Science
High School Course of Study
2019

THE DIOCESE OF COLUMBUS

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OVERVIEW

This overview restates the visions and goals of the Columbus Diocese 2019 Science Course of Study. The Course of Study is based upon the Ohio's Learning Standards and Model Curriculum for Science and the Science-Ohio Learning Standards-Extended. It also includes the guiding principles that framed the development and contains definitions of terms used in the document.

STANDARDS

These standards for Science outline what all students should know and be able to do to become scientifically literate citizens. This includes the knowledge and skills they need for the 21st century workforce and higher education. The standards provide the Columbus Diocese educators with the content and expectations for learning they can use to develop science curriculum at each grade level. By the end of high school, students should be proficient in science in order to:

- Know, use and interpret scientific explanations of the natural world;
- Generate and evaluate scientific evidence and explanations, distinguishing science from pseudoscience;
- Understand the nature and development of scientific knowledge; and discourse.
- Participate productively in scientific practices and discourse.[1]

"Knowledge of science can enable us to think critically and frame productive questions. Without scientific knowledge, we are wholly dependent on others as "experts." With scientific knowledge, we are empowered to become participants rather than merely observers. Science, in this sense, is more than a means for getting ahead in the world of work. It is a resource for becoming a critical and engaged citizen in a democracy." -Ready, Set, SCIENCE! (2008)[2]

The K-8 and high school course of study offer guidance for educators who teach science in the Columbus Diocese. Each Content Statement and Content Elaboration presents what students should know about a given discipline of science. The accompanying Evidence of Learning in this document provide a structure for teachers to reflect on their plans for teaching science, to monitor observable evidence of student learning, and to develop summative and formative assessments. The correlation to the Next Generation Science standards have also been added for additional instructional support. The Diocesan committee also elected to include the Ohio Extended Standards for Science. These Extended Standards are standards that reflect increasing complexity based on learning progressions so that teachers can more effectively differentiate for their students.

The *Ohio Learning Standards* also provide more support through the Visions into Practice section, which offer optional examples of tasks students can perform to learn about science and demonstrate their understanding of the grade-level materials. The Diocesan committee decided to include the Visions into Practice information as suggestions for students to demonstrate their evidence of learning. The Ohio Leaning Standards also included an Instructional Supports section which includes subsections on Instructional Strategies and Resources, Common Misconceptions, Diverse Learners, and Classroom Portals.

[1] Taking Science to School Learning and Teaching Science in Grades K-8. National Research Council of the National Academies
[2] Michaels S., Shouse, A.W., & Schweingruber H. A. (2008). Ready, Set, SCIENCE! Washington DC: The National Academies Press.

GOALS

The goal of revising the standards was to improve K-12 science education by providing clarity, focus and a logical, vertical progression in each discipline. All Ohio students deserve rigorous, scientifically accurate instruction that makes them college or career ready and scientifically literate. These standards serve as a road map for Ohio science teachers to use as they customize instruction to fit individual student needs.

Ohio’s student-centered goals (Duschl et. al., 2007; Bell et.al., 2009) for science education include helping students:

1. Experience excitement, interest and motivation to learn about phenomena in the natural and physical world.
2. Come to generate, understand, remember and use concepts, explanations, arguments, models and facts related to science.
3. Manipulate, test, explore, predict, question, observe and make sense of the natural and physical world.
4. Reflect on science as a way of knowing; on processes, concepts and institutions of science; and on their own process of learning about phenomena.
5. Participate in scientific activities and learning practices with others, using scientific language and tools.
6. Think about themselves as science learners and develop an identity as someone who knows about, uses and sometimes contributes to science.

These goals are consistent with the expectations of Ohio law.

GUIDING PRINCIPLES

Ohio’s Learning Standards for Science and subsequently, the Diocesan Course of Study reflect knowledge drawn from international and national studies, education stakeholders and academic content experts. The guiding principles include:

- **Definition of Science:** Science is a systematic method of continuing investigation based on observation, scientific hypothesis testing, measurement, experimentation and theory building. It leads to explanations of natural phenomena, processesor objects that are open to further testing and revision based on evidence.[3] Scientific knowledge is logical, predictive and testable and expands and advances as new evidence is discovered.
  •
- **Scientific Inquiry:** There is no science without inquiry. Scientific inquiry is a way of knowing and process of doing science. Scientific inquiry includes the diverse ways scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities that help students develop knowledge of scientific ideas and understanding of how scientists study the natural world.[4] Teachers model scientific inquiry throughout their instruction.

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[3] National Research Council (1996), National Science Education Standards (Washington, DC: National Academy Press) and including excerpts with minor revision, of The Ohio Academy of Science (2000) definition of science: http://www.ohiosci.org/s/whatisscience.pdf
[4] Research Council (1996), National Science Education Standards (Washington, DC: National Academy Press), p 192.

- **21st Century Skills:** According to Ohio law, 21st century skills include creativity and innovation; critical thinking, problem-solving and communication; information, media and technological literacy; personal management, productivity, accountability, leadership and responsibility; and interdisciplinary, project-based, real-world learning opportunities.[5]

  21st century skills are integral to the revised science standards and model curriculum. The model curriculum incorporates and integrates these skills through scientific inquiry, science skills and process, and technological and engineering design.

  - **Technological Design:** Technological design is a problem-or project-based way of applying creativity, science, engineering and mathematics to meet a human want or need. Modern science is an integrated endeavor. Technological design integrates learning by using science, technology, engineering and mathematics and fosters 21st century skills.

  - **Technology and Engineering:** Technology modifies the natural world through innovative processes, systems, structures and devices to extend human abilities. Engineering is design under constraint that develops and applies technology to satisfy human wants and needs. Technology and engineering, coupled with the knowledge and methods derived from science and mathematics, profoundly influence the quality of life.

  - **Depth of Content:** It is vital that the Content Statements and Content Elaborations within the *Course of Study* communicate the most essential concepts and the complexity of the discipline in a manner that is manageable and accessible for teachers. The focus is on what students must know to master the specific grade-level content. The Evidence of Learning provide the means by which students can demonstrate this grade-level mastery.

  - **Internationally Bench marked:** Ohio's Learning Standards and Model Curriculum for Science incorporate findings from research on the science standards of:
    - Countries whose students demonstrate high- performance on both the Trends in International Mathematics and Science Studies (TIMSS) and Program in Student Assessment (PISA) tests; and
    - States with students who perform well on the National Assessment of Education Progress (NAEP).

    As a result, the revised standards and model curriculum are rigorous, relevant, coherent and organized, emphasizing horizontal and vertical articulation of content within and across disciplines.

  - **Assessment:** Ohio's StateTests will align with the Content Statements, Content Elaborations and Expectations for Learning in the *2018 Ohio Learning Standards for Science*.

  - **Standards and Curriculum:** The *2018 Ohio Learning Standards for Science* provide a framework for developing local curricula. They do not constitute the local curriculum. The *2019 Science Course of Study* is the curriculum for the Columbus Diocese.

[5] http://www.battelleforkids.org/networks/p21

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STANDARDS FORMAT AND DEVELOPMENT

The standards are web-based resources that provide the content to be taught in science classrooms. The standards define what all students should know and be able to do, not how teachers should teach. While the standards focus on what is most essential, they do not describe all that teachers can or should teach. Teachers and curriculum developers maintain a great deal of discretion in this area. The model curriculum will offer information and support for planning, developing, implementing and evaluating instruction directly aligned to standards.

Work to revise Ohio's Learning Standards Science took place from November 2016 through September 2017, with input from stakeholders around the state. The Ohio Department of Education started the process by seeking public comment on the existing standards in fall 2016. An advisory committee of representatives from various Ohio agencies and organizations related to science and science education reviewed this public feedback. The advisory committee forwarded suggestions for revisions to working groups consisting of K-12 and higher education professionals. There were three main working groups based on the individual science disciplines: life sciences, Earth and space sciences, and physical sciences.

When comment on the initial public survey pointed to the need for a new human anatomy and physiology course, the Department formed a related subcommittee of the life science working group. These four groups constructed the proposed 2017 standards with Ohio students in mind. The Department presented the proposed standards revisions for public feedback through a summer 2017 survey. The Department made more revisions based on that feedback. The State Board of Education reviewed the revised science standards during its October 2017 meeting and adopted them in February 2018.

In the 2018/2019 school year, various educators across the Columbus Diocese volunteered to update and revise the Diocesan Course of Study for Science based on these new Ohio Learning Standards. The committee also reviewed *the Next Generation Science Standards* and the *Science-Ohio Learning Standards-Extended* to incorporate more instructional supports for diocesan educators.

TRANSITION PERIOD

Ohio allows districts until the 2019-2020 school year to fully implement the revised Ohio's Learning Standards Science to give them time to align instruction and resources to the standards. State tests aligned to the standards will be available in spring 2020.

The *Diocesan Science Course of Study* was updated in 2018-2019 and will be put into practice in 2019-2020. Diocesan educators added a section titled Evidence of Learning to provide concrete examples of what students should be able to do at the end of the grade level or course for that particular standard or topic. These examples were aligned to specific cognitive demands which reflect the revised Bloom's Taxonomy and Webb's Depth of Knowledge. The committee decided to add them to provide clarification on not only the content requirements but the skill requirements of the standards as well. Most of these examples were taken directly out of the Ohio's Model Curriculum for Science.

DIOCESE OF COLUMBUS SCIENCE COURSE OF STUDY

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INTRODUCTION

Following is the revised Science Course of Study for the Catholic Diocese of Columbus. This course of study reflects the Science Standards set forth by the Ohio Department of Education.

PHILOSOPHY

We believe the purpose of science education in Catholic Schools is to help students become scientifically literate citizens that are able to use science as a way of knowing about the natural and material world and to actively apply scientific knowledge and skills to contemporary, technological, moral, and social issues. This will be accomplished by recognizing God's design and promoting personal responsibility. All students should have sufficient understanding of scientific knowledge and scientific processes to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact not only themselves but others too.

We believe the science curriculum will provide minds-on, as well as hands-on, opportunities for students to practice scientific literacy, critical thinking and problem solving skills. It will also build a foundation for life-long discovery in sciences that will carry over into other disciplines.

We believe that students have a natural curiosity and appreciation of science. Teachers will encourage students by using the many scientific methods, providing a variety of learning experiences and assessment strategies, and utilizing various materials, technologies, and community resources as well as Catholic values.

PROGRAM GOALS

Students, utilizing a broad-based curriculum, will acquire higher-level thinking skills and in-depth knowledge necessary to solve problems in creative and productive ways.

Students will be able to engage intelligently in public discourse and to debate matters of scientific and technological concern.

Students will use their scientific knowledge and Catholic values to lead well-balanced and ethical lives. Students will use scientific literacy to enhance life and career opportunities.

PRINCIPLES OF COURSES OF STUDY-DIOCESE OF COLUMBUS CATHOLIC SCHOOLS

Equity. Excellence in education requires equity – high expectations and assessable content for all students based on the new Ohio Learning Standards.

Curriculum. A curriculum is more than a collection of activities. It must be coherent, focused, well-articulated, and integrated with our Catholic values.

Teaching. Effective teaching requires understanding what students know and need to learn and be able to do while supporting them as they

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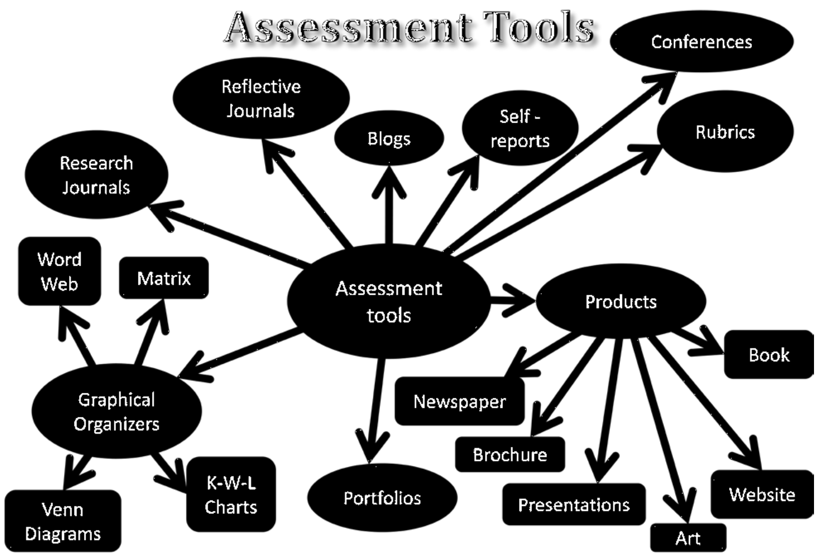
learn.

Learning. Students must learn with understanding by actively building new knowledge from prior knowledge and experiences.

Technology. Technology is essential in teaching and learning and should be integrated in the teaching and learning process. The technology should influence and enhance students' learning.

Assessment. Assessment should support the learning of important skills and content, be formative as well as summative, and furnish useful information to teachers, students and parents.

Assessments need to be aligned to the standards in the Course of Study both in what a student needs to know and be able to do. Assessments should match what the student is expected to learn. There are many tools (e.g. portfolios, rubrics, interviews) other than the standard paper and pencil tests to assess a student's understanding of the material.



One method that has continued to increase student achievement is involving them in the assessment process. Students should be involved in all steps of this process. At the most basic level, students can simply understand how their grades will be determined. As assessment becomes more student- centered, the students can develop rubrics, maintain their own assessment records, self- assess, and communicate their achievement to others (student-led conferences).

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INQUIRY-BASED SCIENCE AND PRACTICES

The Diocesan Catholic Schools will continue to focus on inquiry based learning. Inquiry based learning is based on the philosophy of constructivist learning, that students must be able to create their own understanding of concepts.

There are several levels to inquiry based learning. These range from no inquiry to open inquiry. When there is no inquiry, teachers tell the students the facts and they are expected to repeat these facts to prove their knowledge. Guided inquiry includes various levels of guidance from the teacher and in open inquiry, students are given the materials to learn with minimal teacher direction. The students are expected to create their own knowledge. This will lead them to a greater understanding and long-term retention of the material.

Think of a time when you wanted to understand something in greater depth. It is rare that the learning process is a linear one. As an example, imagine trying to figure out why ice melts in the sun. In trying to understand this, you make judgments based on both previous knowledge and personal experiences. You wonder why this happens. You research, experiment and observe. Through this process, you see that the sun and melting ice fit together, but you are not exactly sure how that happens. You come to the conclusion that the sun melts the ice. However, sometimes old ideas must be broken down and reconstructed. The ice still melted at night; why? You continue to experiment. It is through these experiences that understandings are extended. An idea is tested and if it does not work, we go back and retest it. If we go back to the ice example, you realize through your observations that the ice will melt on a warm night just as it will during a warm day. You realize that it is not the sun by itself that melts the ice, instead, it is the heat that causes ice to melt. In the Columbus Diocese, we have adopted the research-based 5E instructional model. This model provides a structure for teachers for planning and using the inquiry-based science approach.

Engage	This lesson mentally engages students with an activity or question. It captures their interest, provides an opportunity for them to express what they know about the concept or skill being developed, and helps them to make connections between what they know and the new ideas.
Explore	Students carry out hands-on activities in which they can explore the concept or skill. They grapple with the problem or phenomenon and describe it in their own words. This phase allows students to acquire a common set of experiences that they can use to help each other make sense of the new concept or skill.
Explain	Only after students have explored the concept or skill does the teacher provide the concepts and terms used by the students to develop explanations for the phenomenon they have experienced. The significant aspect of this phase is that explanation follows experience.
Elaborate	This phase provides opportunities for students to apply what they have learned to new situations and so develop a deeper understanding of the concept or greater use of the skill. It is important for students to discuss and compare their ideas with each other during this phase.
Evaluate	The final phase provides an opportunity for students to review and reflect on their own learning and new understandings and skills. It is also when students provide evidence for changes to their understandings, beliefs and skills.

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Engage

A question, problem or activity can engage students in an inquiry lesson. This piece sets the stage for future exploration. It is important that the teacher starts any inquiry lesson with something that “hooks” the students.

Explore

Students explore the concepts through hands-on activities. They are directly involved with the materials. This is where they develop the experiences to build their knowledge. The classroom teacher is necessary to provide the materials and guided focus.

Explain

After the students have completed their explorations, they need to explain what they have learned through the activities and connect these learnings to the scientific concepts they are studying. During the explanation process, teachers have a vital role of correcting misconceptions or introducing formal vocabulary. As an example, a student who learned that a ball will continue rolling until friction and gravity act upon it will have something concrete to think of when Newton’s First Law of Motion is mentioned.

Elaboration

The students must then extend their learning new situations. They can now knowledgeably predict and then, test out their predictions. It is not possible to explore every situation, but the knowledge the students gained during the exploration stage will help them extend their learning based on the scientific concepts. It is important for the teacher to plan for students to collaborate and work together as they discuss their learnings. The teacher can also raise questions that were not brought up in the exploration stage to deepen their knowledge.

Evaluate

Finally, there is the evaluate piece. This is where the students review and reflect on their learning. It allows the teacher to determine whether the students truly understand the material. Students can provide evidence of their learning through a variety of ways. Some examples include summative assessments, performance tasks, interviews, demonstrations, and portfolios. Assessments must guide future lesson planning and may even be cause for modification in the future. For example, if there is a misconception with many students, the teacher can revisit the concept. If there is high student interest in a specific area, the class can be refocused to take advantage of this high level of Interest.

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SCIENCE AND ENGINEERING PRACTICES

In addition, the Columbus Diocese recognizes the importance of students engaging in the practices of science. According to the *Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas,* engaging in the practices of science helps students understand how scientific knowledge develops as well as knowledge of the wide range of approaches that are used to investigate, model and explain the world. It makes the students' knowledge more meaningful and embeds it more deeply into their worldview. The actual doing of science or engineering can awaken their sense of curiosity, capture their interest and motivate them to continue to study. Students may also recognize that by actively applying scientific and engineering knowledge and skills, they can contribute to solving many complex contemporary, technological, moral, and social issues. Students may then recognize that science and engineering can contribute to meeting many of the major challenges that confront society today, such as generating sufficient energy, preventing and treating disease, maintaining supplies of fresh water and food, and addressing climate change.[6]

These practices might look differently when applied in an engineering context versus a scientific one. The table below lists the eight practices and examples of how they would be applied in each context.

PRACTICES FOR K-12 SCIENCE CLASSROOMS		
PRACTICES	**SCIENCE APPLICATION**	**ENGINEERING APPLICATION**
Asking questions (for science) and defining problems (for engineering)	**Science** begins with a question about a phenomenon, such as "Why is the sky blue?" or "What causes cancer?" and seeks to develop theories that can provide explanatory answers to such questions. A basic practice of the scientist is formulating empirically answerable questions about phenomena, establishing what is already known, and determining what questions have yet to be satisfactorily answered.	**Engineering** begins with a problem, need, or desire that suggests an engineering problem that needs to be solved. A societal problem such as reducing the nation's dependence on fossil fuels may engender a variety of engineering problems, such as designing more efficient transportation systems, or alternative power generation devices such as improved solar cells. Engineers ask questions to define the engineering problem, determine criteria for a successful solution, and identify constraints.
Developing and Using Models	**Science** often involves the construction and use of a wide variety of models and simulations to help develop explanations about natural phenomena. Models make it possible to go beyond observables and imagine a world not yet seen. Models enable predictions of the form "if … then … therefore" to be made in order to test hypothetical explanations.	**Engineering** makes use of models and simulations to analyze existing systems so as to see where flaws might occur or to test possible solutions to a new problem. Engineers also call on models of various sorts to test proposed systems and to recognize the strengths and limitations of their designs.

