket: Students will explain what they have learned about how to find a wanted mass when they are given one mass in a stoichiometry problem. They should also respond to this prompt:

How could this process be helpful in cooking or in a factory?
Extension
Additional practice problems may be found in Chemistry on pp. 412-416; #64 involves methane, and #68 involves ammonia, which would reinforce and extend some of the previous problems students have completed. Students may also complete additional problems selected from websites listed in the resource section.

Lesson 10
Stoichiometry Assessment (2 Days)

Goal
Students will calculate the molecular mass and molar mass of a substance and convert from molecular mass to moles and molar mass. Students will use dimensional analysis to compute the amounts of substances that take part in a chemical reaction and solve problems in stoichiometry.

SEE: Explore Learning Gizmo on Stoichiometry

Do Now (time: 10 minutes)
Students will complete the prior knowledge question on the Gizmo student exploration sheets, which are in the stoichiometry lesson.

Hook (time: 10 minutes)
Students will complete the pastrami sandwich activity suggested in the Gizmo, using ratios.

Presentation (time: 20 minutes)
The teacher will lead the Gizmo exploration with a laptop and projector, using discussion questions from the teacher guide to focus instruction, or have students work individually or in small groups.

Practice and Application (time: 60 minutes)
Beginning on Day 1 and continuing on Day 2, students will complete stoichiometry problems involving limiting reagents on the Gizmo with teacher and peer help as necessary.

Review and Assessment (time: 10 minutes)
Students write an Exit Ticket stating what they have learned about converting between molecular mass and molar mass, and how limiting reagents impacts chemical reactions. They should also have an opportunity to ask any additional questions they have about stoichiometry.

Extension
Web resources are listed in the Gizmo for further explanation or re-teaching.
CULMINATING LESSONS

Includes the Performance Task, i.e., Summative Assessment—measuring the achievement of learning objectives

Lesson 11

Vocabulary Game (2 Days)

Goal
Students will demonstrate understanding of the vocabulary and concepts learned in this unit by creating a game to teach others about stoichiometry.

Do Now (time: 10 minutes)
Students should organize the vocabulary words compiled during the unit, grouping words that are used to describe processes, words with the same roots, etc. Students should refer to the graphic organizer introduced in Lesson 2 (located on p. 5.6.2 of the Supplement) as well as the class word wall and their notebooks. They should make sure that the chemistry meaning is included for all words.

Hook (time: 5 minutes)
The teacher will ask students to respond to this question:

What is your favorite game and why?

Note: If it is a computer game, they may not be able to create it in class, but they can plan it. This would be a good opportunity to talk about career opportunities in creating computer games. Becker College in Worcester/Leicester has a great program.

Presentation (time: 20 minutes)
The teacher may scaffold the process of planning and designing a game to meet the objectives outlined in the rubric on p. 5.6.5. The teacher may wish to suggest two or three common game formats (e.g., Trivial Pursuit, Life, and Jeopardy) and ask students to choose one of them. The teacher will present the rubric and discuss the standards for knowledge of subject, providing examples of know questions, such as “What is Avogadro’s number?”; understand questions, which can be true/false, such as “2H₂O₂ can be broken down into two water molecules and one oxygen molecule—True or False”; and analysis questions, which may require players to interpret a graph or determine how much of a reactant needs to be added to obtain a certain amount of product. Students should use the vocabulary compiled in the Do Now, as well as a bank of chemistry equation problems from their binders, to create games that can be played in about 10 minutes. All questions should have something to do with the content learned in this unit.

Practice and Application (time: 50 minutes over 2 days)
Students should plan and develop their games, either individually or with partners, using the template and rubric on pp. 5.6.4 to 5.6.5 in the Supplement. Students should receive feedback from the teacher and other students during the production process.

Review and Assessment (time: 25 minutes)
Once the games have been created, the students will present their games to each other and play them. Peers will evaluate the games on the basis of the rubric, and the game makers will ask questions of the players to determine what they learned from playing the game.
Extension
Students may be given additional time to develop and share their games as needed. They may also revise and refine their games based on peer and teacher feedback.

Lesson 12

Curriculum Performance Assessment (3 Days)

Goal
Working individually or as a group, students will use their knowledge of stoichiometry to calculate and report on the carbon emissions of different fuels burned to create electricity as outlined in the following scenario:

Goal: To analyze, evaluate, and report on the environmental impact of burning different kinds of fuels in a proposed power plan

Role: A city or county engineer with expertise in carbon emission

Audience: City or county policy makers who will decide on the type of power plant to be built

Situation: The city or county needs a new power plant to meet electricity demand, and several types have been proposed, including those that burn fossil fuels (coal, oil, and natural gas). The policymakers must decide whether to approve one of these types or to seek alternatives such as biofuel wood. Ongoing carbon emissions will be an important consideration.

SEE: www.icr.org/life-science

Product: A report and oral presentation explaining the environmental impact of each option, including stoichiometric equations showing the amounts of CO$_2$ produced by each type of fuel, and an evidence-based recommendation to the policy makers

Standards: Completeness and accuracy of stoichiometric equations, clarity of explanations, support for final recommendation, organization and correctness of report materials, and coherence of oral presentation

Note: The chemistry of burning fuel to create electricity is in reality very complex and variable depending on the source of the fuel, the efficiency of the power plant, and many other factors. For the purposes of this Performance Task, some chemical formulas and processes have been simplified to allow for easier calculations. The teacher may further adjust the task by limiting the number of fuels compared or by providing more or less information to students in advance.

Do Now (time: 5 minutes)
Students should write or brainstorm responses to the following questions then discuss them as a group:

1. Where does the electricity we use when we flip on a switch come from?
2. How is it produced?
3. How does electricity production affect the environment?
Hook (time: 15 minutes)
The teacher will use information and illustrations from the websites listed below to introduce the ideas that all means of producing electricity have environmental impacts and any decision about how to produce electricity involves trade-offs. The U.S. Energy Information Administration site provides an overview of power plant emissions, including carbon dioxide, which will be the focus of the performance assessment. The Carnegie-Mellon University site includes diagrams illustrating how power is produced by various fuel sources as well as a table highlighting key aspects of each method of generating electricity. (The first four rows of this table should be highlighted, as they focus on CO₂-producing methods.) Based on the information in the table, students should discuss the advantages and disadvantages of the various methods.

SEE: “Electricity and the Environment”
www.eia.gov/EnergyExplained/?page=electricity_environment
“Energy Sources, Technologies, and Impacts”
http://environ.andrew.cmu.edu/m3/s3/11sources.shtml

Presentation (time: 35 minutes)
The teacher will introduce the Performance Task using the three-page handout included on pp 5.6.6 to 5.6.8 in the Supplement, explaining that students will take on the role of an engineer providing information that will inform a decision about what kind of power plant to build. The task involves using stoichiometry to analyze the generation methods that involve burning fuels to produce electricity with an eye toward emissions of CO₂. The teacher will illustrate the analytical process by working through the first and second columns of the table, coal and oil, with students, asking them to balance the equations and compute the amounts of CO₂ produced per mole of fuel and per kilowatt hour (kWh). The teacher will highlight the grams of CO₂ per kilowatt-hour results for coal and oil and ask students to discuss the difference in environmental impact of these two fuels.

Practice and Application (time: 55 minutes)
On Day 2, before students continue the work of completing the Electricity Production Stoichiometry Calculation Sheet, the teacher will lead a review of the standards for success for the project and work with them to develop descriptors for each of the performance levels in the rubric. Then, working individually or as a group, students should complete the remaining equations and calculations to finish the table. The following websites illustrate the combustion reactions for coal, natural gas, and wood, and students may find them helpful to check their work in balancing equations:

SEE: “Chemistry of Fossil Fuels”
environ.andrew.cmu.edu/m3/s3/09fossil.shtml
“Combustion of Methane”
www.whatischemistry.unina.it/en/combust.html
“The Combustion Reaction”
www.whatischemistry.unina.it/en/burn.html

When students have completed the calculations, the teacher should check their work and encourage them to compare the CO₂ emissions created by the various types of fuel. The students should then decide what recommendation they would make to policy makers about choosing a power plant fuel. They might, for example, choose natural gas because it has the lowest emissions, or wood because it is
renewable, or none of the above because they all contribute to global warming. Whatever their choice, they should create diagrams and/or slides illustrating the relevant data and assemble a report that delivers their findings.

**Review and Assessment** (time: 55 minutes)

On Day 3, students should use the rubric to review their work in progress and revise it as necessary to create an effective report. Then students should present their findings to the class using technology, like PowerPoint or Scratch or PhotoStory by Windows, respond to questions, and receive feedback based on the rubric from peers and the teacher. Students should write a final reflection on the process of using chemistry to make public policy decisions.

**Extension**

If students are ready to pursue more complex calculations and are interested in learning more about power plant emissions, they could repeat the analysis using real chemical formulas for coal, such as $C_{137}H_{97}O_{9}NS$ for bituminous coal and $C_{240}H_{90}O_{4}NS$ for high-grade anthracite.

SEE: chemed.chem.purdue.edu/genchem/topicreview/bp/1organic/coal.html

This kind of analysis would reveal other by-products of coal burning that contribute to pollution. Students may also wish to research the chemical processes used to create “clean coal” and other alternatives to traditional fossil fuel power plants.

**POST–UNIT REFLECTION**

*On meeting the Learning and Language objectives*
Connections to Empower Your Future
UNIT: Balancing Chemical Equations

Future Ready Connections

This unit is connected with Future Ready skills. Youth have many opportunities to strengthen their communication skills through group discussions, partner work, and presentations of their Performance Task, posters from Lessons 1, 2, and 6, and their game from Lesson 11.

Youth can also be evaluated for initiative and self-direction as they plan and develop their games in Lesson 11. Teachers should reflect on whether or not youth stay on task without prompting and if they push themselves to create a detailed final product instead of only addressing the minimum required information.

The game development is also an excellent opportunity to emphasize Positive Youth Development and Culturally Responsive Practice as youth will be able to bring their experiences and expertise to the task. There are multiple opportunities for youth to give and receive feedback from peers which will allow teachers to evaluate students on their accountability for their own work and to their peers.

Teachers are encouraged to use the Future Ready Rubric to evaluate students and are encouraged to support students as they self-evaluate their demonstration of Future Ready skills.

Essential Questions Connections

Teachers are encouraged to make connections among Future Ready skills, EYF topics, and the two Essential Questions that ask: “Why are recipes important in science?” and “Why is it important, in chemistry and in life, for things to balance?” These Essential Questions lead students to consider how chemical reactions and creating final products depend on a specific recipe of ingredients and steps in a process. Teachers can pull in personal, academic, and professional planning topics by discussing the following questions that relate to the idea of recipes, ingredients, and steps in a process: How does the idea of creating or following a recipe apply to a person’s life? Do certain ingredients and steps lead to happiness and success? Can there be substitutions if something doesn’t work out or is not available? Teachers should emphasize Positive Youth Development by encouraging youth to consider how certain elements, like completing a high school education, pursuing postsecondary education, or attaining certifications, securing employment, and maintaining a healthy, drug free life, play a role in the recipe for a happy and successful life. Classes should discuss what happens when you need to make a substitution to a recipe (such as exchanging a banana for oil) and what they can do in their personal or professional lives if they need to make a substitution (such as if a youth cannot attend his/her first-choice post-secondary program). These connections to the Essential Questions also provide an opportunity for Culturally Responsive Practice since teachers can encourage students to make personal connections to the concepts and use examples from their own experience.

Transfer Goal Connections

The following two Transfer Goals connect with EYF concepts: Students will explain how the energy sources they consume impact the world around them. Students will create presentations to express their opinions to others, using evidence and reasoning to support their claims. As students consider how their own consumption of energy sources and resources impacts the world around them, teachers can ask students to also consider what sources of support and resources exist for them in the DYS system and in the community.
What happens when they take advantage of that support? What happens when they let it go to waste? Students can also discuss opportunities to give back to their communities through volunteer work as a way to reflect on how they can impact the world in a positive way and not simply consume but create resources and a source of energy for others. To connect to the second Transfer Goal mentioned above, teachers should also emphasize that students use evidence and reasoning to support claims during their presentations not only in their science classes but in EYF and other classes. Students present several EYF projects in their assessment and treatment programs in order to express their own voice and advocate for their needs and goals. These EYF projects and presentations must be based on research, evidence, and critical thinking, just like a scientific presentation would be.

**Lesson 1, 6, and 8 Connections**

Lesson 1 asks students to identify the difference between reactants and products and the role that energy plays in the chemical reaction necessary to turn the reactants into the product. This is very similar to the concept of elements interacting to create a system, but it adds the important concept of the role of energy and how that allows the reactants to turn into a product. Youth can discuss the reactants in their lives and how these elements/ingredients create a final product (such as attaining their long-term or short-term goals). An important idea to discuss is the energy source that allows this chemical reaction (the final product) to happen. What is the energy source that takes the reactants and helps them become the final product? In a youth's life, what is the energy source that will take all of their experience, skills, talents, etc. and turn it into a realized goal? Teachers may wish to encourage youth to see support systems like family, teachers, counselors, coworkers, etc. as the energy source that is needed to change the reactants into a final product. Other energy sources needed to change reactants to a final product may be a youth's personal attributes such as determination, perseverance, hard work, honesty, creativity, etc. For example, by taking their skills, talents, and interests and adding in determination, youth will be able to create a bright future for themselves.

**Teachers can use the concept of equilibrium and homeostasis and connect it to EYF lessons**

Stoichiometry Practice, Lesson 6 that address positive mental health and physical health. Teachers can discuss how personal equilibrium and homeostasis may be achieved through coping strategies, resilience, overcoming obstacles, affirmations, and optimism. Consider using the following questions to begin the conversation: What does homeostasis look like or feel like in your personal life? How do you maintain equilibrium when you have many feelings, ideas, or responsibilities pulling you in different directions? What healthy choices can you make to regain equilibrium and maintain your own homeostasis?

Teachers may consider expanding on Lesson 8’s Do Now that asks students to look at a photo of a chemical industrial plant and speculate on what is produced there. Classes can speculate on what types of jobs are required to run the plant and then complete research either online or on MassCIS to discover the variety of jobs. Examples of jobs may include: engineer, assembler, fabricator, operations manager, safety supervisor, maintenance worker, payroll specialist, etc.
Cupcake Recipe
Lesson 1

Ingredients

2 cups flour
1/2 teaspoon salt
2 teaspoons baking powder
1/2 cup butter, softened
3/4 cup sugar
2 eggs
1 cup milk

Directions

1. Preheat oven to 400 degrees.
2. Mix batter until smooth. Pour into greased cupcake tins 1/2 to 2/3 full.
3. Bake in oven for 15-20 minutes. Insert toothpick or pasta in center of cupcake to test if cooked through.
4. Cool on rack for 5-10 minutes, then remove from pan.
5. Frost gently with your favorite frosting when cupcakes are cool.

Guidance

Students should identify the following:

- reactants (flour, salt, baking powder, butter, sugar, eggs, milk)
- products (cupcakes)
- energy source (heat)

The class will then discuss the difference between reactants and products and the role energy plays in the chemical reaction. These terms should be used to begin a unit word wall.

Materials Needed

Large bowl, mixer, large mixing spoon, teaspoon, tablespoon, measuring cups, muffin tin(s)
Words with Multiple Meanings  
Lesson 2

**DIRECTIONS:** The following words are words you may use in your daily lives and in math classes. They also have uses in chemistry, which are similar but different from the meanings you may be familiar with. Fill in this chart with sentences using each word in as many contexts as you can. If you do not know the math or chemistry definitions, you can leave them blank and fill in examples as we encounter the words. The first row at the top is filled in as an example.

<table>
<thead>
<tr>
<th>WORD</th>
<th>DAILY USAGE</th>
<th>MATH USAGE</th>
<th>CHEMISTRY USAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>Her little brother is a constant bother while she is talking on the phone.</td>
<td>A number can be a constant, as in y=2x+5. Five is the y-intercept and it is a constant.</td>
<td>Avogadro’s number, or $6.02214179 \times 10^{23}$, is a constant that represents one mole of a substance.</td>
</tr>
<tr>
<td>Reaction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratio</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proportion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluate</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Table: Finding Molecular Mass**

**Lesson 3**

**DIRECTIONS:** In class, the teacher and students will work together to find the molecular mass of the compounds CO$_2$, O$_2$, H$_2$O, NH$_3$ using the table below for each calculation. The teacher may create tables on the board to demonstrate as the students create their own tables (one for each compound).

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Atomic Mass</th>
<th>Number of Atoms</th>
<th>Total Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**MOLECULAR MASS COMPUTATION FOR THE COMPOUND ____________________________**

**TOTAL MOLECULAR MASS OF COMPOUND:**
Game Planning Template
Lesson 11

**START**

Give your game a title.

**Objective:**
What will the players learn from this game?

**Learners and Context of Use:**
What needs to happen before the game is played? What do players need to know? (Players will need to know some algebra and the common meaning of some words that are used in chemistry. What else? Do you have to teach them anything in order for them to succeed?)

**Object of the Game:**
What is the game goal? What is the end state that the players are trying for? (For example, to be the first to reach the finish square, or to be the first to reach 100 points.)

**Time and Rules:**
How long should the game last? Include a short numbered list of simple and clear rules for the game.

**Game Materials:**
List each of the objects you would find in the game box.

**FINISH**
**Game Rubric**  
**Lesson 11**

**DIRECTIONS:** Use the rubric below to evaluate game quality.

<table>
<thead>
<tr>
<th>Category</th>
<th>Excellent</th>
<th>Good</th>
<th>Satisfactory</th>
<th>Needs Work</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subject Knowledge</strong></td>
<td>Game designed so that players had opportunities to answer at least 3 knowledge questions (perhaps vocabulary), 3 understanding questions (perhaps true/false), and 3 analysis or application questions (solving problems)</td>
<td>Game designed so that players had opportunities to answer at least 3 knowledge questions (perhaps vocabulary), 2 understanding questions (perhaps true/false), and 2 analysis or application questions (solving problems)</td>
<td>Game designed so that players had opportunities to answer at least 3 knowledge questions (perhaps vocabulary), 1 understanding question (perhaps true/false), and 1 analysis or application question (solving problems)</td>
<td>Game not designed in a way that required players to use any knowledge of material learned in the unit to succeed</td>
</tr>
<tr>
<td><strong>Content Accuracy</strong></td>
<td>All information cards made for the game were correct</td>
<td>All but one of the information cards made for the game were correct</td>
<td>All but two of the information cards made for the game were correct</td>
<td>Several information cards made for the game were inaccurate</td>
</tr>
<tr>
<td><strong>Design Appearance</strong></td>
<td>Colors and original graphics were used to give the cards and the gameboard visual appeal</td>
<td>Colors and at least 1 original graphic were used to give the cards and the gameboard visual appeal</td>
<td>Colors and borrowed graphics were used to give the cards and the gameboard visual appeal</td>
<td>Little or no color was used and/or no graphics were included</td>
</tr>
<tr>
<td><strong>Rules</strong></td>
<td>Rules were written clearly enough that all could easily participate</td>
<td>Rules were written, but one part of the game needed slightly more explanation</td>
<td>Rules were written, but people had some difficulty figuring out the game</td>
<td>Rules were not written</td>
</tr>
</tbody>
</table>
Using Chemistry to Evaluate Power Plant Options
Lesson 12

DIRECTIONS: In this assignment, you will use your knowledge of stoichiometry to calculate and report on the environmental impact of different fuels burned to create electricity. The situation is that your city or county needs a new power plant to meet electricity demand, and several types have been proposed, including those that burn fossil fuels (coal, oil, and natural gas). The policymakers must decide whether to approve one of these types or to seek alternatives such as biofuel (wood). Ongoing carbon emissions will be an important consideration. You will take the role of a city or county engineer with expertise in carbon emissions, and you will be reporting to city or county policymakers who will decide on the type of power plant to be built. You must produce a report and oral presentation explaining the environmental impact of each option, including stoichiometric equations showing the amounts of CO$_2$ produced by each type of fuel, and an evidence-based recommendation to the policymakers.

To complete this task, you will need to apply the skills you have learned in this unit, including balancing equations and computing the mass of reactants and products. Use the calculation sheet to generate data, following these steps:

• Combustion Reaction: Create balanced equations showing reactions of each fuel with O$_2$
• Mole/Mass Calculation: Compute the molecular masses of all reactants and products
• g CO$_2$/g fuel: Compute the grams of CO$_2$ produced per gram of fuel consumed
• g CO$_2$/kWh: Using the grams of fuel per kilowatt-hour (g fuel /kWh) figures provided, calculate the amount of CO$_2$ produced per kilowatt-hour for each fuel
• Comparison Values: Use the websites provided in the footnote to view other researchers’ calculations of CO$_2$ produced per kilowatt-hour for each fuel (results vary with conditions)

Use the data to develop your report and oral presentation, including your recommendations about the choice of an energy source. Be sure to state your conclusions clearly and support them with evidence. Use visual aids such as diagrams and/or slides to illustrate your key points.

Work with your teacher to develop descriptors for each level of performance in the rubric:

<table>
<thead>
<tr>
<th>Standards for Success</th>
<th>Excellent</th>
<th>Good</th>
<th>Satisfactory</th>
<th>Needs Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completeness and accuracy of stoichiometric equations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clarity of explanations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support for final recommendation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organization and correctness of report materials</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coherence of oral presentation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Electricity Production Stoichiometry

**Calculation Student Organizer**

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Coal</th>
<th>Oil</th>
<th>Natural Gas</th>
<th>Wood</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Formula</strong>*</td>
<td>C</td>
<td>C_{16}H_{34}</td>
<td>CH_{4}</td>
<td>C_{6}H_{12}O_{6}</td>
</tr>
<tr>
<td><strong>Combustion Reaction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mole/Mass Calculation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g CO\textsubscript{2} /g fuel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g fuel /kWh\textdagger</td>
<td>476g (1.05 lbs.)</td>
<td>233g (.07 gal.)</td>
<td>197g (10.1 feet\textsuperscript{3})</td>
<td>442g (.975 lbs.)</td>
</tr>
<tr>
<td>g CO\textsubscript{2} /kWh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparison Values\textdaggerdbl</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Chemical formulas have been simplified. In reality, coal includes small amounts of many elements, but for the purposes of this assignment, it is treated as pure carbon. Fuel oil is actually a blend of many compounds with various numbers of carbon atoms; C_{16}H_{34}, or hexadecane, is used as an example. The chemistry of wood is close to that of sugar, so the formula for sugar is used here.


‡Estimated g CO\textsubscript{2} /kWh by generation method from the following websites (respectively):
1 Kilowatt-Hour: http://blueskymodel.org/kilowatt-hour
Distributed Generation: http://www.dg.history.vt.edu/ch2/impact.html.
### Electricity Production Stoichiometry

**Calculation Answer Sheet**

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Coal</th>
<th>Oil (C_{16}H_{34})</th>
<th>Natural Gas</th>
<th>Wood (C_{6}H_{12}O_{6})</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Combustion Reaction</strong></td>
<td>(C + O_2 \rightarrow CO_2)</td>
<td>(2C_{16}H_{34} + 49O_2 \rightarrow 32CO_2 + 34H_2O)</td>
<td>(CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O)</td>
<td>(C_{6}H_{12}O_{6} + 6O_2 \rightarrow 6CO_2 + 6H_2O)</td>
</tr>
<tr>
<td><strong>Mole/Mass Calculation</strong></td>
<td>(1(12) + 1(16x2) = 1(12x1 + 16x2))</td>
<td>(2(12x16 + 1x34) + 49(16x2) = 32(12x1 + 16x2) + 34(1x2 + 16x1))</td>
<td>(1(12x1 + 4x) + 2(16x2) = 1(12x1 + 16x2) + 2(1x2 + 16x1))</td>
<td>(1(12x6 + 1x12) + 6(16x2) = 6(12x1 + 16x2) + 6(1x2 + 16x1))</td>
</tr>
<tr>
<td></td>
<td>(1(12) + 1(32) = 1(44))</td>
<td>(2(226) + 49(32) = 32(44) + 34(18))</td>
<td>(1(16) + 2(32) = 1(44) + 2(18))</td>
<td>(1(180) + 6(32) = 6(44) + 6(18))</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(44 = 44)</td>
<td>(2,020 = 2,020)</td>
<td>(80 = 80)</td>
</tr>
<tr>
<td><strong>g CO(_2) /g fuel</strong></td>
<td>(44/12 = 3.67)</td>
<td>(1,408/452 = 3.11)</td>
<td>(44/16 = 2.75)</td>
<td>(264/180 = 1.47)</td>
</tr>
<tr>
<td><strong>g fuel /kWh†</strong></td>
<td>476g (1.05 lbs.)</td>
<td>233g (.07 gal.)</td>
<td>197g (10.1 feet(^3))</td>
<td>442g (.975 lbs.)</td>
</tr>
<tr>
<td><strong>g CO(_2) /kWh</strong></td>
<td>476(3.67) = 1,747</td>
<td>233(3.11) = 725</td>
<td>97(2.75) = 542</td>
<td>442(1.47) = 649</td>
</tr>
<tr>
<td><strong>Comparison Values‡</strong></td>
<td>909g CO(_2)/kWh</td>
<td>821g CO(_2)/kWh</td>
<td>465g CO(_2)/kWh</td>
<td>1,500g CO(_2)/kWh</td>
</tr>
</tbody>
</table>

*Chemical formulas have been simplified. In reality, coal includes small amounts of many elements, but for the purposes of this assignment, it is treated as pure carbon. Fuel oil is actually a blend of many compounds with various numbers of carbon atoms; \(C_{16}H_{34}\), or hexadecane, is used as an example. The chemistry of wood is close to that of sugar, so the formula for sugar is used here.


‡Estimated g CO\(_2\)/kWh by generation method from the following websites (respectively): 1 Kilowatt-Hour: http://blueskymodel.org/kilowatt-hour Distributed Generation: http://www.dg.history.vt.edu/ch2/impact.html.
Why and How Chemicals React

TOPIC SEASON: Reaction Rates and Equilibrium

This unit is designed for use in short-term programs, but it may be extended for long-term settings.

Unit Designers: H. Hay and M. McMahon Chappell

Introduction

From the 1930s to the 1980s, DuPont used the advertising slogan, “Better Things for Better Living … through Chemistry,” and other chemical companies adopted variants of it. While it is hard to imagine a similar campaign being mounted today, given the amount of negative press about chemical pollution there has been in the past several decades, there is no getting around the fact that chemical reactions play a huge role in our daily lives, from processing food to manufacturing pharmaceuticals, health and beauty aids, household cleaners, and automotive products; and the chemical industry offers career in fields ranging from research to retail marketing.

Regardless of the fields students pursue when they leave DYS, however, they will be expected to construct explanations and design solutions to problems, as called for in the standards for this unit. By studying and experimenting with chemical principles at work in the world, they can develop means to harness the power of temperature, pressure, concentrations of reactants, mixing, particle size, surface area, and addition of a catalysts to achieve a particular result. These strategies can be applied to the fields of culinary arts, automotive mechanics, and construction, as well as medicine, engineering, and scientific research.

There are many opportunities in this unit for students to connect to the content by participating in labs and making decisions about how to prove a hypothesis. For the Summative Assessment, students are encouraged to apply Le Châtelier’s principle to an everyday situation that shows the importance of balance in their own lives, allowing them to personalize the concepts they learned in the unit. They are allowed a great deal of creativity in the Performance Task, which provides students multiple means of expression to create a narrative and present the results of their lab reports.

This unit is designed to take about two weeks at the start of the seven-week Reaction Rates and Equilibrium season (February to March), but it can be modified in a number of ways according to the needs of the program and the participating students. It could easily be divided into two shorter units, one focusing on the factors that affect reaction rate, and the other focusing on equilibrium. The summative narrative requirement could be waived for those who are in attendance for a short time, and students could focus on one component of the unit instead of both:

- Short-term facilities may choose to focus on the factors that influence reaction rates followed by the Alka-Seltzer lab. Completion of the lab and a lab report would satisfy standard HS-PS1-5 and could serve as a summative assessment. Students should include their lab reports in their portfolios.
- The teacher may choose to focus on equilibrium and Le Châtelier’s principle, followed by an explanation
REACTION RATES: Introduction

of equilibrium. In this case the Summative Assessment could be limited to the following to address standard **HS-PS1-6**: Construct an explanation of equilibrium by generating a slide show, rap, or essay to share with peers. Analyze the factors in chemical equilibrium and apply Le Châtelier’s principle to an everyday situation that shows the importance of balance in our lives.

This unit gives attention to both Emphasized Standards in the Reaction Rates and Equilibrium season. **HS-PS1-5** focuses on collision theory and asks students to construct explanations of how varying conditions influence the rate of a chemical reaction or a dissolving process. It also asks students to design and test ways to alter various conditions to influence rates of processes as they occur. **HS-PS1-6** asks students to design ways to control the extent of a reaction at equilibrium by altering various conditions using Le Châtelier’s principle and make arguments based on collision theory to account for how altering conditions would affect the forward and reverse rates of the reaction until a new equilibrium is established. The phrases “construct an explanation,” “design and test,” and “make arguments” imply that there should be some very active participation on the part of the students to demonstrate an understanding of the material presented in this unit. The inclusion of several labs serves to meet this expectation. The most important component of this unit is for the students to learn how to use the scientific method to conduct an experiment to verify the importance of different variables on the reaction rate and to control the extent of a reaction at equilibrium.

It would help if students have some experience with cooking, since many of the concepts covered can be illustrated with examples from cooking. Teachers may be able to bring students to the kitchen or bring a hot plate into the class to illustrate factors that affect rates of reaction. If that is not possible, illustrations and videos can provide the necessary background knowledge. There is also a strong link to biology and the concept of homeostasis, so some knowledge of anatomy and physiology would be helpful. Perhaps prefacing the lesson on Le Châtelier’s principle with a review of homeostasis, especially as it pertains to the circulatory and respiratory systems, would be very helpful. All teachers should have access to the Miller and Levine Biology textbook that would provide this background information.

The experiments may be challenging in some facilities given the space needed to work with the materials. Because of that, multiple points of entry have been provided. If one or more experiments cannot be done, there are online and text resources that can be used to demonstrate virtual experiments. Most lessons include materials that are safe and easily accessible.

The lessons also include multiple means of differentiating instruction to provide access to the curriculum for all students:

- Lessons include graphic organizers, particularly top-down webs and two-column notes.
- Pre-reading activities include a Teacher Think Aloud and scaffolding of the text by presenting the material with associated PowerPoints. If students are strong independent readers, the teacher may decide to forego the PowerPoint pre-reading activity.
- Students watch demonstrations of labs before designing their own labs for the Alka-Seltzer experiment. Students can participate in the Dancing Raisins lab and the Elephant Toothpaste lab according to their abilities and comfort levels, as the labs can be demonstrated, performed with partners or in small groups, or conducted individually.
- Students have an opportunity to express their understanding orally, in writing, and using mathematics and graphs throughout the unit.
- Applications such as Microsoft Word, PowerPoint, StoryBoard, posters, Audacity, and/or other tools may be used to construct the portfolio for the Summative Assessment.