[6] *A Framework for K-12 Science Education*. (2012). https://doi.org/10.17226/13165

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PRACTICES	SCIENCE APPLICATION	ENGINEERING APPLICATION
Planning and Carrying Out Investigations	**Scientific investigation** may be conducted in the field or the laboratory. A major practice of scientists is planning and carrying out a systematic investigation, which requires the identification of what is to be recorded and, if applicable, what are to be treated as the dependent and independent variables (control of variables). Observations and data collected from such work are used to test existing theories and explanations or to revise and develop new ones.	**Engineers** use investigation both to gain data essential for specifying design criteria or parameters and to test their designs. Like scientists, engineers must identify relevant variables, decide how they will be measured, and collect data for analysis. Their investigations help them to identify how effective, efficient, and durable their designs may be under a range of conditions.
Analyzing and Interpreting Data	**Scientific investigations** produce data that must be analyzed in order to derive meaning. Because data usually do not speak for themselves, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Sources of error are identified and the degree of certainty calculated. Modern technology makes the collection of large data sets much easier, thus providing many secondary sources for analysis	**Engineers** analyze data collected in the tests of their designs and investigations; this allows them to compare different solutions and determine how well each one meets specific design criteria—that is, which design best solves the problem within the given constraints. Like scientists, engineers require a range of tools to identify the major patterns and interpret the results.
Using Mathematics and Computational Thinking	In **science**, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks, such as constructing simulations, statistically analyzing data, and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable predictions of the behavior of physical systems, along with the testing of such predictions. Moreover, statistical techniques are invaluable for assessing the significance of patterns or correlations.	In **engineering**, mathematical and computational representations of established relationships and principles are an integral part of design. For example, structural engineers create mathematically based analyses of designs to calculate whether they can stand up to the expected stresses of use and if they can be completed within acceptable budgets. Moreover, simulations of designs provide an effective test bed for the development of designs and their improvement.

PRACTICES	SCIENCE APPLICATION	ENGINEERING APPLICATION
Constructing Explanations and Designing Solutions	The goal of **science** is the construction of theories that can provide explanatory accounts of features of the world. A theory becomes accepted when it has been shown to be superior to other explanations in the breadth of phenomena it accounts for and in its explanatory coherence and parsimony. Scientific explanations are explicit applications of theory to a specific situation or phenomenon, perhaps with the intermediary of a theory-based model for the system under study. The goal for students is to construct logically coherent explanations of phenomena that incorporate their current understanding of science, or a model that represents it, and are consistent with the available evidence.	**Engineering design,** a systematic process for solving engineering problems, is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technological feasibility, cost, safety, esthetics, and compliance with legal requirements. There is usually no single best solution but rather a range of solutions. Which one is the optimal choice depends on the criteria used for making evaluations.
Engaging in Argument from Evidence	In **science,** reasoning and argument are essential for identifying the strengths and weaknesses of a line of reasoning and for finding the best explanation for a natural phenomenon. Scientists must defend their explanations, formulate evidence based on a solid foundation of data, examine their own understanding in light of the evidence and comments offered by others, and collaborate with peers in searching for the best explanation for the phenomenon being investigated.	In **engineering,** reasoning and argument are essential for finding the best possible solution to a problem. Engineers collaborate with their peers throughout the design process, with a critical stage being the selection of the most promising solution among a field of competing ideas. Engineers use systematic methods to compare alternatives, formulate evidence based on test data, make arguments from evidence to defend their conclusions, evaluate critically the ideas of others, and revise their designs in order to achieve the best solution to the problem at hand.
Obtaining, Evaluating, and Communicating Information	**Science** cannot advance if scientists are unable to communicate their findings clearly and persuasively or to learn about the findings of others. A major practice of science is thus the communication of ideas and the results of inquiry—orally, in writing, with the use of tables, diagrams, graphs, and equations, and by engaging in extended discussions with scientific peers. Science requires the ability to derive meaning from scientific texts (such as papers, the Internet, symposia, and lectures), to evaluate the scientific validity of the information thus acquired, and to integrate that information.	**Engineers** cannot produce new or improved technologies if the advantages of their designs are not communicated clearly and persuasively. Engineers need to be able to express their ideas, orally and in writing, with the use of tables, graphs, drawings, or models and by engaging in extended discussions with peers. Moreover, as with scientists, they need to be able to derive meaning from colleagues' texts, evaluate the information, and apply it usefully. In engineering and science alike, new technologies are now routinely available that extend the possibilities for collaboration and communication.

DEFINITIONS

Standards

Strands: *These are the science disciplines: Earth and space sciences, physical sciences; life science. Overlaying all the content standards and embedded in each discipline are science inquiry and applications.*

Themes: *These are the overarching ideas that connect the strands and the topics within the grades. Themes illustrate a progression of increasing complexity from grade to grade that is applicable to all the strands.*

Connections: *Overarching ideas that connect the strands and topics within a grade. Connections help illustrate the integration of the content statements from the different strands.*

Topics: *The Topics are the main focus for content for each strand at tha tparticular grade level. The Topics are the foundation for the specific content statements.*

Content Statements: *The science content to be learned. These are the "what" of science that should be accessible to students at each grade level to prepare them to learn about and use scientific knowledge, principles, and processes with increasing complexity in subsequent grades.*

Content Elaboration: *This piece will provide more in-depth information and detail about the "what" that should be taught in the classroom and what is eligible for assessment*.

Evidence of Learning: *This section will provide recommendations for how students may be assessed. It will provide a range of examples of the various cognitive levels and depth of learning that students can be expected to demonstrate at grade level for a particular science content statement. The Expectations for Learning will provide guidance for developing assessments.*

Model Curriculum (Ohio Department of Education website)

The Model Curriculum is a web-based resource that will incorporate information on "how" the material in the Content Statement may be taught. It is not included in this document, but it is highly suggested that all science teachers have an understanding of at least the Content Elaboration and the Expectations for learning. You can find the model curriculum at the Ohio Department of Education's website.

CONNECTIONS TO THE *CATECHISM OF THE CATHOLIC CHURCH*

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This is a teacher reference for topics, issues, and/or questions that may arise while teaching science class at any grade level.

Topic	Section
Science and Faith	159
The Natural Moral Law	1954-1960
Abortion	2270-2275
Suicide	2280-2283
Respect for the person and scientific research	2292-2296
Research aimed at reducing human sterility	2375-2379
Care for Creation and Ethical Use	2415
Scientific experiments using animals	2417-2418
Evolution	279-289

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NATURE OF SCIENCE

Nature of Science

One goal of science education is to help students become scientifically literate citizens that are able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science, to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact not only themselves but others too.

Categories	High School
Scientific Inquiry, Practice and Applications All students must use the following scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas:	• Identify questions and concepts that guide scientific investigations; • Design and conduct scientific investigations using a variety of methods and tools to collect empirical evidence; • Use technology and mathematics to improve investigations and communications; • Formulate and revise explanations and models using logic and scientific evidence (critical thinking); • Recognize and analyze explanations and models; and • Communicate and support scientific arguments. • Apply Catholic values to development and application of science concepts.

Science is a Way of Knowing
 	
Science assumes the universe is a vast single system in which basic laws are consistent.
 	
Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.
 	
Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise, and extend this knowledge.
	• Various science disciplines use diverse methods to obtain evidence and do not always use the same set of procedures to obtain and analyze data (i.e., there is no one scientific method).
	    o Make observations and look for patterns.
	    o Determine relevant independent variables affecting observed pattern.
	    o Manipulate an independent variable to affect a dependent variable.
	    o Conduct an experiment with controlled variables based on a question or hypothesis.
	    o Analyze data graphically and mathematically.
	• Science disciplines share common rules of evidence used to evaluate explanations about natural phenomenon:
	    o Use empirical standards, logical arguments, and peer reviews;
	    o Empirical standards include objectivity, reproducibility, and honest and ethical reporting of findings; and
	    o Logical arguments should be evaluated with open-mindedness, objectivity and skepticism.
	• Science arguments are strengthened by multiple lines of evidence supporting a single explanation.
	• The various scientific disciplines have practices, methods, and modes of thinking that are used in the process of developing new science knowledge and critiquing existing knowledge.

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Categories	High School
Science is a Human Endeavor	• Uses curiosity, imagination, creativity, and persistence. • Individuals from different social, cultural, and ethnic backgrounds work as scientists and engineers. • Science and engineering are influenced by technological advances and society; technological advances and society are influenced by science and engineering. • Science and technology might raise ethical, social and cultural issues for which science, by itself, does not provide answers and solutions.
Scientific Knowledge is Open to Revision in Light of New Evidence	• Science can advance through critical thinking about existing evidence. • Science includes the process of comparing patterns of evidence with current theory. • Some science knowledge pertains to probabilities or tendencies. • Science should carefully consider and evaluate anomalies (persistent outliers) in data and evidence. • Improvements in technology allow us to gather new scientific evidence.

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BIOLOGY

INTRODUCTION AND SYLLABUS

COURSE DESCRIPTION

Biology is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires three one-unit courses. Each course should include inquiry-based laboratory experience that engage students in asking valid scientific questions and gathering and analyzing information.

Biology investigates the composition, diversity, complexity and interconnectedness of life on Earth. Fundamental concepts of heredity and evolution provide a framework through inquiry-based instruction to explore the living world, the physical environment and the interactions within and between them.

Students engage in investigations to understand and explain the behavior of living things in a variety of scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications.

Cross Curriculum connections link to ELA and Technology.

COURSE CONTENT SYLLABUS

The following information may be taught in any order; there is no ODE-recommended sequence.

B.H: HEREDITY

- B.H.1: Cellular genetics
- B.H.2: Structure and function of DNA in cells
- B.H.3: Genetic mechanisms and inheritance
- B.H.4: Mutations
- B.H.5: Modern genetics

B.E: EVOLUTION

- B.E.1: Mechanisms
    - Natural selection
    - Mutation
    - Genetic drift
    - Gene flow (immigration, emigration)
    - Sexual selection
- B.E.2: Speciation
    - Biological classification expanded to molecular evidence
    - Variation of organisms within species due to population genetics and gene frequency

B.DI: DIVERSITY AND INTERDEPENDENCE OF LIFE

- B.DI.1: Biodiversity
    - Genetic diversity
    - Species diversity
- B.DI.2: Ecosystems
    - Equilibrium and disequilibrium

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    - Carrying capacity
- B.DI.3: Loss of Diversity
    - Climate change
    - Anthropocene effects
    - Extinction
    - Invasive species

B.C: CELLS

- B.C.1: Cell structure and function
    - Structure, function and interrelatedness of cell organelles
    - Eukaryotic cells and prokaryotic cells
- B.C.2: Cellular processes
    - Characteristics of life regulated by cellular processes
    - Photosynthesis, chemosynthesis, cellular respiration, biosynthesis of macromolecules

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HEREDITY

Cellular Genetics

Life is specified by genomes. Each organism has a genome that contains all the biological information needed to build and maintain a living example of that organism. The biological information contained in a genome is encoded in its deoxyribonucleic acid (DNA) and is divided into discrete units called genes. Genes code for proteins. The sequence of DNA bases in a chromosome determines the sequence of amino acids in a protein. “The many body cells in an individual can be very different from one another, even though they are all descended from a single cell and thus have essentially identical genetic instructions. Different parts of the genetic instructions are used in different types of cells, influenced by the cell’s environment and past history.” (AAAS)Structure and Function of DNA in Cells, Mendel’s laws of inheritance (introduced in grade 8) are interwoven with current knowledge of DNA and chromosome structure and function to build toward basic knowledge of modern genetics. Genes are segments of DNA molecules. The sequence of DNA bases in a chromosome determines the sequence of amino acids in a protein. Inserting, deleting or substituting segments of DNA molecules can alter genes. Sorting and recombination of genes in sexual reproduction and meiosis specifically result in a variance in traits of the offspring of any two parents. This content can be explicitly connected to evolution.

Genetic Mechanisms and Inheritance

Genetic variation in traits among offspring is a result of the movement of chromosomes crossing over, independent assortment, and recombination during gamete formation. Gene interactions described in middle school were limited primarily to dominance and codominance traits. In high school, genetic mechanisms, both classical and modern, including incomplete dominance, sex-linked traits, and dihybrid crosses, are investigated through real-world examples. Statistics and probability allow us to compare observations made in the real world with predicted outcomes.
Dihybrid crosses can be used to explore linkage groups, gene interactions and phenotypic variations. Chromosome maps reveal linkage groups.

Mutations

Genes can be altered by insertion, deletion, or substitution of a segment of DNA molecules. An altered gene is a mutation and will be passed on to every cell that develops from it. The resulting features may help, harm or have little or no effect on the offspring’s success in its environments. Gene mutations when they occur in gametes are passed onto offspring.

Modern Genetics:

Technological developments that lead to the current knowledge of heredity are introduced for study. The development of the model for DNA structure was the result of experimentation, hypothesis, testing, statistical analysis, and technology as well as the studies and ideas of many scientists. James Watson and Francis Crick developed the current model based on the work of Rosalind Franklin and others. Scientists continue to extend the model and use it to devise technologies to further our understanding and application of genetics. The emphasis is not on the memorization of specific steps of gene technologies, but rather on the interpretation and application of the results.

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟷ Least Complex			
B.H: Heredity				
B.H.1 Cellular Genetics:	**B.H.1a**.Describe that different genes code for proteins that determine different traits.	**B.H.1b** Communicate that genes code for specific traits (e.g., eye color, hair color).	**B.H.1c** Recognize that genes are made up of DNA.	HS-LS3-2 Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
B.H.2 Structure and Function of DNA in Cells	**B.H.2a** Recognize that changing the segments of DNA molecules can alter genes.	**B.H.2b** Recognize that genes are made up of DNA, so changing the segments of DNA can alter genes.	**B.H.2c** When given a representation of individuals from the same parents, identify variations in physical traits.	HS-LS1-1 Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. HS-LS3-1 Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
B.H.3 Genetic Mechanisms and Inheritance	**B.H.3a** Predict the possible phenotypes of an offspring when given the genotype of the parents (e.g., using a Punnett square).	**B.H.3b** Recognize that genes combine during sexual reproduction which causes the traits of offspring to not be exact replicas of either parent.	**B.H.3c** Identify X and Y as female and male chromosomes.	NONE
B.H.4 Mutations	**B.H.4a** Describe how some mutations can be helpful and some can be harmful to organisms.	**B.H.4b** Recognize that genes can be altered and that those changed genes may then be passed to offspring.	**B.H.4c** Identify traits that can vary among a population (e.g., eye color, beak shape, etc.).	HS-LS3-2 Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
B.H.5 Modern Genetics	**B.H.5a** Describe specific ways in which scientists have used DNA to help people or the environment (e.g., sweeter fruit, etc.).	**B.H.5b** Identify one reason DNA would be purposely altered by humans.	**B.H.5c** Identify a model of DNA.	NONE

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EVIDENCE OF LEARNING

Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

Designing technological / engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.H.1 Cellular Genetics			
	Using information from the Human Genome Project, show how DNA testing companies have developed and what information is used to show how people are related. Develop a proposal to explain the choice of a particular testing company and how the results can be used to address health issues (Ancestry.com or 23 and Me).	Compare the DNA sequences of different cells from the same organism to discover that the DNA is the same although cells have specialized functions. Discuss gene expression and the fundamental point that specialized cells use specific and different genes.	Describe the central dogma (DNA to RNA to Protein) and its relationship to heredity.
B.H.2 Structure and Function of DNA in Cells			
		Discuss and provide evidence that inheritable genetic variations may result from new genetic combinations through meiosis (e.g. sorting, recombination, crossing over) and sexual reproduction.	Given one strand of DNA, create the complementary strand and/or the mRNA molecule transcribed from it. Describe the process of meiosis in relationship to the role of DNA and chromosomes in coding the instructions for traits passed from parents to offspring. Use the genomes of several members

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			of the same species to identify a mutation. (Great connection to cladograms)
B.H.3 Genetic Mechanisms and Inheritance			
	Propose hypotheses, design experiments, and analyze a real world population (e.g., dog breeds, fruit flies, Fast Plants, virtual simulations) to identify the genotypes of one or more unknown individuals utilizing Punnett Squares and pedigrees based on their phenotypes and the phenotypes of their offspring. Use the principles of statistics to compare real world data to predicted outcomes. (i.e. Chi Square).	Explain the outcomes of a series of genetic crosses from a real world population (e.g., fruit flies, virtual simulation, Fast Plants) by using Mendel's principles of segregation and independent assortment. Explain the outcomes of a series of genetic crosses from a real world population (e.g. fruit flies, virtual simulation, Fast Plants) using Mendelian and non-Mendelian genetics (i.e., incomplete dominance, sex-linked traits, and dihybrid crosses). Include a discussion on gene interactions, gene linkage, and the source of phenotypic variation. Analyze chromosome maps to reveal linkage groups.	Use a model of meiosis to demonstrate crossing over and genetic recombination as well as independent assortment during gamete formation. Compare the similarities and differences between mitosis and meiosis with discussion.
B.H.4 Mutations			
		Given examples of original and mutated DNA segments, analyze the mutation (e.g., nonsense, missense, or silent) and identify the relationship between genetic mutations and their phenotypical impacts (e.g., change vs no effect). **Make a connection to how natural selection might favor, select against, or be neutral on the resulting changes in the protein (phenotype).	Recall the types of mutations and describe the effects they might have on a protein. Classify these mutations as gene mutations (e.g., insertion, deletion and substitution) or chromosomal mutations (e.g. trisomy 21, trisomy 18, Turner Syndrome, etc.). Evaluate chromosome maps to identify linkage groups.

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B.H.5 Modern Genetics			
Research current Genetic Engineering practices (e.g., CRISPR, GMO, Transgenic Organisms, Specially modified bacteria, Cloning, epigenetic technology, etc). Evaluate the tradeoffs (e.g., disadvantages versus advantages) of implementing Genetic Engineering practices. Using knowledge of genetic technology, create a proposal for the design of a product to solve a current world problem. (e.g., Golden Rice, oil eating bacteria, insulin producing bacteria, pigs for producing human organs, etc.)	Given a real world problem (e.g., diseases, hunger, pests, water concerns), propose a solution that uses genetic technology (e.g. specially modified bacteria, GMO, CRISPR, stem cells technology, epigenetic technology, etc.) and defend your reasoning.	Use Gel electrophoresis (actual or virtual) technology to evaluate DNA results (e.g., crime scene analysis, paternity, phylogenetic relationships.)	Create a timeline of the significant discoveries in genetics.

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EVOLUTION[7]

B.E.1--Mechanisms

Natural selection is used to describe the process by which traits become more or less common in a population due to consistent environmental effects upon the survival and reproduction of the individual with the trait. Mathematical reasoning must be applied to solve problems, (e.g., use Hardy-Weinberg principle to explain deviations in observed gene frequency patterns in a population compared to expected patterns based on the assumptions of the principle).

Populations evolve over time. Evolution through natural selection is the consequence of the interactions of:

1. The potential for a population to increase its numbers;
2. The genetic variability of offspring due to mutation and recombination of genes;
3. A finite supply of the resources required for life; and
4. The differential survival and reproduction of individuals with the specific phenotypes.

Mutations are described in the content elaboration for Heredity. Apply the knowledge of mutation and genetic drift to real-world examples. Biological evolution explains the natural origins for the diversity of life. Emphasis shifts from thinking in terms of selection of individuals with a particular trait to changing proportions of a trait in populations as a result of the mechanisms of genetic drift, movement of genes into and out of populations and sexual selection.

[7] **Note:** Catholic teaching does not oppose the theory of evolution. According to Pope St. John Paul II, “from the viewpoint of the doctrine of the faith, there are no difficulties in explaining the origin of man in regard to the body by means of the theory of evolution” (General Audience, 16 April 1986). The Catholic Church permits the faithful to believe in the theory of evolution with regard to the development of the human body, while also insisting that the spiritual soul of the human person is not the result of material processes alone. God, creator of all things, is the ultimate source of both the material and the spiritual.

B. E.2—Speciation

Biological Classification Expanded to Molecular Evidence

Classification systems are frameworks developed by scientists for describing the diversity of organisms, indicating the degree of relatedness between organisms. Recent molecular-sequence data generally support earlier hypotheses regarding lineages of organisms based upon morphological comparisons. Both morphological comparisons and molecular evidence must be used to describe biodiversity (cladograms can be used to address this).

Modern ideas about evolution provide a natural explanation for the diversity of life on Earth as represented in the fossil record, in the similarities of existing species and in modern molecular evidence. From a long-term perspective, evolution is the descent with modification of different lineages from a common ancestor.

Variation of Organisms within a Species due to Population Genetics and Gene Frequency

Different phenotypes result from new combinations of existing genes or from mutations of genes in reproductive cells. At the high school level, the expectation is to combine grade-8 knowledge with explanation of genes and the function of chromosomes. Natural selection works on the phenotype.

Heritable characteristics influence how likely an organism is to survive and reproduce in a particular environment. When an environment changes, the survival value of inherited characteristics may change. This may or may not cause a change in species that inhabit the environment. Use real-world examples to illustrate natural selection, flow, sexual selection, and genetic drift.

As Pope St. John Paul II explained in his encyclical *Fides et Ratio* (1998), “human beings attain truth by way of reason because, enlightened by faith, they discover the deeper meaning of all things and most especially of their own existence” (*Fides et Ratio* 20). Furthermore, the Catholic Church teaches that science, philosophy, and theology should work together in the search for truth and meaning, for faith and reason “offer to each other a purifying critique and a stimulus to pursue the search for deeper understanding.” (*Fides et Ratio* 100)

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟵		⟶ Least Complex	
B.E: Evolution				
B.E.1 Mechanisms ○ Natural selection ○ Mutation ○ Genetic drift ○ Gene flow (immigration, emigration) ○ Sexual selection	**B.E.1a** Describe how the presence or absence of traits may help some individuals in a plant or animal population survive and reproduce in their environment (e.g., natural selection).	**B.E.1b** When given a population of animals or plants, identify how variation in traits impacts their ability to survive and reproduce (e.g., populations of endangered species).	**B.E.1c** When given a plant or animal, identify traits that help it to survive in its environment.	HS-LS4-2 Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. HS-LS4-3 Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. HS-LS4-4 Construct an explanation based on evidence for how natural selection leads to adaptation of populations. HS-LS4-5 Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. HS-ESS2-7 Construct an argument based on evidence about the simultaneous co-evolution of Earth's systems and life on Earth.
B.E.2 Speciation ○ Biological classification expanded to molecular evidence	**B.E.2a** Identify evolutionary changes to a given species that have allowed the species to continue to survive and reproduce.	**B.E.2b** Diagram and describe the evolutionary change in a species.	**B.E.2c** Given a visual representation, identify a species that has changed over the course of many generations (e.g., cladogram	HS-LS3-3 Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

○ Variation of organisms within a species due to population genetics and gene frequency			diagram).	HS-LS4-1 Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. HS-LS4-3 Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.

EVIDENCE OF LEARNING

Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

Designing technological / engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.E.1--Mechanisms			
Design a solution to lessen the impact of genetic drift acting in a real world situation (e.g. increasing genetic variation in cheetah populations or planning matings among the small population of lowland gorillas housed in zoos around the world). **Modeling Hardy Weinberg** Students build and alter the gene pool of a model population (using tactile items e.g. beads of two colors, beans of two types, red/white cars in a parking lot, etc. to represent alleles) to test the components and assumptions of the Hardy-Weinberg principle	Generate alternative hypotheses to explain a real world example of genetic drift. Consider a commercial, organic farmer growing a heritage variety of sweet corn next to a large, industrial corn farm planting GMO (genetically modified organism) corn. Describe how gene flow and genetic drift may affect the commercial success of the two farming businesses. Expand on a classic exercise	Use media sources (newspaper, journal, etc.) to explain how a real world model demonstrates genetic drift and then translate the information into an appropriate visual representation. For example, design materials to support a campaign to preserve a threatened or endangered species in Ohio (Bald eagle, paper-shell mussel, xxxxx trillium)	Differentiate between gene flow and genetic drift (e.g. Genetic drift--limited variation within corn crops, Gene flow--pollen from GMO (genetically modified organism) crops blowing over to an organic farmer's crop)

Optional extension: Assist students in developing a mathematical model describing their above observations ($p^2 + 2pq + q^2 = 1$ & $p + q = 1$: Hardy-Weinberg)	demonstrating natural selection that documents allele frequency changes on a variety of habitats over multiple generations. Repeat the exercise with a blindfolded student to model chance events that lead to genetic drift, then compare the allele frequency changes with the initial data.		
Critique a real-world solution to the arrival of an invasive species (Center for Invasive Species Prevention) and how it changed native populations and/or the invasive population with respect to Hardy-Weinberg assumptions. (Ohio examples, Japanese honeysuckle, zebra and quagga mussels, Emerald Ash Borers, purple loosestrife, West Nile Virus?) Design an engineering or technical solution to keep/remove an invasive species out of local habitats (e.g. invasive fish out of Lake Michigan; removal of invasive lampreys from Great Lakes tributaries). Construct a program to remove all descendants of invasive species in a habitat (e.g. rats on small Pacific island). Design an engineering/ technical solution to help return native species following the intentional removal of all invasive species (e.g. rats on small Pacific islands). Design and construct a habitat that maintains the gene pool of a transplanted population at equilibrium.	Generate a change in the model that would violate a Hardy-Weinberg assumption. Generate hypotheses to predict the ecological changes following the invasion of an exotic species into a new habitat (e.g. fire ants invading Ohio) based upon reports of the impact of that same species into other habitats in the recent past.	Explain the results of the change they generated in the model population using a visual representation of their choice. Identify the likely stakeholders (commercial or sporting groups) affected by the arrival of the invasive species students researched. Prepare a presentation for those stakeholders about your predicted changes and your bases for making these predictions. NOTE: Increase the effectiveness of this example by using local examples.	Use Hardy-Weinberg principles to explain the concept of an individual acting as a "carrier" of a rare genetic disorder. Differentiate between gene flow and genetic drift. Illustrate the concepts of genetic drift, random mating, sexual selection, natural selection, mutation, migration. Recognize that populations, not individuals, evolve. (genetic change within a population occurs across generations, not within individuals). Describe the nature of the biological relationship with each native species for the changes predicted because of the appearance of an invasive species, (predator, competitor, other).

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B.E.2--Speciation			
Design a medical facility or procedure to discourage the persistence (spread) of antibiotic resistance through natural selection in populations of bacteria. OR Design an agricultural solution/ procedure to discourage the persistence (spread) of herbicide resistance in crop plants/ pesticide resistance in insects through natural selection. Design a public exhibit that attracts tourists by demonstrating convergent evolution of plants on different continents; e.g. The Desert Botanical Garden, Phoenix.	For two closely related species "sibling species"; (e.g. tassel-eared squirrels, yellow-rumped and Audubon's warbler, plant examples, etc.) propose hypotheses to explain their current distributions.	Given information about the current range and population size of a species, predict the effect of a change in environmental factors on the species. Examples: Retreat of the last glaciers, rapid increase in water temperatures in the Gulf of Maine. **Real World Natural Selection** Explore a real world example of natural selection (Darwin's Finches, peppered moths, Hawaiian honeycreepers, Galapagos tortoises) **Species Collection** Collect and measure traits within several groups of local species (e.g. oak trees [leaves and/or acorns], maples, pines, lightning bugs, monarchs, ducks, spiders, etc.) **Modern and Historical Theory** Explore modern and historical evidence from various disciplines that support the theory of evolution through natural selection. **Evaluating Relatedness** Explore evolutionary relatedness of the living world.	Compare and contrast the work of Lamarck and Darwin/Wallace. (Lamarck and Darwin/Wallace all recognized the core question in biology of the origin of species; they proposed different hypotheses regarding the selection process that shaped traits.)
Propose an engineering solution to block or allow interbreeding between neighboring populations (e.g. tassel-eared squirrels).	Using a real-world example, generate a hypothesis of why neighboring populations of similar species might or might not represent distinct species. Then propose one or more analyses to determine if they are distinct species.	Present graphically the distribution of a specific trait within and between species in a group (e.g. needle length and or number in needles of multiple pine species, weights of acorns, degree of indentation or leaf points in oak or maple trees). Interpret your data in light of evolution through natural selection and descent from a common ancestor with modification.	Identify a geographical barrier likely responsible for distinct, yet similar populations in an area (e.g. tassel-eared squirrels) and how it might account for the close similarity of multiple forms.

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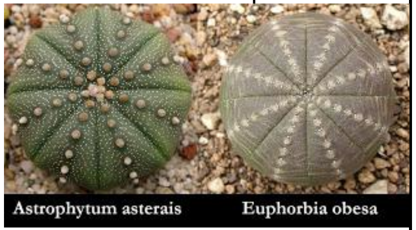
	Provide classic examples of convergent evolution, e.g. cactus vs Old World succulents), provide (natural selection?) hypotheses that predict the similarities of these species 	Research and interpret the observational basis of natural selection through various disciplines (e.g. molecular, anatomical, and/or paleontological). Use this insight to construct a visual/oral presentation via a multidisciplinary team approach.	Recognize data as molecular, anatomical and/or paleontological evidence of evolution through natural selection.
Design a technological solution to determine identification in species where visual cues alone cannot determine identity. (e.g. bird species that can only be identified by their song or mating behaviors) E.g., compare images and songs of Empidonax flycatchers here.  A comparison of Acadian (above) and Yellow-bellied (below) Flycatchers being banded in Baltimore Co., Maryland (6/1/1980). Photo by Jim Stasz. (MBP list)	Generate a hypothesis, represented with a cladogram, using researched data (molecular, anatomical, nomenclature [eg. binomial]) about a group of organisms.	Interpret the degree of evolutionary relatedness (phylogenetic closeness) based on information found in a cladogram. Evaluate two or more cladograms representing different hypotheses of the evolution of a given clade. Evaluate cladograms produced by classmates. Argue for or against proposed evolutionary relationships.	Given data in a table (molecular, anatomical, nomenclature [binomial]) illustrate evolutionary relatedness (phylogenetic closeness) using a cladogram.

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DIVERSITY AND INTERDEPENDENCE OF LIFE

Building on knowledge from elementary school (interactions of organisms within their environment and the law of conservation of matter and energy, food webs) and from middle school (flow of energy through organisms, biomes and biogeochemical cycles), this topic at the high school level focuses on the study of diversity and similarity at the molecular level of organisms. Additionally, the effects of physical/chemical constraints on all biological relationships and systems are investigated. The unidirectional flow of energy and the cycling of matter as organisms survive, reproduce and die occurs at all levels of biological organization, from ecosystems to molecules. Previous knowledge focused on biological systems at equilibrium; at high school, biological systems not at equilibrium and their responses are considered. Diagrams and models are used to explain the effects of real-world interactions and events within an ecosystem.

B.DI.1 Biodiversity

The great diversity of organisms and ecological niches they occupy result from more than 3.8 billion years of evolution. Populations of individual species and groups of species comprise a vast reserve of genetic diversity. Loss of diversity alters energy flow, cycles of matter, and persistence within biological communities. Loss of genetic diversity in a population increases its probability of extinction.

B.DI.2 Ecosystems

Ecosystems change as geological and biological conditions vary due to natural and anthropogenic factors. Like many complex systems, ecosystems have **cyclical fluctuations** around a state of equilibrium. The rate of these fluctuations in ecosystems can increase due to anthropogenic factors. Changes in ecosystems may lead to disequilibrium which can be seen in variations in carrying capacities for many species. Authentic data are used to study the rate of change in matter and energy relationships, population dynamics, carbon and nitrogen cycling, population changes, and growth within an ecosystem. Graphs, charts, histograms, and algebraic thinking are used to explain concepts of carrying capacity of populations and homeostasis within ecosystems by investigating populations changes that occur locally or regionally. Mathematical models can include the exponential growth model and the logistic growth model. The simplest version of the logistic growth model is Population Growth Rate = rN (K-N) / K, which incorporates the biological concept of (limited, non-infinite) carrying capacity (based upon intra- and interspecies competition for resources such as food) as represented by the new variable K for carrying capacity. Carrying capacity is defined as the population equilibrium sized when births and deaths are equal; hence Population Growth Rate = zero.

B.DI.3 Loss of Diversity

An ecosystem will maintain equilibrium with small fluctuations in its abiotic and biotic components, but significant fluctuations can result in long term alterations of the ecosystem and ultimately a loss of biodiversity. This can be caused by anthropogenic and natural events. Humans are a biotic factor in all ecosystems and can impact critical variables within these systems. Climate is dependent on a number of feedback loops between sunlight, the ocean, the atmosphere and the biosphere. Increasing mean global temperatures cause increased variance in weather that impacts both biotic and abiotic factors. Multiple changes happening simultaneously can stress ecosystems. Extreme events such as prolonged drought, floods, and introduction of an invasive species can result in long-term alterations ecosystems and their functions. The current rate of extinction is at least 100-1000 times the average background rate observed in the fossil record. The observed rates of biodiversity loss are indicative of a severe and pervasive disequilibrium in ecosystems. At the high school level, students should examine the factors that contribute to the accelerated extinction rates observed today and the implications of declining biodiversity carrying capacity.

Misconceptions about population growth capacity, interspecies and intra-species competition for resources, and what occurs when a species immigrates to or emigrates from ecosystems are included in this topic. Technology must be used to access real-time/authentic data to study population changes and growth in specific locations.

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Ohio Learning Standard	***Complexity a***	***Complexity b***	***Complexity c***	***NGSS Alignment***
Generic	Most Complex ←		→ Least Complex	
B.DI: Diversity and Interdependence of Life				
B.DI.1 Biodiversity ○ Genetic diversity ○ Species diversity	**B.DI.1a** Explain how low genetic diversity impacts population size, energy flow or the cycle of matter in a given environment (e.g., Isle Royale Wolf population).	**B.DI.1b** When given two examples of an animal or plant in a given environment, describe which one would have the higher chance to survive or reproduce based on traits (e.g., fur coat thickness, coloration).	**B.DI.1c** When given an environment, recognize a plant or an animal that could survive in that environment.	HS-LS4-1 Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
B.DI.2 Ecosystems ○ Equilibrium and disequilibrium ○ Carrying capacity	**B.DI.2a** Identify how both populations will change in a predator/prey relationship, when given a model of an ecosystem that is not in balance (e.g., carrying capacity).	**B.DI.2b** Identify how a human or natural change to an ecosystem results in a change to a predator or prey population.	**B.DI.2c** When given a set of before and after pictures of an ecosystem, (e.g., meadow changed to farm, forest changed to apartment buildings) observe the human caused changes.	HS-LS2-1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. HS-LS2-6 Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
B.DI.3 Loss of Diversity ○ Climate change ○ Anthropocene effects ○ Extinction ○ Invasive species	**B.DI.3a** Describe how drought, flood, volcanic eruption, habitat loss, or introduction of a new species may affect the diversity in an ecosystem.	**B.DI.3b** Match the cause (e.g., drought, flood, habitat loss, new species) to its effect on organisms in an ecosystem.	**B.DI.3c** Identify factors that can harm organisms in an environment (e.g., drought, floods, volcanic eruption, habitat loss, new species etc.).	

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EVIDENCE OF LEARNING

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Designing technological or engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.DI.1.1 Biodiversity: Genetic Diversity			
Investigate a species of extremely low abundance (e.g, Vaquita porpoise or Sumatran/Javan rhinos or native bees) and propose monitoring or management methods to increase the genetic diversity.	Investigate various agricultural/crop production practices then propose a hypothesis to explain how these practices might impact a species genetic diversity. Review data (ex. recorded by NCBI, NIH, CDC) to examine genetic diversity within populations. Evaluate populations with specific genetic traits and how these are related to the survival abilities of the population (ex. Northern White Rhino, British Royal family and hemophilia, Sickle Cell and Malaria). Compare and contrast the factors that influence growing/propagating different varieties (ex. Heirloom and GM) of plants of the same species. (This could include growing each variety if resources permit.) Using this information, advise the stakeholders of a country/community about the trade-offs of growing each type of plant in the country/community.	Use a model or simulation to analyze the impact of an environmental stressor on the genetic diversity and long term survival of a population.	Identify organisms with high (ex: tomatoes or beans) and low (ex: cheetahs) genetic diversity. Recognize that species with low genetic diversity are more likely to be prone to extinction.

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B.DI.1.2 Biodiversity: Species Diversity			
Use historical and real-time data (from ODNR for past and current data sets) to monitor changes in populations of Ohio species and correlate population size to wildlife management policies (river otters, deer, Canada geese, sturgeons…).			Using data on a variety of Ohio species, create a chart comparing the species diversity across the state's ecosystems.
Propose and justify suggestions to increase diversity and stability of the system. (could use Convention on Biological Diversity website for data. Design, evaluate, and refine a solution to reduce the impacts of human activities on the environment and biodiversity.	Investigate species diversity for local populations, which could include school grounds and/or local wildlife areas, by comparing the number of different species to the abundance of each species. (For example, consider a stream survey or investigate the influence introducing wolves to Isle Royale or Yellowstone back into the ecosystem.) Investigate the practice of stocking fish in Ohio then explore the factors that influence stakeholders decisions about this practice. Examine how this practice impacts the environment. Develop a PSA to inform the community about a specific fish that will be stocked in the community's local water way.	Examine historical and current lake or stream fish populations in local bodies of water in order to make predictions of future population numbers. Compare this to past years ODNR data and project future population numbers for individuals interested in fishing. Investigate the species diversity within a biome. Analyze the number of different types of vertebrates, invertebrates, and plant species in a biome. Identify patterns in distribution between different biomes and consider the influence latitude and/or altitude plays with species diversity. Evaluate correlations between the loss of diversity with changes in energy flow, cycles of matter, and persistence within biological communities.	

B.DI.2.1 Ecosystems: Equilibrium and Disequilibrium			
Investigate an invasive species in Ohio (e.g. Zebra mussels, purple loosestrife, emerald ash borer, sea lamprey, honeysuckle), analyze its impacts,	Devise an experiment to investigate an ecosystem in equilibrium and an ecosystem in disequilibrium. Gather data and analyze the results.	Examine predator/prey population cycles (e.g. Moose/Wolf or Hare/Lynx) and predict what changes in predator or prey numbers	Compare and contrast equilibrium and disequilibrium. Give examples of each in real populations. Relate this to Ohio animals and plants. For

predict the ecological and economic impacts on communities. Research should include analyzing the factors that contribute to the organism's success, and various ideas to provide a solution to managing the species. Devise a plan to implement which addresses the ecological and economic impacts of the species. The plan should address lessening the species' impacts. Design, evaluate, and communicate to stakeholders the strategies to restore equilibrium to an ecosystem previously altered by human impact (e.g., dams, channelization, urbanization, nutrient overload/algal blooms in the Great Lakes).	An example could be changing populations of algae species in an aquarium as a function of phosphorus concentration over time.	would do for cycle amplitude or period. Research human intervention/impact on the predator/prey relationships (E.g. Hunting large predators, such as wolves;hunting large herbivores, such as bison; Tragedy of the Commons in oceans; Nile Perch)	example, consider the impact of stocking fish on a native population of the same or similar (able to interbreed) fish (e.g. rainbow trout).
B.DI.2.2 Ecosystems: Carrying Capacity			
Use real-time data to analyze devices used in tracking populations to monitor populations. (https://www.movebank.org/) Analyze data collected from those devices to determine population cycles and carrying capacity. (https://www.movebank.org/) Design a tracking device for a specific organism (in its natural habitat) to analyze its population size and carrying capacity.	Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. [Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood and extreme changes such as volcanic eruption or sea level rise.] Use data to explain ecosystem differences resulting from varying levels of modest (recreational hunting or seasonal flooding) and extreme (volcanic eruption or sea level rise) changes.	Analyze population data for patterns in population cycles and determine carrying capacities. Identify and explain correlations between variables in population data After interpreting a data set, correlations between population variables will be communicated via informational methods. (e.g. Infographic, Twitter, discussion boards)	Identify and label various features of population growth curves (e.g., fast or slow growth rates, carrying capacity, equilibrium, population boom and bust). Describe characteristics of exponential and logistical growth.
	Investigate the effects of urban sprawl and unusual weather/climate on wildlife and native plant populations. For		

	example, loss of native populations of shrubs (spicebush) upon the invasion of Japanese honeysuckle; growth in white-tailed deer populations.		
B.DI.3.1 Loss of Diversity: Climate Change			
Using satellite temperature data, students analyze ocean temperature and evaluate temperature effects on marine life. Design a solution for a species at risk. The earth's climate is changing due to many factors. At the high school level, students should examine factors that lead to climate change (e.g. heat retention due to increasing levels of atmospheric greenhouse gases) consider how climate change poses challenges for species, and use data and models to predict how current rates of change will reshape and eliminating the range and distribution of species.	Investigate a local species impacted by climate change. Use historical and real time data to investigate the impact of changing climate on the ranges or migration patterns of local species (trees, insects, amphibians, reptiles). Create a profile of the species that examines the impact of the changes on the organism, and its response to the changes. Create a presentation to share with stakeholders. Conduct an experiment to measure changes in temperature of an enclosed environment (terrarium, 2L bottle) by altering variables such as light intensity, CO_2, and/or water gas concentrations. Compare and contrast the effect of different factors on the enclosed ecosystem.	Given real world data charts (NASA and NOAA) construct graphs to examine factors involved in climate change. Using Claim, Evidence, Reasoning, select the factor that you feel has the most impact on climate change and biodiversity. Plan a project utilizing real-time/authentic data (e.g. interview local farmers, Department of Agriculture, ODNR) to explain strategies (pest control, water supply, crop rotations) used by the agricultural industry to adapt to changes in climate. Explain how climate change impacts global diversity. (e.g. coral reefs, desertification, ocean acidification) Gather newspaper/media reports of local weather and then relate examples of climate change with local weather phenomena and relate how these data would change future climate categories for Ohio if they continue	Explain the historical climates of Ohio and how the biotic and abiotic conditions have changed. Describe the feedback loop that exists between sunlight, the ocean, the atmosphere and the biosphere. Relate this to photosynthesis and cellular respiration. List examples of environmental impacts caused by global climate change (Ex. desertification, sea level rise) Draw and label a feedback loop for carbon dioxide and/ or water vapor. Identify the factors within this loop that influence climate change.