For **long-term adaptation ideas for this unit**, see p. 5.7.3 on the right.
### Why and How Chemicals React
Adapting This Short-Term Unit for Long-Term Programs

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Why and How Chemicals React</th>
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</thead>
<tbody>
<tr>
<td>Overview</td>
<td>Throughout this unit, students will be focusing on two standards that are connected in principle, and both parts are important when designing experiments. Standard HS-PS1-5 expresses the importance of understanding collision theory and determining how different conditions affect chemical reaction rates. The standard’s expectations include students’ designing tests to change the rate of reaction. In standard HS-PS1-6, the students work with developing different experiments to study equilibrium and Le Châtelier’s principle. In long-term programs, the unit may be extended to provide the time that may be needed to address all aspects of both standards, including designing and testing different reaction rates.</td>
</tr>
<tr>
<td>Desired Results</td>
<td>While moving through the unit, it is essential to follow the KUDs and offer more opportunities and practice of the Do section. The equilibrium <strong>Know</strong> could be expanded into students’ creating an argument supporting Le Châtelier’s principle by creating an experiment to demonstrate their understanding. A class may also want to include reflection points into the unit to monitor comprehension, since the KUDs build on each other. A teacher could have the students write reflections on the daily KUDs to include in their summative portfolios.</td>
</tr>
<tr>
<td>Assessment Evidence</td>
<td>Throughout this unit, the Performance Task focuses on creating a portfolio of the students’ work on the Formative Assessments in the unit as well as an introduction, an experiment at the end, and a piece of work to explain the importance of equilibrium. To extend this assignment and further address the standards, a teacher could encourage students to develop a real-life situation and describe different tests to examine how various factors and conditions affect reactions and show understanding about how the product and the reactants have an inverse relationship. A student may develop different trials using their own knowledge and research surrounding car engines. For example, students could examine how starting a car on a cold day is different from starting it on a warmer day. Adding various real-life applications could help students see the importance of chemistry.</td>
</tr>
</tbody>
</table>
| Learning Plan | To pursue opportunities for further enrichment, the class may complete two different Gizmos from ExploreLearning.com during the unit.  
In **Lesson 2**, students could work independently or in pairs with the Gizmo on Collision Theory (https://www.explorelearning.com/index.cfm?method=cResource dspDetail&ResourceId=553). The site includes a vocabulary list and student handouts, which may be added as a Formative Assessment.  
In addition, **Lesson 7** could be extended by using an Equilibrium and Concentration Gizmo (https://www.explorelearning.com/index.cfm?method=cResource dspDetail&ResourceId=1046). This activity allows students to watch the inverse relationships of products and reactants and notice how equilibrium is achieved in the chemical reactions.  
Finally, **Lesson 6** could also make connections between catalysts and protein enzymes. A similar experiment could take place using hydrogen peroxide and cow’s liver to see the reaction with differently shaped pieces of meat and how the amount of enzymes changes the reaction to the hydrogen peroxide. |
Emphasized Standards *(High School Level)*

**HS-PS1-5:** Construct an explanation based on kinetic molecular theory for why varying conditions influence the rate of a chemical reaction or a dissolving process. Design and test ways to alter various conditions to influence (slow down or accelerate) rates of processes (chemical reactions or dissolving) as they occur.

*Clarification Statements:*
- Explanations should be based on three variables in collision theory: (a) quantity of collisions per unit time, (b) molecular orientation on collision, and (c) energy input needed to induce atomic rearrangements.
- Conditions that affect these three variables include temperature, pressure, concentrations of reactants, agitation, particle size, surface area, and addition of a catalyst.

*State Assessment Boundary:*
- State assessment will be limited to simple reactions in which there are only two reactants and to specifying the change in only one variable at a time.

**HS-PS1-6:** Design ways to control the extent of a reaction at equilibrium (relative amount of products to reactants) by altering various conditions using Le Châtelier’s principle. Make arguments based on kinetic molecular theory to account for how altering conditions would affect the forward and reverse rates of the reaction until a new equilibrium is established.

*Clarification Statements:*
- Conditions that can be altered to affect the extent of a reaction include temperature, pressure, and concentrations of reactants.
- Conditions that can be altered to affect the rates of a reaction include temperature, pressure, concentrations of reactants, agitation, particle size, surface area, and addition of a catalyst.

*State Assessment Boundary:*
- Calculations of equilibrium constants or concentrations are not expected in state assessment.
- State assessment will be limited to simple reactions in which there are only two reactants and to specifying the change in only one variable at a time.
Essential Questions (Open-ended questions that lead to deeper thinking and understanding)

- How is the balance in chemical systems like homeostasis?
- Why and how do outside forces affect chemical reactions?
- How can we control chemical reaction rates in the kitchen, in our cars, or at work?

Transfer Goals (How will students apply their learning to other content and contexts?)

Students will be able to apply knowledge of Le Châtelier’s principle to control reactions while cooking, cleaning, creating art, or doing anything that involves a chemical reaction. They will also explain how catalysts can speed up reactions, and why this can be important to our health.
## Learning and Language Objectives

*By the end of the unit:*

**Tier III Vocabulary:**
- reactant
- product
- reaction
- constant
- collision theory
- activation energy
- activated complex
- inhibitor
- exothermic
- endothermic
- catalyst
- reversible reaction
- chemical equilibrium
- equilibrium position
- Le Châtelier’s principle
- equilibrium constant

**Tier II Vocabulary:**
- measurement
- balance
- evaluate
- progress
- progression
- rate

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<table>
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<tr>
<th>Students should know...</th>
<th>understand...</th>
<th>and be able to...</th>
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<tr>
<td><strong>Reaction rate</strong> is the change in the amount of a reactant or product over a period of time. Reaction rates depend on the reactivity of reactants, concentration of reactants, temperature, and addition of a catalyst.</td>
<td>There is an inverse relationship between reactants and products. If reactants decrease, product increases, and vice versa. Colliding particles need a certain amount of energy to create a reaction. Particles can have different amounts of energy depending on external factors, such as temperature, concentration, particle size, and catalysts.</td>
<td>Differentiate exothermic and endothermic reactions. Demonstrate how catalysts increase the rate of a chemical reaction. Prove that the rate of a chemical reaction can be changed by manipulating external factors, e.g., heat, concentration, and addition of a catalyst.</td>
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<tr>
<td><strong>Factors that change equilibrium position in a chemical system</strong> are concentration of the reactants and products, temperature, and pressure (Le Châtelier’s principle)</td>
<td>Equilibrium in a chemical system means that the rates of forward and backward motion are equal. Stresses including concentration of products and reactants, temperature, and pressure can upset equilibrium (Le Châtelier’s principle). The size of the equilibrium constant indicates whether reactants or products are more common at equilibrium. A large value indicates more product, while a very small value indicates that a mixture is mostly reactant.</td>
<td>Explain the three factors that can cause a change in the equilibrium position in a chemical system: concentration of products and reactants, temperature, and pressure.</td>
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Assessment Evidence
Quality questions raised and tasks designed to meet the needs of all learners

Performance Task and Summative Assessment (see pp. 5.8.18 to 5.8.20)

Aligning with Massachusetts standards

Students will create a portfolio of completed and new work that summarizes and applies their learning in the unit. Instructions for collation of the portfolio are as follows:

- Assemble all assignments from this unit to create a collection that should read like a narrative for someone who is unfamiliar with chemical reaction rates.
- Compose an introduction to the portfolio that explains its contents and illustrates the following with real-life applications: collision theory, the four factors that influence reaction rate, and Le Châtelier’s principle.
- Provide proof of factors that influence reaction rate by performing an experiment with Alka-Seltzer. Include your lab report in the portfolio.
- Construct an explanation of equilibrium by generating a slide show, rap, or essay to share with peers. Analyze the factors in chemical equilibrium and apply Le Châtelier’s principle to an everyday situation that shows the importance of balance in our lives.

Students may use a combination of Microsoft Word, PowerPoint, StoryBoard, posters, Audacity, or other tools to construct the portfolio. Students will receive assistance from teacher and/or peers as necessary to organize materials. All lessons will be scaffolded according to student need, and the Summative Assessment will be put together in pieces throughout the unit, leaving only the introduction and the explanation and analysis of equilibrium for them to do at the end of the unit.

Note: Students will collect materials for the Performance Task in binders or folders throughout the unit, beginning with Lesson 2. The teacher should inform students about this project at that point and remind them throughout the remaining lessons.

Pre-Assessment (see pp. 5.8.9 to 5.8.10)

Discovering student prior knowledge and experience

Make predictions about how various factors influence reaction rate and equilibrium.
Discuss: What is the difference between a fast and slow person and a fast and slow chemical reaction? What factors contribute to automobile collisions? Could microscopic particles collide for the same reasons (random and not planned)?

For Empower Your Future Connections, see pp. 5.9.1 - 5.9.2
Formative Assessments

Monitoring student progress through the unit

Students complete two-column notes with illustrations for collision theory graph analysis and critical thinking questions.

Students complete top-down web to summarize four factors affecting reaction rates with examples and analyze four demo experiments involving Alka-Seltzer.

Students observe a demonstration about the decomposition of hydrogen peroxide with yeast, and answer questions about how yeast acts as a catalyst.

Students interpret graphs pertaining to exothermic and endothermic reactions.

Students interpret graphs pertaining to catalysts.

Students relate Le Châtelier’s principle to homeostasis, applying knowledge to complete a chart about how a reaction returns the body to equilibrium in response to a stimulus.

Students participate in labs that require them to predict, observe, analyze, conclude, and share their results.

Students give examples of how systems can be disrupted by natural or artificial means and explain how to prevent or control some chemical reactions, such as food spoilage.
Access for All

Considering principles of Universal Design for Learning (UDL), Positive Youth Development/Culturally Responsive Practice (PYD/CRP), differentiation, technology integration, arts integration, and accommodations and modifications

Students will relate Reaction Rates and Equilibrium to events and activities in their own lives throughout the unit. The teacher can relate this unit to the roller coaster unit in the EYF book that encourages students to look at strengths as well as threats that could derail them. Staying on course is similar to maintaining equilibrium. You don’t want to go too fast or too slowly through your life, or be exposed to outside influences that could derail your plans.

Multiple Means of Engagement

Throughout the unit plan, the student will be provided with as many choices in the level of challenge and complexity as possible in order to recruit and sustain engagement. For example, the teacher will encourage and support students in setting their own personal, academic, and behavioral goals. The teacher will use many strategies to guide students, including reminders, guides, rubrics, checklists, and prompts among other things that focus students on self-regulatory goals. Student tasks will be varied, allowing for active participation, exploration, and experimentation. The teacher will provide differentiated models, scaffolds, and feedback, as well as content material that is culturally relevant and responsive to student’s backgrounds. Most important is that teachers design assignments and tasks with authentic outcomes, and that are purposeful and convey meaning. The hands-on experiments in Lessons 4, 6, and 8 are excellent opportunities for student engagement.

Multiple Means of Representation

Throughout the unit, the teacher will provide information and materials in several modalities such as visual diagrams, videos, vocabulary cards, and word walls, posters, and charts with formulas for calculations and models, videos, and audio for text. The teacher will also demonstrate concepts through hands-on activities. Materials will be collected throughout the unit in individual binders or folders and in classroom displays to provide reinforcement of key concepts.

Multiple Means of Action and Expression

Students will be provided options for demonstrating what they know and can do including assistive technology as needed. In composing or writing activities, the teacher will provide students with multiple options. For example, students will have access to word processors with grammar checks, word prediction, and spell checkers. Students could complete projects by making PowerPoint presentations, rapping through music videos, or drawing illustrations. In addition, students will have access to calculators. The teacher will scaffold writing or composing activities using tools such as concept maps, outlining tools, or graphic organizers. Students may need sentence starters and story webs to complete writing or composing tasks. The teacher will also break down long-term goals such as the final portfolio into short-term reachable goals such as lesson-by-lesson additions to the binder or folder.
Literacy and Numeracy
Across Content Areas

Reading
Students will read from the *Pearson Chemistry* textbook (Lessons 18.1 and 18.3) and read PowerPoint slides during teacher presentations. Students will also read instructions for labs, word walls, and posters.

Writing
Students will give written responses to textbook and teacher-created questions. Students will also use two-column notes, top-down webs, and brainstorming activities to organize information. In addition students will write lab reports and complete Exit Tickets.

Speaking and Listening
Students will participate in discussions throughout the unit and speak and listen to other students during the Pre-Assessment interactive activities.

Language
Students will think critically using the vocabulary presented in this unit and will discuss the origin of science vocabulary. For example, Le Châtelier’s principle is named after a scientist, a common practice in the sciences. Students will also decipher and discuss words with the prefixes *endo* and *exo*.

Students will also expand their vocabulary and be able to apply it to understand the lesson through the use a word wall and repetition throughout the unit. Reading, writing and discussion will emphasize the use of vocabulary.

Numeracy
Students will do dimensional analysis to solve rate of speed problems.
Students will also measure time and quantity to find rate of change in various experiments.
Students will create mathematical science models illustrating rate of change and create and analyze graphs.

Resources (in order of appearance by type)

Print

Websites
Web supplement to the *Pearson Chemistry* textbook:
www.harpercollege.edu/tm-ps/chm/100/dgodambe/thedisk/chemrxn/signs.htm.

www.scifun.org.


www.youtube.com/watch?v=yvyHVA1Ww_M.

www.youtube.com/watch?v=KYD5LNVWne8.

www.youtube.com/watch?v=-RRTnlGr6fg.

www.coolscience.org/CoolScience/KidScientists/h2o2.htm.

http://ths.talawanda.org/~bramblen/classroom/Chemistry/Notes/Section%205A/LeChâteliersprinciple.htm.

“Students know mass is conserved in physical and chemical changes.” Regional Professional Development Program. 2016.
www.rpdp.net/sciencetips_v3/P8A5.htm.

www.youtube.com/watch?v=7zuUV455zFs.

www.youtube.com/watch?v=XhQ02egUs5Y.


“Qualitative changes in Equilibrium—Le Châtelier’s Principle.” Google Images.
http://tinyurl.com/z2rst7m.

www.alkaseltzer.com/science-experiments/.


Materials
Paper, pencils, textbooks, student computers and/or teacher laptop and projector, whiteboard and markers, poster and markers as indicated for assessments, index cards and a word wall for vocabulary instruction throughout the unit.

The Decomposition of Hydrogen Peroxide (p. 5.10.1), Le Châtelier’s Principle (p. 5.10.2), Alka-Seltzer Lab Report Template (p. 5.10.3), Alka-Seltzer Rubric (p. 5.10.4)
Outline of Lessons

Introductory, Instructional, and Culminating tasks and activities to support achievement of learning objectives

INTRODUCTORY LESSONS

*Stimulate interest, assess prior knowledge, connect to new information*

Lesson 1

Rates of Chemical Reactions

**Goal**

Students will explain how a rate of a chemical reaction is expressed.

**Do Now (time: 5 minutes)**

Students do several math problems involving rate of speed, writing down key information from the board and plugging it into the distance formula \(d=rt\), after the teacher reviews it. The teacher should present the following three problems, which are increasingly challenging, and students can choose to do only the first or all three. This activity should be scaffolded if it requires a review of conversions and fractions, or simpler problems could be given and problems differentiated by writing them on paper per student need.

1. A cheetah runs after a gazelle at a rate of 60 mph (or 1 mile per minute) for 15 seconds. How far did it travel in 15 seconds?
2. It takes you 30 minutes to get to school and 45 minutes to get home. If you average 5 mph on the way to school, how far away is school? What is your average rate of speed on the way home? Why would it be different?
3. Bonus: How far will the cheetah go in 30 minutes at its optimal rate of speed, and how much faster is it than you are?

**Hook (time: 10 minutes)**

The teacher asks students:

Would we use the same measurement to express the rate of a chemical reaction, such as miles per hour or meters per minute?

Access the website below or find appropriate images to show and discuss the five signs of a chemical reaction. (Students take notes on the five signs: color change, formation of a precipitate, formation of a gas, odor change, and temperature change. If appropriate, they could each take one to create a classroom poster.) Introduce the unit by telling students that they will be discovering how scientists measure the rate of a chemical reaction, and it is different from the way we find the rate of speed using math.

See: www.harpercollege.edu/tm-ps/chm/100/dgodambe/thedisk/chemrxn/signs.htm
**Presentation** (time: 15 minutes)

The teacher writes this on the board:

In chemistry, the rate of a chemical reaction, or the reaction rate, is usually expressed as the change in the amount of reactant or product per unit of time.

Use this analogy to illustrate the concept:

How many hamburgers can the cook make in 30 minutes, given all of the ingredients and a stove to cook with? What would happen if we reduced the number of buns or the amount of meat, or one of the burners wasn’t working? Is measuring the amount of product over time different from measuring how fast the cook was working to try to get the meal completed?

The teacher shows slides 1-8 from *Pearson Chemistry*, Lesson 18.1, from the supplementary web resource:

[SEE: www.successnetplus.com](http://www.successnetplus.com)

**Practice and Application** (time: 15 minutes)

Students independently read *Pearson Chemistry* pp. 594-595 to review the presentation and take two-column notes with illustrations. They should create an illustration to show rate of reaction, using the illustrations on p. 595 of *Pearson Chemistry* as a model.

**Review and Assessment** (time: 10 minutes)

Students write and/or illustrate how a rate of chemical reaction differs from a rate of speed and describe how they might measure the rate of a chemical reaction. (What tools would you need?) To help students understand how we can measure change, beyond just observation, discuss how we can weigh the reactants and the resulting products, use gas syringes (below) to measure gas production, or use colorimeters to measure color. A photo of a colorimeter is located at the website below.

Lesson 2

Collision Theory

Goal
Students will explain that particles must collide at the proper orientation and with enough kinetic energy for a reaction to occur.

Do Now (time: 5 minutes)
Students write responses to this prompt:
- What happens when people collide?
- Knowing what you know about atomic structure, what do you think happens when atoms collide?
- How do you think these collisions are the same and how are they different?

Hook (time: 5 minutes)
The teacher leads a discussion of what sets a person or an object in motion, and who or what is most likely to win a race and why.
- Where do people and objects get their energy from?
- How is this similar or different from chemical reactions?

Presentation (time: 15 minutes)
The teacher shows slides 9-20 from Pearson Chemistry, Lesson 18.1, from the supplementary web resource below and discusses the role of collision theory in the rate of reaction, or as a determinant of whether or not a reaction happens since the atoms have to have activation energy to react.

SEE: www.successnetplus.com

Practice and Application (time: 20 minutes)
Students independently read Pearson Chemistry pp. 596-597 to review the presentation and take two-column notes with illustrations. They complete the Interpret Graphs activity on p. 597 to analyze how the activation-energy barrier must be crossed for reactants to be converted into products.

Review and Assessment (time: 10 minutes)
Students explain how and why collisions can set a reaction in motion and demonstrate understanding by answering questions 1, 3, and 4 on p. 601 in Pearson Chemistry.

Note: Students will place all paperwork in a folder to be used as evidence for their Summative Assessment. The teacher should tell students that they should continue to do this throughout the unit, as they will need the evidence to write about what they have learned when they compile their portfolios at the end of the unit.
INSTRUCTIONAL LESSONS

Build upon background knowledge, make meaning of content, incorporate ongoing Formative Assessments

Lesson 3

Factors Affecting Reaction Rate

Goal
Students will list the factors that affect reaction rate (temperature, concentration, particle size and catalysts) and explain how and why these factors affect the reaction rate.

Do Now (time: 5 minutes)
Students will watch “Kinetic Art: Collision Theory” on 18.1 of the Pearson Chemistry web resource and write at least one sentence about what they think the effect of temperature is on the rate of a reaction.

Hook (time: 5 minutes)
The teacher will lead a discussion based on the following prompts:

Think about making a Ramen noodle dinner.

What happens to boiling water when the flavor pack is added? What happens to the boiling water when the noodles are added? Why do some people break the noodles before they add them? What collisions are seen? What changes the force of the collisions? What if the water wasn’t boiling?

Presentation (time: 20 minutes)
The teacher shows and explains slides 21-36 from Pearson Chemistry, Lesson 18.1. The key idea is this:

“Factors that can affect the rate of a chemical reaction are temperature, concentration, particle size, and the use of a catalyst.”

Slides 21-36 explain and support this key idea.

Practice and Application (time: 20 minutes)
Students will read pp. 598-601 from Pearson Chemistry and create a top-down web to summarize the four factors that affect reaction rate, giving examples of each. Students can work on this individually or in pairs, providing an opportunity for Think-Pair-Share. Depending upon the size of the group, this activity could be done as a jigsaw, then students could combine their work to add to a poster and discuss what they have done. The results can be posted on the wall for review and for the benefit of new students.

Review and Assessment (time: 5 minutes)
Students participate in whole group discussion to relate cause and effect (#5 on p. 601 Pearson Chemistry), explaining why food spoils quicker at room temperature than it does in the refrigerator.
Lesson 4

The Power of Carbon Dioxide Fizz

Goal
Students will explain that chemical reactions involve kinetic energy that is influenced by temperature, concentration, particle size, and density.

Do Now (time: 5 minutes)
Students will complete a quick write:
- Where do you see chemical reactions happening on a daily basis?
- Explain how one or more of the factors talked about in class (temperature, concentration, particle size, and density) had an influence on the rate of reaction.

Hook (time: 5 minutes)
The teacher leads a discussion based on this prompt:
- Predict what will happen to raisins if we put them into a glass of ginger ale. Will there be any reaction?

Presentation (time: 15 minutes)
The teacher will demonstrate the “Raisin Dance from Home Experiments.”
SEE: http://scifun.chem.wisc.edu/homeexpts/dancingraisins.htm

Materials: Colorless soda, plastic cup, 6 or 7 raisins (plus additional materials for student experimentation)

Procedure: Pour the soda into the cup. Notice the bubbles coming up from the bottom. The bubbles are carbon dioxide gas released from the liquid. Drop 6 or 7 raisins into the cup. Watch the raisins for a few seconds. Describe what is happening to the raisins.
- Do they sink or float? Keep watching; what happens in the next several minutes?

Explanation: Raisins are denser than the liquid in the soda, so initially they sink to the bottom of the glass. The carbonated soft drink releases carbon dioxide bubbles. When these bubbles stick to the rough surface of a raisin, the raisin is lifted because of the increase in buoyancy. When the raisin reaches the surface, the bubbles pop, and the carbon dioxide gas escapes into the air. This causes the raisin to lose buoyancy and sink. This rising and sinking of the raisins continues until most of the carbon dioxide has escaped, and the soda goes flat. Furthermore, with time the raisin gets soggy and becomes too heavy to rise to the surface.

Practice and Application (time: 20 minutes)
Students will write down the materials and the process they will need to replicate the experiment then collect necessary materials from teacher. Students should write a hypothesis about what will happen. (Alternatively, the teacher can provide students with the materials list, as well as the process, then tell students to write down a guess about what will happen, which is a hypothesis.) When they perform the...
experiment, students should record what happens, noting how long the raisins dance, then write an analysis and interpretation of what they see and a conclusion that validates the hypothesis or requires revision. Students should be allowed to try cold and warm soda, more or fewer raisins or raisins broken into smaller pieces, to support or refute their hypotheses.

**Review and Assessment** (time: 10 minutes)
Students should share the results and discuss how temperature, concentration, and particle size and density contributed to the success of the dance of the raisins.

## Lesson 5

The Effects of Heat on Chemical Reactions

**Goal**
Students will demonstrate how heat can affect reaction rates.

**Do Now** (time: 5 minutes)
Students discuss the meaning of the prefixes *exo* and *endo*. The teacher should prompt them by asking what the difference is between exit and enter. Students brainstorm words that begin with these prefixes in whole group (teacher can provide dictionaries and appropriate illustrations of scientific words as necessary) and consider:

- How can this prefix help us to know what reactions need energy to get started and what reactions give off energy?

**Hook** (time: 5 minutes)
The teacher posts on the board the following chemical reactions:
- Boiling an egg (what is the difference between hard and soft boiled?), a banana ripening, and lighting a match (or creating a spark for a campfire in the woods without matches)
- How can you slow down these chemical reactions? How can you speed them up?

**Presentation** (time: 10 minutes)
The teacher presents the video “Exothermic and Endothermic Reactions” at the website below. Students will take notes on the video, which explains how some reactions require energy to get started while other reactions give off energy. To expand upon this short video, the teacher reviews the photosynthesis reaction that happens when the reactants carbon dioxide and water results in products of glucose and oxygen when the plant takes in energy in the form of light and heat from the sun (endothermic).

SEE:  www.youtube.com/watch?v=yyYHVA1Ww_M

**Practice and Application** (time: 20 minutes)
The teacher should review with students how heat can affect a chemical reaction. A pencil and paper assessment of the presented material is available in Revisit Endothermic and Exothermic: *Pearson Chemistry* p. 597, Figure 18.5, Interpret Graphs, which compares endothermic and exothermic reactions, and p.558, Sample Problem 17.1, which is a question about recognizing endothermic and exothermic reactions.
Lesson 6

The Effects of Catalysts on Chemical Reactions

Goal
Students will explain that reaction rate depends on the reactivity of the reactants, which can be influenced by a catalyst.

Do Now (time: 5 minutes)
The teacher asks students if anything acts as a catalyst in their lives. For instance:

If you are allowed to play video games when you get all of your chores done, does it motivate you to get your chores done more quickly? How do incentives that act as catalysts help us to function better as a community?

Students write for a couple of minutes.

Hook (time: 5 minutes)
The teacher does a demonstration of a catalyst by sprinkling pepper in a deep pie plate full of water. S/he asks several students to push the pepper to the side of the plate using toothpicks while another student times them. She then sprinkles in some more pepper and calls on a student to touch the surface of the water with a toothpick dipped in soap. The pepper will scatter immediately to the sides of the plate, because the soap acts as a catalyst. Ask students to define catalyst in their own words.

Presentation (time: 20 minutes)
The teacher posts on the board the following chemical reactions: rusting of a car, digesting food, food spoilage, taking medication to recover from an infection. He or she asks:

How can you slow down these chemical reactions? How can you speed them up?

(Recall Lesson 3, Factors Affecting Reaction Rates: Temperature can speed up or slow down a reaction, a catalyst will lower activation energy and speed up the reaction, some chemicals are more reactive than...
others, and the amount of the chemical will influence how quickly the reaction will proceed.) Explain that they will be exploring how catalysts work in chemical reactions.

The teacher should present “Catalysts” from Bozeman Science for a scientific explanation of catalysts. The video shows a picture of elephant toothpaste that is created with hydrogen peroxide, yeast, and dish soap. For a complete demonstration and explanation of this experiment, watch the second video. If possible, do a classroom demonstration of the decomposition of hydrogen peroxide to show a catalyst at work. The lab is provided below. The lab produces quite a lot of foam, so ample space and a catch bucket are needed to do the demonstration in class. Students can take notes and illustrate to document their observations of the demonstration.

SEE: www.youtube.com/watch?v=KYD5LNVWne8
www.youtube.com/watch?v=–RRTnIGr6fg

Practice and Application (time: 20 minutes)

Students watch the teacher demonstrate the following lab taken from Cool Science. Students may participate as much as possible in the preparation and measuring of the materials. Students should all write down predictions or hypotheses about what will happen and why, record observations with illustrations, and state whether their hypotheses were confirmed by the experiment. The class can do additional experiments with more or less soap and colder water with the yeast.

What are the results of the modified experiments and why?

A lab sheet is located in the Supplement on p. 5.10.1.

SEE: “The Decomposition of Hydrogen Peroxide”
www.coolsceince.org/CoolScience/KidScientists/h2o2.htm

Review and Assessment (time: 5 minutes)

Students will review the role of factors that affect reaction rates: concentration (teachers will use a 3% concentration of hydrogen peroxide—what would happen if it were 8%?), the heat of the water used to dissolve the yeast, the concentration of soap, and the use of yeast as a catalyst in this demonstration. Students will explain how each factor played a role in the reaction in the demonstration.

Extension

For a pencil and paper assessment of the presented material, see Catalysts in Pearson Chemistry, p. 601, Figure 18.9, Interpret Graphs; p. 601, 18.1, Lesson Check #2 and #5. Discuss problems and vocabulary: endothermic, exothermic, activated complex, activation energy, products, reactants, energy, and heat.

Lesson 7

Le Châtelier’s Principle or “The Equilibrium Law”

Goal

Students will explain Le Châtelier’s principle, which states that when a stress is applied to a chemical system at equilibrium, the equilibrium will shift to relieve the stress, and apply Le Châtelier’s principle to a chemical reaction, identifying the ways the equilibrium position is changed in response to the stresses of concentration, pressure, and temperature.

SEE: http://tinyurl.com/z2rst7m (for further clarification)
Do Now (time: 5 minutes)

Students will copy this diagram from the board:

Then they will brainstorm:

What could move the equilibrium position?
(Review the concept of equilibrium from the Balancing Chemical Equations unit.)

Hook (time: 15 minutes)

Students will copy the diagram below from the board. The teacher should lead a discussion:

Why is this an example of the Law of Conservation of Matter? (Review stoichiometry as needed.) Is this equation balanced? Why or why not? Would you consider this equation as being in equilibrium? Why or why not? What do you think would happen if the amounts of reactants increased?

Note: This diagram also appears on p. 5.10.2 of the Supplement in a worksheet for this lesson.

Presentation (time: 15 minutes)

Students will watch the video, “Le Châtelier’s Principle Part I,” which shows the shifts in equilibrium caused by concentration and pressure. They should take notes on how equilibrium is shifted by concentration and pressure, and the teacher will lead a discussion to clarify the concepts (see first video below). Students should then watch the second video, “Le Châtelier’s Principle Part II,” which shows shifts in equilibrium caused by temperature. They should take notes on how equilibrium is shifted by concentration and pressure, and the teacher will lead a discussion to clarify the concepts.

SEE: “Le Châtelier’s Principle Part I”
www.youtube.com/watch?v=7zuUV455zFs
“Le Châtelier’s Principle Part II”
www.youtube.com/watch?v=XhQ02egUs5Y

Practice and Application (time: 15 minutes)

Students will apply their understanding of chemical equilibrium by completing the table in the Supplement on p. 5.10.2, which focuses on analogous processes in the body. Students may need coaching to come to the right answers, but they should develop a good grasp of what causes shifts in equilibrium and how Le Châtelier’s principle isn’t just for chemists.
**Review and Assessment** (time: 5 minutes)
Students should share their tables, analyze the different answers, and, with the teacher’s aid, clear up any misunderstandings.

**Extension**
Review notes taken from Le Châtelier’s principle videos and write a paragraph comparing and contrasting this information with that presented in Pearson Chemistry, pp. 612 - 614: three stresses that affect equilibrium position.

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**CULMINATING LESSON**

*Includes the Performance Task, i.e., Summative Assessment—measuring the achievement of learning objectives*

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**Lesson 8**

**Culminating Performance Assessment (3 days)**

**Goal**
Students will create a portfolio of completed and new work that summarizes and applies their learning in the unit. Instructions for collation of the portfolio are as follows:

- Assemble all assignments from this unit to create a collection that should read like a narrative for someone who is unfamiliar with chemical reaction rates.
- Compose an introduction to the portfolio that explains its contents and illustrates the following with real-life applications: collision theory, the four factors that influence reaction rate, and Le Châtelier’s principle.
- Provide proof of factors that influence reaction rate by performing an experiment with Alka-Seltzer. Include your lab report in the portfolio.
- Construct an explanation of equilibrium by generating a slide show, rap, or essay to share with peers. Analyze the factors in chemical equilibrium and apply Le Châtelier’s principle to an everyday situation that shows the importance of balance in our lives.

Students may use a combination of Microsoft Word, PowerPoint, StoryBoard, posters, Audacity, or other tools to construct the portfolio.

**Overview:**

**Day 1**
Students review the expectations of the Performance Task and co-create a rubric with the teacher. Students collect their assignments from the unit to write portfolio introductions, explain the contents and illustrate collision theory, demonstrate the four factors that influence reaction rates with real-life applications, and Le Châtelier’s principle.

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For *Empower Your Future Connections*, see pp. 5.9.1 - 5.9.2
Day 2
Students design and conduct experiments with Alka-Seltzer, record data, and complete the lab template, which should be added to the portfolio compiled on Day 1.

The Alka-Seltzer Lab Report template can be found on p. 5.10.3 of the Supplement.

Day 3
Students construct slide shows, raps, or essays that apply the concept of equilibrium to everyday life. Students share their creations with partners or the class, add them to their portfolios, and complete a final self-assessment using the rubric.

Instructions for the lab:

Students perform an experiment with Alka-Seltzer to demonstrate the role of heat, particle size, and amount of catalyst (water) on the rate of reaction. They must create a hypothesis and use the scientific method to confirm it. There should be a control (using one Alka-Seltzer tablet per directions) and an experiment that changes just one variable that is critical to rate of reaction. See Alka Seltzer Interactive Experiments for methods and materials needed to complete two experiments, “Temperature vs. Rate of Reaction” and “Size vs. Rate of Reaction.”

SEE:  Alka Seltzer Interactive Experiments
www.alkaseltzer.com/as/student_experiment.html

Note: Students can also conduct a third experiment (not included on the website) by adjusting the amount of catalyst (in this case, water) to determine the effect on reaction rate.

Materials needed to complete the Alka Seltzer experiments:

- clear cups, measuring cups, thermometers, stopwatches, Alka-Seltzer, source of hot water, ice cubes, graph paper, mortar and pestle or some type of pill crusher

In addition to performing an experiment of their choice, students compare the results of their experiments. Students can work together to gather data and graph the rate of reaction in each of the scenarios to support their hypotheses about how a change in temperature or particle size influences the rate of reaction. Students also explain how water works as a catalyst. A teacher note on the chemistry of the effervescence is available at:


Alka-Seltzer is a combination of aspirin (acetylsalicylic acid), sodium bicarbonate (NaHCO₃), which is baking soda, and citric acid. Though important to the overall effect of the medication, the aspirin does not contribute to the effervescent action of Alka-Seltzer; the effervescence is produced by the baking soda and the citric acid reacting to form sodium citrate and carbon dioxide gas. The chemical reaction for this is as follows:

\[ C₆H₈O₇ + 3 \text{NaHCO}_₃ \rightarrow 3 \text{H}_₂\text{O} + 3 \text{CO}_₂ + \text{Na}_3\text{C}_₆\text{H}_₆\text{O}_₇ \]

Citric acid + baking soda  \( \rightarrow \)  water + baking soda + sodium citrate

A Lab Report template for students can be found in the Supplement on p. 5.10.3.
Do Now (time: 10 minutes)

Students will collect all previous assignments from the unit and organize them by topic: collision theory, factors that affect reaction rate (heat, concentration, particle size, catalysts), and Le Châtelier’s principle.

Hook (time: 5 minutes)

The teacher leads a brief discussion based on these prompts:

- What have you learned about reaction rates? What factors affect them?
- What examples can you cite? What is chemical equilibrium? How is it achieved?

Presentation (time: 10 minutes)

The teacher reintroduces the Performance Task and the schedule for completing it. The teacher should ask students to suggest criteria for assessing the work and with them create a rubric that will guide their efforts. The table above is a possible starting point.

Practice and Application (time: 120 minutes)

The teacher should monitor the work carefully in progress, scaffolding the assignments as needed and assisting students who need clarification.

Day 1 (30 minutes)

Students will write introductions to their portfolios explaining the contents and illustrating the following with real-life applications: collision theory, the four factors that influence reaction rate, and Le Châtelier’s principle.
Day 2 (55 minutes)
Students will review experiments conducted during this unit and discuss how these reactions reached equilibrium.

How did they know a reaction reached equilibrium?
The teacher should then introduce the Alka-Seltzer experiment, show the materials to be used, and set expectations on lab technique and data collection. Students will state hypotheses, conduct experiments, collect data, and complete the lab template with particular attention to conclusions and applications.
The lab should conclude with a discussion of Le Châtelier’s principle and the effects on reaction rate.

When were the experiments in equilibrium?

Day 3 (35 minutes)
Students will brainstorm ways they could teach peers about Le Châtelier’s principle and each create a PowerPoint, rap, or essay on the topic. The product should include scientific theory as well as application of the concept of equilibrium to an everyday situation.

Review and Assessment (time: 20 minutes)
Students will share their equilibrium products with peers and give and receive feedback on their effectiveness in conveying the concept. Students will also self-assess their portfolios using the rubric, noting strengths and areas for growth.

Extension
If time permits, this Performance Task can be extended to a full week, allowing time for additional experiments, for polishing and presenting the equilibrium product, and for revising parts of the portfolio as warranted.
POST–UNIT REFLECTION

On meeting the Learning and Language objectives

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Connections to Empower Your Future
UNIT: Why and How Chemicals React

Future Ready Connections

The experiments in Lesson 4 and Lesson 8 provide opportunities for students to practice Future Ready skills and be evaluated on them.

Lesson 4 has youth analyze the “raisin dance” that happens when raisins are placed into a cup of carbonated soda and continuously float to the top and sink back down to the bottom. Youth must create a hypothesis about what is happening and why, experiment, reassess their hypothesis and understanding, and then present a final conclusion. This lesson requires students to be accountable and take the initiative for their own learning because they must create and test their own hypothesis. Students must also effectively communicate their findings and the process they followed to come to a conclusion. Lesson 8 has similar Future Ready connections and opportunities as youth experiment with Alka-Seltzer tablets and predict and measure reactions.

The Performance Task provides an excellent opportunity to practice and be assessed on Future Ready skills. For the Performance Task, students will create a portfolio that demonstrates their learning from the unit. Students will create an overview for the portfolio that explains real-life applications for understanding and using chemical reactions and will summarize their findings and lab experiments with an explanation of equilibrium (which may be completed through different mediums). Students will need to demonstrate initiative and self-direction to compile assignments and complete labs thoroughly. To demonstrate accountability for their own learning students will need to complete labs, independently take notes, and complete the final equilibrium project. Youth also have many opportunities to demonstrate strong communication skills throughout the lesson, such as in the presentation of their final projects and during class and group discussions. The Performance Task includes an opportunity for students to self-assess using the assessment rubric which increases their accountability and buy-in for the project. Teachers should reflect on whether or not youth stay on task without prompting and if they push themselves to create a well-designed and effective final project. There are multiple opportunities for youth to give and receive feedback from peers which will allow teachers to evaluate students on their accountability for their own work and to their peers. Teachers are encouraged to use the Future Ready Rubric to evaluate students and are encouraged to support students as they self-evaluate their demonstration of Future Ready skills.

Essential Questions Connections

The Essential Questions for this unit address why and how outside forces affect chemical reactions and how we can control chemical reactions to achieve a specific outcome for a product or process. Students will analyze what the catalysts are for these chemical reactions (emphasized in Lesson 6) and make predictions about the impact of different variables that may change. Teachers can expand on these concepts of the impact of outside forces and the reaction by asking youth to apply them to their own personal lives. Students can discuss:

• What outside forces consistently impact your life? (family, friends, teachers, neighborhood, etc.)
• How do these forces impact your life? In a positive or negative way?
• How can you control, emphasize, or limit the impact these forces have?
• If you can't control these outside forces, how can you control your reaction to them?
To tie into the skill of understanding and creating mathematical equations and visual representations for chemical reactions, teachers can consider asking students to create the equation or chemical diagram that represents their lives. Ask students:

• What aspects of your lives will you need to include in your equation for happiness and success?
• What other aspects or elements do you have to avoid?

Teachers can tie in the concept of long- and short-term goal setting to this discussion and have students identify what are the elements and catalysts necessary to achieve the final chemical reaction (achieve the goal).

PYD/CRP Connections

This unit reflects Culturally Responsive Practice and Positive Youth Development by providing opportunities for speculation, experimentation, and independent discovery through the different labs. Students have the opportunity to work at their own pace, experiment, and reflect on their thought processes. Students also have opportunities to activate prior knowledge (Do Now prompts and Hooks), and understand real-world applications and examples of chemistry in action (Lesson 1 hamburger, Lesson 3 Ramen noodle examples) which creates buy-in and a sense of ownership over their own learning. Youth are also not simply reporting out answers for the Performance Task, but are explaining their thought processes and theories, which encourages youth voice and active participation in understanding the topic fully. The lessons are also flexible and allow for students to work and discover in different ways (independently, with a partner, as a class, and with different mediums and activities), which respects their individual needs and abilities. The Performance Task also allows students to decide how they want to represent their findings (rap, PowerPoint, or essay) which encourages them to embrace a challenge and practice a new skill or strengthen an existing skill and interest area.

Lesson 7 Connections

Lesson 7's practice and application activity asks youth to apply their understanding of chemical equilibrium to processes in the body. One goal of this activity is for youth to develop a good understanding of what causes the shifts in equilibrium and how Le Châtelier’s principle isn’t just for chemists. Teachers can expand on this goal by asking youth to consider what professions are affected by and must understand this principle.

• Who needs to be concerned about the concentration of oxygen in tissues? (Surgeons, nurses, doctors, dentists, etc.)
• Who should understand air pressure changes? (Pilots, tire service technicians, manufacturing personnel that produce bottled goods like soda.)

Teachers should consider discussing other chemical reactions and having youth brainstorm how these reactions impact different professional fields.

“\What outside forces consistently impact your life?\”
### The Decomposition of Hydrogen Peroxide

**Lesson 6**

#### Introduction and Safety

Something decomposes when it breaks down into its component parts.

The chemical formula for hydrogen peroxide is $\text{H}_2\text{O}_2$. It looks pretty similar to the chemical formula for water, which is $\text{H}_2\text{O}$, except that hydrogen peroxide has an extra “O,” an extra oxygen. Hydrogen peroxide is not a very stable compound, so it is always decomposing to water and oxygen, but under normal conditions, the decomposition goes very slowly. In this reaction, yeast catalyzes the decomposition, making the reaction go much more quickly. If you add a little dishwashing detergent, you get foam! If you add food coloring, you get colored foam!

Do this experiment in the sink (or in a large container that can be brought into the classroom.)

#### Supplies

- An empty 20 oz soda bottle (or any tall skinny clear container)
- Hydrogen peroxide (you can get 3% at the grocery store, or 8% at a beauty supply store)
- Active yeast
- Warm water
- Liquid dish soap
- Food coloring—optional, but it does make a nice color!

#### Directions

Mix 4 oz. of hydrogen peroxide with 2 oz. of liquid dish soap and a few drops of food coloring.

Add this mixture to the soda bottle and place it in the sink.

In a separate container, mix one packet of active yeast with warm water and let sit for 5 minutes.

When you are ready, pour the yeast mixture into the soda bottle (a funnel might be helpful) and watch the reaction!

#### Observations

- How much foam is produced, and how quickly?
- Does it matter if you use lukewarm water to activate the yeast or cold water?
- What happens if you add more or less soap?
- What happens if you don’t add any soap?

#### What’s Happening?!?

Hydrogen peroxide ($\text{H}_2\text{O}_2$) decomposes into water and oxygen gas, but normally the reaction is so slow as to be imperceptible. 

$$2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2(\text{g})$$

What happens when you pour hydrogen peroxide onto a cut? It bubbles! That’s because there is something in your bodily fluids that catalyzes the decomposition. A catalyst is a substance that speeds up a reaction, without being consumed itself.

In this experiment we use a 3% hydrogen peroxide solution. The production of oxygen gas is made more noticeable by adding some dish soap, which makes the foam. The reaction is catalyzed by the active yeast added to the container. The yeast changes the mechanism, or pathway, by which the reaction occurs. The rapid production of bubbles of oxygen gas, along with the dish soap, quickly creates a large quantity of foam.

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**Website:** [www.coolsceience.org/CoolScience/KidScientists/h2o2.htm](http://www.coolsceience.org/CoolScience/KidScientists/h2o2.htm)

Permission for use granted by Cool Science. Experiment furnished by Angela Howard of the Society of Women Engineers.
Le Châtelier’s Principle or “The Equilibrium Law”
Lesson 7

**DIRECTIONS:** Complete the table below.

<table>
<thead>
<tr>
<th>Stress</th>
<th>Shift this will happen...</th>
<th>Why because...</th>
</tr>
</thead>
<tbody>
<tr>
<td>When the concentration of oxygen in tissues increases</td>
<td>hemoglobin in the red blood cells will carry less oxygen</td>
<td>because the tissues have an adequate supply</td>
</tr>
<tr>
<td>When the concentration of oxygen in tissues decreases</td>
<td>hemoglobin in the red blood cells ...</td>
<td></td>
</tr>
<tr>
<td>When air pressure increases (at lower altitudes)</td>
<td>breathing ...</td>
<td></td>
</tr>
<tr>
<td>When air pressure decreases (at higher altitudes)</td>
<td>breathing ...</td>
<td></td>
</tr>
<tr>
<td>When body temperature increases on a hot day</td>
<td>the body ...</td>
<td></td>
</tr>
<tr>
<td>When body temperature decreases on a hot day</td>
<td>the body ...</td>
<td></td>
</tr>
<tr>
<td>When a person takes Alka-Seltzer for indigestion</td>
<td>stomach acid ...</td>
<td></td>
</tr>
</tbody>
</table>
Alka-Seltzer Lab Report Template
Lesson 8

**DIRECTIONS:** Complete the table below.

<table>
<thead>
<tr>
<th>Question (give purpose of experiment)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothesis (include a “because”)</td>
<td></td>
</tr>
<tr>
<td>Procedures (list and number steps in order)</td>
<td></td>
</tr>
<tr>
<td>Results (record data, make notes NS observations)</td>
<td></td>
</tr>
<tr>
<td>Conclusions (analyze data, accept/reject hypothesis, explain lab results, note any mistakes)</td>
<td></td>
</tr>
<tr>
<td>Applications (compare to “real-life” situations)</td>
<td></td>
</tr>
</tbody>
</table>
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Introduction to Physics

Consider physics to be the rule book of the universe. It explains how matter moves, how forces push and pull, how energy is transferred, and how sound and light waves operate.

Introduction

Youth are often asked, “What do you want to do after you graduate?” As technology helps our world move, change, and evolve at an ever faster pace, figuring out an answer to that question is more complex than ever. Looking at a list of hot and fast-growing jobs in America, many of the jobs—from medicine to construction to technology—involves science generally and the principles of physics specifically.

Physics teacher and author Paul Hewitt writes in *Conceptual Physics*, “Physics is about the nature of basic things such as motion, forces, energy, matter, heat, sound, light, and the composition of atoms” (1). While chemistry focuses on the matter that makes up our universe and how it combines or reacts, and biology involves matter that is alive, Hewitt reminds us that we can understand all other sciences better if we understand physics.

Consider physics to be the rule book of the universe, explaining how matter moves, how forces push and pull, how energy is transferred, and how sound and light waves operate. From driving cars to riding bikes, the rules of physics guide our motion. People follow the rules of physics to control electricity and to see more clearly at night. Physics impacts your everyday ability to see, hear, and move. From staying safe during an accident to staying warm while traveling in space, knowing physics helps us survive and thrive.

Using mathematics as a way to model motion, energy, and waves, physicists are able to map unimaginably small and large objects in motion, make predictions about past and future events, and research tools that can change the way and the speed by which we communicate with others. Physicists design both physical and theoretical experiments in order to solve problems. Based on the results of the experiments, scientists in the field of physics can rethink their ideas and make new predictions. The world is changing, and physicists drive that change.

Physics.org, the website of the Institute of Physics, informs visitors that knowing physics is the foundation for many careers. Physicists are involved in technology and game design, the law, building design, medicine, energy, space exploration, protecting the environment and climate, music, transportation, and cutting-edge fields such as nanotechnology. People working in physics-related fields can manipulate sound waves to make music or harness light waves to do laser surgery. Field researchers are figuring out ways to slow climate change, harness the tides to produce energy, and thinking ahead about colonizing Mars.

In physics, the future has yet to be imagined, let alone fully realized. While great thinkers and religious leaders once thought the sun revolved around the earth, scientists proved that belief was exactly backwards. Through detailed observations, the use of tools such as telescopes,
and having a scientific attitude that was open to new ideas, scientists such as Galileo and Newton showed that what we see happening is not exactly as it first appears. Modern-day physicists such as Marie Curie and Sally Ride have helped unlock the secrets of radiation so our injuries can be x-rayed and made it possible to travel into space to explore the widest mysteries imaginable.

**Physics Course Content**

Traditionally, high school physics courses emphasize mechanics and motion, forces, energy, waves (often in the form of sound and light), electricity, and, occasionally, more modern topics such as quantum and nuclear physics. Some programs take a conceptual approach toward physics while other programs emphasize mathematics, focusing on trigonometry as a way to solve problems related to motion and forces.

The standards in the 2016 Massachusetts Science and Technology/Engineering Curriculum Framework are based on the Next Generation Science Standards (NGSS) and shift how we think about teaching physics, prompting science educators to find more authentic ways to teach concepts through real-world applications. While not written as a curriculum, these standards focus on performance expectations and what students should know and be able to do at different points in their K-12 experience. The NGSS physics standards are found in the Physical Science group of standards.

According to the American Association of Physics Teachers, “While most standard high school physics courses will include the ‘big topics’ addressed by the NGSS (Motion, Forces, Energy, and Waves), the NGSS also places a heavy emphasis on interdisciplinary understandings and engineering. Teachers might find that they need to make more room for teaching these additional skills, shift their instructional approach, and/or take more professional development themselves in order to help students address these standards” (“Physics and the NGSS” 2).

The NGSS are performance objectives that define content (Disciplinary Core Ideas) and skills (Science and Engineering Practices) that students should know and be able to do at different points in their K-12 experience.
The Five Seasons of Physics: 4-5

**MARCH TO APRIL**

**Thermodynamics** shows that energy flows. How energy moves can be monitored, modeled, and measured, and students working in the role of scientist can explore the conservation of energy as a way to solve problems.

This fourth season includes units on the movement of heat energy and thermal equilibrium.

**WAVES AND THEIR APPLICATIONS IN TECHNOLOGY AND INFORMATION TRANSFER**

connects mathematics and science through the exploration of waves. Although mostly invisible, waves are all around us. Students will see and hear that waves tend to follow patterns and can be modeled mathematically to predict their motion.

This fifth season includes units on sound waves, light waves, and information transfer.

able to do. The NGSS also includes connections to other science disciplines (Crosscutting Concepts) that are not emphasized in the Massachusetts science standards but are included at the bottom of the Scope and Sequence in this Guide. The exemplar unit on motion and forces addresses the intent of the NGSS and the Massachusetts science standards by adding emphasis on engineering through a Performance Task that focuses on bridge design and construction. The included unit on waves shifts to meet the intent of the NGSS. The Performance Task for this unit provides an opportunity for students to research different types of common waves (light, sound, or seismic) and create a model and presentation that explains the formation and distribution of waves to an audience of elementary students.

A number of different storylines guide the Physics Scope and Sequence. The year begins with the kind of physics students can see and feel in motion any time they move, run, jump, play sports, or go to sleep. Called kinematics by physicists, this field is known as the “geometry of motion,” as it allows student-scientists to model motion to find patterns and make predictions. From concrete motion and forces, the year shifts to the abstract topic of electricity and magnetism in season two. Once again, students can use math to model how electricity flows and how it can be used to produce a magnetic field. The centerpiece of the year is the study of how and why energy flows. Energy can be generated, transmitted, and stored allowing us to have power when we need it. The fifth season on waves is the end of the story. It examines sound and light waves and how waves can be harnessed to enable us to communicate and transfer energy. This topic is abstract, and mathematics can help students see the patterns and frequency of waves that are too large, small, or fast for us to see by eye or hear by ear.

Movement, forces, energy and energy flow, and wave physics are topics that cross over to biology, chemistry, and technology/engineering in subjects including ecosystems, chemical reactions, and construction. The Physics Scope and Sequence offers related Essential Questions that inspire student thinking.

**Teaching Physics in DYS Schools**

Whether studying motion, waves, or other topics in physics, knowledge of mathematics is critically important as it allows students to explain physical phenomena quantitatively. From calculating velocity to predicting the time it takes for sound to travel a certain distance, the approach to teaching the topics in this course is impacted by the mathematical background students bring to your classroom. Students with a strong background in math will be able to calculate solutions to the problems presented in the textbook. However, some students may require a more conceptual approach to instruction to master the big ideas prior to tackling the math. For these students, teachers may
need to scaffold the mathematics by providing notes and by providing one-to-one instruction to support the use of calculations to discover the scientific concept when possible.

Using a variety of methods including sharing simulations, constructing physical models, and drawing on life experiences of our physical world makes the science behind physics easier to master. A helpful comprehensive source is *Hewitt Drew-It! PHYSICS*, a website with simulations and videos designed to accompany Hewitt’s *Conceptual Physics* textbook.

As a way to personalize learning for DYS students, multiple methods have been integrated into the lesson plans in the exemplar units. Students will be able to know, understand, and do physics by writing arguments, building models, creating explanations for others, and experimenting with simple forces. The philosophies behind Universal Design for Learning guide instruction so that the facts, skills, and concepts are accessible to all students. Formative and Summative Assessments measure success and inform instruction. Links are made to literacy and other content areas including biology, chemistry, earth science, and mathematics so that students see how topics such as Conservation of Energy span all of the sciences and how math can be used to model concepts.

In addition, with multiple sciences in a classroom, the teacher may look for ways to connect the sciences. A physics concept may add to a biology topic being studied simultaneously. During class, the teacher could also provide a general lesson to the entire class on a similar scientific skill or idea and then personalize the individual or pair practice work for the remaining instructional time. When students are able to apply physics to other sciences, those students develop a deeper understanding of the material. When completing labs in physics during the science class, the teacher may invite all students to participate and have them make connections to the topics they are studying. This will help highlight the importance of physics for all the students.

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"... with multiple sciences in a classroom, the teacher may look for ways to connect the sciences."

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**Works Cited**


### Reading the Physics Scope and Sequence Chart

The amount of information contained in the Scope and Sequence on the following pages may seem overwhelming at first. The best way to study it is to read across from left to right. The keys in both the left and right hand columns below on this page offer guidance on how to properly access the Scope and Sequence Chart on pp. 6.2.2 to 6.2.5.

The Scope and Sequence is COLOR-CODED. Each color is important, and its meaning is described in detail in the key in the LEFT column below. The key in the RIGHT hand column below is information you will see in the first column in the Scope and Sequence. This key lists out the physics topics (seasons) and the approximate timeframe in which they may be taught during the academic year.

Emphasized Standards listed with an asterisk (*) in the Scope and Sequence are utilized in units in this Guide.

<table>
<thead>
<tr>
<th>Scope and Sequence Chart Key</th>
<th>Physics Topics (Seasons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The GREEN columns provide the focus for each season. This focus includes the title, timeframe, Essential Questions, and Emphasized Standards.</td>
<td>Motion and Stability: Forces, Interactions and Momentum</td>
</tr>
<tr>
<td>The BLUE column indicates the <em>Pearson Physics</em> textbook sections that apply to the topic and timeframe.</td>
<td>Electricity, Polarity, and magnetism</td>
</tr>
<tr>
<td>The GOLD column indicates the ELA and Math standards that are connected or could be connected to the Topic/Season indicated.</td>
<td>Energy</td>
</tr>
<tr>
<td>The RED column indicates other science disciplines that are connected to the Topic/Season indicated.</td>
<td>Thermodynamics</td>
</tr>
<tr>
<td>The PURPLE column indicates possible Performance Tasks which can be used during the Topic/Season indicated.</td>
<td>Waves and Their Applications in Technology and Information Transfer</td>
</tr>
<tr>
<td>The GRAY row across the bottom indicates Crosscutting Science Concepts that should be emphasized throughout the entire subject year.</td>
<td></td>
</tr>
</tbody>
</table>

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Massachusetts DYS Education Initiative—*Science*—2016 Edition | Chapter 6, Section 2
### Chapter 6, Section 2 | Massachusetts DYS Education Initiative–Science–2016 Edition

#### Physics Topics

<table>
<thead>
<tr>
<th>Physics Topics</th>
<th>Essential Questions</th>
<th>Emphasized Standards</th>
<th>Pearson Physics Textbook Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motion and Stability: Forces, Interactions, and Momentum</strong>&lt;br&gt;September to October</td>
<td>What forces control our lives? How can forces be used to make objects move, change direction or stop? How are Newton’s laws of motion relevant to our lives? Why do astronauts have weight on Earth, but are weightless in space? How do forces impact our lives? How does knowing about forces influence design?</td>
<td><em>HS-PS2-1.</em> Analyze data to support the claim that Newton’s second law of motion is a mathematical model describing motion and change in motion (acceleration) of objects with mass when acted on by a net force. Use free-body force diagrams and algebraic expressions representing Newton’s laws of motion to predict changes to velocity and acceleration for an object moving in one dimension in various situations.</td>
<td>Chapter 5: 150-185 (Newton’s laws) 235 (impulse) 286 (rotation) 322 (circular motion) 889 (electrons)</td>
</tr>
<tr>
<td><strong>Electricity, Polarity, and Magnetism</strong>&lt;br&gt;November to December</td>
<td>How is electricity related to magnetism? How can electricity be used to produce magnetism and vice versa? How is Coulomb’s Law similar to Newton’s Gravitational Law? How would you recognize an electric field? How is a battery’s potential similar to the potential of a roller coaster? Why does a charged balloon make your hair stand up?</td>
<td>HS-PS2-5. Provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.</td>
<td>Chapters 21: 744-750 (electric current) 751 (Ohm’s Law) 757-760 (circuits)</td>
</tr>
<tr>
<td><strong>Energy</strong>&lt;br&gt;January to February</td>
<td>How does energy flow? What does it mean to be energetic? How are work, power, and energy related? What is the relationship between kinetic and potential energy? Do people contain energy? When we sit quietly and think, are we working? How does a battery store energy?</td>
<td>HS-PS1-8. Develop a model to illustrate the energy released or absorbed during the processes of fission, fusion, and radioactive decay. HS-PS1-3. Use algebraic expressions and the principle of energy conservation to calculate the change in energy of one component of a system when the change in energy of the other component(s) of the system, as well as the total energy of the system including any energy entering or leaving the system, is known. Identify any transformations from one form of energy to another, including thermal, kinetic, gravitational, magnetic, or electrical energy, in the system.</td>
<td>Chapter 6: 188-205 (work and energy)</td>
</tr>
<tr>
<td><strong>Cross-Cutting Concepts</strong></td>
<td>Patterns</td>
<td>Cause and Effect</td>
<td>Scale, Proportion, and Quantity</td>
</tr>
<tr>
<td></td>
<td>Electromagnetic spectrum, waves, flow of energy, circuits</td>
<td>Newton’s Laws, Laws of Thermodynamics, electric and magnetic fields</td>
<td>Electromagnetic spectrum, Newton’s Law of Gravitation, Coulomb’s Law</td>
</tr>
</tbody>
</table>

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### SCOPE AND SEQUENCE

**Science | Physics, Chapter 6**

**Focus of inquiry in unit:**

- How does a battery store energy?
- Working?
- When we sit quietly and think, are we energetic?
- Do people contain energy?
- Kinetic and potential energy?
- What is the relationship between work, power, and energy?
- How are forces related?
- How are work, power, and energy related?
- How does energy flow?
- What does it mean to be energetic?
- How does energy flow?
- Your hair stand up?
- Why does a charged balloon make the potential of a roller coaster?
- How is a battery’s potential similar to the potential of a magnetic field?
- How is electricity related to magnetism? How can electricity be used to produce magnetism and vice versa?
- How is Coulomb’s Law similar to Newton’s Gravitational Law?
- How would you recognize an electric field?
- How is a battery’s potential similar to the potential of a roller coaster?
- Why does a charged balloon make your hair stand up?
- How is electricity related to magnetism? How can electricity be used to produce magnetism and vice versa? How is Coulomb’s Law similar to Newton’s Gravitational Law? How would you recognize an electric field? How is a battery’s potential similar to the potential of a roller coaster? Why does a charged balloon make your hair stand up?
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- How does energy flow? What does it mean to be energetic? How are work, power, and energy related? What is the relationship between kinetic and potential energy? Do people contain energy? When we sit quietly and think, are we working? How does a battery store energy?
- Patterns
- Electromagnetic spectrum, waves, flow of energy, circuits
- Cause and Effect
- Newton’s Laws, Laws of Thermodynamics, electric and magnetic fields
- Scale, Proportion, and Quantity
- Electromagnetic spectrum, Newton’s Law of Gravitation, Coulomb’s Law

---

**Emphasized Standards**

- *HS-PS2-1.* Analyze data to support the claim that Newton’s second law of motion is a mathematical model describing motion and change in motion (acceleration) of objects with mass when acted on by a net force. Use free-body force diagrams and algebraic expressions representing Newton’s laws of motion to predict changes to velocity and acceleration for an object moving in one dimension in various situations.
- *HS-PS2-2.* Use mathematical representations to show that the total momentum of a system of interacting objects moving in one dimension is conserved when there is no net force on the system.
- *HS-PS2-3.* Apply scientific principles of motion and momentum to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
- *HS-PS2-4.* Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to both qualitatively and quantitatively describe and predict the effects of gravitational and electrostatic forces between objects.
- *HS-PS2-10(MA).* Use free-body force diagrams, algebraic expressions, and Newton’s laws of motion to predict changes to velocity and acceleration for an object moving in one dimension in various situations.
- HS-PS2-5. Provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
- HS-PS2-9(MA). Evaluate simple series and parallel circuits to predict changes to voltage, current, or resistance when simple changes are made to a circuit.
- HS-PS3-1. Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to both qualitatively and quantitatively describe and predict the effects of gravitational and electrostatic forces between objects.
- HS-PS3-5. Develop and use a model of magnetic or electric fields to illustrate the forces and changes in energy between two magnetically or electrically charged objects changing relative position in a magnetic or electric field, respectively.
- HS-PS1-8. Develop a model to illustrate the energy released or absorbed during the processes of fission, fusion, and radioactive decay.
- HS-PS1-3. Use algebraic expressions and the principle of energy conservation to calculate the change in energy of one component of a system when the change in energy of the other component(s) of the system, as well as the total energy of the system including any energy entering or leaving the system, is known. Identify any transformations from one form of energy to another, including thermal, kinetic, gravitational, magnetic, or electrical energy, in the system.
- HS-PS3-2. Develop and use a model to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles and objects or energy stored in fields.
- HS-PS3-3. Design and evaluate a device that works within given constraints to convert one form of energy into another form of energy.
### ELA Season 1 standards:
- W1. Write arguments
- R1. Cite textual evidence
- R2. Determine central ideas

**Related Math standards:**
- A-CED. Create equations that describe relationships
- S.ID.1. Summarize and interpret data

**Earth and Space Science:**
- Kepler’s law of planetary motion

**Biology:**
- Flow of nutrients, migration

**Chemistry:**
- Specific properties of materials, bonding

**Technology/Engineering:**
- Engineering design process, planning a prototype or designing a solution

**Performance Assessment**
Compose an argument as to why a particular bridge design would work best for a given application. Design, build, and test the bridge using Popsicle sticks (or West Point Bridge Design). Reflect on the results of the design project, explaining its success or failure.