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B.DI.3.2 Loss of Diversity: Anthropocene Effects			
Design, evaluate, or refine a solution for reducing the impacts of human activities on the environment and biodiversity.(E.g.of human activities can include urbanization, building dams, and dissemination of invasive species, rebuilding coral reefs by sinking ships.]	Use real world data to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] Design an experiment or study to examine how ocean acidification can have an impact on marine organisms. Research how domestication and selective breeding have impacted animal and plant biodiversity. (e.g. apples, dogs). Analyze the impacts from the changes. Predict how biodiversity will be impacted in the future. Will humans positively or negatively impact systems biodiversity? Blog your research and thoughts.	Provide examples of Genetically Modified Organisms and explain their impact on the environment. Use real-world data to investigate and explain a human-influenced issue and how it impacts biodiversity such as genetically modified organisms, agriculture, acid rain, etc.	Describe anthropogenic generated factors (acid rain, ozone depletion, landfill leaching, thermal pollution, etc.) and correlate these influences to their impacts on the environment. Use principles of evolution through natural selection to explain the rise in the occurrence of herbicide-resistant weeds in areas using herbicide-resistant GMO corn and soy seeds. Compare this process with the rise of antibiotic-resistant microbes.
B.DI.3.3 Loss of Diversity: Extinction			
Research efforts by zoos to prevent the extinction of charismatic species. Analyze the impact of these efforts to address the potential loss of diversity within the species or within the ecosystem. Identify the limitations of zoo-based captive	Analyze an ecosystem, examine the ecological variables within the ecosystem. Given a factor that may impact the ecosystem (weather event, pesticide, climate change) predict the influence of the impact to the ecosystem. Predict which species would be most vulnerable to	Explore a region of the world that is experiencing high rates of extinction. Examine the cause of the high rates of extinction. Connect the extinction to the impacts to the biome or ecosystem. Analyze impact of extinction to food webs, niches, and cycling of matter. Relate this to food webs and chains, keystone species and	Compare and contrast the current extinction rate vs the historical extinction rate. Construct a list of the top events that cause species extinction. Recognize the impact that species

breeding programs (inbreeding) and propose solutions to minimize such problems Investigate a species of extremely low abundance (e.g, Vaquita porpoise or Sumatran/Javan rhinos) and propose monitoring or management methods to improve the genetic diversity. Research the possibility of bringing back extinct species. Examine species restoration methods and techniques to bring back extinct species. Debate the possibility of bringing an organism back, its ecological impacts, moral implications, and economic values.	extinction and which species would be most resilient. Defend your reasoning. Examine the established programs to repopulate animal species that are endangered. Pick a species involved in the restoration and describe current methodology and costs of these programs. Project the benefits to society and why these species are critical to their ecosystem. Examine the role social media, national economy, politics, energy use, commercial interests, and local traditions play in the decision process.	pyramids of numbers~~.~~	extinction has on biodiversity.
B.DI.3.4 Loss of Diversity: Invasive Species			
Research an invasive species in Ohio, analyze its impacts, predict the ecological and economic impacts on communities. Analyze factors that contribute to the species' success and propose solutions to reduce the ecological and economic impacts of the species.	Population Sampling in a School Yard: Students will learn about local biodiversity, population sampling techniques, and calculate invasive species abundance analyzing a plot of land on school grounds. Students can compare and contrast various sampling techniques and explore density dependent factors. Observe invasive species in your local area, analyze changes in their population numbers, and propose hypotheses for these fluctuations.	Use biological concepts to explain the impact of various invasive species control methods on invasive and native species populations. Investigate increase of human disease due to expanded distribution of transmission vectors. Examine both human and natural means for vector movement (e.g. SARS, West Nile, Bird Flu, Tsetse fly, nematodes, etc…).	Describe the most common ways invasive species are introduced to a new habitat. Describe the characteristics of successful invasive species Create a list of invasive species for your local area and describe what native species with which they compete. Relate this to the native predators and controls in the area and how the invasive species outcompetes/escapes local population control factors.

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Resources

B.DI.1.1 Biodiversity: Genetic Diversity

National Center for Biotechnology Information is a resource providing access to genomic information. Information about genes, gene expression, gene maps, genetic codes, and tools to manipulate genetic data.

National Human Genome Research Institute website is a national research database of research, new discoveries, genetic technologies, and genetic resources related to human genetics.

Center for Disease Control and Prevention Genomics and Diseases Information on genetic diseases and disorders in the human populations

Low Genetic Variation information and examples of low genetic variation.

Impacts of low genetic diversity in Maize and Potatoes The Irish potato famine and Southern Corn Leaf Blight had huge impacts on human health and sustenance.

Project WILD and Aquatic WILD help students learn basic concepts about wild animals, their needs and importance and their relationships to people and the environment. The activity guides are available to educators low cost or free of charge when they attend a workshop. Information about upcoming workshops are available on the ODNR Website at http://wildlife.ohiodnr.gov/education-and-outdoor-discovery/conservation-education-project-wild. In the Project WILD activity *Bottleneck Genes*, students investigate how genetic diversity within a population affects a species' ability to adapt and survive.

B.DI.1.2 Biodiversity: Species Diversity

Ohio Department of Natural Resources (ODNR)- This resource provides historic and real-time data on Ohio's Natural Resources. Click home to search wildlife and other topics.

Convention on Biological Diversity website (COBD)- This site provides resouces related to the restoration of the ecosystem

BiomeViewer-**This is an interactive to explore biomes, climate, biodiversity and human impact.** The accompanying Student worksheet provides students with the opportunity to explore the viewer and biomes. The viewer can then be used to investigation Biomes.

The Association of Fish and Wildlife Agencies has a Conservation Toolkit that includes guides on conducting field investigations with students, schoolyard habitat investigations, technology for field investigations, and more. https://www.fishwildlife.org/afwa-informs/ce-strategy/north-american-conservation-education-strategy
Projects that involve the collection/monitoring/tagging/etc of native Ohio wildlife require a permit. Information and applications for both a Scientific Collection Permit and an Education Permit can be found online through the ODNR-Division of Wildlife at http://wildlife.ohiodnr.gov/licenses-and-permits/specialty-licenses-permits Permits are annual and require a $25 fee, along with reporting about your projects.
Species diversity Indices can (but is not required to) include: comparing the number of different species to the abundance of each species, calculating Simpsons or Shannon-Wiener diversity indices

B.DI.2.1 Ecosystems: Equilibrium and Disequilibrium

Invasive Species of Ohio Information on invasive species in Ohio. Guide to invasive species in Ohio, how Ohio is managing the invasive species and the impact the organism is having on the ecosystem.

Dam Removal in Ohio A review by the Ohio EPA of impacts of dams on ecosystems and the process of dam removal. Information on trying to reestablish equilibrium in an ecosystem.

Phosphorus and Algal Growth Guide to growing algae in an aquarium and exploring the impacts of various levels of phorphorus and nitrogen, analyzing changing impacts on equilibrium

Moose/Wolf Populations on Isle Royale Background on the fluctuations on the moose/wolf populations on Isle Royale, data, and management policies, as well as influential factors that impact populations.

Human Impacts on Top Marine Predators Researchers study the movements and human impacts on top ocean predators.

Harmful Algal Blooms in Ohio Ohio Department of Health guidelines on harmful algal blooms in Ohio.
Tragedy of the Commons in the Oceans Background information on human influences on the oceans and the resulting impact.
US EPA Nutrient Load Impacts on Waterways EPA assess the impacts of nutrient loads on waterways, and the data reported from each state.
Ohio Plants and Animals; Ohio Department of National Resources information on Ohio's wildlife species

B.DI.2.2 Ecosystems: Carrying Capacity

Carrying Capacity worksheet- This worksheet is a perfect fit for recalling accurate science
Population Dynamics- This is a Biointeractive resource that provides basic information related to Logistic and Expoential Growth. A simple click and learn activity that can be done in a one to one classroom or a one computer classroom. Teacher guide provided. This could be a good example for Cognitive Demand Demonstrating Science Knowledge.
MoveBank-Movebank is a free, online database of animal tracking data hosted by the Max Planck Institute for Ornithology.
ODNR Examine wildlife populations in Ohio like bald eagles, beavers or white-tailed deer. The Ohio Department of Natural Resources provides population data over the years. Examine the factors that have impacted the carrying capacity. http://wildlife.ohiodnr.gov/species-and-habitats/fish-and-wildlife-research

B.DI.3.1 Loss of Diversity: Climate Change

Historical Climates of Ohio-These links provide access to descriptive information and explanatory notes, maps, searches, visualizations and more. Global datasets are provided.
Chasing Coral-Documentary about how our oceans are changing.
Chasing Coral video guide with key
Feedback loops- This site provides information on climate feedback loops.
NOAA's Ocean Acidification Program has a variety of lessons and resources for learning how marine biodiversity is being impacted by increased carbon levels and how marine life can actually mitigate the effects of climate change. Some examples include:

- Impacts of Carbonated Seawater on Mussel and Oyster Populations
- Impacts of Ocean Acidification on Shells
- Balancing Act: Otters, Urchins and Kelp

NASA Global Change Master Directory Data sets, charts and graphs, tools to analyze climate change. Earth Science data and services.
NOAA Daily Weather Records Trends in US weather patterns.
Claim Evidence Reasoning Claim Evidence Reasoning in the Science Classroom
NASA GLOBAL Climate Change, Vital Signs of the Planet: Climate Change one minute videos explaining the earth science of climate change.
Climate Change Impacts in Ohio EPA information on projected impacts to Ohio as climate change.
Nasa Climate change inquiry labs A variety of activities online activities related to Climate change (some looking at greenhouse gases, ocean temperatures, and sea level rising)
Data Nugget Coral Bleaching and climate change this site has a variety of research activities that are currently going on. The research utilizes CER and data analysis. They also provide differentiated handouts.
Data Set related to Coral Bleaching-This is a classroom activity in which students use authentic data to assess the threat of coral bleaching around the world.
NOAA's Climate Program Office maintains CLEAN, a clearinghouse of scientifically and pedagogically reviewed digital resources for teaching about climate's influence on you and society and your influence on climate.
Ohio Sea Grant has a variety of lessons addressing climate change on a regional level. Some examples include:

- Climate Change and Aquatic Invaders

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Trees on the Move
Estuary Values and Changes
Climate Change Bird Atlas

B.DI.3.2 Loss of Diversity: Anthropocene Effects

Anthropocene Click and Learn activity- An engaging activity where students can explore key human impacts on the environment and how they have affected Earth's landscape, ocean, atmosphere, and biodiversity.

Poster Biodiversity in the age of humans-this poster illustrates the many ways humans affect the earth.

Anthropocene Resources- The pack presents a selection of evidence and asks pupils to decide for themselves if the Earth has entered the Anthropocene yet and if so, when? It can be used either as a group or individual exercise, and provides experience in developing analytical skills.

Anthropocene Click and Learn- an engaging interactive that explores key human impacts on the environment and how they have affected Earth's landscape, ocean, atmosphere, and biodiversity.

HHMI Anthropocene: Human impact on the environment

Educator guide

Project WILD and Aquatic WILD help students learn basic concepts about wild animals, their needs and importance and their relationships to people and the environment. The activity guides are available to educators low cost or free of charge when they attend a workshop. Information about upcoming workshops are available on the ODNR Website at http://wildlife.ohiodnr.gov/education-and-outdoor-discovery/conservation-education-project-wild

- In the Project WILD activity *Ecosystem Architects*, students simulate the restoration of a healthy, sustainable ecosystem on the site of an abandoned shopping center or an island in a river corridor within an urban area. Students share their ecosystem designs, comparing and contrasting the two types of systems and the influencing factors on these systems.

NOAA's Ocean Acidification Program has a variety of lessons and resources for learning how marine biodiversity is being impacted by increased carbon levels and how marine life can actually mitigate the effects of climate change. Some examples include:

Impacts of Carbonated Seawater on Mussel and Oyster Populations
Impacts of Ocean Acidification on Shells

B.DI.3.3 Loss of Diversity: Extinction

Earth Viewer- This is an interactive view that allows students to investigation deep time. The accompanying student worksheet allows students to investigate mass extinction.

Mass Extinction Events: American Museum of Natural History explanations for Mass Extinction Events

Mass Extinction Crisis: Center for Biological Diversity examines mass extinction events

Biodiversity Hot Spots: Location, development, and threats to biodiversity hot spots.

Reintroduction Programs Reintroduction programs in collaboration with zoos to boost natural populations.

Should we bring back Extinct Species? Process and consideration of bringing back extinct species.

Project WILD and Aquatic WILD help students learn basic concepts about wild animals, their needs and importance and their relationships to people and the environment. The activity guides are available to educators low cost or free of charge when they attend a workshop. Information about upcoming workshops are available on the ODNR Website at http://wildlife.ohiodnr.gov/education-and-outdoor-discovery/conservation-education-project-wild

- In the Aquatic WILD activity *Conservation Messaging*, students research threats to fish and aquatic habitats; explain what can be done to conserve and restore aquatic habitats; and plan and produce a public service announcement (PSA) that helps inform people about actions they can take to conserve fish and their habitats.

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B.DI.3.4 Loss of Diversity: Invasive Species

Ohio Invasive Species: Invasive species in Ohio

Population Sampling local species Use population sampling techniques to analyze invasive species populations

US Global CHange Research Program Health Assessment: Information on vector borne diseases and the expansion of disease associated with climate change and expansion of vectors in habitats.

Project Learning Tree STEM Invasive Species: Resources and activities on invasive species

Introduction to Invasive Species: National Geographic activities and videos related to invasive species

Ohio Sea Grant has a variety of lessons addressing climate change on a regional level. Some examples include:

Climate Change and Aquatic Invaders

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CELLS

Building on knowledge from middle school (cell theory, cell division and differentiation), this topic focuses on the cell as a system itself (single-celled organism) and as part of larger systems (multicellular organism), sometimes as part of a multicellular organism, always as part of an ecosystem. The cell is a system that conducts a variety of functions associated with life. Details of cellular processes such as photosynthesis, chemosynthesis, cellular respiration, biosynthesis of macromolecules is addressed at this grade level. The concept of the cell and its parts as a functioning biochemical system is more important than just memorizing the parts of the cell.

B.C.1- Cell Structure

Every cell produces a membrane through which substances pass differentially maintaining homeostasis. Molecular properties and concentration of the substances determine which molecules pass freely and which molecules require the input of energy. In all but quite primitive cells, a complex network of proteins provides organization and shape. **Within the cell** are specialized parts that transport materials, transform energy, build proteins, dispose of waste, and provide information feedback and movement. Many chemical reactions that occur in some cells of multicellular organisms do not occur in most of the other cells of the organism.

Prokaryotes, simple single-celled organisms.are first found in the fossil record about 3.8 billion years ago. Cells with nuclei, eukaryotes, developed one billion years ago and from which increasingly complex multicellular organisms descended.

B.C.2 Cellular Processes

Living cells interact with, and can have an impact on, their environment. Carbon is a necessary element that cells acquire from their environment. Cells use carbon, along with hydrogen, oxygen, nitrogen, phosphorus and sulfur, during essential processes like respiration, photosynthesis, chemosynthesis, and biosynthesis of macromolecules (e.g., proteins, lipids and carbohydrates). Chemical reactions that occur within a cell can cause the storage or release of energy by forming or breaking chemical bonds. Specialized proteins, enzymes, lower the activation energy required for chemical reactions, increasing reaction rate.

Positive and negative feedback mechanisms regulate internal cell functions as external conditions vary. Most cells function within a narrow range of temperature and pH. Variations in external conditions that exceed the optimal range for a cell can affect the rate at which essential chemical reactions occur in that cell. At very low temperatures, reaction rates are slow.

High temperatures can irreversibly change the structure of most protein molecules. Changes in pH beyond the optimal range of the cell can alter the structure of most protein molecules and change how molecules within the cell interact.

The sequence of DNA bases on a chromosome determines the sequence of amino acids in a protein. Enzymatic **proteins catalyze** most chemical reactions in cells. Protein molecules are long, folded chains made from combinations of the 20 common amino-acids found in the cell. The activity of each protein molecule results from its sequence of amino acids and the shape the chain takes as a result of that sequence.

Note 1: The idea that protein molecules assembled by cells conduct the work that goes on inside and outside the cells in an organism can be learned without going into the biochemical details. It is sufficient for students to know that the molecules involved are different configurations of a few amino acids and that the different shapes of the molecules influence what they do.
Note 2: Emphasis is on inputs and outputs of matter and the transfer and transformation of energy in biological processes. Specific steps, names of enzymes, and intermediates of the pathways for these processes are beyond the scope of the standards.

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ↔		Least Complex	
B.C: Cells				
B.C.1 Cell Structure ○ Structure, function and interrelatedness of cell organelles ○ Eukaryotic cells and prokaryotic cells	**B.C.1a** Compare and contrast a prokaryotic cell and a eukaryotic cell.	**B.C.1.b** Match the organelle with the process it helps to execute (e.g., chloroplast, photosynthesis).	**B.C.1.c** Identify the function of the cell membrane.	NONE
B.C.2 Cellular Processes ○ Characteristics of life regulated by cellular processes ○ Photosynthesis, chemosynthesis, cellular respiration, biosynthesis of macromolecules	**B.C.2a** Describe how the cell needs specific conditions (e.g., temperature, pH) in order to perform its essential functions (e.g., respiration, photosynthesis).	**B.C.2b** Complete a diagram that depicts the process of photosynthesis.	**B.C.2c** Identify photosynthesis and cellular respiration as occurring in a cell.	HS-LS1-3 Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. HS-LS1-5 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. HS-LS1-6 Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. HS-LS1-7 Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.