Compare the forces of gravity on different planets in our solar system and calculate the weight of a 100-pound dog on each planet.

Complete a Gizmo on gravitational force. Then, using inductive reasoning, complete the Universal Formula for Gravity based on what you have learned.

Use two ExploreLearning Gizmos (Air Track & 2D Collisions) to calculate momentum and the conservation of momentum in a system. Explain how seat belts, helmets, air bags, and other safety gear can prevent injuries in collisions.

### ELA Season 2 standards:
- W3. Write narratives
- R5. Analyze text structures

**Related Math standards:**
- A.REI.11. Represent equations graphically
- A-CED. Create equations that describe relationships
- S.ID.1. Summarize and interpret data
- F.LE.1a,b,c. Construct and compare models to solve problems
- S.ID.5. Summarize and represent data

**Earth and Space Science:**
- Magnetic reversals and moving continents (Alfred Wegener)

**Biology:**
- Nervous system

**Chemistry:**
- Conservation of energy, electron flow

**Technology/Engineering:**
- Circuit design

**Performance Assessment**
Use a simulation site or app to build and test circuits, such as http://www.docircuits.com, and https://phet.colorado.edu/en/simulation/magnets-and-electromagnets. Explain the flow of energy through the circuit, specifically mentioning switches and capacitors.

Construct physical models of circuits using Snap Circuit kits. Once constructed, write a narrative account about how each part of the circuit connects to allow electricity to flow.

Complete a Gizmo on Coulomb's Law (Electrostatic Forces). Based upon what you learned, use inductive reasoning to complete the formula for Coulomb's law.

State the similarities and differences between Coulomb's Law and Newton's Law of Gravitation.

### ELA Season 3 standards:
- W2. Write explanatory texts
- R9. Compare related texts

**Related Math standards:**
- A.REI.11. Represent and solve equations graphically
- F.BF.2. Create a function to model a relationship between two quantities

**Earth and Space Science:**
- Roles of water and wind in erosion and weathering

**Biology:**
- Food chains and the flow of energy through a system

**Chemistry:**
- Conservation of energy

**Technology/Engineering:**
- Dams’ storing water as potential energy and releasing it as kinetic energy

**Performance Assessment**
Construct a pendulum and track the motion over time using different lengths. If unable to build a physical model, simulate a model using a Gizmo simulation. Sliding objects down an inclined plane is an alternative experiment.

Create a compare and contrast board and draw or place pictures of the physics definition of work and your definition of work.

Using the Roller Coaster Gizmo, manipulate the heights of three hills, along with the mass of the car and the friction of the track. A graph of various variables of motion can be viewed as the car travels, including potential, kinetic, and total energies; and position, velocity, acceleration. Write a narrative describing the motion.
<table>
<thead>
<tr>
<th>Physics Topics</th>
<th>Essential Questions</th>
<th>Emphasized Standards</th>
<th>Pearson Physics Textbook Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermo-</td>
<td>*Why does energy</td>
<td>*HS-PS3-4a. Provide evidence that when two objects of</td>
<td>Chapter 10: 342-349 <em>(temperature and heat)</em></td>
</tr>
<tr>
<td>dynamics</td>
<td>flow? Why does</td>
<td>different temperature are in thermal contact within a</td>
<td>Chapter 11: 400-402 <em>(Second Law of Therromodynamics)</em></td>
</tr>
<tr>
<td>March to April</td>
<td>a hot cup of</td>
<td>closed system, the transfer of thermal energy results</td>
<td>Chapter 22: 789-790 <em>(magnetic fields)</em></td>
</tr>
<tr>
<td></td>
<td>coffee get</td>
<td>in thermal equilibrium, or a more uniform energy</td>
<td>Chapter 23: 817-820 <em>(electromagnetic induction)</em></td>
</tr>
<tr>
<td></td>
<td>cool? Why do you</td>
<td>distribution among the objects (second law of</td>
<td></td>
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<tr>
<td></td>
<td>get chilled after</td>
<td>thermodynamics) and that temperature</td>
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<td></td>
<td>swimming even on</td>
<td>changes at thermal equilibrium depend on the specific</td>
<td></td>
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<tr>
<td></td>
<td>a hot day?</td>
<td>heat values of the two substances.</td>
<td></td>
</tr>
<tr>
<td>Waves</td>
<td>How do waves</td>
<td>*HS-PS4-1. Use mathematical representations to</td>
<td>Chapter 15: 529-544 <em>(electromagnetic waves)</em></td>
</tr>
<tr>
<td>and Their</td>
<td>influence</td>
<td>support a claim regarding relationships among the</td>
<td>Chapter 13: 452-461 *(oscillations and periodic</td>
</tr>
<tr>
<td>Applications</td>
<td>everything that</td>
<td>frequency, wavelength, and speed of waves traveling</td>
<td>motions)* 470-475 <em>(waves)</em></td>
</tr>
<tr>
<td>in Technology</td>
<td>we see and hear?</td>
<td>in various media. Recognize that electromagnetic</td>
<td>Chapter 14: 492-500 <em>(sound waves)</em></td>
</tr>
<tr>
<td>and Information</td>
<td></td>
<td>waves can travel through empty space (without a</td>
<td>Chapter 17: 596-625 *(refraction and</td>
</tr>
<tr>
<td>Transfer</td>
<td></td>
<td>medium) as compared to mechanical waves that require</td>
<td>lenses)*</td>
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<tr>
<td>May to June</td>
<td></td>
<td>a medium.</td>
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<td>*HS-PS4-3. Evaluate the claims, evidence, and</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>reasoning behind the idea that electromagnetic</td>
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<td></td>
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<td>radiation can be described either by a wave model</td>
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<td></td>
<td>or a particle model, and that for some situations</td>
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<td>involving resonance, interference, diffraction,</td>
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<td>refraction, or the photoelectric effect, one model</td>
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<td>is more useful than the other.</td>
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<td>*HS-PS4-5. Communicate technical information about</td>
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<td></td>
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<td>how some technological devices use the principles of</td>
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<td>wave behavior and wave interactions with matter to</td>
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<td></td>
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<td>transmit and capture information and energy.</td>
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</tbody>
</table>

**Cross-Cutting Concepts**

- **Patterns**: Electromagnetic spectrum, waves, flow of energy, circuits
- **Cause and Effect**: Newton’s Laws, Laws of Thermodynamics, electric and magnetic fields
- **Scale, Proportion, and Quantity**: Electromagnetic spectrum, Newton’s Law of Gravitation, Coulomb’s Law
### Connections to Literacy and Math Standards

**ELA Season 4 standards:**
- **W7.** Conduct research
- **R8.** Evaluate arguments
- **F.LE.3.** Construct and compare models and solve problems
- **S.ID.5.** Summarize and represent data

**Related Math standards:**
- **F.LE.3.** Construct and compare models and solve problems
- **S.ID.5.** Summarize and represent data

**Earth and Space Science:** Magnetic reversals and moving continents

**Biology:** Conservation and transfer of energy

**Chemistry:** Conservation of energy, properties of water

**Technology/Engineering:** Generation of electricity, magnetic railways

### Performance Assessment

From Project WET Curriculum Guide, “Cold Cash in the Icebox,” create a mini-insulator to prevent ice from melting. Compare and contrast results, and make a case for what materials serve as the most effective insulators.

Conduct an experiment comparing the relative strengths of magnets and explain the strategy and results. (TIMMS: http://timss.bc.edu/timss1995i/TIMSSPDF/PAreport.pdf).

### ELA Season 5 standards:

**W6.** Use technology to write

**R4.** Interpret words/phrases

**Related Math standards:**
- **S.IC.3,4,5,6.** Make inferences and justify conclusions from experiments and studies

**Earth and Space Science:** Role of the atmosphere and solar flares in broadcasting

**Biology:** Conservation and transfer of energy, medical treatments, perception of waves through senses

**Chemistry:** Conservation of energy; light, and sound signals

**Technology/Engineering:** Broadcast signals and communication devices

### Performance Assessment

Create a model and presentation that explain the physical phenomenon of waves simply and clearly for students in an elementary school setting. The project should focus on a common example of waves such as seismic waves leading to an earthquake, ripples in a pond causing motion and sound, music coming from a speaker, or an echo in a stadium, and should be accompanied by a written explanation and a mathematical model (algebraic equation).

Write a prescription for eyeglasses for a far-sighted friend. Explain how they work, and why they help him/her to read in class. Illustrate as needed, either within the text or as a cartoon. (From NASA, Making Waves)
Newton’s Laws of Motion, Forces, and Gravity

TOPIC SEASON: Motion and Stability—Forces, Interactions, and Momentum

This unit is designed for use in long-term programs, but it may be adapted for short-term settings.

Unit Designers: J. Czajkowski and M. Sarr

Introduction

Newton’s Laws of Motion and Law of Universal Gravitation provide a “user’s guide” to how forces operate on Earth. In the same way schools and sports have rules, motion and forces follow rules that depend on their size and direction. Knowing that objects in motion tend to stay in motion in a straight line unless acted on by other forces can help predict how well a sled will slide on new snow or where a baseball will go when hit. Newton’s Laws also guide the work of designers, builders, and rocket scientists. Physical actions produce reactions. Controlling these reactions—with helmets, seat belts, and air bags, for example, can help keep people safe. Calculating the balance of forces helps architects and engineers ensure that the houses and bridges they construct will hold up against the forces of nature. Knowing that gravity is a pulling force that varies across the universe helps astronauts predict the motion of objects—including humans—on the space station or moon.

In this unit, students will use their knowledge about science to solve real-world problems, including constructions of bridges. Students will be engaged in learning through authentic and relevant topics and choices in what they research in Formative and Performance Assessments. This unit develops career skills in design, mathematics, engineering, architecture, construction, data analysis, and problem solving.

This unit is designed to take place during the first several weeks of the two-month Motion and Stability: Forces, Interactions, and Momentum season that begins the school year. Because the unit takes place at the start of the year, extra time may be needed to create community in the classroom. This unit can serve a prelude for a unit on space (Kepler’s Law) or the engineering design cycle.

Connections to engineering come in the form of building design, with a focus on resisting forces (compression, tension, and gravity). In short-term settings, some of the experiments and simulations may be adjusted or omitted to abbreviate the unit. It may also be divided into subsections, with some of the Formative Assessments transformed into Summative Assessments.

Two of the season’s three Emphasized Standards are addressed in the unit. HS-PS2-1 asks students to “analyze data to support the claim that Newton’s Second Law of Motion is a mathematical model describing motion and change in motion (acceleration) of objects with mass when acted on by a net force.” This standard applies to motion in sports, space, and all other aspects of life. Three variables are present in the equation at the heart of Newton’s Second Law: force, mass, and acceleration. Changing one variable will impact the equation. For example, a baseball thrown gently will generate a relatively small force, while a ball thrown quickly will generate a large force, even though the mass of the ball remains the same in both scenarios. This law comes into play often in daily life. Cars driven slowly can still generate large forces.
This unit also shows that something with a small mass can create a very large force when moving swiftly. Thus it is wise to wear a helmet when riding a bicycle or playing football. A rock hitting a windshield is another example of Newton’s Second Law in action. The story behind such actions and reactions can be shown in images or mapped out in graphical form to show acceleration, deceleration, and constant velocity.

Standard HS-PS2-4 requires students to “use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to both qualitatively and quantitatively describe and predict the effects of gravitational and electrostatic forces between objects.” While generally constant on Earth, gravity varies in space depending on the mass of the object (planet or moon). The planets with larger masses have a stronger gravitational pull, and less massive objects have less gravity. That is why astronauts’ mass remains the same both on the moon and earth, but their weight decreases, and they can jump farther. In the *Principia*, Newton defined the force of gravity in the following way: “Every particle of matter in the universe attracts every other particle with a force that is directly proportional to the product of the masses of the particles and inversely proportional to the square of the distance between them.” This means that the force of gravity gets weaker at an exponential rate as distances grow. As objects get much further apart, the force of gravity drops very quickly. At most distances, only objects with very high masses such as planets, stars, galaxies, and black holes have any significant gravity effects on other objects in space. Coulomb’s Law follows the same rules as gravity, but at a microscopic scale inside molecules.

Prior knowledge required for this unit includes a variety of math skills: solving algebraic equations and ratios, measuring values, determining proper units, analyzing data sets, and graphing. Practicing calculations with students will help them see patterns and solve complex equations. Sketches will help students visualize what they are calculating. Some mathematical concepts and operations may require considerable scaffolding.

Some students may struggle with the abstract nature of motion, forces, and gravity. The scientific readings and vocabulary will need to be reviewed and practiced as a class. Using concrete models will help students understand how forces act and react on Earth and how that changes in space. In examples related to space, distances may need to be scaled to provide students with proper context.

Writing an argument for the Performance Task may be difficult for some of the students and need teacher support. Since the timing of this unit coincides with the ELA season in which argument is taught, there may be opportunities for collaboration with the ELA teacher. The final project puts the students in the role of the bridge designer and builder. Students may need assistance in planning, creating, and testing their models.

The unit provides many options and multiple means of engagement, representation, and expression. Students are able to access the content through print, teacher presentations, video, and real-world connections and articles. Simulations help students see concepts such as the forces, motion, and gravity. The teacher can differentiate notes and graphic organizers depending on students’ needs. Extension activities are provided for students who are working ahead. The teacher can allow students to choose topics that they find interesting to keep them focused during the culminating project and may modify the requirements for the assessment to match students’ abilities.

For short-term adaptation ideas for this unit, see p. 6.3.3 on the right.
# Newton’s Laws of Motion, Forces, and Gravity

Adapting This Long-Term Unit for Short-Term Programs

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Newton’s Laws of Motion, Forces, and Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overview</strong></td>
<td>Throughout this unit, the focus is on students’ understanding Newton’s Laws of Motion and Law of Universal Gravitation. The standards’ emphasis is on using mathematics to represent forces between objects. During the lessons, the students will be applying Newton’s Laws to various realistic situations to allow for deeper connections to the scientific theories. These concepts are essential to an understanding of physics. In short-term programs, the best strategy for abbreviating the unit is to break it into smaller parts and create artifacts that can serve to assist students who enter while the unit is underway.</td>
</tr>
<tr>
<td><strong>Desired Results</strong></td>
<td>The Knows of this unit include vocabulary tied to Newton’s Laws, and the Understands provide meaning to the different aspects of the Laws. With an emphasis on mathematical computations, many of the Dos in the unit revolve around analyzing and modeling data and diagrams. For example, one Do has students analyzing Newton’s Second Law by examining free-body diagrams. In a short-term program, this unit can be broken up by separating the KUDs. For example, Newton’s Second Law could be a mini-unit by itself with students creating a free-body diagram with accompanying math expressions used as a Summative Assessment, rather than as a Formative Assessment as written in the unit.</td>
</tr>
<tr>
<td><strong>Assessment Evidence</strong></td>
<td>During the unit, the students will be able to complete labs and real-life demonstrations as Formative Assessments. While providing students with these experiences, the teacher should review safety standards and protocols in the classroom to make students, especially new students, aware of the expectations and class rules. In addition, with students possibly missing prior information, the teacher will need to provide review using anchor charts or differentiate assessments to account for the gaps in information. For example, in Lesson 7, students are asked to draw two diagrams of a car at rest and traveling and the forces acting on it. With a new student, it may be easier to ask for one drawing to show understanding or pair the student with another student to act as a tutor. Moreover, Lesson 10, the Summative Assessment, could be shortened to two days. Students may rely more on the computer program to help build the bridge and apply only a few mathematical expressions and scientific theories to support their techniques.</td>
</tr>
<tr>
<td><strong>Learning Plan</strong></td>
<td>Although there are many ideas in the unit for short-term programs, it is essential that the teacher not feel rushed, properly scaffold the math, and allow time for students to process the concepts. Lesson 1 will be vital to complete, so that future students will have a poster to provide context and examples for the vocabulary discussed in class. If a teacher has a short timeframe to complete the unit, Lessons 2 and 3 could be combined by removing videos from the presentation in each lesson. Since both lessons support Newton’s First Law, the teacher may be able to summarize certain parts. Many of the lessons following could be shortened to fewer days; however, with the difficulty of the material, students may need more time to practice and apply the information.</td>
</tr>
</tbody>
</table>
UNIT PLAN For Long-Term Programs

Newton’s Laws of Motion, Forces, and Gravity
Designed by: J. Czajkowski and M. Sarr
Theme or Content Area: Physics—Kinematics
Duration: 10 Lessons / 3 Weeks

Emphasized Standards (High School Level)

HS-PS2-1: Analyze data to support the claim that Newton’s second law of motion is a mathematical model describing change in motion (the acceleration) of objects when acted on by a net force.

Clarification Statements:
• Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, and a moving object being pulled by a constant force.
• Forces can include contact forces, including friction, and forces acting at a distance, such as gravity and magnetic forces.

State Assessment Boundary:
• Variable forces are not expected in state assessment.

HS-PS2-4: Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to both qualitatively and quantitatively describe and predict the effects of gravitational and electrostatic forces between objects.

Clarification Statements:
• Emphasis is on the relative changes when distance, mass or charge, or both are changed; as well as the relative strength comparison between the two forces.

State Assessment Boundary:
• State assessment will be limited to systems with two objects.
• Permittivity of free space is not expected in state assessment.
**Essential Questions** *(Open-ended questions that lead to deeper thinking and understanding)*

What forces control our lives?
How can forces be used to make objects move, change direction, or stop?
How can measurement describe an action?
How are Newton’s laws of motion relevant to our lives?
How does knowing about forces and impact influence design?
Why do astronauts have weight on Earth, but are weightless in space?

**Transfer Goals** *(How will students apply their learning to other content and contexts?)*

Predict how physical forces drive actions and reactions and consider the implications on design of structures such as houses, buildings, bridges.

Explain everyday activities (sports, structure, space, dance, driving) in terms of the laws of motion.
## Learning and Language Objectives

**By the end of the unit:**

<table>
<thead>
<tr>
<th>Students should know...</th>
<th>understand...</th>
<th>and be able to...</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Newton’s First Law (Inertia)</strong>&lt;br&gt;Vocabulary: inertia, force</td>
<td>Objects tend to keep on doing whatever it is they are doing (resting or moving) unless something else exerts a force on them. (Adapted from: Launchpad: Newton's Laws on the ISS)</td>
<td>Provide examples of and explain Newton’s First Law such as why a bike keeps rolling even after you stop pedaling.</td>
</tr>
<tr>
<td><strong>Newton’s Second Law (F = ma)</strong>&lt;br&gt;Vocabulary: weight, mass, velocity, acceleration, net force, vectors.&lt;br&gt;Note: weight = mass x gravity&lt;br&gt;mass x acceleration (F = mg = ma)</td>
<td>The size of the force depends on two variables: mass and acceleration. A net force acting on an object causes the object to accelerate. (Adapted from: Launchpad: Newton’s Laws on the ISS)</td>
<td>Explain how unbalanced forces lead to a change in motion (falling off a skateboard, for example).&lt;br&gt;Draw a free-body diagram that shows all forces acting on an object and use mathematical expressions to model the event.</td>
</tr>
<tr>
<td><strong>Newton’s Third Law (Action/Reaction)</strong>&lt;br&gt;Vocabulary: action-reaction</td>
<td>When one object exerts a force on another object, the second object exerts an equal and opposite force back. (Adapted from: Launchpad: Newton’s Laws on the ISS)</td>
<td>Explain how and why a balloon goes up as air rushes out or how a skateboard moves forward as the rider pushes on the ground.</td>
</tr>
<tr>
<td><strong>Gravity</strong>&lt;br&gt;Vocabulary: free fall, friction, vacuum</td>
<td>Gravity is a pulling force that attracts particles or objects toward the center of the earth, or toward any other physical object having mass.</td>
<td>Recreate and explain Galileo’s experiment at the Tower of Pisa to show that objects of varying mass fall at the same rate when close to Earth.</td>
</tr>
<tr>
<td><strong>Law of Universal Gravitation</strong>&lt;br&gt;Vocabulary: attraction, magnitude</td>
<td>Any two objects in the universe attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. These laws applies at the macro and micro level, respectively, for objects the size of stars and planets and as small as molecules and atoms.</td>
<td>Model the Law of Universal Gravitation with diagrams and/or calculations and analyze the attraction force between two objects via a computer simulation.</td>
</tr>
<tr>
<td><strong>Bridges</strong>&lt;br&gt;Vocabulary: beam, arch, truss, suspension, tension, compression</td>
<td>All bridge designs must balance compression and tension forces.</td>
<td>Design and construct a model bridge that demonstrates an understanding of balanced forces and utilizes a style appropriate to the situation.</td>
</tr>
</tbody>
</table>
Assessment Evidence

Quality questions raised and tasks designed to meet the needs of all learners

Performance Task and Summative Assessment (see pp. 6.4.32 to 6.4.36)

Aligning with Massachusetts standards

Students will apply what they have learned about forces and gravity in an authentic design project:

1. Given a specific bridge design challenge, students will compose an argument as to why a particular design would work best. Include an analysis of the forces acting on the bridge, citing Newton’s laws and using mathematical representations to support the analysis.

2. Design, build, and test the bridge using Popsicle sticks based on the Popsicle Bridge project developed by IEEE as part of TryEngineering:


   Or, construct a bridge using the West Point Bridge Design simulator (requires software download):

   SEE: https://bridgecontest.org

3. Reflect on the results of the design project, explaining its success or failure.

Pre-Assessments (see p. 6.4.14 to 6.4.16)

Discovering student prior knowledge and experience

Students will show what they already know about Newton’s Laws by “explaining the action” in three video scenarios. (An alternative assessment would be to have students complete a teacher-generated survey that uses clip art to represent common situations—a car sliding on ice, for example—and asks students predict what happens next and explain their reasoning. An online Pre-Assessment is available at the following site:


Note: If the site is not available to students, the teacher may need to print out copies before class. For students who have extensive experience in physics already, sample scenarios and related questions are available at The Physics Classroom—Newton’s Law. These three passages focus on reasoning on topics related to mass, motion, friction and changes in velocity.)

SEE: www.physicsclassroom.com/reasoning/newtonslaws

Students will use the graphic organizer provided (see p. 6.6.1 of the Supplement) as the basis for a visual brainstorm, with students’ drawing examples of the vocabulary for this unit. Students will show prior knowledge of words such as vectors, acceleration, and mass. After working individually, students compare answers with classmates to generate a class list of drawings that explain the meaning of the related science vocabulary.
Assessment Evidence

Quality questions raised and tasks designed to meet the needs of all learners

Formative Assessments (see pp. 6.4.14 to 6.4.30)

Monitoring student progress through the unit

Students will complete the Chapter 5 Lab, Hanging Around, on Newton's First Law in the Pearson Physics Lab Manual (pp. 65-69) as a way to visualize vectors and draw sample free-body diagrams, in preparation of upcoming content.

Students will provide and explain examples of Newton's First Law, such as why a bike keeps rolling even after you stop pedaling. As content area background, students can complete the guide sheet on inertia from The Physics Classroom—Minds On Physics: Inertia Questions.

Students will complete the Comet Cratering Activity found on the Indianapolis Library Kids' Blog as a way to witness what happens when objects of varying masses impact other objects in space. This activity models what happens when meteors hit the surface of the moon, leaving a crater.

SEE: www.imcpl.org/kids/blog/?p=8871
(The website includes a materials list, detailed instructions, and inquiry questions.)

Students should record the results of their experiments in a science journal or data sheet. As a way to reflect on the cratering activity, students will draw and write about what they observed. Focus questions can include:

• How did the mass of the object impact the size of the crater?
• How did the height from which the object was dropped influence the size of the crater?
• How does this experiment prove or disprove Newton's Second Law?

Students will use diagrams or words to explain how hitting a ball with a bat sets the balls in motion.

Students will explain how unbalanced forces lead to a change in motion, for example, falling off a skateboard.

Students will conduct the CK-12 Balloon Simulation to learn more about free-body diagrams and to find ways to mathematically represent changes in forces and motion. CK-12 Balloon Simulation link.

Students will complete the Chapter 5 Lab on Newton's Second Law in the Pearson Physics Lab Manual (pp. 75-78), focusing closely on the conclusions, especially the Free-Body Diagram for the cart, plotting the data, and creating a single mathematical relationship involving net force, mass, and acceleration.

Referring to Newton's Laws, students will create a Public Service Announcement informing the audience why bike or motorcycle riders should always wear a helmet. Examples and samples:

SEE: www.youtube.com/watch?v=35SMjUMgIe0
http://elschools.org/sites/default/files/Car%20Safety%20LE_EL_0210_0.pdf
Students will draw a free-body diagram that shows all forces acting on an object and use mathematical expressions to model the event.

Students will recreate and explain Galileo’s experiment at the Tower of Pisa to show that objects of varying mass fall at the same rate when close to Earth. Students may use a Vine format, which means students would have seven seconds to explain and demonstrate the experiment.

Students will compare the forces of gravity on different planets in our solar system and calculate the weight of a 100-pound dog on each planet.

Students will complete the Gizmo on Gravitational Force at explorelearning.com. Then, using inductive reasoning, they will complete the Universal Formula for Gravity based on what they have learned.

Note: This computer simulation is differentiated to support students with various math and science skill sets.

Students will role play the relationship between the Earth and the moon showing how gravity impacts both objects.
Access for All

Considering principles of Universal Design for Learning (UDL), Positive Youth Development/Culturally Responsive Practice (PYD/CRP), differentiation, technology integration, arts integration, and accommodations and modifications

Multiple Means of Engagement

This is the “WHY” of learning. It is what makes students engage or disengage. Throughout the unit plan, the student will be provided with choices in the level of challenge and complexity in order to recruit and sustain engagement. The teacher will encourage and support students in setting their own personal, academic and behavioral goals. The teacher is encouraged to use various strategies to guide students, including reminders, guides, rubrics, checklists, and prompts among others things that focus students on self-regulatory goals. Throughout the unit, teachers will differentiate and scaffold tasks in order to retain student interest and engagement in tasks. Student tasks will be varied, allowing for active participation, exploration, and experimentation. The teacher should provide content material using sources and activities that are relevant and responsive to students’ cultural and ethnic backgrounds. Most important is that teachers design assignments and tasks with authentic outcomes that are purposeful and convey meaning to real audiences.

The chief means of recruiting engagement in this unit is through hands-on activities—opportunities for students to experiment with Newton’s Laws using everyday materials. Lesson 2 includes tossing a Nerf ball at a target to demonstrate inertia. Lesson 3 uses an “air soccer” game to demonstrate forces acting on an object; Lesson 4 incorporates Newtonian charades. Lesson 5 has a lab in which students make and measure craters using different sized marbles, and Lesson 8 includes a balloon demonstration. Most significantly, the final Performance Task is a hands-on activity that includes designing, building, and testing a bridge.

Multiple Means of Representation

This is the “WHAT” of learning. There are many pathways to conveying information to students. Throughout the unit, the teacher should present material in several modalities such as diagrams, videos, charts, and sound, among others. Whenever possible, the teacher should provide text equivalents, such as automated text-to-speech programs (e.g., Kurzweil, Read & Write for Google Chrome, and WordTalk). The teacher should try to display information in a multiple formats. For example, when viewing videos, or listening to music, provide transcripts when possible. To accommodate the variability of how students take in, act on, and engage with information, teacher should include varied materials and flexible tools.

While this unit makes some use of the Pearson Physics textbook, many other means of representation are included to make the concepts accessible to all students. These include videos depicting Newton’s Laws in action in a variety of contexts, ranging from everyday activities to space travel. Lessons 4, 8, and 9, as well as the alternative Performance Task, incorporate computer simulations. Throughout the unit visuals are used to supplement verbal explanations, with a particular emphasis on free-body diagrams in the later lessons.
Multiple Means of Action and Expression

This is the “HOW” of learning. In reading and writing activities students will be provided options for demonstrating what they know and can do in each unit. Students should have access to assistive technology and multiple media including text, videos, illustrations, storyboards, and visual art if necessary. In composing or writing activities, teacher will provide students with multiple options. For example, students will have access to word processors with grammar checks, word prediction, and spell checkers. Students could complete projects by making PowerPoint presentations, rap music videos, illustrations or drawings. In addition, students should have access to calculators including graphing calculators. The teacher should scaffold writing or composing activities using tools such as concept maps, outlining tools, or graphic organizers. Students may need sentence starters and story webs to complete writing or composing tasks. The teacher should provide checklists and planning templates for setting and prioritizing goals. The teacher should also break down long-term tasks into short-term reachable goals.

Students will have many options for expressing their learning in this unit. In addition to the hands-on activities listed above, the lessons include informal and formal writing in the form of Exit Tickets, open response questions, and arguments or reflections. Students are also frequently asked to create drawings and diagrams with labels and explanations, to participate in thought experiments, and to hypothesize and discuss outcomes. The Performance Task and other activities throughout the unit are broken down into small steps, and scaffolding is provided for students who need support.
Literacy and Numeracy Across Content Areas

Reading
Throughout the unit, the students will be reading nonfiction texts from the Pearson Physics textbook and informational websites. The students will be reading the information to gain understanding and to scaffold their knowledge base of the material being explained in class. Students will also be reading to provide feedback on other peer’s work.

Writing
The students will be utilizing writing to process and display their knowledge and understanding of concepts. Students will be writing their conclusions to labs and to explorations of the content. The writing will help teachers to assess the students’ skills to complete the assignments and meet the standard. The unit’s writing will include an array of formal and informal formats focusing on the argumentative style.

Speaking and Listening
Throughout the unit, there are ample opportunities for students to speak in class. Students will be making presentations to the class or the teacher for their Galileo experiment, Public Service Announcement, and other opportunities to explain their understanding of the concepts.

Listening will occur with a number of audio options. The teacher will be delivering the information through direct instruction, short videos, and computer simulations with sound. Students will provide acknowledgement of comprehension through responding to questions or adding their own extensions to the materials.

Language
Within the unit, the students will be exposed to various examples of academic language. During the lessons, the teacher will scaffold the language through modeling, turn and talks, and class discussion about the content. In addition, students will learn and utilize Tier II and Tier III academic vocabulary dealing with motion and stability. The students will determine general and physics-specific meanings of words with multiple meanings, like force, which could be described as a Tier II and a Tier III word.

Providing students with opportunities to present to the class will allow practice using Standard English conventions. In addition, students will be responding in class with simple and complex sentences. The teacher will encourage full responses during answers and will model formal English when possible. In addition, students’ written work will foster improvement in using capitalization, spelling, and punctuation conventions.

Numeracy
Numeracy plays an important part in Newton’s Laws and is needed to support theories and ideas. Throughout this unit, students will be working with numbers in equations and with data in virtual simulations. Students will need to create graphics that visualize computations and equations. Students will be viewing and creating models using scales to explain the Law of Universal Gravitation. While creating a bridge to compute forces, the students will be using a chart of data for the structure to reinforce and support the bridge.
Resources (in order of appearance by type)

Lesson Plans and Resources

http://betterlesson.com/home

Note: As the Next Generation Science Standards (NGSS) go into practice around the country, teachers are sharing lesson plans and resources. BetterLesson is a website sponsored by the Gates Foundation. Given that the Revised MA Science Technology and Engineering Standards are based on the NGSS, plans and resources found on this site are applicable and useful.

In addition to the ideas shared in this curriculum guide, over one hundred lessons related to Newton’s Second Law can be found at the following BetterLesson link:


Print


Note: This text is a handy reference book on forces, motion, and other topics in physics. The examples are clear and easy to model for students at all levels.


Note: Reprints are still available of this illustrated guide to physics. The author explains key ideas in physics through pictures, examples, and words. Students who struggle with mathematical and numerical representations of concepts may find this visual guide helpful in simplifying ideas and offering a different entry point into the topics of motion and forces.


Note: Currently out of print, but available online, this book provides simple explanations of complex concepts in the form of a graphic novel.

Websites


www.imcpl.org/kids/blog/?p=8876.


“Study finds heading ball not biggest concussion threat in school soccer.” *Newsela*. (Adapted from *LA Times*). 2015.


http://udlexchange.cast.org/lesson/33466.

“AIM Explorer.” *National Center on Accessible Education Materials*. N.P.
http://aem.cast.org/navigating/aim-explorer.html#mainContent.
Websites (continued)

“UDL Strategies.” Goalbook Toolkit. ENOM. 2016. (A subscription is required to access all the features.)

www.youtube.com/watch?v=6gzCeXDhUAA.

www.youtube.com/watch?v=9XewqINsvJE.

www.youtube.com/watch?v=Xx9kiF00rts.

www.pbslearningmedia.org/resource/9c9ea5a4-4649-4e8d-a153-693c4ae75047/9c9ea5a4-4649-4e8d-a153-693c4ae75047/.


www.youtube.com/watch?v=08BFCZJDN9w.

“Newton’s Laws of Motion Interactive.” Science Channel. N.P.

“BULLSEYE | Runaway Train: Fox. 2015.
www.youtube.com/watch?v=Hjv8y9Qld68.

“Spheres of Influence.” Scope, Sequence, and Coordination. N.P.
http://dev.nsta.org/ssc/pdf/v4-0916t.pdf.


“Elevator Type Problems.” Dann, James. 2010.
www.youtube.com/watch?v=2Qil1bCLmbc.

“Newton’s Second Law.” CK-12. N.P.

www.pinterest.com/search/pins/?q=Newton%27s+Second+Law.


www.youtube.com/watch?v=iwP4heWdhvw.

“The Martian | Teaser Trailer” 20th Century Fox. 2015. www.youtube.com/watch?v=Ue4PCl0NamI.


Websites (continued)


“Bridges. 1 of 5” Building Big. WGBH. www.dailymotion.com/video/x1rvnpp_pbs-building-big-1-of-5-bridges_tv.


Materials (some located in the Supplement)
Popiscle sticks and building materials, Vocabulary Illustration (p. 6.6.1), Bridge Builder’s Rubric (p. 6.6.2), Bridge Builders Questions (p. 6.6.3)
Outline of Lessons
Introductory, Instructional, and Culminating tasks and activities
to support achievement of learning objectives

INTRODUCTORY LESSON
Stimulate interest, assess prior knowledge, connect to new information

Note: Teachers should vet all videos included in this unit according to program standards and create templates or graphic organizers for students to follow along.

Lesson 1
Forces and Motion

Goal
Students will explain that Newton's Laws show that motion and forces follow certain rules on Earth and in space and that these forces follow predictable patterns.

Do Now (time: 8 minutes)
Students will respond to the following prompt by writing or drawing:
What forces are at work in this classroom right now and what rules do they follow? Explain your answer.

Hook (time: 12 minutes)
As a Pre-Assessment for the unit, the teacher will survey the students about what they already know about Newton's Laws by having them “explain the action” in three video scenarios during which each video presents a different law of motion.
For Newton's First Law, show the YouTube video below from 1:50 to 2:00; mute the sound on this and the next two video clips so that students can explain the action in their own words. Newton’s First Law is the Law of Inertia:
An object at rest stays at rest, and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.
SEE: “Egg Drop Inertia Challenge—Cool Science Trick”
www.youtube.com/watch?v=6gzCeXDhUAA

For Newton's Second Law, show all of the video below. Remember to mute the sound before hitting play. This law can be stated as follows:
The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object. A simpler definition is Force = Mass x Acceleration.
SEE: “Newton's 2nd Law of Motion Demonstration”
www.youtube.com/watch?v=9XewqfNSvJE
For Newton’s Third Law, show the video below from 3:41 to the end. Newton’s Third Law is stated as follows:

For every action, there is an equal and opposite reaction. The statement means that in every interaction, there is a pair of forces acting on the two interacting objects. The size of the forces on the first object equals the size of the force on the second object. This law is also known as the law of action-reaction.

SEE: “Nick Warner: Newton’s Third Law—Physics in Action with a Skateboard and a Makeshift Rocket”
www.youtube.com/watch?v=Xx9kiF00rts

In response to the video clips, students will work to develop their own examples of “explain the action.” Working individually or in pairs, they should create three original examples that they will share as part of the Presentation.

More examples of Newton’s Laws in action are available at Circus | Physics: Newton’s Laws of Motion.

SEE: www.pbslearningmedia.org/resource/9c9ea5a4-4649-4e8d-a153-693c4ae75047/9c9ea5a4-4649-4e8d-a153-693c4ae75047

Presentation (time: 10 minutes)
Building on what was shared in the previous discussion, the teacher should replay each video clip with the sound on as a way to frame and define each of the three Laws of Motion and have students share their original examples, possibly through role play (acting out the forces).

Practice and Application (time: 20 minutes)
As an additional Pre-Assessment for the unit, the teacher should use a graphic organizer like the one Vocabulary Illustration, on p. 6.6.1 in the Supplement, as the basis for a visual brainstorm and have students draw examples of the vocabulary for this unit. Students can show prior knowledge of words such as forces, vectors, acceleration, and mass. After working individually, students should compare answers with classmates to generate a class set of drawings that explain the meaning of the related science vocabulary. Depending on time constraints and the number of students, this application activity can be split and spread out over more than one day. The number of words on this list can be shortened or expanded depending on students’ prior knowledge.

The teacher will review the student drawings posted on the board and, with the group, analyze the accuracy of these first-draft drawings, looking for examples of words and drawings that correctly align with or stray from scientific conventions.

Students should keep this graphic organizer as a place to contain their notes. This sheet will serve as a study guide throughout the unit.


Review and Assessment (time: 5 minutes)
Students will respond to the following two questions on an Exit Ticket:

1. Thinking back on today’s lesson, choose one word, concept, or idea about forces and motion that is now clear to you. Explain this item in your own words.

2. Thinking back on today’s lesson, choose one word, concept, or idea about forces and motion that remains confusing to you. What questions do you have about this item?


**Extension**

Newton’s Laws link to everyday life in hundreds of ways. As a way to uncover prior knowledge and reveal possible misconceptions, the teacher can ask students how they have experienced these laws in everyday life and while playing sports. A concrete example of Newton’s First Law is when a rider leans up against a seat belt during a sudden stop. As a way to get students thinking more deeply, share animated examples such as “The Truck and Ladder” from the *Physics Classroom*, which show how objects in motion tend to stay in motion once they start in motion.

SEE: “Physics Classroom—The Truck and Ladder”

www.physicsclassroom.com/mmedia/newtlaws/il.cfm

**INSTRUCTIONAL LESSONS**

*Build upon background knowledge, make meaning of content, incorporate ongoing Formative Assessments*

**Lesson 2**

What Moves You? Newton’s First Law (2 Days)

**Goal**

Students will explain that a force must act upon an object to set it in motion, and that when an object is in motion, it takes a force to change or stop that motion.

Key vocabulary: *inertia, force*

**Do Now** (time: 5 minutes)

1-2-3 Draw: Students will draw ONE object at rest, TWO objects in motion, and THREE objects that keep moving (rolling, spinning) once the power is stopped or switch is shut off.

**Hook** (time: 20 minutes)

Body in Motion Activity: As a way to witness the meaning of inertia (the resistance of an object to any change in its motion, including a change in direction—an object will stay still or keep moving at the same speed and in a straight line, unless it is acted upon by an outside force), students do the following activity (5 steps):

1. The teacher creates a landing zone using a paper towel in which students draw a target in the center. The target should be placed in the center of the desk or lab table top.
2. Next, students stand next to their target, holding a Nerf ball.
3. After warming up their arms, students follow a sweeping “letter C” motion over their targets, releasing the ball at the point where they think it will land in the center bullseye.
4. Students carefully observe the motion of the ball when it lands, noting what happens at impact.
5. Following the protocol of the scientific process, students repeat this experiment three times, recording the results—as a drawing—after each attempt.

**Extension**

Newton's Laws link to everyday life in hundreds of ways. As a way to uncover prior knowledge and reveal possible misconceptions, the teacher can ask students how they have experienced these laws in everyday life and while playing sports. A concrete example of Newton’s First Law is when a rider leans up against a seat belt during a sudden stop. As a way to get students thinking more deeply, share animated examples such as “The Truck and Ladder” from the *Physics Classroom*, which show how objects in motion tend to stay in motion once they start in motion.

SEE: “Physics Classroom—The Truck and Ladder”

www.physicsclassroom.com/mmedia/newtlaws/il.cfm
Presentation (time: 30 minutes)
The teacher will begin by showing the following YouTube video:

SEE: “Newton’s First Law of Motion—Science of NFL Football”
www.youtube.com/watch?v=08BFCZJDn9w

Next, the teacher will model the opposing forces by drawing force arrows on the board or acting it out with other adults in the room, when feasible. This demonstration can be reinforced with material from the Pearson Physics textbook. Chapter 5, pp. 150-185, provides an overview of Newton’s laws, and p. 179 provides a study guide of the big idea that all motion is governed by Newton’s laws; pp. 151-153 focus on Newton’s First Law.

At the end of class, students should submit a 3-2-1 Exit Ticket: 3 things they learned, 2 questions they still have, and 1 application of Newton’s First Law to everyday life.

Practice and Application (time: 20 minutes- Day 2 starts here)
As a Do Now activity at the start of Day 2 of this lesson, the teacher will list the questions compiled from the previous day’s Exit Tickets and ask students to work in pairs to try to answer them. Then, working at computer stations, students will watch the following video from Discovery Science Channel.


Note: This website should be projected by the teacher if students do not have internet access.
Students should click on Law of Inertia and follow on-screen prompts. After watching this video, students will reflect on the content by taking a “writing break” and responding to the following prompt: Suggest three ways that objects are set in motion and three ways that objects come to a fast stop.

Review and Assessment (time: 35 minutes)
Students will repeat the Body in Motion Activity one more time.

Knowing what they know about inertia, how can they change their release of the Nerf ball to make sure it stops on target? Discuss the results.

Next the teacher should show a clip from the TV show Bullseye, where contestants were challenged to hit the target. Knowing about Newton’s First Law mattered mightily to the success of the contestants.

SEE: “BULLSEYE—Runaway Train”
www.youtube.com/watch?v=Hjv8y9QId68

Play the video from 4:20 to 5:30. Finally, students will write an Exit Ticket in which they explain the Law of Inertia in their own words and pictures and apply it to the contest in the video or an everyday occurrence or phenomenon.

Extension
NSTA Activity ideas for Newton’s First Law include Activity 3, Spheres of Influence. This activity includes five inquiry-based lab activities and five assessments that teachers should use to extend thinking and deepen understanding of Newton’s First Law. These activities and assessments all focus on inertia and can be done with common objects and can be used to gather and plot data on simple spreadsheets, if available.

SEE: “NSTA—Activity 3, Spheres of Influence”
http://dev.nsta.org/ssc/pdf/v4-0916t.pdf (p. 9)
Lesson 3

Newton’s First Law in Action

**Goal**

Students will explore application of Newton’s First Law in and outside of the classroom.

Key vocabulary: *velocity, acceleration*

**Do Now** (time: 5 minutes)

Students will create a list of four examples of when they see applied forces change motion, either by stopping or redirecting an object or person.

**Hook** (time: 10 minutes)

Simulating an air hockey game or a soccer game, students will use straws and blow air to move a ping pong ball into the opposite goal. Students who are able should keep their hands behind their backs and blow puffs of air to move the ping-pong ball, watching how the motion of the ping-pong ball changes as each puff of air is applied. This action demonstrates the second half of Newton’s First Law of Motion:

- Objects tend to keep on doing whatever it is they are doing (resting or moving)
- unless something else exerts a force on them.

See detailed instructions below.

**Note:** Be sure to collect all supplies after completing this activity.

**Air Straw Soccer Game:**

- Number of participants: 2 per table
- Intensity level: Medium
- Preparations: Put down masking tape at either end of a table to serve as the two goals
- Equipment: Soda straws for each player, a ping pong ball, two pencils

Clear a table and place pencils at either end as the goals. Give each player a soda straw. To start the game, put the ping-pong ball in the center of the table. Players then try to blow jets of air through their straws to control the movement of the ball. If the ball leaves the table, simply replace it wherever it went out. A point is scored whenever the ball hits a pencil goal. No use of hands. The first player to score five points wins.

**Presentation** (time: 15 minutes)

**RELATED GRAPHIC FOLLOWS ON THE NEXT PAGE.**

The teacher will draw on the board, project, or distribute the graphic that follows and ask students to explain it simply, in their own words. As the students and teacher analyze its meaning, the teacher may need to instruct students that \( v = \text{velocity} \) and that \( a = \text{acceleration} \) in this example.

- Velocity is a measure of how fast something has moved in a particular direction (meaning that it is a vector value). Acceleration is a measure of how fast velocity changes. Acceleration is the change of velocity divided by the change of time. Acceleration is a vector and therefore includes both a size and a direction.
Lesson 3: Presentation—related graphic

Adapted from: “Newton’s First Law.” www.physicsclassroom.com/Class/newtlaws/u2l1a.cfm

One way to show the meaning of velocity and acceleration is to show the following simulation:

**SEE:** “PhET—The Moving Man”
https://phet.colorado.edu/en/simulation/legacy/moving-man

In this simulation, students set the starting point, velocity (m/s), and acceleration (m/s²), and can vary these values to see how motion changes.

**Practice and Application** (time: 15 minutes)

Newton’s First Law of Motion shows up in applications that are all around us. Here are several examples taken from *The Physics Classroom* website:

- Blood rushes from your head to your feet while quickly stopping when riding on a descending elevator.
- You can tighten the head of a hammer onto its wooden handle by banging the bottom of the handle against a hard surface.
- To dislodge ketchup from the bottom of a bottle, you can turn the bottle upside down, thrust it downward at a high speed, and then abruptly halt it.
- Headrests are placed in cars to prevent whiplash injuries during rear-end collisions.
- While riding a skateboard (or wagon or bicycle), you fly forward off the board when hitting a curb or rock or other object that abruptly halts the motion of the skateboard.

Students will explain how the Law of Inertia applies to each of these examples and brainstorm individually three more examples to add to the list. After writing down their examples, students will share their ideas with their classmates.
Review and Assessment (time: 10 minutes)
Students will respond to what their classmates shared as examples of Newton’s First Law of Motion, explaining how the examples fit the definition of this law. Feedback should include specific use of keywords such as inertia and force.

Additional or alternate assessments:
Students will complete Practice Problem 14 in Pearson Physics, p. 52, to show how distance and velocity relate. Given that \( \text{velocity} = \frac{\text{distance}}{\text{time}} \), \( \text{time} = \frac{\text{distance}}{\text{velocity}} \): 50m/-1.5 m/s = 33.3 seconds—meaning it takes the runner 33.3 seconds to walk back to the starting point at a velocity of 1.5 m/s in the reverse direction.

Students will provide and explain examples of Newton’s First Law, such as why a bike keeps rolling even after the rider stops pedaling. As content area background, students can complete questions on inertia:

**SEE:** “The Physics Classroom—Minds on Physics: Inertia and Mass”

Extension

Lesson 4
Having an Impact: Newton’s Second Law (2 Days)

**Goal**
Students will demonstrate that there is a direct relationship between the amount of mass, the size of acceleration, and the force generated.

**Key vocabulary:** acceleration, mass, Newton

**Do Now** (time: 5 minutes)
Students will list the following objects in order according to the amount of mass they contain (the amount of matter in the object):
mouse, elephant, the sun, motorcycle, whale, you, sunflower seed, squirrel, dump truck

**Hook** (time: 10 minutes)
Students will act out “things that move fast or stop suddenly” in a charades format. Classmates will guess the object and comment on the speed of acceleration.

**Presentation** (time: 20 minutes, Day 1)
Using the PhET simulation “Forces and Motions: Basics,” the teacher will model the tug-of-war example, focusing on what happens when the people pulling for the two teams are the same sizes or different sizes. (Move one or more red or blue people into place on each side, then click Go!) After modeling the first simulation, the teacher will show the motion and acceleration examples, varying the mass and applied force (and, in the latter case, friction force) to demonstrate effects on speed and acceleration.
This demonstration can be reinforced with material from the *Pearson Physics* textbook. Chapter 5, pp. 150-185, provides an overview of Newton’s laws, and p. 179 provides a study guide of the big idea that all motion is governed by Newton's laws; pp.153-155 focus on Newton's Second Law.

**SEE:** “PhET—Forces and Motions: Basics”

**Practice and Application** (time: 20 minutes, Day 1)
Students will try all the simulations—force, motion, and acceleration—and observe what happens when inputs are changed. Students will record their observations in a science journal or data sheet. The teacher will facilitate a discussion of the results. At the end the first day of the lesson, students will write Exit Tickets explaining what they learned from the simulations.

**Presentation** (time: 20 minutes, Day 2)
As a Do Now at the start of the second day of this conceptual and mathematical review of Newton’s Second Law, students will explain the law in their own words, and the teacher will clarify any misconceptions. Then students will view the following video clip from CK-12, which demonstrates how acceleration is calculated using elevator problems. The teacher will review the calculations with the students and clarify concepts and terms (e.g, Newton as a unit of force).

**SEE:** “CK-12—Elevator Type Problems”
www.youtube.com/watch?v=2QiL1bCLmbc

**Practice and Application** (time: 20 minutes, Day 2)
The second day of this lesson focuses on students’ use of the readings, simulations, videos, activities, and practice problems related to Newton’s Second Law found on CK-12. The teacher should select items from the site that best fit students’ needs. For some students, it may be best to begin by reading the background information and discussing the sample equations. Others may benefit more from the interactive demonstration on determining the net force or the hot air balloon simulation. The teacher will look for evidence that students understand the concept behind this law before moving on to the calculations. The practice questions provide opportunities for students to solve simple problems.

**SEE:** www.ck12.org/physics/Newtons-Second-Law/?referrer=conceptdetails&by=ck12&difficulty =at%2Bgrade&filterReferrer=level#text

**Review and Assessment** (time: 15 minutes)
To finish the second day, students will complete the Practice Problems on p. 158 in the *Pearson Physics* text. The teacher will discuss the results with students and relate them to the law $F = ma$.

**Extension**
This Pinterest page includes ideas for constructing models that demonstrate Newton’s Second law in action.

**SEE:** www.pinterest.com/search/pins/?q=Newton%27s+Second+Law

This lesson plan can be found on BetterLesson. The site, sponsored by the Gates Foundation, offers teacher resources and banks of lesson plans written to address the Next Generation Science Standards:

**SEE:** “Better Lesson—Newton’s Second and Third Laws of Motion: Bumper Boats Investigations”
Lesson 5

Newton’s Second Law in Action

Goal
Students will explore application of Newton’s Second Law in and outside of the classroom.

Key vocabulary: mass, inertia, acceleration, net force, vector

Note: weight = mass x gravity = mass x acceleration (F = mg = ma)

Do Now (time: 5 minutes)
MassQuest Activity: Students will look around the room to find objects that represent three different small masses and estimate the mass of each object in grams.

Hook (time: 10 minutes)
Using a small kitchen scale—either digital or analog—students will find the mass of the three items they have identified in the classroom and record the results on the board. The scale should be set to measure in grams, the metric measure of mass. Students should compare the masses of the items in light of the similarities and differences of their materials and constructions.

Presentation (time: 15 minutes)
As a review, the teacher will show the first YouTube clip below about Newton’s Second Law (the video from Introductory Lesson) again, this time with the sound on. The teacher should ask students to discuss what students observe during this second viewing, being sure to integrate key vocabulary.

Next, the teacher should show the second clip below from the MacMillan Space Centre, stopping the video to ask students to predict the results of the experiment.

See: “Newton’s 2nd Law of Motion Demonstration”
www.youtube.com/watch?v=9XewqIjNSvJE
“MacMillan Space Centre—Newton’s Second Law of Motion”
www.youtube.com/watch?v=iwP4heWDhwv

Practice and Application (time: 15 minutes)
Students will complete the Comet Cratering Activity found on the Indianapolis Library Kids’ Blog as a way to witness what happens when objects of varying masses impact other objects in space. This activity models what happens when meteors hit the surface of the moon, leaving a crater. Students should record the results of their experiments in a science journal or data sheet.

See: www.imcpl.org/kids/blog/?p=8871

Review and Assessment (time: 10 minutes)
As a way to reflect on the cratering activity, students will draw and write about what they observed. Focus questions can include:

How did the mass of the object impact the size of the crater?
How did the height from which the object was dropped influence the size of the crater?
How does this experiment prove or disprove Newton’s Second Law?
As an alternative, the teacher could ask students to answer the following in words and pictures:

Explain how unbalanced forces lead to a change in motion (falling off a skateboard, for example).

**Extension**

Students could complete Chapter 5 Lab on Newton’s Second Law in the *Pearson Physics Laboratory Manual* (pp. 75-78). They should focus closely on the conclusions, especially the free-body diagram for the cart, plotting the data, and creating a single mathematical relationship involving net force, mass, and acceleration.

Another extension involves using a section of the opening of *The Martian* by Andy Weir. On p. 2, Weir writes:

*Hermes* is powered by ion engines. They throw argon out the back of the ship really fast to get a tiny amount of acceleration. The thing is, it doesn’t take much reactant mass, so a little argon (and a nuclear reactor to power things) let us accelerate the whole way there. You’d be amazed at how fast you can get going with a tiny acceleration over a long time.

Reading this passage can initiate a discussion about how astronauts use Newton’s Laws in navigating through space.

**Note:** Parts of this novel have inappropriate language, but the science is interesting. Be sure to pre-read any pages used with students. The movie trailer can be used as an activator:

SEE:  *The Martian* (movie trailer)

www.youtube.com/watch?v=Ue4PCI0NamI

**Lesson 6**

**Diagramming Forces: Drawing Vectors (2 Days)**

**Note:** In physics, quantities are described as either vector or scalar. Vectors are quantities that consist of both a numerical value with its unit and a direction, such as force, weight, velocity; vectors have both length and direction. Scalar quantities have no direction (temperature, mass, sound levels, and age, for example). Adapted from Scalars and Vectors.

SEE:  www.physicsclassroom.com/Class/1DKin/U1L1b.cfm

**Goal**

Students will demonstrate that the horizontal and vertical motions of an object are independent of one another. Also, students will use images to model the direction and value of forces.

**Do Now** (time: 10 minutes)

Students will consider and discuss the problem presented in the video link below.

How does gravity affect the motion of falling objects?

The students who created the video set up an experiment with a pneumatic cannon and a target suspended from an electromagnet. They asked the question, “How do you aim the cannon to compensate for the falling target?” The teacher should play the first part of the video, stopping it exactly at 0:45, then engage

For *Empower Your Future Connections*, see pp. 6.6.1 to 6.6.2
students in a discussion of the question. Students should state their hypotheses and explain their reasoning. 

SEE: “Pneumatic Camera and Free Falling Target”  
www.youtube.com/watch?v=aWDv-vuH0_4

Hook (time: 5 minutes)  
The teacher should then play the remainder of the video, which reveals the answer: Aim directly at the target because the target and the projectile are affected by gravity in exactly the same way. Students should compare this answer to their hypotheses and discuss the outcome of the experiment.

Presentation (time: 20 minutes)  
The demonstration video should lead into an explanation of how to diagram forces. The Pearson Physics textbook, Chapter 5, pp. 161-162, provides basic information on free-body diagrams. The Vectors and Direction section of The Physics Classroom supplements the explanation provided in the text and adds explanations of common conventions for describing the direction and magnitude of vectors.  
SEE: www.physicsclassroom.com/class/vectors/Lesson-1/Vectors-and-Direction

Practice and Application (time: 50 minutes, beginning Day 1 and continuing to Day 2)  
Students should complete the following lab activities to develop an understanding of how vectors represent directional forces and how they combine to yield a net force:

Day 1—The Physics Classroom: Vector Addition Interactive  
This applet allows students to align vectors and generate outcomes as a way to see how combining two or more forces creates a new, resultant force. This applies when someone is paddling a canoe at the confluence of two rivers, for example. Students should drag two or three vectors into the applet screen after clicking Components ON. They should use the vectors to model a situation of their own choosing, such as an airplane flying north at 90 miles per hour into a crosswind blowing due east at 20 miles per hour. By combining the x and y components of the two vectors, they should be able to predict the length and direction of the resultant vector. They can check their predictions by clicking Show Resultant. As an Exit Ticket for Day 1 of the lesson, students should draw the problem they modeled with vectors and explain the result.  
SEE: www.physicsclassroom.com/Physics-Interactives/Vectors-and-Projectiles/Vector-Addition/Vector-Addition-Interactive

As an alternative approach to learning about vectors, students can complete Pearson Physics Laboratory Manual: Chapter 5, Hanging Around, on Newton’s First Law (pp. 65-69). This lab enables students to visualize vectors and draw sample free-body diagrams.

Day 2—TeachEngineering.org: Vector Voyage  
As a Do Now at the start of Day 2 of the lesson, students will respond to this question:  
In order to reach their destinations, what do sailors need to worry about besides the direction and speed of travel? (Answer: wind and current, which are vectors.)  
In this activity, students are in the role of sailors and navigators, cruising along while considering the importance of velocity vectors (which tell speed and direction). This activity includes vector worksheets and answer sheets to print out.  
**Review and Assessment** (time: 25 minutes)

Students will complete the Inquiry Lab in *Pearson Physics*, p. 113, to assess their understanding of the concept of independence of motion in two dimensions. Students will complete both the Explore and Think sections, writing and diagramming responses to the Analyze, Identify, and Predict components using appropriate terminology. Students should then compare and discuss their results.

**Extension**

Chapter 4 labs, Projectile Motion and X Marks the Spot, in the *Pearson Physics* Laboratory Manual, pp. 57-64, extend the work of this lesson. There are also video tutorials that explain vectors in other ways:

**SEE:** “Khan Academy—Introduction to Vectors and Scalars”

This lesson has students use compass directions as a way to navigate around the classroom as an analogy for using vectors on a larger scale and in other applications:

**SEE:** “Better Lesson—Vector vs. Scalar Quantities”
http://betterlesson.com/community/lesson/722/vector-vs-scalar-quantities

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**Lesson 7**

**Action/Reaction: Newton’s Third Law and Free-Body Diagrams**

*Note:* Free-body diagrams are used to show the relative magnitude and direction of all of the forces acting on an object in a given situation. Drawing all forces helps students see how forces are balanced and unbalanced and provide an entry point into Newton’s Third Law. It is important that all the forces acting on an object be shown and all forces are labeled.

Newton’s Third Law, taken from p. 158 of the *Pearson Physics* textbook: For every action force acting on an object, there is a reaction force acting on a different object. The action and reaction forces are equal in magnitude and opposite in direction.

**Goal**

Students will demonstrate how Newton’s Third Law describes the forces that objects exert on one another by drawing free-body diagrams that show opposing forces.

*Key vocabulary:* action-reaction, magnitude, free-body diagram

**Do Now** (time: 5 minutes)

In words and pictures, students will answer and discuss the following question:

How are actions and reactions related?

(Students may use non-physical examples such as social actions and reactions.)

**Hook** (time: 10 minutes)

While it is easy to see a person pushing on a wall, it is hard to understand that the wall exerts a force back onto the person. The teacher should show Newton’s Third Law of Motion by Professor Mac, an animated video that explains this law through concrete examples, and invite student questions about it. Students
should compare the information in the video to their responses in the Do Now.