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EVIDENCE OF LEARNING

Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

Designing technological / engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.C.1- Cell Structure			
	Observe how materials transport across a selectively permeable membrane and how various cells respond to different environmental conditions to maintain a dynamic equilibrium. Construct a model of the phospholipid bilayer and predict the movement of various materials across the membrane.	Use a model of the phospholipid bilayer and demonstrate transport of various materials across a semipermeable membrane that maintains homeostasis. Provide an evolutionary explanation for why some cell organelles have double membranes.	Identify different types of transport and how materials move within a selectively permeable membrane and may or may not require the input of energy.
		Model the synthesis of a hormone such as insulin as it is synthesized within the cell and becomes modified along the way. Represent cell organelle interaction along with the dynamic nature and complexity of a cell.	Identify the interactivity of organelles resulting in cellular processes such as protein synthesis and metabolism
	Collect and analyze microscopic organisms from a local pond or stream. Infer evolutionary relationships between organisms according to	Create a graphic organizer consisting of various cells (eg. unicellular and multicellular) and cell structures. Have students organize them according to size. Investigate	

	ancestral traits and derived characteristics like cell parts and multicellularity.	which type of microscope would be best to visualize the cell or structure.	
Research the cause and effect of various homeostatic diseases (Type 2 diabetes, high blood pressure, gout) and develop solutions to achieve homeostatic balance for patients that suffer from this disease. Suggest an evolutionary explanation (novel environments) to explain the increased incidence of diabetes worldwide.	Plan and conduct an investigation that feedback mechanisms maintain homeostasis. Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.	Illustrate a model of negative or positive feedback including sensor, control center, effectors, and variables being regulated.	Compare and contrast negative and positive feedback mechanisms.
B.C.2- Cellular Processes			
Develop a product such as yogurt that could address dietary concerns, restraints, and restrictions for individuals like diabetics, infants, and body builders. In addition, students evaluate how yogurt has impacted society consider topics such as lifestyle, culture, economics, and how this product has played a role in society.	Design a lab studying yeast and adjust variables such as temperature, pH, food sources, etc. Use probes to measure gas exchange.	Provide data from fermentation activities and evaluate variables and outcomes such as yeast, Kombucha, and sauerkraut.	Identify location, inputs and outputs associated with a cell energy process.
Plan and design an investigation using algae, mushrooms or other microorganisms to biosynthesize a natural product that can be used for commercial application.	Research various biomolecules found in food. Investigate an unknown food source and identify its biomolecule components. Evaluate and critique popular food options on the market and determine if nutritional analysis is factual. Using nutritional data	Research various techniques to extract oil or hormones from algae.Infer the structural changes(cellular inclusions, smooth endoplasmic reticulum proliferation) to the algal cells that these techniques may incur .Which strains of algae utilize the most cost-efficient metabolic pathways of oil or hormone production?	Construct models of various biomolecules. Identify basic building blocks, functions, and location of biomolecules in food and/or the environment.

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	create a new marketing promotion for healthier food choices and present findings.	.	
.	Plan and design an investigation to determine the factors (e.g. temperature, pH, substrate concentration, etc.) that affect the activity of enzymes on their substrates (e.g. peroxidase). Research diseases caused by enzymatic deficiencies and propose possible solutions or evaluate how medical breakthroughs have solved the problem (eg. lactase persistence, adrenoleukodystrophy, mitochondrial disorders)	Using a simulation or data predict the effects of different variables (temperature, pH or salinity) on enzyme structure and function. Given a graph, interpret and analyze activation energy with optimal pH and temperature.	Identify the structure and function of enzymes and substrates applying models such as lock and key or induced fit.
Design a “green” environment (school, house, microenvironment) that demonstrates sustainable environmental practices, such as vegetated green roof systems to improve air quality.The design will encompass efficient use of fuel resources and building materials to lower carbon footprint and reduce greenhouse gas emissions. Students generate an argument and present data justifying how their design improves sustainability.Rationale: Promote awareness of photosynthetic processes as a component of the Earth’s CO_2 recycling system.	Design experiments to study gas exchange in photosynthetic organisms. Analyzing the data generated and argument to justify which environmental conditions are the most efficient for the photosynthetic organism. Optional extension: Utilize probes to measure gas exchange	Generate a model to depict the role of photosynthesis and cellular respiration and the cycling of matter and energy through biogeochemical cycles(see National Geographic website below).	Identify key organelles as well as the inputs and outputs of matter and energy utilized by photosynthesis and cellular respiration

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Resources

B.C.1- Cell Structure

University of Toledo- Scope The SCOPE program provides classroom access to cyber-enabled microscopes (a scanning electron microscope [SEM] and a confocal light directly from their classrooms free of charge. They will work with the teacher to set up this service. microscope).

Virtual Lab Membranes: Investigate how pressure, temperature, and extracellular solute concentration affect water movement through cell membranes. You'll interact with this virtual lab to collect data, make observations, analyze findings, and draw conclusions. (Requires Java Plug-In)

Variety of activities on Cells.

An extensive general resource for teachers to enhance the study of the cell in the classroom.

Resolving power:

This link will provide a guide for the size of a variety of objects with magnification and they type of microscope to use to view the item.

B.C.2- Cellular Processes

Fermentation Lab Good resource to use when time and materials are limited. Mr. Carter demonstrates a simple demonstration on the fermentation of sucrose and flour by yeast.

Virtual Lab Fermentation Experiment Interactive animation illustrating Yeast Fermentation.

Virtual Lab: Organic Molecules Cells contain many organic molecules. These molecules are essential to life. Many of them are acquired from the food we eat. In this virtual lab you will study carbohydrates, proteins and fats.

Murder and a Meal Lab This lab guides students to solve a murder mystery utilizing the presence of macromolecules in the evidence.

Enzyme lab: In this investigation students will determine the effects of substrate concentration and pH on the initial rate of an enzyme-catalyzed reaction.

The Ecological Footprint Dilemma A case study found through the **National Center for Case study Teaching in Science** that focuses on the design of eco-friendly environments and the challenge of developing a more sustainable lifestyle:

NOAA - Chemosynthesis for the Classroom **- Laboratory Experience** that utilizes chemosynthetic bacteria in the classroom to determine what changes affect succession in the development of chemosynthetic bacterial communities.

Input/Output Energy photosynthesis / cellular respiration This virtual lab allows students to review and order the processes that make up photosynthesis and cellular respiration.

Glencoe Labs-Comparing Plant growth Under Different Colored Lights This virtual lab allows students to perform an experiment to investigate what colors of the light spectrum cause the most plant growth.

Feedback (negative or positive) can stabilize or destabilize a system Paul Andersen explains how feedback loops allow living organisms to maintain homeostasis. He uses thermoregulation in mammals to explain how a negative feedback loop functions. He uses fruit ripening to explain how a positive feedback loop functions. He also explains what can happen when a feedback loop is altered.

Teaching Energy Across the Sciences, K-12 This book, from NSTA, gives you the strategies and tools you need to help your students understand energy as a concept that cuts across all sciences.

National Geographic Website-The Earth Has Lungs This website uses satellite imagery to demonstrate the vast planetary breathing system- a giant green machine that pulls enormous quantities of carbon dioxide out of the air,especially in the warmer months.This site is great for demonstrating the effect of photosynthesis on the Earth's CO2 recycling system.

CHEMISTRY

INTRODUCTION AND SYLLABUS

COURSE DESCRIPTION

Chemistry is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires three one-unit courses. Each course should include inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

Chemistry comprises a systematic study of the predictive physical interactions of matter and subsequent events that occur in the natural world. The study of matter through the exploration of classification, its structure and its interactions is how this course is organized. Investigations are used to understand and explain the behavior of matter in a variety of inquiry and design scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications. An understanding of leading theories and how they have informed current knowledge prepares students with higher order cognitive capabilities of evaluation, prediction and application.

Cross Curriculum connections link to ELA and Technology.

COURSE CONTENT SYLLABUS

The following information may be taught in any order; there is no ODE-recommended sequence.

C.PM: STRUCTURE AND PROPERTIES OF MATTER

- C.PM.1: Atomic structure
  - Evolution of atomic models/theory
  - Electrons
  - Electron configurations
- C.PM.2: Periodic Table
  - Properties
  - Trends
- C.PM.3: Chemical bonding
  - Ionic
  - Polar/covalent
- C.PM.4: Representing compounds
  - Formula writing
  - Nomenclature
  - Models and shapes (Lewis structures, ball and stick, molecular geometries)
- C.PM.5: Quantifying matter
- C.PM.6: Intermolecular forces of attraction
  - Types and strengths
  - Implications for properties of substances
  - Melting and boiling point
  - Solubility

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  - Vapor pressure

C.IM: INTERACTIONS OF MATTER

- C.IM.1: Chemical reactions
  - Types of reactions
  - Kinetics
  - Energy
  - Equilibrium
  - Acids/bases
- C.IM.2: Gas laws
  - Pressure, volume and temperature
  - Ideal gas law
- C.IM.3: Stoichiometry
  - Molecular calculations
  - Solutions
  - Limiting reagents

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Structure & Properties of Matter

C.PM.1- Atomic Structure

The Physical Science course included properties and locations of protons, neutrons and electrons, atomic number, mass number, cations and anions, isotopes and the strong nuclear force that hold the nucleus together. In this course, the historical development of the atom and the positions of electrons are explored in greater detail. Atomic models are constructed to explain experimental evidence and make predictions. The changes in the atomic model over time exemplify how scientific knowledge changes as new evidence emerges and how technological advancements like electricity extend the boundaries of scientific knowledge. Thompson's study of electrical discharges in cathode-ray tubes led to the discovery of the electron and the development of the plum pudding model of the atom. Rutherford's experiment, in which he bombarded gold foil with α-particles, led to the discovery that most of the atom consists of empty space with a relatively small, positively charged nucleus. Bohr used data from atomic spectra to propose a planetary model of the atom in which electrons orbit the nucleus, like planets around the sun. Later, Shrödinger used the idea that electrons travel in waves to develop a model in which electrons travel randomly in regions of space called orbitals (quantum mechanical model).

Based on the quantum mechanical model, it is not possible to predict exactly where electrons are located by there is a region of space surrounding the nucleus in which there is a high probability of finding an electron (electron cloud or orbital). Data from atomic spectra (emission and absorption) gives evidence that electrons can only exist at certain discrete energy levels and not at energies between these levels.

Atoms are usually in the ground state where the electrons occupy orbitals with the lowest available energy. However, the atom can become excited when the electrons absorb a photon with the precise amount of energy (indicated by the frequency of the photon) to move to an orbital with higher energy. Any photon without this precise amount of energy will be ignored by the electron. The atom exists in the excited state for a very short amount of time. When an electron drops back down to the lower energy level, it emits a photon that has energy equal to the energy difference between the levels. The amount of energy is indicated by the frequency of the light that is given off and can be measured. Each element has a unique emission and absorption spectrum due to its unique electron configuration and specific electron energy jumps that are possible for that element. Being aware of the quantum mechanical model as the currently accepted model for the atom is important for science literacy as it explains and predicts subatomic interactions, but details should be reserved for more advanced study.

Electron energy levels consist of sublevels (s, p, d, and f), each with a characteristic number and shape of orbitals. Orbital diagrams and electron configuration can be constructed to show the location of the electrons in an atom using established rules. Valence electrons are responsible for most of the chemical properties of elements. In this course, electron configuration (extended and noble gas notation) and orbital diagrams can be shown for any element in the first three periods.

Although the quantum mechanical model of the atom explains the most experimental evidence, other models can be helpful. Thinking of atoms as indivisible spheres is useful in explaining many physical properties of substances, such as the state (solid liquid or gas) of a substance at room temperature. Bohr's planetary model is useful to explain and predict periodic trends in the properties of elements.

Note: Quantum numbers and equations of de Broglie, Shrödinger and Planck are beyond the scope of this course.

C.PM.2- Periodic Table

In the Physical Science course, the concept that elements are placed in order of increasing atomic number in the periodic table such that elements with similar properties are placed in the same column is introduced. How the periodic table is divided into groups, families, periods, metals, nonmetals and metalloids is also included. In this course, with more information about the electron configuration of elements, similarities in the configuration of the valence electrons for a particular group can be observed. The electron configuration of an atom can be written from the position on the periodic table. The repeating pattern in the electron configuration for elements on the periodic table explains many of the trends in the properties observed. Atomic theory is used to describe and explain trends in properties across periods or down columns including atomic radii, ionic radii, first ionization energies, electron negativities and whether the element is a solid or gas at room temperature. Additional ionization energies, electron affinities and periodic properties of the transition elements, lanthanide and actinide series is reserved for more advanced study.

C.PM.3- Chemical Bonding

Content in the Physical Science course included atoms with unpaired electrons tend to form ionic and covalent bonds with other atoms forming molecules, ionic lattices or network covalent structures. In this course, electron configuration, electronegativity values and energy considerations will be applied to bonding and the properties of materials with different types of bonding.

Atoms of many elements are more stable as they are bonded to other atoms. In such cases, as atoms bond, energy is released to the surroundings resulting in a system with lower energy. An atom's electron configuration, particularly the valence electrons, determines how an atom interacts with other atoms. Molecules, ionic lattices, and network covalent structures have different, yet predictable, properties that depend on the identity of the elements and the types of bonds formed.

Differences in electronegativity values can be used to predict where a bond fits on the continuum between ionic and covalent bonds. The polarity of a bond depends on the electronegativity difference and the distance between the atoms (bond length). Polar covalent bonds are introduced as an intermediary between ionic and pure covalent bonds. The concept of metallic bonding also is introduced to explain many of the properties of metals (e.g., conductivity). Since most compounds contain multiple bonds, a substance may contain more than one type of bond. Carbon atoms can bond together and with other atoms, especially hydrogen, oxygen, nitrogen and sulfur, to form chains, rings and branching networks that are present in a variety of important compounds, including synthetic polymers, fossil fuels and the large molecules essential to life. Detailed study of the structure of molecules responsible for life is reserved for more advanced courses.

C.PM.4- Representing Compounds

Using the periodic table, formulas of ionic compounds containing specific elements can be predicted. This can include ionic compounds made up of elements from groups 1, 2, 17, hydrogen, oxygen and polyatomic ions if given the formula and charge of the polyatomic ion. Given the formula, a compound can be named using conventional systems that include Greek prefixes and Roman numerals where appropriate. Given the name of an ionic or covalent substance, formulas can be written.

Many different models can be used to represent compounds including chemical formulas, Lewis structures, and ball and stick models. These models can be used to visualize atoms and molecules and to predict the properties of substances. Each type of representation provides unique information about the compound. Different representations are better suited for particular substances.

C.PM.5- Quantifying Matter

In earlier grades, properties of materials were quantified with measurements always associated with some error. In this course, scientific protocols for quantifying the properties of matter accurately and precisely are studied. Using metric measuring systems, significant digits or figures, scientific notation, error analysis and dimensional analysis are vital to scientific communication. There are three domains of magnitude in size and time: the macroscopic (human) domain, the cosmic domain and the submicroscopic (atomic and subatomic) domain. Measurements in the cosmic domain and submicroscopic domains require complex instruments and/or procedures.

Matter can be quantified in a way that macroscopic properties such as mass can reflect the number of particles present. Elemental samples are a mixture of several isotopes with different masses. The atomic mass of an element is calculated given the mass and relative abundance of each isotope of the element as it exists in nature. Because the mass of an atom is very small, the mole is used to translate between the atomic and macroscopic levels. A mole is equal to the number of atoms in exactly 12 grams of the isotope carbon-12. The mass of one mole of a substance is equal to its molar mass in grams. The molar mass for a substance an be used in conjunction with Avogadro's number and the density of a substance to convert between mass, moles, volume, and number of particles of a sample.

C.PM.6- Intermolecular Forces of Attraction

In middle school, solids, liquids and gases were explored in relation to the spacing of the particles, motion of the particles, and strength of attraction between the particles, motion of the particles, and strength of attraction between the particles that make up the substance. The intermolecular forces of attraction between particles that determine whether a substance is a solid, liquid or gas at room temperature are addressed in greater detail in this course. Intermolecular attractions are generally weak when compared to the intramolecular bonds, but span a wide range of strengths.

The composition of a substance and the shape and polarity of a molecule are particularly important in determining the type and strength of bonding and intermolecular interactions. Types of intermolecular attractions include London dispersion forces (present between all molecules), dipole-dipole forces (present between polar molecules) and hydrogen bonding (a special case of dipole-dipole where hydrogen is bonded to a highly electronegative atom such as fluorine, oxygen, or nitrogen), each with its own characteristic relative strength.

The configuration of atoms in a molecule determines the strength of the forces (bonds or intermolecular forces) between the particles and therefore the physical properties (e.g., melting point, boiling point, solubility, vapor pressure) of a material. For a given substance, the average kinetic energy (temperature) needed for a change of state to occur depends upon the strength of the intermolecular forces between the particles. Therefore, the melting point and boiling point depend upon the amount of energy that is needed to overcome the attractions between the particles. Substances that have strong intermolecular forces or are made up of three-dimensional networks of ionic or covalent bonds tend to be solids at room temperature and have high melting and boiling points. Nonpolar organic molecules are held together by weak London dispersion forces. However, substances with longer chains provide more opportunities for these attractions and tend to have higher melting and boiling points. Increased branching of organic molecules results in lower melting and boiling points due to interference with the intermolecular attractions.

Substances will have a greater solubility when dissolving in a solvent with similar intermolecular forces. If the substances have different intermolecular forces, they are more likely to interact with themselves than the other substance and remain separated from each other. Water is a polar molecule and it is often used as a solvent since most ionic and polar covalent substances will dissolve in it. In order for an ionic substance to dissolve in water, the attractive forces between the ions must be overcome by the dipole-dipole interactions with the water. Dissolving of a solute in water is an example of a process that is difficult to classify as a chemical or physical change and it is not appropriate to have students classify it one way or another.

Evaporation occurs when the particles with enough kinetic energy to overcome the attractive forces separate from the rest of the sample to become a gas. The pressure of these particles is called vapor pressure. Vapor pressure increases with temperature. Particles with larger intermolecular forces have lower vapor pressures at a given temperature since the particles require more energy to overcome the attractive forces between them. Molecular substances often evaporate more due to the weak attractions between the particles and can often be detected by their odor. Liquids boil when their vapor pressure is equal to atmospheric pressure. In solid water, there is a network of hydrogen bonds between the particles that gives it an open structure. This is why water expands as it freezes and why solid water has a lower density than liquid water. This has important implications for life (e.g., ice floating on water acts as an insulator in bodies of water to keep the temperature of the rest of the water above freezing.)

Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟵⟶		Least Complex	
Structure and Properties of Matter				
C.PM.1 Atomic structure ○ Evolution of atomic models/theory ○ Electrons ○ Electron configurations	**C.PM.1a** Identify the location of a valence electron and/or how valance electrons affect an atom's interactions.	**C.PM.1b** Identify part(s) of an atom (i.e., protons, neutrons, electrons).	**C.PM.1c** Identify a diagram or model of an atom.	NONE
C.PM.2 Periodic table ○ Properties ○ Trends	**C.PM.2a** Use the periodic table to answer questions about types of elements and the properties of elements (e.g., number of outer electrons, groupings).	**C.PM.2b** Recognize that elements are organized on the periodic table by their properties, number of protons, and number of outer electrons.	**C.PM.2c** Identify an element(s) on the periodic table.	HS-PS1-1 Use the periodic table as a model to predict the relative properties of elements based on patterns of the electrons in the outermost energy levels of atoms.
C.PM.3 Chemical bonding ○ Ionic ○ Polar/covalent	**C.PM.3a** Identify the type of chemical bonding that has occurred in a given compound.	**C.PM.3b** Compare the characteristics of an ionic bond and a covalent bond.	**C.PM.3c** Identify bonding as an interaction between atoms.	HS-PS1-1 Use the periodic table as a model to predict the relative properties of elements based on patterns of the electrons in the outermost energy levels of atoms.
C.PM.4 Representing compounds ○ Formula writing ○ Nomenclature ○ Models and shapes (Lewis structures, ball-and-stick, molecular geometries)	**C.PM.4a** Represent a chemical compound with a ball-and-stick model or chemical formula.	**C.PM.4b** Build a model of a chemical compound in a variety of ways (e.g., ball-and-stick model).	**C.PM.4c** Identify a compound as two or more elements coming together (combining).	HS-PS1-2 Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
C.PM.5 Quantifying matter	Complex and advanced learning standards in Ohio's New Learning Standards are not included in the extended standards.			HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
C.PM.6 Intermolecular chemical bonding forces of attraction ○ Types and strengths	**C.PM.6a** Explore the properties of water and how they change when water is part of a solution (e.g., salt	**C.PM.6b** Perform a task with a fixed amount of water and given amounts of a solute (e.g., powdered drink mix) to	**C.PM.6c** Identify a solution when given a field of choices.	HS-PS1-3 Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟷		Least Complex	
○ Implications for properties of substances ▪ Melting and boiling point ▪ Solubility ▪ Vapor pressure	water solutions).	observe solutions and supersaturated solutions.		scale to infer the strength of electrical forces between the particles. HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

EVIDENCE OF LEARNING

Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

Designing technological / engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
C.PM.1- Atomic Structure Evolution of Atomic Models			
Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence to critique the atomic models based on the technology available at the time of their development. Develop, communicate, and justify an evidence-based scientific explanation	Plan an activity which utilizes principles used to develop atomic models (e.g. a black-box problem)	Compare the nature of protons, neutrons, and electrons among different atomic models Compare/contrast the pros and cons of picking a particular model.	Identify atomic models (Dalton's, Thomson's, Rutherford's, and Bohr's) and the work used to produce each of these models. Recognize differences which exist among atomic models

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supporting the current model of an atom			
C.PM.1- Atomic Structure Electrons			
Using knowledge and/or understanding of various ions and their electron location construct a plan or proposal for a community firework show. Proposal must contain a list of materials, including the chemicals, safety procedures, environmental impact and possible cost.	Identify different colors emitted from ions through the use of the flame test. Using these colors generate a hypothesis of energy emitted with understanding of the electromagnetic spectrum.	Compare and contrast the shapes of s and p orbitals Compare various wavelengths of light (visible and nonvisible) in terms of frequency and relative energy. Explain why an atom can absorb only certain wavelengths of light. Contrast the mechanism of energy changes and the appearance of absorption and emission spectra. Describe the relationship between the electron structures of atoms and light absorption and emission.	Interpret the classic historical experiments that were used to identify the components of an atom and behavior of electrons Describe the sublevels of electron energy levels Identify valence electrons as the highest energy electrons in the atom and use the octet rule to predict the most stable ion formed.
C.PM.1- Atomic Structure Electron Configurations			
	Design an investigation using group 2 elements that illustrates the reactivity of the elements as you move down the group. Interpret data to explain this reasoning based on the electron configurations of each element.	Compare the electron configuration of various ions based on data from an experiment (e.g. flame test, spectral tubes). Then explore the color of various salts by looking at the electromagnetic spectrum.	Identify the extended and noble gas notation electron configurations for elements in the first three periods. (See link for electron configuration bingo in resources). Using the periodic table, determine the electron configuration of the valence level of an atom.

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			Construct an orbital diagram or electron configuration to show the location of electrons in an atom
C.PM.2- Periodic Table Properties			
	Critique a variety of manufactured goods (containers to transport chemicals and hazardous material, copper wires used for electricity, disposable methods for chemicals) and show how the chemical properties of the component materials were used to achieve or not achieve the desired qualities.	Compare and contrast different elements on the periodic table including their different properties and locations. Given a metalloid off of the periodic table judge whether the metalloid is more likely to behave as a metal or nonmetal. Defend your choice.	Recall the organization of the periodic table by increasing atomic number and identify groups, periods, metals, metalloids, and nonmetals.
C.PM.2- Periodic Table Trends			
Develop a proposal for the construction of an outdoor art installation in various environments/climates. Det ermine which metal(s) would have the optimal properties for your project. Present and defend your proposal to a panel of experts.	Predict the properties of a new element and its potential applications.	Create a concept map to show the relationships between the trends of the periodic table and their electron configurations. Predict relative properties of elements using the periodic table and the patterns of electrons in the outermost energy level of atoms (valence) Develop a hypothesis using two different elements and identify which element will be more reactive. Defend your answer.	Describe ionization energy and relate to the atomic structure. Describe electronegativity and relate to the atomic structure. Describe periodic trends in ionic size, electron affinity, melting and boiling points and relate them to atomic structure. Describe atomic radius and relate to the atomic structure.

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C.PM.3- Chemical Bonding Ionic			
Critique the efficacy and potency of drugs designed by engineers to address crystallization problems in the human body.	Design and conduct an investigation to distinguish between ionic, polar covalent, nonpolar covalent, and metallic bonds based on properties (e.g. melting point, solubility, conductivity) Design an experiment to test the effectiveness of a water softener system's ability to remove ions from water.	Compare and contrast the stability of ions when they are separated vs when they are in their lattice. Construct models or diagrams (Lewis Dot structures, ball and stick models, or other models) of common compounds and molecules (e.g., NaCl, SiO_2, O_2, H_2, CO_2) and distinguish between ionically and covalently bonded compounds. Explain the tendency of elements to transfer or share electrons based on their location Periodic Table. Using electron configurations, hypothesize how an atom becomes a cation or anion, and illustrate how and why they would form ionic compounds.	Define Bond energy and recognize that bond-breaking is an endothermic process and bond-forming is an exothermic process. Represent the formation of a bond using electron configurations of the individual atoms.
C.PM.3- Chemical Bonding Polar/Covalent			
Propose a method to evaluate the ability of plastics to be recycled based on the understanding of the plastics polarity. Evaluate the properties of DNA based on the bonds (polar and nonpolar) within its chemical structure and how it relates to DNA sequencing and/or a	Devise a procedure to evaluate the physical and chemical properties to develop predictions and support claims about compounds' classification as ionic, polar or covalent.	Determine if bonds and molecules are polar by determining the direction of dipole moment of the individual bonds. Using electron dot diagrams, generate models showing that molecular compounds result from atoms sharing electrons. Include carbon bonds showing the formation of chains, rings, and branching networks.	Distinguish between ionic and polar/nonpolar covalent bonds based on their electronegativity values. Write equations for covalent bond formation between two atoms using Lewis structures. Explain the difference between a single, double, and triple bond in terms of electrons shared.

forensic/medical applications. Evaluate and critique the impact of a synthetic polymer, fossil fuel, or biological macromolecule on society/environment/health.		Distinguish between bond polarity and molecular polarity. Construct models illustrating how a nonpolar molecule can be formed from polar bonds. Compare and contrast the stability of atoms when they are separated vs when they are bonded. Explain using experimental evidence how the properties of macromolecules depend on the properties of the molecules used in the formation, the length, and structure of the polymer chain. Apply the relationship between bond energy and length of single, double, and triple bonds (conceptual, no numbers).	Recognize that certain small molecules (monomers) react with one another in repetitive fashion (polymerization) to form long chain macromolecules (polymers). Recall that polymers can be natural or synthetic.
C.PM.3- Chemical Bonding Metallic			
Critique the advantages and disadvantages of different metals and alloys for bridge construction.	Plan an experiment to illustrate how freely moving electrons in metallic bonds affect properties such as conductivity, malleability, and ductility.	Compare and contrast electrons in a metallic bond vs. a covalent bond. Explain how the structure of metal atoms gives it the ability to conduct heat and electricity. Explore the extent to which a variety of solid materials conduct electricity in order to rank the materials from good conductors to poor conductors. Based on the conductivity data, determine patterns of location on the Periodic Table for the good conductors versus the poor conductors.	Illustrate how valence electrons of metals can be modeled as a sea of electrons moving freely that are not associated with individual atoms Recognize a metal's capability of conductivity of electricity and heat due to its metallic bonding.

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C.PM.4- Representing Compounds Formula Writing			
		Complete an activity that involves identifying chemical compounds on household items and developing their formulas based on their names. Construct a prototype of a game to enhance the understanding of formula writing and nomenclature. Allow other students to evaluate and critique appropriateness of game.	Given elements from periodic table and/or polyatomic ions predict the formula of a compound. Write a formula from the name of an acid.
C.PM.4- Representing Compounds Nomenclature			
		Construct a concept map to illustrate the correct path to take to write an appropriate formula when given certain elements.	Given the formula of an ionic compound or a binary covalent compound determine the compounds name (student should be able to use the stock system and given a list polyatomic ions names). Name an acid based on its chemical formula.

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C.PM.4- Representing Compounds Models and Shapes (Lewis Structures, Ball and Stick, Molecular Geometries)			
		Determine for different scenarios which type of model (chemical formula, Lewis structure, and ball-and-stick model) is the best representation. Implementing VSEPR identify the different shapes within a large macromolecule (caffeine, dopamine, serotonin)	Construct simple Lewis structures of compound made up of hydrogen, carbon, nitrogen, oxygen, phosphorus, sulfur and the halogens. Predict the three-dimensional shapes of simple Lewis structures using valence shell electron pair repulsion (VSEPR) theory. Construct three-dimensional ball-and-stick models to determine the shapes of simple covalent compounds
C.PM.5- Quantifying Matter			
Design an investigation to show that the volume of any liquid sample is constant when divided by its mass Devise a method to determine the value of a non-quantifiable variable (e.g. thickness of aluminum foil, number of sand particles, volume of a drop of a liquid)	Design an procedure to measure volume of an irregular solid using metric system. Provide your answer using correct significant figures and unit. Evaluate the conclusion of a scientific experiment based on the understanding of error, accuracy, and precision.	Communicate situations when scientific notations are appropriate to be used and the reason why. Compare and contrast accuracy and precision using data. Carry out laboratory measurements with a variety of equipment (e.g. graduated cylinders, beakers, balances, etc.) report measurements to the correct number of significant figures and compare the accuracy of each measuring device	Use scientific notation to represent very small and large quantities Apply the rules for determining significant digits or figures to the result of multiplication/ division and addition/subtraction. Carry out conversions between metric units. Use dimensional analysis to convert a value from one measurement system to another. Determine the average atomic mass of an element based on the percent abundance of its

	Design a method to determine the empirical formula or percent composition of an unknown hydrate/compound.	Using Socratic seminar, research and discuss the pros and cons of the metric vs English measuring systems. Use calculations to compare the ratios the size of the atom to the size of different objects such as a cell, a person, a tree, etc. Compare/contrast moles and mass.	naturally occurring isotopes. Convert between mass, moles, volume, and number of representative particles using Avogadro's number, molar mass and density.
C.PM.6- Intermolecular Forces of Attraction Types and Strengths			
Construct a chromatography technique to separate the components of different dyes (hair color, food additives, skittles, etc.) applying principles of inter- and intra-molecular forces. Construct an explanation about the importance of molecular-level structure in the functioning of designed materials. (Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and	Design an experiment to identify which solvent would be best to dissolve a particular solute. Design an experimental procedure to determine the polarity of a substance Investigate why water doesn't follow predicted trends (surface tension, density, vapor pressure, boiling point, etc.) based on its intermolecular interactions (e.g. drops on a penny, capillary tube,mixing oil and water, water on glass vs. wax paper) Apply the idea of intermolecular forces to biological implications. (e.g. hydrogen bonding between	Explain why intermolecular forces are weaker than ionic, covalent or metallic bonds Create a concept map that illustrates the differences between intermolecular forces. Explain why hydrogen bonds are stronger than dipole-dipole forces which are stronger than dispersion forces Represent the cause of intermolecular forces between molecules using models Compare and contrast the relative intermolecular strengths between similar substances by comparing their states of matter under standard conditions.	Define and identify types of intermolecular forces including London dispersion forces, dipole-dipole, and H-bonding Classify the intermolecular forces that exist in a given compound Recognize that nonpolar organic molecules are held together by London dispersion forces. Longer chains have greater LDF attractions; Increased branching of molecules results in decreased LDF attractions Recognize that intermolecular forces occur between different molecules

pharmaceuticals are designed to interact with specific receptors.)	two DNA strands, cell membrane formation of lipids)	Describe intermolecular forces for molecular compounds. • H-bond as attraction between molecules when H is bonded to O, N, or F. • Dipole-dipole attractions between polar molecules. • London dispersion forces (electrons of one molecule attracted to nucleus of another molecule) – i.e. liquefied inert gases. • Relative strengths (H>dipole>London/van der Waals).	
C.PM.6- Intermolecular Forces of Attraction **Implications for Properties of Substances (Melting and boiling point, solubility, vapor pressure)**			
Prepare a soap and evaluate effectiveness on hard water. Evaluate the design of shampoo samples using properties (e.g. viscosity, pH) to determine effectiveness Evaluate the variations and similarities between sweeteners (e.g. regular table sugar, high fructose corn syrup, Stevia, Aspartame (Equal®), saccharin (Sweet n' Low ®), sucralose (Splenda ®), honey and Agave). Research these products and potential impacts (e.g.	Design an experiment to demonstrate strength of intermolecular forces on a given property (e.g. change in evaporation temperature, polarizability; viscosity)	Explain how a graph of vapor pressure versus temperature can be used to determine boiling point and strength of intermolecular forces Predict which compound will have the highest/lowest vapor pressure and melting/boiling point based on intermolecular forces Sketch hydration of ionic substances and explain how the ions separate and bond to the water molecules Show how to determine if a molecule is polar or nonpolar (relate to symmetry) Explain the relationship of polarity of molecules to solubility of 2 compounds—"like dissolves like"	Explain how intermolecular forces impact properties (including melting and boiling point, solubility, and vapor pressure) Describe bond polarity and molecular polarity Recognize that greater solubility occurs when dissolving a substance in a solvent with similar intermolecular forces ("like dissolves like")

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human, environment). Present your findings in multiple formats. Variation for this project could be made with oils (e.g., canola, coconut, olive, vegetable).			

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Resources

Atomic Structure

- From PBS this site has the students explore the atom and learn how to build a carbon atom from its elementary particles.
- The modifiable Lesson is based on Jonathan Bergmann's TED talk, "Just How Small is an Atom?" Students will get an appreciation of just how small an atom is by comparing it to a blueberry the size of a stadium.
- Student experiment modeling the "black box" problem (JJ Thomson and Rutherford's exploration of the atom
- Lesson Plan: The Structure of the atom and its particles
- phet Simulation of the Atom.
- Simulation of the atom
- Understanding fireworks and relationship to electron energies
- How a Microwave Works
- Inquiry based lessons based on historical landmark discoveries in chemistry: https://www.acs.org/content/acs/en/education/whatischemistry/landmarks/lesson-plans.html
- Video,Chemistry of Fireworks
- Electron Bingo Game
- American Chemical Society Recommendations for Teaching High School Chemistry

Periodic Table

- Periodic Table Activities ACS
- Periodic table Game
- American Chemical Society Recommendations for Teaching High School Chemistry

Chemical Bonding

- Laboratory investigations, demos, student readings, and multimedia you can use to teach the big ideas about energy. . http://highschoolenergy.acs.org/content/hsef/en.html
- Polarity Simulation
- Simulation for properties of ionic and covalent compounds
- Fossil fuel exploration published by NEED
- American Chemical Society Recommendations for Teaching High School Chemistry

Representing Compounds

- Lesson plan for writing ionic compounds
- Inquiry lesson naming ionic compounds
- American Chemical Society Recommendations for Teaching High School Chemistry

Quantifying Matter

- Significant Figure Puzzle Challenge Game
- National Institute Of Standards and Technology Guide to the proper use of units.

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- Lesson plan for introducing the mole

American Chemical Society Recommendations for Teaching High School Chemistry

Intermolecular Forces of Attraction

- Molecular polarity demonstrates how polar molecules are affected by the magnetic field but does not address how polar molecules interact with each.
- https://phet.colorado.edu/en/simulation/legacy/sugar-and-salt-solutions Simulation is currently only set for JAVA and not HTML 5
- American Chemical Society Recommendations for Teaching High School Chemistry

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Interactions of Matter

C.IM.1- Chemical Reactions

In the Physical Science course, coefficients were used to balance simple equations. Other representations including Lewis structures and three-dimensional models also were used and manipulated to demonstrate the conservation of matter in chemical reactions. In this course, more complex reactions will be studied, classified and represented with chemical equations and three-dimensional models. Classifying reactions into types can be a helpful organizational tool in recognizing patterns of what may happen when two substances are mixed. Teachers should be aware that the common reaction classifications that are often used in high school chemistry courses may lead to misconceptions because they are not based on the actual chemistry, but on surface features that can be similar from one system to another (e.g., exchanging partners), even though the underlying chemistry is not the same. However, these classifications may be useful in making predictions about what happens when two substances are mixed.

Some general types of chemical reactions are oxidation/reduction, synthesis, decomposition, single replacement, double replacement (including precipitation reactions and some acid-base neutralizations) and combustion reactions. Some reactions can fit into more than one category. For example, a single replacement reaction also can be classified as an oxidation/reduction reaction. Identification of reactions involving oxidation and reduction as well as indicating what substance is being oxidized and what is being reduced are appropriate in this course. However, balancing complex oxidation/reduction reactions is reserved for more advanced study.

Organic molecules release energy when undergoing combustion reactions and are used to meet the energy needs of society (e.g., cellular respiration). When a reaction between two ionic compounds in aqueous solution results in the formation of a precipitate or molecular compound, the reaction often occurs because the new ionic or covalent bonds are stronger than the original ion-dipole interactions of the ions in solution. Laboratory experiments (3-D or virtual) with different types of chemical reactions must be provided. Reactions occur when reacting particles collide in an appropriate orientation and with sufficient energy. The rate of a chemical reaction is the change in the amount of reactants or products in a specific period of time. Increasing the probability or effectiveness of the collisions between the particles increases the rate of the reaction. Therefore, changing the concentration of the reactants, changing the temperature or the pressure of gaseous reactants, or using the catalyst, can change the reaction rate. Likewise, the collision theory can be applied to dissolving solids in a liquid solvent and can be applied to dissolving solids in a liquid solvent and can be used to explain why reactions are more likely to occur between reactants in the aqueous or gaseous state than between solids. The rate at which a substance dissolves should not be confused with the amount of a solute that can dissolve in a given amount of solvent (solubility). Mathematical treatment of reaction rates are reserved for more advanced study. Computer simulations can help visualize reactions from the perspective of the kinetic-molecular theory.

In middle school, the differences between potential and kinetic energy and the particle nature of thermal energy were introduced. For chemical systems, potential energy is in the form of chemical energy and kinetic energy is in the form of thermal energy. The total amount of chemical energy and/or thermal energy in a system is impossible to measure. However, the energy change of a system can be calculated from measurements (mass and change in temperature) from calorimetry experiments in the laboratory. Conservation of energy is an important component of calorimetry equations. Thermal energy is the energy of a system due to the movement (translational, vibrational and rotational) of its particles. The thermal energy of an object depends upon the amount of matter present (mass), temperature and chemical composition. Some materials require little energy to change their temperature and other materials require a great deal to change their temperature by the same amount. Specific heat is a measure of how much energy is needed to change the temperature of a specific mass of material a specific amount. Specific heat values can be used to calculate the thermal energy change, the temperature (initial, final or change in) or mass of a material in calorimetry. Water has a particularly high specific heat capacity, which is important in regulating Earth's temperature.

As studied in middle school, chemical energy is the potential energy associated with chemical systems. Chemical reactions involve valence electrons forming bonds to yield more stable products with lower energies. Energy is required to break interactions and bonds between the reactant atoms and energy is released when an interaction or bond is formed between the atoms in the products. Molecules with weak bonds (e.g., ATP) are less stable and tend to react to produce more stable products, releasing energy in the process. Generally, energy is transferred out of the system (exothermic) when the products have stronger bonds than the reactants and is transferred into the system (endothermic) when the reactants have stronger bonds than the products. Predictions of the energy requirements (endothermic or exothermic) of a reaction can be made given a table of bond energies. Graphic representations can be drawn and interpreted to represent the energy changes during a reaction, including the activation energy. The roles of energy and entropy in determining the spontaneity of chemical reactions are dealt with conceptually in this course. Avoid describing entropy as the amount of disorder since this leads to persistent misconceptions. Mathematical treatment of entropy and its influence on the spontaneity of reactions is reserved for advanced study.