SEE: www.youtube.com/watch?v=r9yuR7e9qf4

Presentation (time: 15 minutes)
To provide a more detailed introduction to this law, the teacher should show Newton’s Laws of Motion (3) from the European Space Agency. This video clip shows how this law works in space and on the ground, along how varying the mass impacts how far an object will travel. This video concludes with a review of all three laws in action in outer space.

SEE: www.youtube.com/watch?v=cP0Bb3WXJ_k

To elaborate on what was shown, the teacher can share the following explanation, taken from Engineering for Every Kid (see link below). “Newton’s third law of motion explains that forces act in pairs. This law states that for every action there is an equal and opposite reaction. Newton realized that if one object applies a force on another, the second object applies an equal force on the first object but in the opposite direction. Each force in an action-reaction pair of forces is equal and acts in the opposite direction. But each force in the pair acts on a different object, so they are unbalanced forces” (25). The teacher may wish to act out the explanation by pushing against a wall or a chair.

SEE: “Engineering for Every Kid”
www.arvindguptatoys.com/arvindgupta/engineering-janice.pdf

This explanation can be reinforced with material from the Pearson Physics textbook, Chapter 5, pp. 150-185, provides an overview of Newton’s laws, and p. 179 provides a study guide of the big idea that all motion is governed by Newton’s laws; pp. 158-160 focus on Newton’s Third Law

Practice and Application (time: 15 minutes)
Free-body diagrams show how forces impact and effect objects. The link below provides an explanation in greater detail than the text and includes a link to an explanation of the different types of forces as well as an interactive applet for drawing free-body diagrams that students can use to test their thinking. Students should complete several of the scenarios in the applet, consulting each other and the teacher as needed for clarification if they make errors creating free-body diagrams.

SEE: “Drawing Free-Body Diagrams”

Review and Assessment (time: 10 minutes)
A SAMPLE DIAGRAM FOLLOWS ON THE NEXT PAGE.

To demonstrate their understanding of forces, students will draw, label, and explain free-body diagrams that show all of the forces acting on a car at rest and one traveling down a road. The drawing should resemble the sample diagram illustration on p. 6.4.27, adapted from Terminal Velocity (see link below).

The teacher should remind students to draw diagrams carefully because details are important.

SEE: “Terminal Velocity—Physics and Chemistry for IG and A Level”
https://esfsciencesnew.wordpress.com/2008/10/10/terminal-velocity

Explanations should clarify that weight is equal to the normal force, and thus the vertical acceleration of the car equals zero. The weight of the car (mass x gravity), pointing down, is opposed by the normal force, pointing up. Friction forces from air resistance and the road oppose the thrust of the engine, reducing the horizontal acceleration.
Lesson 7: Review and Assessment—sample diagram

The arrows representing forces have a size, a point of application, and a direction.

1. Car at Rest
   - Normal Reaction
   - Weight

2. Car accelerating
   - Up and Down Fs are equal
   - Normal Reaction
   - Frictional forces (air resistance + friction between tires and road)
   - Thrust of engine
   - Weight

Extension

The teacher may wish to show this video, which shows action-reaction along with simple drawings that parallel free-body diagrams.

SEE: “Khan Academy—Newton’s Third Law of Motion”

Lesson 8
Newton’s Third Law in Action

Goal
Students will explain how Newton’s Third Law describes the forces that objects exert on one another.

Do Now (time: 5 minutes)
AN ILLUSTRATION FOR THIS ACTIVITY APPEARS ON THE NEXT PAGE.

Students will view the images in the following illustration (pp. 6.4.28) of Newton's Third Law in action in sports, everyday life, and nature and then draw two additional examples from their own experience.
Lesson 8: Do Now—activity illustration

**Two forces on every object**

<table>
<thead>
<tr>
<th>Barbell</th>
<th>100 lbs. up</th>
<th>Air pushes bird up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Book on a Table</td>
<td>100 lbs. down</td>
<td>Wing pushes air downwards</td>
</tr>
</tbody>
</table>

Hook (time: 10 minutes)

With teacher supervision students will conduct the following demonstration:

**Hook (continued)**

**Balloon Races**

Materials: balloons (the fat, long ones work well), string, straws, tape, chair

Procedure:
1. Blow up the balloon (don’t tie it).
2. Let it go and watch what happens.
3. Tie one end of the string to a chair.
4. Blow up the balloon (again, don’t tie it).
5. Tape a straw to it so that one end of the straw is at the front of the balloon and the other is at the nozzle of the balloon.
6. Thread the other end of the string through the straw and pull the string tight.
7. Let go. The balloon should move five to ten feet along the string.
8. Explain the balloon’s movement in term of Newton’s Third Law.

Adapted from Newton’s Third Law.

SEE: “Bite Size Physics—Bite 6: Newton’s Third Law”
http://tinyurl.com/hu7pqke (PDF)

Presentation (time: 10 minutes)

The following 25-slide presentation from Wisconsin Online provides more examples of action and reaction pairs of forces and five assessments in an easy to understand and self-paced format. Before the teacher moves from slide to slide, students should draw their predictions for force pairings on paper or sticky notes.
SEE: “Construction of Free-Body Diagrams”

Note: The slide show does not play on Chrome. Use a different browser.

**Practice and Application** (time: 20 minutes)
As a way to simulate changes in forces, learn more about free-body diagrams, and find ways to mathematically represent changes in forces and motion, students will use the CK-12 Balloon Simulation. This simulation begins with a guiding question:

How do you control a hot air balloon?

Text boxes introduce forces and motion before students move on to a simulation that allows them to adjust the payload mass, vent, and burner, while showing the free-body diagram and graphs of the time vs. altitude and time vs. velocity. Students should change variables and observe the results. To end this practice session, they should compare what happens with the free-body diagram when the load and burner are at maximum and minimum values.

SEE: http://tinyurl.com/hbcktrf

Note: The tutorial in the simulation explains its connections to Newton's Second Law.

**Review and Assessment** (time: 10 minutes)
As a Formative Assessment, students will respond to the following two prompts in words and diagrams:

1. Explain how unbalanced forces lead to a change in motion, for example, falling off a skateboard.
2. Explain how hitting a ball with a bat sets the ball in motion.

**Extension**
Since students have learned about and practiced all three of Newton's laws, they could complete Lesson Check 5.1 on p. 160 of *Pearson Physics* to assess understanding. Students could also complete Chapter 5 Lab, Finding the Mass of the Block, in the *Pearson Physics Laboratory Manual*, pp. 83-84. This lab is designed as open inquiry where students apply what they have learned to design an experiment that shows how mass can be found by knowing the friction force acting on an object. As a connection to the Common Core writing standards, students could write an argument as a letter to the editor or public service announcement about the value of wearing seatbelts or helmets, including reference to gravity as an impactful force.

**Lesson 9**

Gravity and The Law of Gravitation

**Goal**
Students will explain that gravity is a pulling force between two objects that have mass.

Key vocabulary: gravity, free fall, friction, vacuum, attraction, magnitude
Do Now (time: 5 minutes)

Students will respond to the following thought problem:

Imagine that you are standing next to a tunnel dug completely through the Earth, from one pole to the other. Draw a line from the person’s hand showing the path the rock travels when you drop it down that opening. Show what you think happens when that rock gets to the center of the Earth and explain your thinking in writing.

Note: As humans have never dug deeper than the crust of the Earth, this experiment is not yet possible, but the laws of gravity explain what, in theory, should happen. The expectation is that the rock would travel to the center of the Earth—and just a little bit beyond—before gravity pulls it back to the center, where it would hover. Galileo posed and thought about this question more than 400 years ago. Remind students that this is theoretical physics, and factors such as heat and pressure are ignored as the focus is just on gravity as a pulling force.

Hook (time: 5 minutes)

Anticipation Guide

Before starting the lesson activities, students will mark whether they agree (+) or disagree (-) with each statement below.

<table>
<thead>
<tr>
<th>Before</th>
<th>After</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1. Earth’s gravity does not affect objects outside the Earth’s atmosphere.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. The moon is too small to have a gravitational pull on another object.</td>
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<tr>
<td></td>
<td></td>
<td>3. There is no gravity in outer space.</td>
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<tr>
<td></td>
<td></td>
<td>4. An object that is freely falling has mass.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. An object orbiting Earth is pulled toward Earth by gravity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. Gravity is the force that governs the motion of our solar system.</td>
</tr>
</tbody>
</table>


Presentation (time: 20 minutes)

The teacher will explain that in 1589, Galileo climbed to the top of the Tower of Pisa in Italy with two steel balls, one that weighed one pound and one that weighed 10 pounds, and dropped them. The teacher should ask the students to speculate:

Which ball do you think hit the ground first?

Next the teacher should recreate and explain Galileo’s experiment off the Tower of Pisa to show that objects of varying mass fall at the same rate when close to Earth, and students could try it as well, using a variety of objects. Ideally, the teacher should make a video of these experiments and play it back, stopping the action at the moment the objects hit the floor.

Wind and air resistance can impact gravity experiments and free fall. The best way to show what Galileo thought is to do the experiment in an airless vacuum or in space. As those conditions only exist in a lab
on Earth, but do exist on the moon, the teacher should show “Feather & Hammer Drop on Moon,” so students will see that in the absence of air resistance—the moon has no atmosphere—the objects drop at the same rate and hit the surface at the same time.

SEE: www.youtube.com/watch?v=5C5_dOEyAfk.

**Practice and Application** (time: 20 minutes)

The following activity reinforces how gravity varies by planet. While we have not set foot on any other planets, we can use mathematical calculations to show that while mass remains the same, weight varies because gravity varies by the mass of the planet (weight = mass x gravity). Students should use a gravity calculator, such as Your Weight on Other Worlds, to compare the forces of gravity on different planets in our solar system and calculate the weight of a 100-pound dog on each planet. Depending on the strengths and needs of the students, this can be done as a whole-group activity with each student focusing on the gravity values of one or two planets.

To reinforce the concept that gravity varies with the mass of an object, students should complete the Gravitational Force Gizmo (second below). In this Gizmo, students can drag two objects around and observe the gravitational force between them as their positions change. The mass of each object can be adjusted, and the gravitational force is displayed both as vectors and numerically. This computer simulation is differentiated to support students with various math and science skill sets. Using values obtained from the Gizmo, students can complete Newton’s universal gravitation equation:

\[
F_{\text{grav}} \propto \frac{m_1 \cdot m_2}{d^2}
\]

Where \( F_{\text{grav}} \) represents the force of gravity between two objects
\( \propto \) means “proportional to”
\( m_1 \) represents the mass of object 1
\( m_2 \) represents the mass of object 2
\( d \) represents the distance separating the object’s centers

SEE: “Your Weight on Other Worlds”
www.exploratorium.edu/ronh/weight

“Gravitational Force Gizmo”

“Circular Motion and Satellite Motion—Lesson 3 Gizmo”
www.physicsclassroom.com/class/circles/Lesson-3/Newton-s-Law-of-Universal-Gravitation

In addition to using the Gizmo on gravity, or as an alternative, this PhET simulation provides students with a chance to see how varying the mass and distance of two objects impacts the related force, reinforcing the idea behind Newton’s Universal Law of Gravitation: Gravity Force Lab.

SEE: “Gravity Force Lab”
https://phet.colorado.edu/en/simulation/gravity-force-lab
These activities can be reinforced with material from the *Pearson Physics* textbook. Chapter 9, pp. 307-310, provides explanations of how gravity affects everything in the universe, that gravity is the weakest force of nature, and how gravity decreases rapidly with distance.

**Note:** Curiously, gravity in space acts in an unusual way. Albert Einstein first postulated that space is bent by gravity, as shown in this classroom demonstration:

SEE: “Gravity Visualized”
www.youtube.com/watch?v=MTY1Kje0yLg

**Review and Assessment** (time: 5 minutes)
After completing the activities, students will mark again whether they agree (+) or disagree (-) with each statement in the Anticipation Guide and compare their new answers to their previous ones. Under each statement, they should explain how the activities supported or changed their ideas.

**Extension**
As a way to explore the value of gravity on Earth, students could complete the two Chapter 3 labs, Free Fall Exploration & Finding “g” ... Three Ways, in the *Pearson Physics Laboratory Manual*, pp. 37-44.

Students could role play the relationship between Earth and the moon, showing how gravity impacts both objects, by assigning students to represent each object (Earth and the moon).

**CULMINATING LESSON**

*Includes the Performance Task, i.e., Summative Assessment—measuring the achievement of learning objectives*

**Lesson 10**

**Building Bridges (4 Days)**

**Goal**
Students will apply what they have learned about forces and gravity in an authentic design project, the Performance Task for the unit on motion and forces:

1. Given a specific bridge design challenge, compose an argument as to why a particular design would work best. Include an analysis of the forces acting on the bridge.
2. Design, build, and test the bridge using Popsicle sticks based on the Popsicle Bridge project developed by IEEE as part of TryEngineering, OR Construct a bridge using the West Point Bridge Design simulator (requires software download).
   
   
   https://bridgecontest.org
3. Reflect on the results of the design project, explaining its success or failure.

**Note:** The first portion of this project could be included after Lesson 6 to give students more time to think about how they want to complete the Performance Task.

Key vocabulary: beam, arch, truss, suspension, tension, compression
Do Now (time: 10 minutes)
On Day 1, students will respond to the following prompt:

Think back to the roads and bridges you have traveled over by car or train.
Fold a paper into four squares and draw four different types of bridges you have seen.
Try to name each type of bridge. What common shapes do you see in your drawings?

Hook (time: 15 minutes)
Back in 1940, the Tacoma Narrows Bridge, which spanned the Tacoma Narrows strait of Puget Sound in Washington, connected the city of Tacoma to the Kitsap Peninsula. Design flaws along with windy coastal conditions caused the bridge to collapse. The teacher should show the historic six-minute Tacoma Narrows Bridge Collapse “Gallopin’ Gertie,” then ask students come up with an explanation about why the bridge collapsed. Students should be encouraged to use the language of motion and forces (inertia, gravity, vectors) in their discussion. Drawing on student observations, the teacher should explain that the bridge might have turned into a wing—a phenomenon called aeroelastic flutter—and what engineers should have done to prevent this phenomenon, such as adding cross-bridging.

SEE:  www.youtube.com/watch?v=j-zczJXSxnw

Presentation (time: 30 minutes)
On Day 1 of the Performance Task, the teacher will explain that engineers use their knowledge of forces to figure out what kind of bridge design will work best to span a long or short space in varying conditions. Engineers are always constrained by budgets, and they have to keep costs down while building safe structures. All sorts of design features and forces are considered, especially the strengths of materials (wood, iron, concrete, and steel) and forces including tension (a pulling force) and compression (a force that causes an object to become squeezed, squashed, or compacted).

The Prezi below provides a detailed overview of the four main types of bridge designs (arch, beam, suspension, and truss) and compares and contrasts the designs of actual and virtual bridges along with giving an overview of using West Point Bridge Design, an online simulator for bridge design and construction created by the United States Military Academy at West Point. As the teacher presents the Prezi, students should take notes (including diagrams) on the types of bridges and the forces that act on them. Some students may benefit from having a table or chart to organize their notes.

SEE:  https://prezi.com/pszqczenojif/west-point-bridge-design

Next, the teacher will introduce the Performance Task, explaining the sequence of steps and reviewing the rubric located in the Supplement on p. 6.6.2. Functioning in the role of engineer and applying what they have learned about how forces work in nature and construction, students will build bridges of their own design with Popsicle sticks (or use the alternative West Point Bridge Design computer simulation) and test them for strength and durability. (This Performance Task can be adapted based on the number of students and availability of supplies. Students can work in teams, pairs, or individually to construct a bridge designed to support a load.)

Materials
One set of materials for each student or group of students: paper for drawing and explaining initial design, 200 Popsicle sticks, hot glue gun (or craft glue), standard 5- and 10- pound weights.
**Procedure**

1. Show students the Bridge Basics site below and review the structure and function of each type of bridge and related vocabulary.
   
   **SEE:**  [www.pbs.org/wgbh/buildingbig/bridge/basics.html](http://www.pbs.org/wgbh/buildingbig/bridge/basics.html)

2. Explain that students must develop their own bridge from up to 200 Popsicle sticks and glue. Each bridge must be able to hold a 20-pound weight. The bridge must span at least 14 inches (so it must be longer than 14 inches). When the bridge has been constructed, it will be placed at least one foot above the floor and tested with weights. In addition to meeting the structural and weight bearing requirements, the bridge will also be judged on its aesthetics, so students should be encouraged to be creative. Students will be encouraged to use the fewest Popsicle sticks possible to achieve their goals.

3. Students will review the various types of bridges and develop plans for their bridges. They will draw their plans and write arguments explaining why the chosen designs would work best, including an analysis of forces affecting bridge components, and then present their work to the class.

4. Students next execute their plans, using a set of materials provided by the teacher. Students may need to rethink their designs or even start over.

5. When the bridges are completed, each team will test its bridge's weight capacity by placing it at least one foot above the floor (using blocks or a chair supporting each end of the bridge). The bridge must be able to bear the assigned weight for a full minute.

6. As way to reflect on outcomes, students should evaluate their bridges with the rubric provided and write about how their bridges held the load. If a bridge collapsed, students can write about how they would revise their design and change construction techniques.

**Note:** If the teacher wishes to have students use the West Point Bridge Design simulation, instructions and software download are available at the site below.

**SEE:**  [https://bridgecontest.org](https://bridgecontest.org)

**Practice and Application** *(time: 110 minutes, Days 2 and 3)*

On Day 2 of the Performance Task, the teacher will ask students to think back to the four main types of bridges. After folding a sheet of copy paper into four sections, students will draw their recollection of what each type of bridge (arch, beam, truss, and suspension) could look like. Depending on what students show in their drawings, a brief review of the four main types of bridges might be necessary.

To help students deepen their understanding of the practical applications of bridge design, the teacher will share one of the following resources with students:

1. **PBS’s Building Big** (first link). Show from 4:15 to 27:45 (or more if time permits). Note that the video is periodically interrupted by ads. Students should take notes on the different kinds of bridges and building materials on a response sheet (second link).

   **SEE:**  [www.dailymotion.com/video/x1rvnpp_pbs-building-big-1-of-5-bridges_tv](http://www.dailymotion.com/video/x1rvnpp_pbs-building-big-1-of-5-bridges_tv)

2. **The Nova Build a Bridge** site (first link). This site presents four bridge sites and detailed information on four kinds of bridges. Using a table (such as second link), students should analyze the suitability of each kind of bridge for each site.
Then, working individually or in teams, students will decide what kind of bridge they will build to complete the Performance Task. They will draw their plans and write an argument explaining why the chosen design would work best, including an analysis of forces affecting bridge components, and then present their work to the class for feedback and discussion.

On Day 3 of Performance Task, the teacher will show the class the History Channel show, *Smartest Guy in the Room*, which shows a tongue depressor bridge building competition between two of the stars on the show “Randy’s Build-a-Bridge Challenge.” The teacher should show the first 30 seconds of the video to provide a visual model of what a bridge could look like (a truss bridge, in this example).

The teacher will ask students to discuss the problem presented in the video: lack of stability.

The teacher will record student-generated potential solutions on a piece of newsprint and post those comments nearby to use as an anchor chart throughout the construction project.

**SEE:** “History Channel—Smartest Guy in the Room: Randy’s Build-a-Bridge Challenge”

www.youtube.com/watch?v=KCj5ZcrBiOY

Note: The teacher should show the rest of this video part way through the class, after students have had a chance to begin construction, but before they have completed their bridges, as it shows the value of cross-bracing.

Most of the class period (and additional time, if needed) should be spent on students’ building their bridges, refining their designs as needed to maximize stability and strength while staying within the budget of Popsicle sticks. The teacher will remind the students to use the rubric to guide their work.

**Review and Assessment** (time: 55 minutes, Day 4)

On Day 4 of Performance Task, prior to testing their bridges students will share their designs, reasons for particular design decisions, and construction techniques. The materials used should be reviewed and costs calculated. When the bridges are tested with weights as outlined in the procedure, the teacher should make videos of the tests for future analysis and reflection if possible.

Students will then reflect on their work by evaluating their work with the rubric on p. 6.6.2 in the Supplement and answering the following questions:

1. Did you succeed in creating a bridge that held the required weight for a full minute? If not, why did it fail?
2. Did you decide to revise your original design while in the construction phase? If so, why?
3. How many Popsicle sticks did you end up using? Did this number differ from your plan? If so, what changed?
4. If you had to do it all over again, how would your planned design change? Why?
5. What designs or methods did you see others try that you thought worked well?
6. Do you think that engineers have to adapt their original plans during the construction of systems or products? Why might they?
7. What sort of trade-offs do you think engineers make between functionality, safety, and aesthetics when building a real bridge?

Note: Questions are also on a separate sheet on p. 6.6.3 in the Supplement section.
Questions adapted from: http://tryengineering.org/sites/default/files/lessons/popsiclebridge.pdf (pp. 8-9).

Extension
Once students have had a chance to construct and test their bridges they may be motivated to learn more about building and construction. The following books elaborate on construction, design, and the way things work:

- *Why Buildings Stand Up* by Mario Salvadori
- *The Art of Construction* by Mario Salvadori
- *To Engineer is Human* by Henry Petroski
- *The Way Things Work* by David Macaulay

This is a logical place to introduce the Engineering Design Process to students. Resources related to teaching about the EDP are available at following sites:

**SEE:** “The Engineering Design Process”
- www.eie.org/overview/engineering-design-process
- www.teachengineering.org/engrdesignprocess.php
- www.sciencebuddies.org/engineering-design-process/engineering-design-process-steps.shtml#theengineeringdesignprocess
POST–UNIT REFLECTION

On meeting the Learning and Language objectives

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Future Ready Connections

This unit allows youth to demonstrate Future Ready skills. Youth have many opportunities to strengthen their communication skills through group discussions, partner work, and presentations of their Performance Task when they will share their designs, reasons for particular design decisions, and construction techniques. Students even have the opportunity to practice non-verbal communication skills in Lesson 4's Hook when they will play charades. Youth can also be evaluated for initiative and self-direction as they plan and develop their bridges for the Performance Task. The Performance Task includes an opportunity for students to self-assess using the assessment rubric, which increases their accountability and buy-in for the project. Teachers should reflect on whether or not youth stay on task without prompting and if they push themselves to create a well-designed and effective final product. There are multiple opportunities for youth to give and receive feedback from peers which will allow teachers to evaluate students on their accountability for their own work and to their peers.

Teachers are encouraged to use the Future Ready Rubric to evaluate students and are encouraged to support students as they self-evaluate their demonstration of Future Ready skills.

Essential Question Connections

The overarching Essential Question for this unit asks youth to consider “What forces control our lives?” In the unit, students will analyze how gravity, mass, force, and motion control our movements and our interaction with other objects and elements. Teachers can expand on this idea and ask youth to consider how the laws of force and motion appear in their personal, academic, and professional lives as well. Ask youth to reflect on the rule that an object in motion will stay in motion unless another object or force changes its motion or path. Gravity is often the factor that exerts a force on a object in motion and drags it off course or to a stopping point. How does this apply to our lives? What is the gravity factor in your personal life that pulls you back, either in a good way or a negative way? When we set down a path we want to be on, how can we avoid anything that will slow us down or stop us? If we are on a path we don’t want to be on, what can we do to change our path or stop? Ask students to consider the positive and negative influences in their lives that can act as gravity or another factor that influences their lives.

To make connections to this concept, consider using Lessons 7 and 8 as opportunities to make this metaphor and encourage students to make a personal connection to the content.

PYD/CRP Connections

This unit reflects Culturally Responsive Practice and Positive Youth Development by providing opportunities for critical thinking and independent discovery, activating prior knowledge (Do Now prompts and Hooks), and making personal connections to the content. The explanations of the Laws of Motion use examples that are likely familiar to and engaging for youth, such as examples of biking, skateboarding, and playing tug-o-war. The lesson also demonstrates element of CRP and PYD by encouraging youth to actively participate in how they will be assessed which allows for a sense of ownership, empowerment, and accountability. Youth are also not simply reporting out for the Performance Task, but are explaining their thought processes and theories, which encourages youth voice and active participation in
“Emphasize for students that the skills that they develop in this unit can apply to many areas of their lives.”

understanding the topic fully. The lessons are also flexible and allow for students to work and discover in different ways (independently, with a partner, as a class, and with different mediums and activities), which respects their individual needs and abilities.

Career Research Connections

This unit focuses on Newton’s Laws of Motion, which allows students to consider how gravity and force affect our lives and the functioning of the world in which we live. Students can explore careers that are influenced by and work with these laws of motion. Students should consider who needs to understand these laws in order to do their job or design something safe and functional. Career fields that depend on a strong understanding of Newton’s Laws of Motion include engineers, architects, designers, safety experts (such as car safety inspectors and designers), astronomers, even game developers (who need to make realistic actions and reactions to movement and force).

Teachers can have students access MassCIS to explore careers that are related to the field of physics. Under “Occupations,” access the “Science, Technology, Engineering, and Mathematics” or the “Architecture and Construction” career cluster to view jobs in this field.

Lesson 6 Connections

Lesson 6 asks students to make predictions based on their understanding of Newton’s Laws of Motion. The ability to make predictions based on anticipating outcomes, accessing prior knowledge, and utilizing experience is essential for all critical thinking, including thinking about one’s personal, academic, and professional lives.

Teachers should encourage students to use a similar scientific method for making predictions when setting short term and long term goals. It is essential for personal goals to be a challenge, but also realistic and based on fact and good decision making. Emphasize for students that the skills that they develop in this unit can apply to many areas of their lives.

Lesson 9 Connections

Lesson 9 focuses on the effects of gravity, which provides teachers an interesting opportunity to ask students to consider their own personal gravity and influence on people and the world around them. Have students imagine that they are a celestial body like Earth or the sun and brainstorm what or whom their gravity influences and affects. Ask students: How do you affect other people? What do you do to influence them? What positive traits may pull someone in? What may you do that pushes people away? Have students consider these questions for their personal, academic, and professional lives and reflect on how their actions, behaviors, and feelings can influence other people.
**Vocabulary Illustration**

**Lesson 1**

**DIRECTIONS:** Fill out this graphic organizer by filling in empty cells and drawing out actions in the right column to show understanding of vocabulary. If more room is needed for illustrations, please use a blank sheet of paper.

<table>
<thead>
<tr>
<th><strong>Vocabulary Word</strong></th>
<th>Defined (from the glossary in the Pearson textbook starting on p. 874)</th>
<th>Explained simply (put the definition into your own words)</th>
<th>In action (draw it out)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force</td>
<td>A push or a pull</td>
<td>To make someone or something do something</td>
<td><img src="image" alt="Hand pushing" /></td>
</tr>
<tr>
<td>Mass</td>
<td>The measure of amount of matter in an object</td>
<td>How much stuff is in something</td>
<td></td>
</tr>
<tr>
<td>Inertia</td>
<td>The tendency of an object to resist any change in its motion</td>
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<td>Acceleration</td>
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<td>Net Force</td>
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<td>Vector</td>
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<tr>
<td>Reaction</td>
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<td>Free Fall</td>
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<tr>
<td>Friction</td>
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<td>Vacuum</td>
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<td>Attraction</td>
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<tr>
<td>Magnitude</td>
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<tr>
<td>CATEGORIES</td>
<td>4</td>
<td>3</td>
<td>2</td>
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<tr>
<td>-------------------------</td>
<td>-------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------</td>
</tr>
<tr>
<td>Construction—Care Taken</td>
<td>Great care taken in construction process so that the structure is neat, attractive and follows plans accurately</td>
<td>Construction was careful and accurate for the most part, but 1-2 details could have been refined for a more attractive product.</td>
<td>Construction accurately followed the plans, but 3-4 details could have been refined for a more attractive product</td>
</tr>
<tr>
<td>Modification/Testing</td>
<td>Clear evidence of troubleshooting, testing, and refinements based on data or scientific principles</td>
<td>Clear evidence of troubleshooting, testing, and refinements</td>
<td>Some evidence of troubleshooting, testing, and refinements</td>
</tr>
<tr>
<td>Function</td>
<td>Structure functions extraordinarily well, holding up under atypical stresses</td>
<td>Structure functions well, holding up under typical stresses</td>
<td>Structure functions pretty well, but deteriorates under typical stresses</td>
</tr>
<tr>
<td>Scientific Knowledge</td>
<td>Explanations indicate a clear and accurate understanding of scientific principles underlying the construction and modifications</td>
<td>Explanations indicate a mostly accurate understanding of scientific principles underlying the construction and modifications</td>
<td>Explanations indicate a relatively accurate understanding of scientific principles underlying the construction and modifications</td>
</tr>
<tr>
<td>Budget</td>
<td>Student was able to build a successful and safe bridge within the pre-established budget</td>
<td>Student built a safe bridge, but slightly exceeded the budget</td>
<td>Student stayed within the budget, but did not build a safe bridge for vehicles to pass over</td>
</tr>
</tbody>
</table>

Adapted from Building A Structure: West Point Bridge Designer RUBRIC
https://sites.google.com/site/engineeringbridgebuilding/rubric
Bridge Builders
Lesson 10 Questions

Reflection Questions:

1. Did you succeed in creating a bridge that held the required weight for a full minute? If not, why did it fail?

2. Did you decide to revise your original design while in the construction phase? If so, why?

3. How many Popsicle sticks did you end up using? Did this number differ from your plan? If so, what changed?

4. If you had to do it all over again, how would your planned design change? Why?

5. What designs or methods did you see others try that you thought worked well?

6. Do you think that engineers have to adapt their original plans during the construction of systems or products? If so, why might they?

7. What sort of trade-offs do you think engineers make between functionality, safety, and aesthetics when building a real bridge?

Chapter Contents
Waves and Their Applications

TOPIC SEASON: Waves and Their Applications in Technology and Information Transfer

This unit is designed for use in all programs, but it may be extended for long-term settings.

Unit Designers: J. Czajkowski and B. Penniman

Introduction

Our senses relay information about our world, and the two senses human beings typically rely on the most, sight and sound, transmit that information through waves. By learning about waves, particularly sound waves, the main focus of this unit, students will deepen their understanding of everyday phenomena, make predictions, and come to conclusions about the world around them. The unit’s emphasis on human hearing also has practical implications. Students will learn why exposure to loud sounds over long periods of time negatively impacts hearing and how wearing ear protection and making wise choices about listening to music preserves it.

In this unit, students will be engaged by learning about relevant topics and having choices in what they want to research. Students will see that the science of waves is used to solve real-world problems in electronic communications and is related to possible careers in mathematics, engineering, data analysis, and music.

This unit is designed to take place during the first two weeks in the six-week season Waves and Their Applications in Technology and Information Transfer, the last of the school year. The Waves and Their Applications unit can serve a prelude for a unit on communications and technological devices such as cell phones and radios. It can also precede a unit on the electromagnetic spectrum and light waves, as the motion of sound and light follow similar physical rules (travel in waves, travel at different speeds in different media, and can be impacted by interference).

The unit addresses aspects of both the Emphasized Standards for the season. HS-PS4-1 asks students to “use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media” and “recognize that electromagnetic waves can travel through empty space (without a medium).” Science is filled with phenomena that are difficult to model physically, as some are too large or too small or invisible to the eye. This certainly holds true with sound waves. These waves cannot be seen, but they can be heard. This standard focuses on how mathematical models can help students understand what is not visible by showing possible and probable patterns. Once modeled, waves can be organized and manipulated to model events such as an echo, the reflection of sound, or harmony, the combination of different musical notes played together to produce a pleasing sound. Also emphasized in this standard is that waves travel differently in different media, as they move faster in a solid than air due to the density of the molecules. HS-PS4-5 requires that students “communicate technical information about
“Using concrete models will help students understand how waves form, repeat, and flow.”

how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.” This standard focuses on the fact that wave behavior can be predicted and largely controlled. Signals can be sent, relayed, and received, and information contained in wave impulses can be decoded. Waves can be influenced by natural forces such as solar flares and storms.

Prior knowledge required for this unit includes an understanding that physical phenomena such as waves and sounds follow rules of nature and can be influenced by outside forces. Mathematical skills such as solving algebraic calculations and ratios, measuring values, determining proper units, analyzing data sets, and graphing are also helpful. Practicing calculations together will help students see patterns and solve complex equations. Using sketches and models will help students see what they are calculating. Simulations will help students understand concepts such as the Doppler Effect.

Some students may struggle with the abstract nature of waves as well as the mathematical formulas that model them. Using concrete models will help students understand how waves form, repeat, and flow. Scientific readings and vocabulary may also be challenging and require detailed reviewed and practice as a class. Too, writing a science argument may be difficult for some of the students and need teacher support, though persuasive writing is a focus in the ELA curriculum. Finally, the culminating Performance Task puts the students in the role of teacher. Some may need assistance in creating their presentations.

The unit provides various differentiation options and multiple means of engagement, representation, and expression. Students are able to access the material through print, teacher presentations, video, and real-world connections. The teacher can tailor class notes and graphic organizers to students’ needs, and some of the experiments and simulations may be adjusted as well. Students who are working ahead may be given the option to complete extension activities for the lessons. The teacher can allow students to choose topics that they find interesting to keep them focused during the culminating project. The teacher may change the requirements for this performance assessment to accommodate students’ abilities and background knowledge.

For long-term adaptation ideas for this unit, see p. 6.7.3 on the right.
Waves and Their Applications
Adapting This Short-Term Unit for Long-Term Programs

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Newton’s Laws of Motion, Forces, and Gravity</th>
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</thead>
<tbody>
<tr>
<td>Overview</td>
<td>Throughout this unit, the focus is on the science of waves and how it can be applied to everyday life. Standard HS-PS4-1 focuses on how waves travel through different media and how they are represented through mathematical computations. The unit also includes standard HS-PS4-5. This standard centers on the application of an understanding of waves into different technologies. Although this is a nine-lesson unit, a long-term program may explore more aspects of waves by utilizing ExploreLearning Gizmos and giving additional attention to the HS-PS4-5 standard, delving into different technologies to explore.</td>
</tr>
<tr>
<td>Desired Results</td>
<td>The KUDs in this unit offer higher-level thinking activities to complete for the Do. Many activities are hands-on; therefore, students will have products to display. In a long-term unit, it may be best to provide an area for students to showcase their work in the classroom and make connections to the concepts building upon each other in the standards. Students may also prefer extra time to work with a partner while completing an activity such as making a musical instrument or experimenting with a pendulum. If group work is occurring, teachers should set expectations with students and the program to provide the best support for the students. It may take more time in a long-term unit to establish the proper norms.</td>
</tr>
<tr>
<td>Assessment Evidence</td>
<td>The Performance Task requires students to simplify the physics of waves and create a kid-friendly product to teach younger students. If a program wanted to go deeper with this task and require a more academic form of writing, students could create a teacher guide to go along with their product. This would allow the teacher to utilize more wave concepts and have students explore what they wanted to reinforce about the topic. In addition, the Summative Assessment could include students’ creating a project showing how waves are used in television, Wi-Fi, MRI scanners, or solar panels. The students could diagram how the machines utilize waves to work.</td>
</tr>
<tr>
<td>Learning Plan</td>
<td>During this unit, ExploreLearning Gizmos would provide students with an opportunity to see waves in action and document their learning through student handouts. There are many Gizmos that establish a clear connection to the concepts, lessons, and the standards being covered.</td>
</tr>
<tr>
<td>Lesson 3, Energy of a Pendulum, has students looking at a pendulum and manipulating factors to alter its energy. Students could complete the lesson before the hands-on demonstration or in lieu of it. See: <a href="https://www.explorelearning.com/index.cfm?method=cResource.dspDetail&amp;ResourceID=390">https://www.explorelearning.com/index.cfm?method=cResource.dspDetail&amp;ResourceID=390</a></td>
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<tr>
<td>Lesson 4, Waves, provides students with an opportunity to control a spring and note the amplitude and wavelength when changing the tension of the spring. See: <a href="https://www.explorelearning.com/index.cfm?method=cResource.dspDetail&amp;ResourceID=1053">https://www.explorelearning.com/index.cfm?method=cResource.dspDetail&amp;ResourceID=1053</a></td>
<td></td>
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<tr>
<td>Lesson 6, Sound Beats and Sine Waves, has the students listening to a musician tuning an instrument and calculating frequency through “sound beats.” Since the students will be learning about the human ear and hearing, this allows the students to test their listening abilities and apply the scientific concept. See: <a href="https://www.explorelearning.com/index.cfm?method=cResource.dspDetail&amp;ResourceID=524">https://www.explorelearning.com/index.cfm?method=cResource.dspDetail&amp;ResourceID=524</a></td>
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<tr>
<td>Lesson 7, Doppler Shift Advanced, has students calculating frequency of a moving object by applying the Doppler Shift. See: <a href="https://www.explorelearning.com/index.cfm?method=cResource.dspDetail&amp;ResourceID=584">https://www.explorelearning.com/index.cfm?method=cResource.dspDetail&amp;ResourceID=584</a></td>
<td></td>
</tr>
<tr>
<td>Energy Conversions is an opportunity to extend the learning of the second standard. It is aimed at a younger student base, but still provides a great deal of information on how waves are used in technology. See: <a href="https://www.explorelearning.com/index.cfm?method=cResource.dspDetail&amp;ResourceID=651">https://www.explorelearning.com/index.cfm?method=cResource.dspDetail&amp;ResourceID=651</a></td>
<td></td>
</tr>
</tbody>
</table>
Emphasized Standards *(High School Level)*

**HS-PS4-1:** Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. Recognize that electromagnetic waves can travel through empty space (without a medium) as compared to mechanical waves that require a medium.

**Clarification Statements:**
- Emphasis is on relationships when waves travel within a medium, and comparisons when a wave travels in different media.
- Examples of situations to consider could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.
- Relationships include \( v = \lambda f \), \( T = 1/f \), and the qualitative comparison of the speed of a transverse (including electromagnetic) or longitudinal mechanical wave in a solid, liquid, gas, or vacuum.

**State Assessment Boundary:**
- Transitions between two media are not expected in state assessment.

**HS-PS4-5:** Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

**Clarification Statements:**
- Emphasis is on qualitative information and descriptions.
- Examples of technological devices could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.
- Examples of principles of wave behavior include resonance, photoelectric effect, and constructive and destructive interference.

**State Assessment Boundary:**
- Band theory is not expected in state assessment.
Essential Questions *(Open-ended questions that lead to deeper thinking and understanding)*

- How do waves influence everything that we see and hear?
- How are waves used to model and explain physical phenomena?
- How does energy transfer from one form to another?

Transfer Goals *(How will students apply their learning to other content and contexts?)*

- Explain how waves can produce motion and transfer energy (music from a speaker, earthquakes vibrating houses, waves in water, for example).
- Show how vibrations can create sound and how sound can be altered by changing the quality and quantity of the waves (changing a chord on a guitar string, for example) and the relative positions of the source and receiver.
- Explain that the speed of waves depends on the type of waves and the media in which they travel.
- Show how waves can be modeled mathematically to demonstrate how they travel.
### Learning and Language Objectives

By the end of the unit:

#### KNOW

KUDs are essential components in planning units and lessons. They provide the standards-based targets for instruction and are linked to assessment.

#### UNDERSTAND

#### AND DO

<table>
<thead>
<tr>
<th>Students should know...</th>
<th>understand...</th>
<th>and be able to...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oscillation and periodic motion</td>
<td>Related to the study of waves, motion that repeats over and over is called periodic. Nature and science are filled with patterns that repeat and allow us to predict what happens next.</td>
<td>Model how the motion of sound can be shown mathematically.</td>
</tr>
<tr>
<td><strong>Vocabulary:</strong> periodic motion, period, frequency, hertz, simple harmonic motion, restoring force, amplitude</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Pendulum</td>
<td>The back and forth cycle of a pendulum depends on its length and on the acceleration due to gravity.</td>
<td>Make a pendulum system that shows simple harmonic motion. Compare the movement of pendulums of different lengths and masses to each other and draw conclusions about the impact of changing lengths and masses.</td>
</tr>
<tr>
<td><strong>Vocabulary:</strong> simple pendulum, natural frequency, resonance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waves and wave properties</td>
<td>Particles within a wave oscillate back and forth while waves move from place to place. How fast a wave moves depends upon the medium in which it is traveling. Waves going through a solid tend to move faster than waves in air.</td>
<td>Use words and picture to describe how a wave is created as well the motion of particles within that wave. Give an example of how changing the media impacts the speed of a wave.</td>
</tr>
<tr>
<td><strong>Vocabulary:</strong> wave, transverse wave, longitudinal wave, crest, trough, wavelength, medium, mechanical wave</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sound waves</td>
<td>Sound is created when air molecules are compressed and expanded by a moving object, from a radio speaker to a hummingbird’s wing. The frequency of a sound wave determines pitch.</td>
<td>Construct a simple instrument using recycled materials. The instrument must be able to create vibrations that generate a sound.</td>
</tr>
<tr>
<td><strong>Vocabulary:</strong> pitch, ultrasonic, beat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doppler Effect</td>
<td>An observer hears a higher frequency when moving toward a sound, but hears a lower frequency when moving away from the sound.</td>
<td>Role play the ways sound moves during a NASCAR race. Show how the particles compress, expand, and change depending on the position of the race cars and spectators.</td>
</tr>
</tbody>
</table>

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6.8.3

Chapter 6, Section 8 | Massachusetts DYS Education Initiative—**Science**—2016 Edition
Human perception of sound

**Vocabulary:**
*power, intensity, decibel*

How we hear sounds depends on our location in relationship to the source of that sound as well as how far we are from the sound.

Justify the ban on muffler pipe whistles that a town is trying to impose to limit noise pollution using claims, evidence, and reasoning to strengthen the argument.

The applications of waves are found throughout our world in motion, music, and technological devices.

Demonstrate how waves can push around a small boat. Explain how tuning forks use vibrations to make sounds. Calculate how different tuning forks have different frequencies.
Assessment Evidence

Quality questions raised and tasks designed to meet the needs of all learners

Performance Task and Summative Assessment (see pp. 6.8.24 to 6.8.25)

Aligning with Massachusetts standards

Create a model and presentation (flip chart, infographic, booklet, Prezi, etc.) that explain the physical phenomenon of waves simply and clearly for students in an elementary school setting. The project should focus on a common example of waves such as seismic waves leading to an earthquake, ripples in a pond causing motion and sound, music coming from a speaker, or an echo in a stadium, and should be accompanied by a written explanation and a mathematical model (algebraic equation). (Lesson 9)

Pre-Assessment (see p. 6.8.11)

Discovering student prior knowledge and experience

Students will create a word web showing where they could find waves, explain what the waves look like, and draw pictures to show their thinking. (Lesson 1)

Formative Assessments (see pp. 6.8.11 to 6.8.24)

Monitoring student progress through the unit

After participating in a lab on wave motion in water, students will write and draw responses asking them to observe, assess, and predict. (Lesson 1)

Students will solve problems on the relationship between period and frequency and provide examples of periodic motion. (Lesson 2)

Students will conduct a lab on pendulums, record and analyze data, and respond to questions calling for conclusions about the experiment. (Lesson 3)

Students will respond to conceptual problems focusing on longitudinal and transverse waves by acting out the waves. Students will also model these waves with movement. (Lesson 4)

Students will then complete practice problems focusing on computing the difference between the speed of light and the speed of sound. (Lesson 5)

Students will complete a diagram of the ear, adding labels and briefly stating the function of all parts of the outer, middle, and inner sections of the ear. (Lesson 6)

For Empower Your Future Connections, see pp. 6.9.1 to 6.9.2
Formative Assessments (continued)

To show understanding of standing waves and the Doppler Effect, students will create, diagram, and explain scenarios that demonstrate these phenomena. Or, if permitted, students can construct simple instruments using recycled materials. The instruments must be able to create vibrations that generate sound. Examples could include tissue paper kazoos or a series of soda bottle flutes with different frequencies based on how much water is inside each container. (Lesson 7)

Students will complete open-ended questions and problems focusing on the concept of intensity. In addition, students will write letters for or against a ban on muffler pipe whistles to limit noise pollution using claims, evidence, and reasoning to strengthen their arguments. (Lesson 8)
Multiple Means of Engagement

This is the “WHY” of learning, what makes students engage or disengage. Throughout the unit plan, the student will be provided with as many choices in the level of challenge and complexity as possible in order to recruit and sustain engagement. For example, the teacher will encourage and support students in setting their own personal, academic, and behavioral goals. The teacher will use many strategies to guide students, including reminders, guides, rubrics, checklists, and prompts among other things that focus students on self-regulatory goals. For example, in Lesson 1 Frayer diagrams are completed for all vocabulary words and posted in the room as an anchor chart for reference throughout the unit. Student tasks will be varied, allowing for active participation, exploration, and experimentation. The teacher will provide differentiated models, scaffolds, and feedback, as well as content material that is culturally relevant and responsive to student’s backgrounds. Most important is that teachers design assignments and tasks with authentic outcomes, and that are purposeful and convey meaning to real audiences.

The unit connects to everyday physical phenomena and includes real-world applications of wave science. The unit also includes hands-on experiments with water, pendulums, springs, and sound; and it employs an inquiry model that draws on students’ natural curiosity and powers of inference to develop and test hypotheses.

Multiple Means of Representation

This is the “WHAT” of learning. There are many pathways to conveying information to students. Throughout the unit, the teacher will provide information and materials in several modalities such as diagrams, vocabulary cards, and word walls, posters, and charts with formulas for calculations; and models, videos, and audio for text. The teacher will also demonstrate concepts through hands-on activities.

This unit places particular emphasis on the relationships between familiar physical phenomena and ways that scientists represent them—in words, pictures, formulas, and graphs. Students will learn to connect the various means of representing the key concepts. The unit makes some use of the Pearson Physics textbook—particularly sections that include detailed explanations and step-by-step calculations to show how formulas are derived and applied. These passages are complemented by demonstrations, labs, videos, and direct instruction. Nearly all of the lessons include supplementary graphics and/or graphic organizers, and Lessons 3-7 and 9 also include online videos, animations, Prezis, or websites to complement the textbook material and provide alternative means of accessing the content.
Multiple Means of Action and Expression

This is the “HOW” of learning. In learning activities students will be provided options for demonstrating what they know and can do. Students will have access to assistive technology and use multiple media. For example, students will have access to word processors with grammar checks, word prediction, and spell checkers. Students could complete projects by making PowerPoint presentations, rapping through music videos, or drawing illustrations. In addition, students will have access to calculators. The teacher will scaffold writing or composing activities using tools such as concept maps, outlining tools, or graphic organizers. Students may need sentence starters and story webs to complete writing or composing tasks. The teacher will also break down long-term goals into short-term reachable goals.

Students will have a variety of opportunities to demonstrate what they have learned and are learning in this unit, including informal writing and drawing, problem-solving using concepts and formulas, conversations among peers, and a final project designed to teach others about waves.
Literacy and Numeracy
Across Content Areas

Reading
Through the unit, students will be reading nonfiction text from the *Pearson Physics* textbook and some informational websites. Students will read the information to gain understanding and to scaffold their knowledge base of material explained in class.

Writing
The students will be utilizing writing (and drawing) to process information and concepts and to develop understanding. Students will write their conclusions to labs and to explorations of the content. The writing will help teachers to assess students’ ability to meet the standards. The unit’s writing will include an array of formal and informal formats including the argument mode.

Speaking and Listening
Throughout the unit, there are ample opportunities for students to speak and reason in class, particularly during discussions of new concepts and lab experiments. Listening will occur with a number of audio options. The teacher will be delivering the information through direct instruction, short videos, and demonstrations. Students will provide acknowledgement of comprehension through responding to questions or adding their own extensions to the material.

Language
Within the unit, students will be exposed to various forms of academic language. During the lessons, the teacher will scaffold the language through modeling, turn and talks, and class discussion about the content. In addition, students will learn and utilize Tier II and Tier III academic vocabulary dealing with waves and their applications. The students will determine denotations of words with multiple meanings, like *period* and *intensity*, which could be described as Tier III and Tier II words.

Providing students with opportunities to engage in formal writing and to present to the class will allow practice using Standard English conventions. The teacher will encourage full responses to prompts and will model formal English when possible. In addition, students’ written work will follow conventions of capitalization, spelling, and punctuation.

Numeracy
Through this unit, students will be working with numbers when interpreting data and when setting up and solving equations. Students will also need to create graphics that model situations and lead to accurate calculations.
Resources (in order of appearance by type)

Print


Websites

www.youtube.com/watch?v=yVkdJ9PqRQ.


www.physicsclassroom.com/class/waves/LESSON-0/Pendulum-Motion.

www.youtube.com/watch?v=M8rrWUII_Z_U.

www.acs.psu.edu/drussell/Demos/waves/wavemotion.html.

www.youtube.com/audiolibrary/soundeffects.

https://prezi.com/bnsckhfkgby/how-the-ear-works/.

www.youtube.com/watch?v=RxzMzSZF_b4&cb=ANyPxKorLUnKN5RV/GCzXwxy2ahCF625w1kNXwi-95ucvasQ1E_3ZyqckhRhg03mhGnaBZXZb9zaTQkbQ4vcl_ax5G9DQkmcg&nohtml5=False.


“Why Do Ducks Make a ’V’ Shape in the Water When They Swim?” CK-12. 2016.

www.osha.gov/SLTC/noisehearingconservation/.


www.youtube.com/watch?v=A CeUOufx2I.

Materials

Frayer Diagram (p. 6.10.1), Pendulum Periods (p. 6.10.2), Parts of the Ear (pp. 6.10.3 to 6.10.4), Human Perception of Sound Vocabulary (p. 6.10.5)
Outline of Lessons
Introductory, Instructional, and Culminating tasks and activities
to support achievement of learning objectives

INTRODUCTORY LESSONS
Stimulate interest, assess prior knowledge, connect to new information

Lesson 1
Introduction and Inquiry Lab: Waves in Water

Goal
Students will recognize that waves are all around us, whether on Earth or in the air, and that waves are vibrations that move energy.

Do Now (time: 5 minutes)
Students will create a word web showing where they could find waves.

Hook (time: 10 minutes)
Working as a group, students will combine all the ideas generated in the Do Now activity. The teacher should ask students to explain what the waves look like and draw pictures to show their thinking. The teacher should create an anchor chart based on the student responses, leaving room for other examples to be added during the unit.

Presentation (time: 5 minutes)
The teacher will introduce the unit, explaining that students will be studying wave motion in a variety of natural and technological phenomena. The teacher should emphasize the point that waves move energy.

Practice and Application (time: 20 minutes)
The teacher will prepare students to do the Inquiry Lab “How do waves move in water?” in the Pearson Physics textbook, p. 453. Materials required include a rectangular pan half full of water and a pencil. Students should explore first and explain their thinking later. As they complete steps 2, 3, and 4, they can compare their observations.

Review and Assessment (time: 15 minutes)
After discussing their observations, students will write and draw responses to the Observe, Assess, and Predict prompts on p. 453. They should share their answers with peers, and the teacher can help them clarify their conclusions.

Extension
The Predict prompt raises the question of what would happen in a thicker liquid. The teacher could extend discussion of this point by asking students what would happen if the pencil struck a bowl of Jello or a book. Would there still be waves?
Lesson 2

Waves Vocabulary

Goal
Students will comprehend vocabulary words related to the motion of waves and apply them effectively in appropriate contexts.

Do Now (time: 5 minutes)
Using a teacher-created two-column handout that will serve as a Pre-Assessment for the unit, students will match the following waves vocabulary terms with their definitions (adapted from the Pearson Physics textbook, pp. 453-457) to the best of their ability.

<table>
<thead>
<tr>
<th>Vocabulary</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>periodic motion</td>
<td>any motion that repeats itself over and over</td>
</tr>
<tr>
<td>period</td>
<td>the time required to complete one full cycle of a motion</td>
</tr>
<tr>
<td>frequency</td>
<td>the number of oscillations (cycles) per unit of time. (Frequency is also expressed as the inverse of the period.)</td>
</tr>
<tr>
<td>hertz</td>
<td>a unit equal to one cycle per second</td>
</tr>
<tr>
<td>simple harmonic motion</td>
<td>a motion in which the force pushing/pulling an object toward equilibrium is proportional to displacement from equilibrium</td>
</tr>
<tr>
<td>restoring force</td>
<td>a force that brings an object back toward equilibrium</td>
</tr>
<tr>
<td>amplitude</td>
<td>the maximum displacement from equilibrium</td>
</tr>
</tbody>
</table>

Hook (time: 5 minutes)
The teacher will ask for volunteers to share their answers on the Do Now to see which words and definitions are familiar to students and which words are new to them. For words that are familiar, students should try to provide examples from everyday life, and the teacher should try to determine the depth of their understanding of the words in the physics context.

Presentation (time: 30 minutes)
The teacher will review the words students do know, clarifying any misconceptions, and then explain in detail the ones they don’t know (e.g., the teacher explains that hertz is not just a car rental company, then unpacks the physics definition and points students to where they can find more information in the textbook). Then, working with the teacher’s supervision and support, students will use the Pearson Physics textbook to fill in a Frayer diagram for each of the new vocabulary. Many of the words (e.g., hertz, harmonic motion, and amplitude) are uncommon and will need processing time. Students should create
and present their findings for each word. The Characteristics or Examples section on each Frayer diagram should include a picture. The Frayer diagrams should be posted on a bulletin board or wall to serve as an anchor chart throughout the unit on waves.

Note: A blank Frayer diagram is located in the Supplement on p. 6.10.1.

Practice and Application (time: 10 minutes)
To make a connection to math and prepare for the upcoming pendulum lab, students will solve Practice Problems 1, 2, and 3 on p. 455 of Pearson Physics. Completing one of the problems as a group and then reviewing will be helpful in determining needs for support and scaffolding regarding the math involved. The teacher should encourage students to focus closely on the relationship between period and frequency, emphasizing that the frequency is calculated by taking the inverse of the period. Another way of saying that is that frequency increases as the period decreases.

Note: The teacher should remind students that units matter in math and science because they give meaning to numbers. The unit for frequency is hertz, while the unit for period is seconds, as periods relate to time. Hertz used to be called “cycles per second,” a descriptor that may be more meaningful to students.

Review and Assessment (time: 5 minutes)
As an Exit Ticket, students will add to the following list of examples of periodic motion: swinging on a tire swing, the moon orbiting the earth, bouncing a basketball, and so on. Student answers could include the following:
- a child swinging on a swing, a back-and-forth ride at Six Flags Park, the pendulum on a grandfather clock, and the spring in a mechanical wristwatch

Extension
Practice Problem 4 on p. 455 of Pearson Physics shows that back-and-forth motion of a tennis ball follows a periodic motion. Students should find the period and frequency for the ball’s motion.

INSTRUCTIONAL LESSONS
Build upon background knowledge, make meaning of content, incorporate ongoing Formative Assessments

Lesson 3
Pendulum Lab: Simple Harmonic Motion

Goal
Students will demonstrate how simple harmonic motion can be explained mathematically.

Do Now (time: 5 minutes)
Students will look at the diagram on p. 6.10.2 in the Supplement showing a collection of pendulums of different lengths hanging on the same type of string and imagine that they are started swinging at the same time at the same angle. Students will identify the pendulum that they think will have the longest period (the time to travel out and back) and explain their answers.
Hook (time: 5 minutes)
After having students discuss the Do Now problem, the teacher should ask students the following questions:

Where have you seen a pendulum? Why are pendulums important?

Note: Pendulums are found in clocks. Galileo found that pendulums are useful as timekeepers, as the period of the pendulum is independent of the mass of the bob. The same holds true for small angles (amplitudes), up to ~30 degrees. He used free-swinging pendulums as timekeeping devices. In the Renaissance, pendulums were used in machines that moved back and forth, such as saws, pumps, and bellows to fan flames at blacksmith shops. In many ways, people’s legs act as pendulums when they walk. Pearson Physics explains this analogy in detail on p. 467.

Presentation (time: 10 minutes)
Section 13.2 (beginning on p. 462) of Pearson Physics provides background on pendulums along with explanations of simple harmonic motion and how different pendulums oscillate at different rates. A central idea for this section is that the period of a pendulum depends on its length and the acceleration due to gravity, but not the amplitude of the motion (the swing back and forth, if the angle is small) or the mass.

Pendulums will swing at different rates on other planets and their moons, as gravity is different due to their mass and their radii—both variables—are different from Earth’s. Using the diagrams in the textbook and a string and different sized washers—or a similar simple system—the teacher should model terms such as period, amplitude, and mass prior to the lab that follows. The period of a pendulum can be modeled by swinging it back and forth to show one cycle. Pointing out the high and low points of the swing will clarify the meaning of amplitude. For the purpose of this lesson, mass relates to the amount of matter in an object. Formal definitions of mass consider it to be a measure of an object’s resistance to change its state of motion when a force is applied, but that definition exceeds what is needed in this lesson. Point out to students that mass is different than weight, as weight is influenced by the force of gravity. Weight is equal to mass x gravity, following the formula at the center of Newton’s Second Law: Force equals mass x acceleration. If possible, use wood and different types of metals to demonstrate the effect of mass on this motion.

Showing this video of pendulum waves produced by the Harvard Natural Science Lecture group will reinforce the idea that length impacts the period of a pendulum:

SEE: “Pendulum Waves”
www.youtube.com/watch?v=yVkdfl9PqRQ

Practice and Application (time: 30 minutes)
The Chapter 6 Lab, “Energy of a Pendulum,” on p. 85 of the Pearson Physics Laboratory Manual, serves as a way for students, working in small groups, to examine potential energy (stored energy that relates to an object’s position), kinetic energy (the energy an object possesses due to its motion), and gravity. While the manual recommends using a photogate timer, students can observe the motion and record values based on those observations by a stopwatch or other simple timer. To eliminate the influence of human reflex on time measurement, students should record the total time for 10 cycles and then divide by 10 to get more accurate results.

To provide even more valid results, students should complete at least three trials and fill in all the data in Data Table 1 on p. 86. Remind students that distance is measured in meters (students may need to
convert centimeters to meters by moving the decimal point by two places to the left) and the time is measured in seconds. Use the formulas listed on p. 87 to calculate the change in potential energy and change in kinetic energy.

Here is a sample of possible results for Data Table 1:

\[ h = \text{height in meters} \]
\[ v = \text{velocity in meters/second} \]
\[ t = \text{time in seconds} \]
\[ \Delta (\text{delta}) = \text{change in value} \]

**Data Table 1**

<table>
<thead>
<tr>
<th>Trial</th>
<th>( h_0 ) (m)</th>
<th>h (m)</th>
<th>( \Delta h ) (m)</th>
<th>( \Delta t ) (s)</th>
<th>v (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5 m</td>
<td>1.0 m</td>
<td>0.5 m</td>
<td>1 sec</td>
<td>0.5/1 = 0.5 m/s</td>
</tr>
<tr>
<td>2</td>
<td>0.5 m</td>
<td>1.5 m</td>
<td>1 m</td>
<td>1.5 sec</td>
<td>1/1.5 = 0.66 m/s</td>
</tr>
</tbody>
</table>

Note: When calculating the change in potential energy (\( \Delta \text{PE} = mg \Delta h \)), remind students that \( m \) represents mass and \( g \) represents gravity (~10 m/s²) rather than grams. The formula for the change in kinetic energy (KE) is \( \frac{1}{2} mv^2 \).

The simulation “Energy Transformation for a Pendulum” shows how the values of PE and KE change over the course of one cycle of a swing of the pendulum. Potential energy is greatest when the bob is at the highest point, ready to be released, and kinetic energy is greatest at the bottom of the swing, as shown in “Energy Analysis” section of Pendulum Motion.

SEE: www.physicsclassroom.com/mmedia/energy/pe.cfm
SEE: www.physicsclassroom.com/class/waves/Lesson-0/Pendulum-Motion

**Review and Assessment** (time: 5 minutes)

Students will complete the four questions at the conclusion of the lab, as those answers reveal how energy changes over the swing of the pendulum. The teacher should work with students to plot how the position of the pendulum changes over time (position vs. time), moving back and forth, as shown below:

![Position vs. Time Graph](http://www.physicsclassroom.com/class/waves/Lesson-0/Pendulum-Motion)

Note: Students who have studied trigonometry will be able to see the mathematical relation to sine and cosine waves.
Extension

As an extension show the YouTube video below, which makes the connections between pendulums, math, and the motion of Earth.

SEE: “Foucault’s Pendulum: Watch the World Turn”
www.youtube.com/watch?v=M8rrWUUIZ_U

As a way to bring the concepts in this section together, have students complete Practice Problems 25-27 on p. 467 of Pearson Physics. Question 27 relates directly to the mathematical formula:

\[ T = 2\pi\sqrt{\frac{L}{g}} \]

T is the period (time, in seconds), L is the length (in meters), and g represents gravity (meters/second squared).

Lesson 4

Wave and Wave Properties—Waves in Action

Goal

Students will explain that waves occur in different settings and in different media (land, water, and air) and can take on a variety of forms.

Do Now (time: 5 minutes)

As a group, students will brainstorm a list of all the places that students have seen or heard waves.

Note: Expect the list to include water. Encourage students to think deeply about sound waves, cell phone signals, waves that shake the ground in earthquakes, waves in the stands at a ballpark, and light waves. Water waves tend to come to mind first, but waves exist all around us, and in different media, including the ground and air.