All reactions are reversible to a degree and many reactions do not proceed completely toward products but appear to stop progressing before the reactants are all used up. At this point, the amounts of the reactants and the products appear to be constant and the reaction can be said to have reached dynamic equilibrium. In fact, the reaction has stopped because the rate of the reverse reaction is equal to the rate of the forward reaction so there is no apparent change in the reaction. If given a graph showing the concentration of the reactants and products over the time of reaction, the equilibrium concentrations and the time at which equilibrium was established can be determined. Some reactions appear to proceed only in one direction. In these cases, the reverse reaction can occur but is highly unlikely (e.g., combustion reactions). Such reactions usually release a large amount of energy and require a large input of energy to go in the reverse direction. If a chemical system at equilibrium is disturbed by a change in the conditions of the system (e.g., increase or decrease in the temperature, pressure on gaseous equilibrium systems, concentration of a reactant or product), then the equilibrium system will respond by shifting to a new equilibrium state, reducing the effect of the change (Le Chatelier's Principle). If products are removed as they are formed during a reaction, then the equilibrium position of the system is forced to shift to favor the products. In this way, an otherwise unfavorable reaction can be made to occur. Mathematical treatment of equilibrium reactions is reserved for advanced study. Computer simulations can help visualize the progression of a reaction to dynamic equilibrium and the continuation of both the forward and reverse reactions after equilibrium has been attained.

In chemistry, the structural features of molecules are explored to further understand acids and bases. Acids often result when hydrogen is covalently bonded to an electronegative element and is easily dissociated from the rest of the molecule to bind with water to form a hydronium ion (H3 O+). The acidity of an aqueous solution can be expressed as pH, where pH can be calculated from the concentration of the hydronium ion. Bases are likely to dissociate in water to form a hydroxide ion. Acids can react with bases to form a salt and water. Such neutralization reactions can be studied quantitatively by performing titration experiments. Detailed instruction about the equilibrium of acids and bases and the concept of Brønsted-Lowry and Lewis acids and bases will not be assessed at this level.

C.IM.2- Gas Laws

The kinetic-molecular theory can be used to explain the properties of gases (pressure, temperature and volume) through the motion and interactions of its particles. Problems also can be solved involving the changes in temperature, pressure, volume and amount of a gas. When two of these four are kept constant, the relationship between the other two can be quantified, described and explained using the kinetic-molecular theory. Real-world phenomena (e.g., why tire pressure increases in hot weather, why a hot air balloon rises) can be explained using this theory. When solving gas problems, the Kelvin temperature scale must be used since only in this scale is the temperature directly proportional to the average kinetic energy. The Kelvin temperature is based on a scale that has its minimum temperature at absolute zero, a temperature at which all motion theoretically stops. Since equal volumes of gases at the same temperature and pressure contain an equal number of particles (Avogadro's law), problems can be solved for an unchanging gaseous system using the ideal gas law ($PV = nRT$) where R is the ideal gas constant (e.g., represented in multiple formats, 8.31 joules / (mole K).

The specific names of the gas laws are not addressed in this course. Deviations from ideal gaseous behavior are reserved for more advanced study. Relationships between the volume, temperature and pressure can be explored in the laboratory or through computer simulations or virtual experiments.

C.IM.3- Stoichiometry

A stoichiometric calculation involves the conversion from the amount of one substance in a chemical reaction to the amount of another substance. The coefficients of the balanced equation indicate the ratios of the substances involved in the reaction in terms of both particles and moles.

Once the number of moles of a substance is known, amounts can be changed to mass, volume of a gas, volume of solutions and/or number of particles. Molarity is a measure of the concentration of a solution that can be used in stoichiometric calculations. When performing a reaction in the lab, the experimental yield can be compared to the theoretical yield to calculate percent yield.

The concept of limiting reagents is treated conceptually and not mathematically. Molality and normality are concepts reserved for more advanced study.

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ←		→ Least Complex	
Interactions of Matter				
C.IM.1 Chemical reactions ○ Types of reactions ○ Kinetics ○ Energy ○ Equilibrium ○ Acids/bases	**C.IM.1a** Use litmus paper to test and determine the pH of a substance.	**C.IM.1b** Given a pH scale with common ingredients (e.g., orange juice, water, baking soda), determine if they are acid, neutral, or basic.	**C.IM.1b** Identify acid, neutral, and/or base on a pH scale.	HS-PS1-2 Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends on the changes in total bond energy. HS-PS1-5 Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. HS-PS1-6 Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
C.IM.2 Gas laws ○ Pressure, volume, and temperature ○ Ideal gas law	**C.IM.2a** Identify types of measurements used for measuring gases (volume, temperature, and pressure).	**C.IM.2b** Define gas as having no definite shape or volume.	**C.IM.2c** Identify a gas.	NONE
C.IM.3 Stoichiometry ○ Molar calculations ○ Solutions ○ Limiting reagents	Complex and advanced learning standards in Ohio's New Learning Standards are not included in the extended standards.			HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

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EVIDENCE OF LEARNING

Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

Designing technological / engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
C.IM.1- Chemical Reactions Types of Reactions			
Critique the impact certain chemical reactions may have on the environment. Evaluate oxidation-reduction reactions that occur in real-world settings such as rusting, electroplating, etc. that cause engineering/manufacturing challenges and propose a solution.	Analyze chemical reactions in the laboratory to differentiate the types of reactions. Apply knowledge of reactions to determine the appropriate fire extinguisher for a given scenario. Research a biome and identify various biological chemical reactions: (metabolic respiration, photosynthesis) within that biome Generate a process for recycling a metal, e.g. copper cycle lab.	Compare and contrast the two classification schemes for chemical reactions: synthesis, decomposition, single-replacement, double-replacement, and organic combustion vs. oxidation-reduction, precipitation, and acid-base reactions. Construct and revise an explanation for the energy changes in photosynthesis and in the combustion of sugar in terms of bond breaking and bond formation. Using activity series and solubility rules construct an outcome of the following chemical reactions: single replacement, double replacement, organic combustion, and acid-base reaction.	Classify a chemical reaction as synthesis, decomposition, single-replacement, double replacement, and organic combustion. Use mathematical representation to balance chemical reactions (excluding oxidation-reduction) showing that atoms and mass are conserved during a chemical reaction. In an oxidation/reduction reaction identify which substance is oxidized and which substance is reduced.

		Draw a particle diagram representing the interactions of particles in a chemical reaction.	
C.IM.1- Chemical Reactions Kinetics			
Critique the effects of a catalyst on everyday examples of chemical reactions (e.g.. biological enzymes, catalytic converters, etc.). Redesign a process which is more cost effective and/or environmentally friendly.	Generate qualitative potential energy diagrams for endothermic and exothermic reactions including reactants, products, and activated complex–with and without the presence of a catalyst through experimentation (e.g. decomposition of H_2O_2 with KI and without KI).	Apply scientific principles and evidence to provide an explanation about the effects of changing concentration, temperature, and pressure on rate of a chemical reactions. Illustrate collision theory using particle diagrams (molecules must collide in order to react and they must collide in the correct or appropriate orientation and with sufficient energy to equal or exceed the activation energy).	Identify the ways the rate of a chemical reaction can be affected (i.e. concentrations of reactions, surface area, changing temperature or pressure of gaseous substances, or using a catalyst).
C.IM.1- Chemical Reactions Energy			
Present the process, results and solutions for a safer and/or cheaper hand warmer given different ionic substances.	Design an experiment to determine the identity of a metal by calculating the heat transfer from the hot metal to cold water, taking conservation of energy into account. Design an experiment to analyze how the weather of a region near water is affected by the high specific heat of water.	Track the flow of energy and explain why a reaction is an exothermic or endothermic process. Compare and contrast how specific heat of different substances impacts temperature change. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.	Calculate the thermal energy change (q), the change of temperature (ΔT), initial or final temperature, and mass of a material using specific heat. Given a table of bond energy, determine whether a given reaction is exothermic or endothermic.

		Implementing the use of household materials show the difference between endothermic and exothermic reactions.	
C.IM.1- Chemical Reactions Equilibrium			
Propose a procedure to shift a commercial equilibrium process to maximize a desired product and construct a risk assessment its implications on society (e.g. Haber process).	Design an experiment to illustrate equilibrium shift due to disturbances.	Indicate whether the forward or reverse reaction is favored to reach equilibrium based on different disturbances (increase or decrease in temperature, pressure on gaseous equilibrium systems, change in concentration of a reactant or product).	Recognize that equilibrium is dynamic and that the rates of the forward and reverse reactions are equal. Carry out a computer simulation to visualize dynamic equilibrium and the continuation of the forward and reverse reactions.
C.IM.1- Chemical Reactions Acids/Bases			
Construct an experiment to determine what type of roof materials would be appropriate in areas with high acid rain. Evaluate and critique why lakes with limestone or calcium carbonate experience less adverse effects from acid rain than lakes with granite beds. Then invent a product or process to minimize these effects.	Design an investigation to determine the effective pH range of natural and synthetic indicators. Devise a method to evaluate the Vitamin C content of commercial product. Design an investigation to determine the most effective antacid per gram for neutralizing stomach acid (HCl), baking soda ($NaHCO_3$) or magnesium hydroxide ($Mg(OH)_2$)	Evaluate neutralization reactions quantitatively by performing titration experiments. Interpret neutralization reactions.	Perform calculations relating pH to hydronium ion concentration. Identify acids based on the formation of the hydronium ion in water. Identify bases by their dissociation in water to form the hydroxide ion.

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C.IM.2- Gas Laws Pressure, Volume and Temperature			
Design a device that measures tire pressure under changing temperature conditions.	Using simulations and/or laboratory experiences monitor the relationships between pressure and volume, pressure and temperature, temperature and volume.	Explain both the quantitative and qualitative relationships between pressure, volume, and temperature. Construct models representing the relationship of pressure, volume, and temperature related to collisions and energy of particles Construct a simulation/balloon/ pamphlet that explains the science principles of the gas laws that cause the hot air balloon to rise. Design a diagram using the kinetic molecular theory to explain the motion of gas particles and how they are affected by changes in pressure, temperature and/or volume.	Apply appropriate gas law equations when solving problems. Recognize and convert between different pressure units.
C.IM.2- Gas Laws Ideal Gas Law			
Research and create an airbag with baking soda and vinegar using the ideal gas law to figure out the amount	Detect and measure the volume of a gas produced during a chemical reaction and relate to molar	Use an Ideal Gas Law Simulator to represent and interpret the connection between pressure, volume,	Apply the ideal gas law to solve for an appropriate variable.

of reactants necessary to fill a given ziplock bag.	volume at standard temperature and pressure	temperature, and number of particles.	
C.IM.3- Stoichiometry Molar Calculations			
Evaluate the efficiency, cost, and environmental impacts of multiple possible chemical processes to determine which process(es) would be best to use. Sustainability and green chemistry should be considered.	Design a procedure to produce an exact amount of a product (e.g., produce silver through the reaction of silver nitrate and copper or zinc and hydrochloric acid).	Using data collected from a multi-step chemical reaction, calculate percent yield.	Use mole ratios from a balanced equation to calculate the quantity of one substance in a reaction given the quantity of another substance in the reaction (given moles, particles, mass, or volume and ending with moles, particles, mass, or volume of the desired substance).
C.IM.3- Stoichiometry Solutions			
Plan and implement an process to test concentration of pollutants in water (e.g., lead, mercury, etc).	Create a solution and a dilution of a known concentration.	Explain how the creation of a standardized solution (a solution of known molarity) allows you to determine the concentration of an unknown solution.	Calculate the molarity of an aqueous solution. Distinguish between solute, solvent, and solution.
C.IM.3- Stoichiometry Limiting Reagents			
Evaluate an environmental problem through the lens of limiting reagents (e.g., algae growths impacted by available phosphates and nitrates).	Plan and carry out an investigation to demonstrate the conceptual principle of limiting reactants.	Compare limiting to excess reagents in a chemical reaction (e.g.copper (II) sulfate and an iron nail).	Determine which reactant is limited using particle diagrams.

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Resources

Chemical Reactions

- Teachers should review nomenclature with the students when teaching chemical reactions.
- Virtual Labs and Tutorials
- Kinetics pHet Simulation http://www.chm.davidson.edu/vce/index.html
- Variety of Simulations
- Computer Simulation Reversible Reactions
- Acid-Base PhET simulation
- Crash Course Chemistry: Intro to Equilibrium:
- Acid, Base, pH and Food
- American Chemical Society Recommendations for Teaching High School Chemistry

Gas Laws

- Gas Properties: a simulator of gas using particle motion.
- Gas Law Simulation
- Investigate relationships of variable involved with gases
- American Chemical Society Recommendations for Teaching High School Chemistry

Stoichiometry

- pHET simulations offer multiple opportunities to models limiting reagents and concentration
- Demonstration of limiting reagents, can be easily done with vinegar and baking soda filling a balloon
- NSTA Resources chemical reactions and engineering design
- Atoms and Baggie Chemistry
- Mole Rockets
- Lab Investigation: Concentration of Kool-Aid

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PHYSICAL SCIENCE

INTRODUCTION AND SYLLABUS

COURSE DESCRIPTION

Physical science is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires three one-unit courses. Each course should include inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

Physical science introduces students to key concepts and theories that provide a foundation for further study in other sciences and advanced science disciplines. Physical science comprises the systematic study of the physical world as it relates to fundamental concepts about matter, energy and motion. A unified understanding of phenomena in physical, living, Earth and space systems is the culmination of all previously learned concepts related to chemistry, physics, and Earth and space science, along with historical perspective and mathematical reasoning.

Cross Curriculum connections link to ELA and Technology.

COURSE CONTENT SYLLABUS

The following information may be taught in any order; there is no ODE-recommended sequence.

PS.M: STUDY OF MATTER

- PS.M.1: Classification of matter
    - Heterogeneous vs. homogeneous
    - Properties of matter
    - States of matter and its changes
- PS.M.2: Atoms
    - Models of the atom (components)
    - Ions (cations and anions)
    - Isotopes
- PS.M.3: Periodic trends of the elements
    - Periodic law
    - Representative groups
- PS.M.4: Bonding and compounds
    - Bonding (ionic and covalent)
    - Nomenclature
- PS.M.5: Reactions of matter
    - Chemical reactions
    - Nuclear reactions

PS.EW: ENERGY AND WAVES

- PS.EW.1: Conservation of energy
    - Quantifying kinetic energy
    - Quantifying gravitational potential energy

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- PS.EW.2: Transfer and transformation of energy (including work)
- PS.EW.3: Waves
  - Refraction, reflection, diffraction, absorption, superposition
  - Radiant energy and the electromagnetic spectrum
  - Doppler shift
- PS.EW.4: Thermal energy
- PS.EW.5: Electricity
  - Movement of electrons
  - Current
  - Electric potential (voltage)
  - Resistors and transfer of energy

PS.FM: FORCES AND MOTION

- PS.FM.1: Motion
  - Introduction to one-dimensional vectors
  - Displacement, velocity (constant, average and instantaneous) and acceleration
  - Interpreting position vs. time and velocity vs. time graphs
- PS.FM.2: Forces
  - Force diagrams
  - Types of forces (gravity, friction, normal, tension)
  - Field model for forces at a distance
- PS.FM.3: Dynamics (how forces affect motion)
  - Objects at rest
  - Objects moving with constant velocity
  - Accelerating objects

PS.U: THE UNIVERSE

- PS.U.1: History of the universe
- PS.U.2: Galaxies
- PS.U.3: Stars
  - Formation: stages of evolution
  - Fusion in stars

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STUDY OF MATTER

PS.M.1- Classification of Matter

Matter was introduced in the elementary grades and the learning progression continued through middle school to include differences in the physical properties of solids, liquids and gases, elements, compounds, mixtures, molecules, kinetic and potential energy and the particulate nature of matter. Content in the chemistry syllabus (e.g., electron configuration, molecular shapes, bond angles) will be developed from concepts in this course.

Matter can be classified in broad categories such as homogeneous and heterogeneous or classified according to its composition or by its chemical (reactivity) and physical properties (e.g., color, solubility, odor, hardness, density, conductivity, melting point and boiling point, viscosity and malleability).

Solutions are homogenous mixtures of a solute dissolved in a solvent. The amount of a solid solute that can dissolve in a solvent generally increases as the temperature increases since the particles have more kinetic energy to overcome the attractive forces between them. Water is often used as a solvent since so many substances will dissolve in water. Physical properties can be used to separate the substances in mixtures, including solutions.

Phase changes can be represented by graphing the temperature of a sample vs. the time it has been heated. Investigations must include collecting data during heating, cooling and solid-liquid- solid phase changes. At times, the temperature will change steadily, indicating a change in the motion of the particles and the kinetic energy of the substance. However, during a phase change, the temperature of a substance does not change, indicating there is no change in kinetic energy. Since the substance continues to gain or lose energy during phase changes, these changes in energy are potential and indicate a change in the position of the particles. When heating a substance, a phase change will occur when the kinetic energy of the particles is great enough to overcome the attractive forces between the particles; the substance then melts or boils. Conversely, when cooling a substance, a phase change will occur when the kinetic energy of the particles is no longer great enough to overcome the attractive forces between the particles; the substance then condenses or freezes.

Phase changes are examples of changes that can occur when energy is absorbed from the surroundings (endothermic) or released into the surroundings (exothermic).

When thermal energy is added to a solid, liquid or gas, most substances increase in volume because the increased kinetic energy of the particles causes an increased distance between the particles. This results in a change in density of the material. Generally, solids have greater density than liquids, which have greater density than gases due to the spacing between the particles. The density of a substance can be calculated from the slope of a mass vs. volume graph. Differences in densities can be determined by interpreting mass vs. volume graphs of the substances.

PS.M.2- Atoms

Content introduced in middle school, where the atom was introduced as a small, indestructible sphere, is further developed in the physical science syllabus. Over time, technology was introduced that allowed the atom to be studied in more detail. The atom is composed of protons, neutrons and electrons that have measurable properties, including mass and, in the case of protons and electrons, a characteristic charge. When bombarding thin gold foil with atomic-sized, positively charged, high speed particles, a few of the particles were deflected slightly from their straight-line path. Even fewer bounced back toward the source. This evidence indicates that most of an atom is empty space with a very small positively charged nucleus. This experiment and other evidence indicate the nucleus is composed of protons and neutrons, and electrons that move about in the empty space that surrounds the nucleus. Additional experimental evidence that led to the development of other historic atomic models will be addressed in the chemistry syllabus.

All atoms of a particular element have the same atomic number; an element may have different isotopes with different mass numbers. Atoms may gain or lose valence electrons to become anions or cations. Atomic number, mass number, charge and identity of the element can be determined from the numbers of protons, neutrons and electrons. Each element has a unique atomic spectrum that can be observed and used to identify an element. Atomic mass and

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explanations about how atomic spectra are produced are addressed in the chemistry syllabus.

PS.M.3- Periodic Trends of the Elements
Content from the middle school level, specifically the properties of metals and nonmetals and their positions on the periodic table, is further expanded in this course. When elements are listed in order of increasing atomic number, the same sequence of properties appears over and over again; this is the periodic law. The periodic table is arranged so that elements with similar chemical and physical properties are in the same group or family. Metalloids are elements that have some properties of metals and some properties of nonmetals. Metals, nonmetals, metalloids, periods and groups or families including the alkali metals, alkaline earth metals, halogens and noble gases can be identified by their position on the periodic table. Elements in Groups 1, 2 and 17 have characteristic ionic charges that will be used in this course to predict the formulas of compounds. Other trends in the periodic table (e.g., atomic radius, electronegativity, ionization energies) are found in the chemistry syllabus.

PS.M.4- Bonding and Compounds
Middle school content included compounds are composed of atoms of two or more elements joined together chemically. In this course, the chemical joining of atoms is studied in more detail. Atoms may be bonded together by losing, gaining or sharing valence electrons to form molecules or three- dimensional lattices. An ionic bond involves the attraction of two oppositely charged ions, typically a metal cation and a nonmetal anion formed by transferring electrons between the atoms. An ion attracts oppositely charged ions from every direction, resulting in the formation of a three dimensional lattice. Covalent bonds result from the sharing of electrons between two atoms, usually nonmetals. Covalent bonding can result in the formation of structures ranging from small individual molecules to three-dimensional lattices (e.g., diamond). The bonds in most compounds fall on a continuum between the two extreme models of bonding: ionic and covalent.