Hook (time: 5 minutes)

Spring demonstration: Use a Slinky or spring to show the motion of waves. Hang the Slinky on a fixed point and shake it left and right in an S-motion to show transverse waves. Pluck the Slinky to show longitudinal waves, starting with a single pulse and then setting up continuous waves by plucking the Slinky repeatedly. See Pearson Physics p. 471 for a diagram of how to set up this demonstration. Ask students to compare what they are seeing to what they would hear when waves bounce back off of a wall or in a stadium: an echo (see p. 475 for a picture of an echo wave).

Presentation (time: 15 minutes)

The teacher will provide a presentation on types of waves and explain that scientists often classify things into groups of two. For example, scientists sort life into living and nonliving and organize cells into plants and animals groupings. Astronomers group the planets into two groups: inner and outer planets,
depending on their size, composition, and distance from the sun. Physicists split forces into scalar and vector groups. Scientists also use two groups to describe waves: transverse and longitudinal.

- **Transverse waves:** In transverse waves the vibrating element moves in a direction perpendicular to the direction of the advance of the wave. Light travels in transverse waves. All the waves in the electromagnetic spectrum are transverse waves.
- **Longitudinal waves:** In longitudinal waves the vibration takes place in the same direction as the advance of the wave. Sound (acoustic) waves are longitudinal waves. (Note: Sound waves travel much faster through solids and water than through air.)
- **Combination waves:** Earthquake waves travel through the ground three-dimensionally, and fit into both categories, transverse (S, or Secondary waves) and longitudinal (P, or Primary waves). Water waves are also a combination of both types of waves.

The teacher can use the following animation to show what particle motion looks like in the various types of waves:

**SEE:** “Longitudinal and Transverse Wave Motion”

www.acs.psu.edu/drussell/Demos/waves/wavemotion.html

**Practice and Application** (time: 20 minutes)

Using a graphic organizer modeled after Figure 13.19 in *Pearson Physics*, p. 473, students will draw a series of waves and label and define the following parts:

- **Crest**
- **Trough**
- **Amplitude**

Students should mark one wavelength, which is the distance over which a wave repeats. The SI unit for wavelengths is meters. The diagram below reinforces the vocabulary in an ocean setting.

**Wave Frequency:** The number of wave crests passing point A (per second)

**Wave Period:** The time required for the wave crest at point A to reach point B

Adapted from https://sp.yimg.com/ib/th?id=OIP.

To help students understand the mathematics of wavelength, the teacher should review Example 13.8 on p. 474 of *Pearson Physics*. Then students should complete Practice Problems 36-38 on p. 474. Completing one of the problems as a group and then reviewing will be helpful in determining needs for support and scaffolding regarding the math involved.
Review and Assessment (time: 10 minutes)

To demonstrate understanding of wave motion, students will write and/or diagram responses to Pearson Physics Practice Problems 34 and 35 on p. 472 (concept checks). In Problem 34, cars in a line braking suddenly act like longitudinal waves because they are traveling in the direction of propagation of the wave. In Problem 35, before composing their responses, students can simulate the motion of transverse and longitudinal waves by acting out the waves. Transverse waves are modeled by students’ alternating between standing and squatting down. For longitudinal waves, students should stand in a line and move back and forth, maintaining a straight-line motion.

Extension

Waves travel at very different speeds in different materials. If available, use a tuning fork to show this fact in action. Strike the tuning fork and place it on a table. Have the students put an ear on the table and listen for the sound vibrations. The vibrations traveling through the table will be louder than the waves traveling through the air.

Pearson Physics, p. 475, shows how waves reflect off hard surfaces to form echoes. This action can also be modeled using string or a Slinky or spring.

Lesson 5

Introduction of Final Project and Introduction to Sound

Goal

Students will explain wave motion to peers to demonstrate their understanding.

Do Now (time: 5 minutes)

Students will complete the Waves 3-2-1 below:

- Define three scientific terms used to explain waves.
- Draw two places where you see or hear waves in motion.
- Write one question that you have about waves.

Hook (time: 10 minutes)

Working from their 3-2-1 Do Now responses, students will list the terms they used to explain waves, the location of waves, and the questions that still remain about waves.

Note: The teacher should explain how students will gain answers to their questions prior to completing their final models and presentations by connecting questions students identify to upcoming lessons, including the current lesson on sound, which introduces concepts that will relate to many of the students’ project ideas.

Presentation (time: 15 minutes)

Pearson Physics, Chapter 14.1, starting on p. 493, reinforces many of the concepts taught in the previous lesson. Sound waves are longitudinal waves and follow the same pattern of compression and expansion explored in Lesson 4. Sound waves are formed when oscillating (vibrating) objects create alternating regions of compressed and expanded air. The alternating regions of air move away from the source of the
sound in the form of longitudinal waves. To show how sound is formed, the teacher should conduct the Inquiry Lab listed on the top of p. 493 and discuss with students the concepts and diagrams on the following pages.

**Practice and Application** (time: 10 minutes)

Students will respond to the Conceptual Example 14.1 on p. 495 with a prediction of the answer (~ one kilometer) as a way to see that while both sound and light move via waves, light moves much faster: light moves at a speed of 186,282 miles per second (299,792 kilometers per second) in space (a vacuum), while the speed of sound is 761 miles per hour (1,225 kilometers per hour or 20.41 kilometers per second). Students will then complete Practice Problems 1 and 2 on p. 495.

**Review and Assessment** (time: 15 minutes)

To process what they have learned about sound and waves and prepare for the final project, students will begin to design a plan to address the following task:

Students will create a model and presentation (flip chart, infographic, booklet, Prezi, etc.) that explain the physical phenomenon of waves simply and clearly for students in an elementary school setting. The project should focus on a common example of waves such as seismic waves leading to an earthquake, ripples in a pond causing motion and sound, music coming from a speaker, or an echo in a stadium, and should be accompanied by a written explanation and a mathematical model (algebraic equation).

As a way to help students create a model and presentation, the teacher will help students determine what needs to be included in the final product. See Lesson 9 for project details.

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**Lesson 6**

**Human Hearing**

**Goal**

Students will show how all the parts of an ear work in unison to detect sound waves and convert those waves into nerve impulses that are perceived as sound in our brains.

**Do Now** (time: 10 minutes)

Students will use words and pictures to explain how the ear catches and converts sound waves into nerve signals and add labels to show the parts of the ear they already know. After five minutes and a signal from the teacher, students will compare their drawings and explanations with partners.

Diagrams of the Ear can be found at a number of sites on the internet, including the one below. There is also a diagram of the ear located on p. 6.10.4 of the Supplement.

SEE:  www.enchantedlearning.com/subjects/anatomy/ear/earanatomy.GIF

**Note:** Depending on the strengths and needs of your students, the Do Now can be done free form or based on a diagram of the ear as a graphic organizer and support. If necessary, include a word bank of the main parts of the ear.
Hook (time: 10 minutes)
Using a site such as YouTube Sound Effects, the teacher should share 10 sound samples and ask students to guess what sounds they are hearing. Along with naming the sounds, students should write down why they made their choices.

Note: Reveal the names of each sound sample after students have had time to make guesses and support their answers. This activity should lead to a discussion about how accurately the ear discriminates among sounds.

SEE: “YouTube Sound Effects”
www.youtube.com/audiolibrary/soundeffects

Presentation (time: 15 minutes)
The anatomy of a human ear is made up of three parts: the outer, middle, and inner ear. The teacher should use an ear diagram (like the one at the Enchanted Learning site or the graphic organizer on p. 6.10.4 of the Supplement) to differentiate the three parts of the ear and the chart on p. 6.10.3 and to teach the form and function of the major parts of the ear.

Note: Blot out some of the blocks on the Parts of the Ear graphic organizer before providing it to students. Use the resource below or a similar public and reusable PowerPoint or Prezi as the basis for completing the notes in the graphic organizer.

SEE: “Show How the Ear Works!”
https://prezi.com/bnsckhfxgkby/how-the-ear-works

Practice and Application (time: 10 minutes)
Using the list of provided analogies as a model, students will work in pairs to develop a list of other analogies that fairly represent the form and function of the parts of the ears listed above. Seeing how students model each part will show understanding and persistent misconceptions.

Review and Assessment (time: 10 minutes)
As a way to document understanding and demonstrate what they have learned from taking notes and creating their own analogies, students will repeat the Do Now diagram of the ear. This time, students should add labels and briefly state the function of all parts of the outer, middle, and inner sections of the ear.

Extension
Students can develop their own Prezis or PowerPoints about the parts of the ear to share with classmates as a way to deepen knowledge.

Lesson 7
Standing Waves and Doppler Effect

Goal
Standing Waves: Students will demonstrate that waves can follow particular patterns based on frequency.
Doppler Effect: Students will show that the apparent frequency of sound waves changes depending on the speed of the observer in relation to the source of sound.
Do Now (time: 5 minutes)

Students will list and draw five things that follow a pattern. One example is the daily schedule at school. What other things follow a pattern in nature or in life? Students will share their ideas.

Note: Sections 14.2 and 14.3 of Pearson Physics examine patterns in waves. This Do Now prompt gets students thinking about common patterns as an analogy for standing waves and the Doppler Effect.

Hook (time: 5 minutes)

The teacher will show a portion of the following video of a laser light reflecting off a mirror activated by sound as a way to make the source of invisible sound waves visible. This video shows how waves follow certain patterns at particular frequencies.

SEE: “Visual Representation of Sound: Laser Patterns of Standing Waves”
https://www.youtube.com/watch?v=RxzMzSZF_b4

Presentation (time: 15 minutes)

The teacher will conduct and explain the following demonstrations, which show the phenomena of standing waves and the Doppler Effect.

- **Standing Waves:** Following the model shown in Figure 14.8 on p. 502 of Pearson Physics, blow across the opening of a soda bottle. Have students listen to the tone. Next, add water to the bottle and repeat. The sound has a higher frequency. Now, pour some water out and listen; the sound has a lower frequency.

- **Doppler Effect:** Following the suggestions on p. 508, tap your finger in a pan of water and watch the concentric ripples form. Slowly move your finger along the pan and watch the separation between the crest of each ripple decrease as you move your finger forward. This demonstration shows how sound waves compress in the direction the source of sound is moving and spread out as the object moves away.

A second way of showing this shift is by looking at a water bug traveling on a the surface of the water on a pond, as illustrated below.

A stationary bug producing disturbances in the water.  
A bug moving to the right and producing disturbances.

Water bug wave graphic adapted from: www.physicsclassroom.com/Class/waves/u10l3d2.gif.
Note: Astronomers use this phenomenon to determine the directions objects are moving in space. Go to this link for an extended definition:

**SEE:** “The Doppler Effect”
www.physicsclassroom.com/class/waves/ Lesson-3/The-Doppler-Effect

**Practice and Application** (time: 15 minutes)
Following Guided Example 14.5 in *Pearson Physics* on p. 504, the teacher should demonstrate the mathematical explanation of standing waves. This example shows how frequency can be measured and modeled and how adding water to a bottle will change the frequency of the sound. Students should then complete Practice Problem 23 independently or in pairs. The teacher should provide scaffolding as needed to help students set up the problem.

As a model of the mathematical calculations related to the Doppler Effect, the teacher should review Guided Example 14.7 on p. 509. This example shows how the frequencies change when objects are approaching and receding. Students should then complete Practice Problem 38 independently or in pairs. The teacher should provide scaffolding as needed to help students set up the problem.

To further practice what happens in the Doppler Effect, have students role play the ways sound moves during a NASCAR race. Show how the particles compress, expand, and change depending on the position of the race cars and spectators.

**Review and Assessment** (time: 15 minutes)
To show understanding of standing waves and the Doppler Effect, students will create, diagram, and explain scenarios that demonstrate these phenomena. These scenarios can be modeled after the Practice Problems on pp. 504 and 510 of the *Pearson Physics* textbook. Or, if permitted, students can construct simple instruments using recycled materials. The instruments must be able to create vibrations that generate sound. Examples could include tissue paper kazoos or a series of soda bottle flutes with different frequencies based on how much water is inside each container.

**Extension**
Students could complete the following CK-12 Simulation, which shows how patterns of waves around ducks swimming in water parallel sound waves in the air. Students can set the velocity of the ducks, the wave speed, and the speed of the boat and watch the resulting changes.

**SEE:** “Why Do Ducks Make a ‘V’ Shape in the Water When They Swim?”
Lesson 8

Human Perception of Sound

**Goal**
Students will show how all the parts of an ear work in unison to detect sound waves and convert those waves into nerve impulses that are perceived as sound in our brains.

**Do Now** (time: 5 minutes)
Students will complete a quick write to the following prompt: A famous saying goes, “Seeing is believing,” but an optical illusion can trick your eyes and brain into seeing things differently than they actually appear. What you hear can also be different from reality. Write (and draw, if you wish) about a time when you perceived something differently than the actual sound. Was the sound caused by an echo, or shifted by the wind? Where were you when this happened?

**Hook** (time: 5 minutes)
The teacher will ask students to close their eyes and listen closely in order to be ready to report what they hear. First, ring a single small bell near to where the students are seated. Next, stand back in the back of the classroom and ring two small bells. Ask the students to share what they heard and if they noticed any difference between the two tones.

**Note:** One bell rung near to the ears sounds similar to two bells rung at a distance because the energy in the air varies with the distance squared distance. “Sound spreads out over a larger area as it moves away from its source. As a result, the intensity of the sound—and its loudness—is reduced” (*Pearson Physics*, p. 514).

**Presentation** (time: 10 minutes)
To understand the concepts in this lesson, students need to be familiar with three key words: *power*, *intensity*, and *decibel*. Using the graphic organizer on p. 6.10.5 to 6.10.6 of the Supplement, the teacher should explain these terms and ask students to draw pictures in the column at the right on the organizer.

**Practice and Application** (time: 15 minutes)
The teacher will work together with students to review the calculations in Guided Example 14.10 on p. 516 and the Quick Example on p. 517 of *Pearson Physics*. The first question explores how power and intensity are calculated and how sound intensity varies depending on proximity to the source of the sound, while the second shows the relationship between intensity and perceived loudness. Then students should work independently or in pairs to complete Practice Problems 49, 50, and 52 on pp. 516 and 517.

**Review and Assessment** (time: 20 minutes)
In the 14.4 Lesson Check on p. 519 of *Pearson Physics*, students will complete questions 53, 55, and 59. Question 53 focuses on the concept of intensity, reinforcing the idea that the sound gets louder because the power (energy) of the sound is packed into a smaller area. If scaffolding is needed, relate this question back to the formula for intensity, Intensity = Power/Area. For question 55, the intensity of a sound decreases by a factor of 4, as sound intensity is inversely proportional to the square of the distance. Refer back to Quick Example 14.11 to help students solve question 59.

In addition to using problem-based Formative Assessments, students will write letters for or against a ban
on muffler pipe whistles to limit noise pollution using claims, evidence, and reasoning to strengthen their arguments. These letters should follow the writing rubrics used at the school. Provide a graphic organizer that scaffolds argumentative writing, or use this organizer to help students take a stand on this issue.

<table>
<thead>
<tr>
<th>Are you</th>
<th>For the ban?</th>
<th>Against the ban?</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is your claim?</td>
<td>Muffler whistles are too noisy and can damage hearing</td>
<td>Muffler whistles are not too loud and should not be banned</td>
</tr>
<tr>
<td>What is your evidence?</td>
<td>Find evidence to support your claim.</td>
<td></td>
</tr>
<tr>
<td>What is your reasoning?</td>
<td>Write an argument that supports your side of this issue.</td>
<td></td>
</tr>
</tbody>
</table>

**Extension**

The Occupational Safety & Health Administration (OSHA) and other governmental agencies monitor and regulate sound levels to protect approximately 30 million people who are exposed to hazardous noise levels for their jobs. This US Department of Labor OSHA website details the warning signs that workplaces may be too noisy along with sharing ways to reduce noise and damage from intense sounds.  

**SEE:** “Occupational Noise Exposure”  
www.osha.gov/SLTC/noisehearingconservation

Activities related to this topic are available in the Dangerous Decibels® Educator Resource Guide

**SEE:** “The Dangerous Decibels® Educator Resource Guide”  

**CULMINATING LESSON**

*Includes the Performance Task, i.e., Summative Assessment—measuring the achievement of learning objectives*

**Lesson 9**

Explaining Waves to Children (2 Days)

**Goal**

Students will synthesize key concepts about waves and explain one type of wave motion clearly using pictures, words, and mathematical models.

Performance Task: Students will create a presentation (model, flip chart, infographic, booklet, Prezi, etc.) that explains the physical phenomenon of waves simply and clearly for students in an upper elementary
school setting. The project should focus on a common example of waves such as seismic waves leading to an earthquake, ripples in a pond causing motion and sound, music coming from a speaker, or an echo in a stadium, and should be accompanied by a written explanation (for a parent or teacher) that includes a mathematical model (algebraic equation). The presentation must be scientifically accurate, easy to understand, and aesthetically pleasing.

**Do Now** (time: 5 minutes)
Using words and diagrams, students will brainstorm how they would explain sound to a child. Possible prompts to spur thinking might include:
- What causes sound?
- How does sound move?

**Hook** (time: 5 minutes)
The teacher will show the video “Bill Nye—Sound Travels in Waves” as an example of how sound can be explained for children. (Another example may be substituted, such as selected pages from David Macaulay’s *The Way Things Work.* ) The teacher will ask students to identify the techniques used to break down a complex phenomenon into concepts children can understand.

**Presentation** (time: 15 minutes)
The teacher will remind students that their Performance task for the unit (introduced in Lesson 5) will be to create a presentation that explains the physical phenomenon of waves simply and clearly for students in an upper elementary school setting. The teacher should explain the requirements of the task (presentation, explanation, and mathematical model) and work with students to establish evaluation criteria (or a full rubric). The criteria should include scientific accuracy, appropriateness for the audience, and visual appeal. Students will then decide what wave phenomena they will examine in their projects and what media they will use for the presentation (model, flip chart, infographic, booklet, Prezi, etc.).

Examples of topics students may research and present include demonstrating how waves can push around a small boat on the ocean or on a large lake, or explaining how tuning forks use vibrations to make sounds at different frequencies.

**Practice and Application** (time: 70 minutes, split over 2 days)
On the first day of the lesson, students will review their unit materials and textbook to compile relevant information, including appropriate explanations and algebraic equations, and then plan the presentation in the form of a storyboard, outline, or diagram. On the second day, they will create the final version of the presentation and write the explanation in their own words, using the evaluation criteria or rubric as a guide.

**Review and Assessment** (time: 15 minutes)
Students will pair up to share their projects and give each other written and oral feedback, including both commendations and recommendations.

**Extension**
If sufficient time is available, students can revise their presentations based on peer and teacher feedback and present them to a larger audience (the entire science class or school staff, for example).
POST–UNIT REFLECTION

On meeting the Learning and Language objectives
Connections to Empower Your Future
UNIT: Waves and Their Applications

Future Ready Connections

This unit allows youth to demonstrate and strengthen Future Ready skills. Students have many opportunities to strengthen their communication skills through group discussions, brainstorming as a class, partner work, and presentations of their Performance Task. The Performance Task asks students to write for an elementary school level audience which increases the demands for the assignment and provides an opportunity to assess youth on effective communication for a particular audience. Students also have the opportunity to practice written communication in Lessons 1, 4, and 8 through predictions and written reflections and responses. Youth can also be evaluated for initiative and self-direction as they plan and develop their models and presentations for an elementary school audience. Teachers should reflect on whether or not youth stay on task without prompting and if they push themselves to create a well-designed and effective final product. Students can also be evaluated on how thoughtfully they make predictions, conduct experiments, and then reflect on their predictions to identify what they learned and how they learned. There are multiple opportunities for youth to give and receive feedback from peers which will allow teachers to evaluate students on their accountability for their own work and to their peers.

Teachers are encouraged to use the Future Ready Rubric to evaluate students and are encouraged to support students as they self-evaluate their demonstration of Future Ready skills.

Transfer Goal Connections

One of the Transfer Goals for this unit aims to have students explain how waves can produce motion and transfer energy. Teachers can take this concept of waves rippling outward and impacting air and mass and apply it to the idea that people’s behaviors, actions, and feelings can have ripple effects as well. Teachers can ask students, “How do your actions, behaviors, and feelings create waves around you?”

Students should identify that both positive and negative behaviors, actions, and attitudes can impact others whether we mean for them to or not. Teachers should encourage students to discuss a time when their positive attitude sent out a wave of positivity to others. Students can also discuss a time when they have either been the cause of a negative wave or have been impacted by the ripple effect of someone else’s negative behavior. Teachers can ask students to consider these waves of positivity and negativity in their personal lives and in a work setting.

PYD/CRP Connections

This unit reflects Positive Youth Development by providing opportunities for students to make predictions, think critically, independently experiment and discover, and activate prior knowledge (Do Now prompts and Hooks). Students are actively engaged in the content and the experiments which encourages them to see themselves as resources in the classroom and directors of their own learning. The unit also includes Culturally Responsive Practice by providing opportunities for students to make personal connections to the content and to see how the content is relevant to their personal, academic, and professional lives. Lesson 6 is a strong example of CRP and PYD because it allows students to make predictions and then uses analogies to help students understand and visualize how each part of the ear works. The use of analogies allows youth to build upon their previous
“Teachers are encouraged to ask students, ‘Which careers and industries must understand how waves function?’”

experience and understandings to make connections to the new content. The unit also demonstrates elements of CRP and PYD by encouraging youth to actively participate in how they will be assessed which allows for a sense of ownership, empowerment, and accountability. The lessons are also flexible and allow for students to work and discover in different ways (independently, with a partner, as a class, and with different mediums and activities), which respects their individual needs and abilities.

Career Connections

This unit encourages students to identify how waves are present everywhere in their lives such as sound waves in music, the ocean's waves, and the shifting ground during earthquakes. Teachers are encouraged to ask students, “Which careers and industries must understand how waves function?”

Students can brainstorm which career fields work with different types of waves and wave properties (transverse, longitudinal, wave, crest, etc.). Some examples of careers include: musician, sound technician in a recording studio, sailors and people in the fishing industry, engineers who design buildings in earthquake-prone areas, toy designers who create objects that swing or undulate, doctors and nurses who specialize in hearing problems, etc. Teachers can ask students to categorize which jobs would use and need to understand specific types of waves and wave properties. Students can also predict what will happen in these career fields if the waves and wave properties are not understood or followed. For example, if a toy designer does not understand the back-and-forth cycle of a pendulum and how it depends on its length and the acceleration due to gravity, the toy may not function as designed and will not be popular with customers.

For Technical Assistance with Empower Your Future connections and lessons, please request support by submitting a Coaching Request ticket using the Coaching Feature on TeachPoint.
Frayer Diagram
Lesson 2

NAME: __________________________________________

DATE: __________________________________________

Definitions

Characteristics

Examples

Non–examples

This graphic organizer was originally designed by Dorothy Frayer and her colleagues at the University of Wisconsin.
Pendulum Periods
Lesson 3

DIRECTIONS: Look at the diagram of the pendulums. Identify the pendulum(s) you think will have the longest period (time to travel back and forth) and use the lines below to explain your answer. You can also use a blank sheet to answer the 4 questions from the Pearson Physics Lab in Lesson 3.

Explaination

Adapted from: http://science-notebook.com/gilbert-sound-01.html
## Parts of the Ear

### Lesson 6

### PARTS OF THE EAR

<table>
<thead>
<tr>
<th>Part of the Ear</th>
<th>Location</th>
<th>Form</th>
<th>Function</th>
<th>Analogy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auricle</td>
<td>Outer ear</td>
<td>Cartilage covered by skin that catches sound waves</td>
<td>Collects the sound</td>
<td>Funnel</td>
</tr>
<tr>
<td>Auditory canal</td>
<td>Outer ear</td>
<td>A tube made out of tissue</td>
<td>Channels to sound toward the eardrum</td>
<td>Hollow pipe</td>
</tr>
<tr>
<td>Eardrum</td>
<td>Outer/Middle ear</td>
<td>A thin layer of membrane</td>
<td>Absorbs the sound waves</td>
<td>Top of a drum</td>
</tr>
<tr>
<td>Ossicles</td>
<td>Middle ear</td>
<td>Three tiny bones (Hammer, Anvil, Stirrup)</td>
<td>Moves the sound vibrations toward the inner ear. As the sound travels through the middle ear, it amplifies and changes from air to liquid</td>
<td>Drumsticks</td>
</tr>
<tr>
<td>Semicircular ducts</td>
<td>Inner ear</td>
<td>Three round tubes that connect to the cochlea and nerves</td>
<td>Filled with fluid, these tubes provide the brain with information on balance and head position</td>
<td>Carpenter’s level</td>
</tr>
<tr>
<td>Cochlea</td>
<td>Inner ear</td>
<td>Spiral-shaped organ</td>
<td>Transforms sounds into nerve signal that get sent to the brain</td>
<td>Radio receiver</td>
</tr>
<tr>
<td>Auditory (Eustachian) tube</td>
<td>Inner ear</td>
<td>Tube made out of tissue</td>
<td>Drains fluid from the middle ear into the back of the throat</td>
<td>Sink drain</td>
</tr>
<tr>
<td>Auditory nerve</td>
<td>Inner ear</td>
<td>A bundle of nerves</td>
<td>Carries nerve signals from the cochlea to the brain</td>
<td>Phone cable</td>
</tr>
</tbody>
</table>
**Parts of the Ear—Diagram**

**Lesson 6**

**DIRECTIONS:** Label the parts of ear from the list of available in the WORD BANK.

**WORD BANK**

Pinna, Outer Ear Canal, Eardrum, Hammer, Stirrup, Anvil, Semi-Circular Canals, Nerves, Cochlea, Eustachian Tube

Human Perception of Sound—Vocabulary
Lesson 8

<table>
<thead>
<tr>
<th>KEY WORD</th>
<th>Draw what it looks or sounds like:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td><img src="image" alt="Diagram" /></td>
</tr>
</tbody>
</table>
| Simple Explanation:   
The amount of work done (or change in energy) in a given amount of time   
Related Formula:   
Power = Work (or Energy) / Time |

<table>
<thead>
<tr>
<th>Intensity</th>
<th><img src="image" alt="Diagram" /></th>
<th></th>
</tr>
</thead>
</table>
| Simple Explanation:   
The amount of sound energy passing through a given area in a given time   
Related Formula:   
Intensity = Power / Area |

<table>
<thead>
<tr>
<th>Decibel (db)</th>
<th><img src="image" alt="Diagram" /></th>
<th></th>
</tr>
</thead>
</table>
| Simple Explanation:   
The unit commonly used to measure loudness |
Human Perception of Sound—Vocabulary: Activity notes for the teacher and related graphic

Power: Responses will vary. Power can be shown in many ways, from water generating energy to someone carrying an object a distance.

Intensity: See Figure 14.16 on p. 513 of Pearson Physics

Decibel (db): Have students draw in points on a scale including the threshold of hearing (0 dB), conversation (60 dB), a lawn mower (90 dB), a rock concert (105 dB), and a jet taking off (140 dB)

Appendix

APPENDIX | TABLE OF CONTENTS

DYS Pedagogical Practices Links........................................................................A.1
DYS Pedagogical Practices Links

Comprehensive Educational Partnership (CEP)

Massachusetts Department of Youth Services
www.mass.gov/eohhs/gov/departments/dys

Commonwealth Corporation
www.commcorp.org

Collaborative for Educational Services
www.ccollaborative.org

Massachusetts Department of Elementary and Secondary Education (ESE)

Massachusetts ESE
www.doe.mass.edu

Massachusetts Curriculum Frameworks (all current)
www.doe.mass.edu/frameworks/current.html

Massachusetts Science and Technology/Engineering Curriculum Framework, 2016 (PDF download)
www.doe.mass.edu/frameworks/scitech/2016-04.pdf

Next-Generation MCAS
www.doe.mass.edu/mcas/nextgen/

Next Generation Science Standards (NGSS)

Next Generation Science Standards: For States, By States
www.nextgenscience.org

A Framework for K–12 Science Education.
www.nextgenscience.org/framework-k%2%E2%8%9312-science-education

Career and College Readiness (CCR)

Achieve.org
www.achieve.org/college-and-career-readiness

Future Ready Massachusetts
futurereadyma.org/about

Helpful Science Links

“GIZMOS” Explore Learning
www.explorelearning.com

Khan Academy
www.khanacademy.org
Helpful Science Links (continued)

- NBC LEARN
  www.nbclearn.com/portal/site/learn

- NOVA Teachers
  www.pbs.org/wgbh/nova/education/resources/subject.html

- PhET Simulations for Biology, Chemistry, and Physics
  https://phet.colorado.edu/en/simulations/category/new

- Physics Classroom
  www.physicsclassroom.com

- Physics 4 Kids
  www.physics4kids.com

- Rubric Generator
  rubistar.4teachers.org

Pedagogy

- Bloom’s Taxonomy
  jimjansen.blogspot.com/2011/01/searching-as-learning.html

- Differentiated Instruction
  www.ascd.org/professional-development/differentiated-classroom-2nd-edition.aspx?
gclid=CNKq-8jUn8ECFFlM7AodVNgABQ

- Empower Your Future Curricula (EYF)
  www.commcorp.org/resources/curricula.cfm

- Essential Questions
  www.authenticeducation.org/ae_bigideas/article.lasso?artid=53

- Positive Youth Development in DYS Educational Programs (PYD/CRP) (PDF download)
  www.commcorp.org/resources/detail.cfm?ID=705

- Understanding by Design (UbD)
  www.ascd.org/Default.aspx

  What is Understanding by Design?
  www.authenticeducation.org/ubd/ubd.lasso

- Universal Design for Learning (UDL) / Access for All

  Access for All (PDF download)

  Center for Applied Special Technology (CAST)
  www.cast.org/udl

  Universal Design for Learning in HCPPS
UDL Chart
www.udlcenter.org/aboutudl/udlguidelines/udlguidelines_graphicorganizer

UDL Checklist
udlonline.cast.org/guidelines

UDL Wheel (two parts: A+B)

   Figure A:
   UDL%20DIY%20Template%20Wheel.jpg

   Figure B:
   www.menacommoncore.com/2013/Reem_Labib_MENA_Commo_Core_
   UDL%20DIY%20Template%20Wheel-1.jpg

World-Class Instructional Design and Assessment (WIDA)
www.wida.us

   WIDA Online Download Library.
   www.wida.us/downloadLibrary.aspx

   WIDA Performance Definitions Booklet, K-12. (PDF download)
   www.wida.us/get.aspx?id=22

Massachusetts Department of Youth Services Instructional Guides, including this Science Guide, are available as PDF downloads.

   SEE: www.collaborative.org/programs/dys/dys-instructional-guides

Please note:
There are a few supporting documents that are available to our teachers via the CES/DYS Google Drive Science Guide Supplement folder. We cannot provide a link as it may change.