Using the periodic table to determine ionic charge, formulas of ionic compounds containing elements from groups 1, 2, 17, hydrogen and oxygen can be predicted. Given a chemical formula, a compound can be named using conventional systems that include Greek prefixes where appropriate. Prefixes will be limited to represent values from one to 10. Given the name of an ionic or covalent substance, formulas can be written. Naming organic molecules is beyond this grade level and is reserved for an advanced chemistry course. Prediction of bond types from electronegativity values, polar covalent bonds, writing formulas and naming compounds that contain polyatomic ions or transition metals will be addressed in the chemistry syllabus.

PS.M.5- Reactions of Matter
In middle school, the law of conservation of matter was expanded to chemical reactions, noting that the number and type of atoms and the total mass are the same before and after the reaction. In this course, conservation of matter is expressed by writing balanced chemical equations. At this level, reactants and products can be identified from an equation and simple equations can be written and balanced given either the formulas of the reactants and products or a word description of the reaction. Stoichiometric relationships beyond the coefficients in a balanced equation and classification of types of chemical reactions are addressed in the chemistry syllabus.

During chemical reactions, thermal energy is either transferred from the system to the surroundings (exothermic) or transferred from the surroundings to the system (endothermic). Since the environment surrounding the system can be large, temperature changes in the surroundings may not be detectable.

While chemical changes involve changes in the electrons, nuclear reactions involve changes to the nucleus and involve much larger energies than chemical reactions. The strong nuclear force is the attractive force that binds protons and neutrons together in the nucleus. While the nuclear force is extremely weak at most distances, over the very short distances present in the nucleus the force is greater than the repulsive electrical forces among protons. When the attractive nuclear forces and repulsive electrical forces in the nucleus are not balanced, the nucleus is unstable. Through radioactive decay, the unstable nucleus emits radiation in the form of very fast-moving particles and energy to produce a new nucleus, thus changing the identity of the element. Nuclei that undergo this process are said to be radioactive. Radioactive isotopes have several medical applications.

The radiation they release can be used to kill undesired cells (e.g., cancer cells). Radioisotopes can be introduced into the body to show the flow of materials in biological processes.

For any radioisotope, the half-life is unique and constant. Graphs can be constructed that show the amount of a radioisotope that remains as a function of time and can be interpreted to determine the value of the half-life. Half-life values are used in radioactive dating.

Other examples of nuclear processes include nuclear fission and nuclear fusion. Nuclear fission involves splitting a large nucleus into smaller nuclei, releasing large quantities of energy. Nuclear fusion is the joining of smaller nuclei into a larger nucleus accompanied by the release of large quantities of energy. Nuclear fusion is the process responsible for formation of all the elements in the universe beyond helium and the energy of the sun and the stars.

Further details about nuclear processes including common types of nuclear radiation, predicting the products of nuclear decay, mass-energy equivalence and nuclear power applications are addressed in the chemistry and physics syllabi.

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟵	⟶	Least Complex	
Study of Matter				
PS.M.1 Classification of matter ○ Heterogeneous vs. homogeneous ○ Properties of matter ○ States of matter and its changes	**PS.M.1a1** Recognize the difference between a solution and mixture. **PS.M.1a2** Classify objects by their physical properties (e.g., weight, melting and boiling points). **PS.M.1a3** Describe how thermal energy moves (e.g., thermal energy as ice melts).	**PS.M.1b1** Identify a method to separate a mixture. **PS.M.1b2** Describe physical properties of matter (e.g., size, weight, shape, magnetic, melting and boiling points). **PS.M.1b3** Identify heat as thermal energy.	**PS.M.1c1** Create a mixture. **PS.M.1c2** Identify a physical property of matter. **PS.M.1c3** Identify heat as the cause of a phase change**.**	HS-PS1-3 Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
PS.M.2 Atoms ○ Models of the atom (components) ○ Ions (cations and anions) ○ Isotopes	**PS.M.2a** Identify parts of an atom (protons, neutrons, electrons).	**PS.M.2b** Identify a diagram or model of an atom.	**PS.M.2c** Identify that all matter is made of atoms.	HS-PS1-1 Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy levels of atoms.
PS.M.3 Periodic trends of the elements ○ Periodic law ○ Representative groups	**PS.M.3a** Use a Periodic Table to answer questions (e.g., number of outer electrons, groupings).	**PS.M.3b** Recognize that elements are organized on the Periodic Table by their properties, number of protons, and number of outer electrons.	**PS.M.3c** Identify an element(s) on the periodic table.	HS-PS1-1 Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy levels of atoms.
PS.M.4 Bonding and compounds ○ Bonding (ionic and covalent) ○ Nomenclature	**PS.M.4a** Recognize that atoms can bond ionically or covalently.	**PS.M.4b** Recognize that atoms can bond (interact).	**PS.M.4c** Identify a chemical compound.	MS-PS1-1 Develop models to describe the atomic composition of simple molecules and extended structures.
PS.M.5 Reactions of Matter				HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟷ Least Complex			
				HS-PS1-8 Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion and radioactive decay.

EVIDENCE OF LEARNING
Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

Designing technological / engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PS.M.1 - Classification of Matter Heterogeneous vs. homogeneous			
Since many surfaces are heterogeneous, they exhibit variations in surface roughness. Investigate boundary friction of heterogeneous surfaces and apply to real world engineering issues (for example, bowling alleys, train tracks, piston movement, etc.). Devise a method to purify water in developing countries.	Using salt, water and samples of iron filings, and sand write a procedure to separate a homogeneous mixture (salt and water) and heterogeneous mixture (salt, iron filings, and sand) using tools of separation techniques.	Using data from various physical separation techniques, construct a particle diagram for various mixtures based on the particulate nature of matter.	Identify samples of matter as homogeneous vs. heterogeneous (ex. salt water vs. chicken noodle soup).

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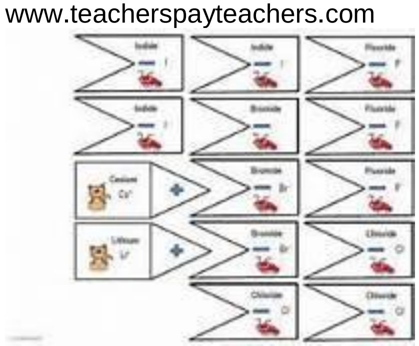
PS.M.1 - Classification of Matter Properties of matter			
Visually compare the inside structure of various balls (tennis ball, golf ball, baseball, basketball/kickball and soccer ball). Determine what makes the ball bounce the highest (and/or travel farthest), compare, analyze the data, draw conclusions and present findings in multiple formats.	Design an experiment to separate a mixture based on its physical and chemical properties (Ex. flammability, reactivity, etc.). Investigate alternative methods of measuring pH (cabbage juice, pH meters, pH paper, liquid indicators, ect.). Design an experiment to test the change in pH of a solution for various antacids. Given scientific tools, propose and critique the fastest procedure to dissolve a sugar cube in a given amount of time (Ex. surface area of solute, temperature, stirring, etc.).	Explain the process of burning a candle in terms of physical and chemical change. Compare acids and bases found in the home using experimental data on pH (Ex. household cleaning products, soaps, coffee, soda, vinegar, fruit juices, antacids, etc.)	Classify properties as chemical or physical based on previous knowledge and give real world examples of them for understanding. Classify homogeneous solutions found in the home as acids, bases, or neutral (Ex. household cleaning products, soaps, coffee, soda, vinegar, fruit juices, antacids, etc.)
PS.M.1 - Classification of Matter States of matter and its changes			
Design a cup that keeps liquid hot/cold. Use cooling/heating curves to verify.	Investigate the evaporation of water using cold water, room temperature water, and hot water placed in sealed ziplock bags with place a piece of paper towels with a drop of water on top. Students can observe the evaporation of the water from the paper towels.	Given mass vs. volume graphs of various substances, determine which substance is more dense. Using a phase diagram, determine the phase of water at different temperatures. Explain, using models, the states of matter in terms of energy movement, distance between particles, and particle behavior including solids, liquids, and gases. Identify the composition of an unknown based on its density using liquid and solid materials.	Define endothermic and exothermic changes. Identify the various phase changes and classify them as endothermic or exothermic. Solve density problems by substituting formulas to find the volume with the following parameters: Using the density of a known material determine and measuring the mass find the width of a piece of copper

		Design a procedure/experiment to create a phase change graph. Perform and design an experiment using irregular solids to determine the density. Create a density curve by varying the amount of salt added to water and measuring the density.	wire and the height of a piece of aluminum formula.
PS.M.2 - Atoms **Models of the atom (components)**			
Research cations and anions in everyday products and how they affect hair products, car washes and dryer sheets.	Investigate technological advances that led to more advanced knowledge of the atom.	Use the periodic table to draw a Bohr model of an element. Calculate the protons, neutrons and electrons in an element from various data (mass number, atomic number, charge, etc.).	Describe the location, charge, and relative size of a proton, neutron, and electron.
PS.M.2 - Atoms **Ions (cations and anions)**			
		Knowing the anions and cations use the manipulatives below to predict a chemical formula. Below is a sample of manipulatives to create at the following web site- www.teacherspayteachers.com 	Define valence electrons and explain their importance. Predict ionic charge using electron models (Lewis electron dot diagrams) and their placement on the periodic table.

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PS.M.2 Atoms Isotopes			
		Compare and model the mass of isotopes using film canisters and pre-1982 and post-1982 pennies (in the instructional strategies).	Define isotope.
PS.M.3 - Periodic Trends of the elements Periodic Law			
		Explain the periodicity/patterns found in the periodic table by organizing real-life objects with common traits (food, student traits, cars, etc.) into groups and categories.	Using the periodic table and/or electron dot diagrams, identify the ionic charge of elements in groups 1, 2, 17, and 18.
PS.M.3 - Periodic Trends of the elements Representative Groups			
Research and predict where any new elements would go on the periodic table when the current table is complete.		Explain the difference between the properties/ionic charge of 2 elements chosen from groups 1, 2, 17, and 18. Given a group number and a period number determine if an element is a metal, nonmetal, or a metalloid.	Identify metals, nonmetals, metalloids, alkali metals, alkaline earth metals, halogens and noble gases based on their positions on the periodic table.
PS.M.4 - Bonding and compounds Bonding (ionic and covalent)			
	Using real-world examples, investigate the differences between an element in its elemental state vs. in a compound (Ex. elemental sodium vs. sodium	Using modeling, compare ionic and covalent compounds in terms of molecular and 3D lattice formation.	In terms of valence electrons, describe how ionic and covalent bonds are formed.

	in table salt, chlorine vs. chlorine in a pool, fluorine vs. fluoride compound like in toothpaste, etc.)	Observe the crystalline structure of salt under a microscope and compare it to the observations of sugar under a microscope.	Determine if a compound is an ionic or covalent compound.
PS.M.4 - Bonding and compounds Nomenclature			
		Given two elements, predict the chemical formula and name of an ionic compound Ex. calcium and chlorine = $CaCl_2$ = calcium chloride). Given a formula, name a covalent compound (ex. CO_2 = carbon dioxide) Research common household products for a headache, cold, swimming pool cleaner, salt, sugar, ammonia etc. and determine if the chemical formula is ionic or covalent. Given the elements and their location on the periodic table, predict if they will form ionic or covalent compounds.	Name the Greek prefixes (#1-10) for the covalent compounds. Identify the steps required to name binary compounds.
PS.M.5 - Reactions of Matter Chemical Reactions			
	Design an investigation to demonstrate and explain the law of conservation of matter (vinegar and baking soda in a ziplock bag).	Balance a chemical equation by placing coefficients in front of chemical formulas that are already written in equation form. Given names of elements and compounds, write and balance a chemical equation. Explain why $Na + Br_2$ yields NaBr and not $NaBr_2$.	Classify endothermic and exothermic reactions using previous knowledge. (ex. hot and cold packs). Give an example where temperature change is observable without measurement, where temperature change is observable with a thermometer, and where

			temperature change is impossible to measure.
PS.M.5 - Reactions of Matter **Nuclear Reactions**			
Explore the benefits of radiation and how it can be used as a tool to sustain life (sterilization and food irradiation processes, nuclear medicine). Include details about how the radiation works to accomplish the benefit and the extent (limit or range) that the benefit will continue as opposed to becoming a harm to life (plants, animals or human beings) on Earth. Draw conclusions and present an argument based on supporting data as to when radiation poses a threat as opposed to being beneficial. Present findings in multiple formats.	Devise a procedure to demonstrate the nuclear decay and half-life of a radioisotope.	Given the type of radioactive decay, write and balance an equation representing the nuclear reaction. Model half-life reactions by collecting and graphing data using everyday objects (ex. candy, pennies, etc). Research carbon dating using the C-14 isotope of carbon. Understand how the radioactive isotopes of several elements are used in nuclear testing. Research why different isotopes are used in specific fields (ex. Why isn't Uranium used in medical applications?, Food irradiation) Research the short and long-term effects of nuclear wastes. Research and interpret the consequences and information resulting from the synthesis of new elements and the technology involved.	Describe alpha, beta, and gamma radiation. Compare nuclear fission and nuclear fusion. Define radioisotope. Compare and contrast nuclear reactions with chemical reactions.

Resources

University of Colorado phet Build an Atom simulation
University of Colorado phet pH scale simulation
University of Colorado phet Balancing Chemical Equations simulation
STEMcoding project interactive on fluids/liquids, video
Atomic Solid interactive atomic lattice simulation
University of Colorado phet solid/liquid/gas simulation
A connection to nuclear chemistry, half-life and radioactive decay- link to activity
The link provided is a sweet simulation of half life- using a variety of colored candy
The following link Food Irradiation FDA will help students understand that the process is for presevation of food and that the food is not radioactive.
The following activity will help explain the separation of homogeneous/ heterogeneous mixtures.
This is a link to The American Chemical Society activities for Inquiry lesson.
University of Colorado phet Build a Molecule simulation
University of Colorado phet Rutherford Scattering simulation) The Rutherford experiment is a simulation that shows high-speed particles bombarding a thin foil. While the simulation is not to scale, it does provide a dynamic visual to help students understand what is happening at the atomic level that explains the experimental evidence

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ENERGY AND WAVES

Building upon knowledge gained in elementary and middle school, major concepts about energy and waves are further developed. Conceptual knowledge will move from qualitative understandings of energy and waves to ones that are more quantitative using mathematical formulas, manipulations and graphical representations.

PS.EW.1- Conservation of Energy

Energy content learned in middle school, specifically conservation of energy and the basic differences between kinetic and potential energy, is elaborated on and quantified in this course. Energy has no direction and has units of Joules (J). Kinetic energy, E_k , can be mathematically represented by $E_k = ½mv^2$. Gravitational potential energy, E_g, can be mathematically represented by $E_g = mgh$,. The amount of energy of an object is measured relative to a reference that is considered to be at a point of zero energy. The reference may be changed to help understand different situations. Only the change in the amount of energy can be measured absolutely. The conservation of energy and equations for kinetic and gravitational potential energy can be used to calculate values associated with energy (i.e., height, mass, speed) for situations involving energy transfer and transformation. Opportunities to quantify energy from data collected in experimental situations (e.g., a swinging pendulum, a car traveling down an incline) must be provided.

PS.EW.2- Transfer and Transformation of Energy

In middle school, concepts of energy transfer and transformation were addressed, including conservation of energy, conduction, convection and radiation, the transformation of electrical energy, and the dissipation of energy into thermal energy. Work also was introduced as a method of energy transfer into or out of the system when an outside force moves an object over a distance. In this course, these concepts are further developed. As long as the force, F, and displacement, Δx, are in the same or opposite directions, work, W, can be calculated from the equation $W = F\Delta x$. Energy transformations for a phenomenon can be represented through a series of pie graphs or bar graphs. Equations for work, kinetic energy and potential energy can be combined with the law of conservation of energy to solve problems. When energy is transferred from one system to another, some of the energy is transformed to thermal energy. Since thermal energy involves the random movement of many trillions of subatomic particles, it is less able to be organized to bring about further change. Therefore, even though the total amount of energy remains constant, less energy is available for doing useful work.

PS.EW.3- Waves

As addressed in middle school, waves transmit energy from one place to another, can transfer energy between objects and can be described by their speed, wavelength, frequency and amplitude. The relationship between speed, wavelength and frequency also was addressed in middle school Earth and Space Science as the motion of seismic waves through different materials is studied.

In elementary and middle school, reflection and refraction of light were introduced, as was absorption of radiant energy by transformation into thermal energy. In this course, these processes are addressed from the perspective of waves and expanded to include other types of energy that travel in waves. When a wave encounters a new material, the new material may absorb the energy of the wave by transforming it to another form of energy, usually thermal energy Waves can be reflected off solid barriers or refracted when a wave travels form one medium into another medium. Waves may undergo diffraction around small obstacles or openings. When two waves traveling through the same medium meet, they pass through each other then continue traveling through the medium as before. When the waves meet, they undergo superposition, demonstrating constructive and destructive interference. Sound travels in waves and undergoes reflection, refraction, interference and diffraction. In the physics syllabus, many of these wave phenomena will be studied further and quantified.

Radiant energy travels in waves and does not require a medium. Sources of light energy (e.g., the sun, a light bulb) radiate energy continually in all directions. Radiant energy has a wide range of frequencies, wavelengths and energies arranged into the electromagnetic spectrum. The electromagnetic spectrum is divided into bands: radio (lowest energy), microwaves, infrared, visible light, X-rays and gamma rays (highest energy) that have different applications in everyday life. Radiant energy of the entire electromagnetic spectrum travels at the same speed in a vacuum. Specific frequency, energy or wavelength ranges of the electromagnetic spectrum are not required. However, the relative positions of the different bands, including the colors of visible light, are important (e.g., ultraviolet has more energy than microwaves). Radiant energy exhibits wave behaviors including reflection, refraction, absorption, superposition and diffraction, depending in part on the nature of the medium. For opaque objects (e.g., paper, a chair, an apple), little if any radiant energy is transmitted into the new material. However the radiant energy can be absorbed, usually increasing the thermal energy of the object and/or the radiant energy can be reflected. For rough objects, the reflection in all directions forms a diffuse reflection and for smooth shiny objects, reflections can result in clear images. Transparent materials transmit most of the energy through the material but smaller amounts of energy may be absorbed or reflected.

Changes in the observed frequency and wavelength of a wave can occur if the wave source and the observer are moving relative to each other. When the source and the observer are moving toward each other, the wavelength is shorter and the observed frequency is higher; when the source and the observer are moving away from each other, the wavelength is longer and the observed frequency is lower. This phenomenon is called the Doppler shift and can be explained using diagrams. This phenomenon is important to current understanding of how the universe was formed and will be applied in later sections of this course. Calculations to measure the apparent change in frequency or wavelength are not appropriate for this course.

PS.EW.4- Thermal Energy

In middle school, thermal energy is introduced as the energy of movement of the particles that make up matter. Processes of heat transfer, including conduction, convection and radiation, are studied. In other sections of this course, the role of thermal energy during heating, cooling and phase changes is explored conceptually and graphically. In this course, rates of thermal energy transfer and thermal equilibrium are introduced.

Thermal conductivity depends on the rate at which thermal energy is transferred from one end of a material to another. Thermal conductors have a high rate of thermal energy transfer and thermal insulators have a slow rate of thermal energy transfer. The rate at which thermal radiation is absorbed or emitted by a system depends on its temperature, color, texture and exposed surface area. All other things being equal, in a given amount of time, black rough surfaces absorb more thermal energy than smooth white surfaces. An object or system is continually absorbing and emitting thermal radiation. If the object or system absorbs more thermal energy than it emits and there is no change in phase, the temperature increases. If the object or system emits more thermal energy than is absorbed and there is no change in phase, the temperature decreases. For an object or system in thermal equilibrium, the amount of thermal energy absorbed is equal to the amount of thermal energy emitted; therefore, the temperature remains constant. In chemistry, changes in thermal energy are quantified for substances that change their temperature.

PS.EW.5- Electricity

In earlier grades, these concepts were introduced: electrical conductors and insulators; and a complete loop is needed for an electrical circuit that may be parallel or in a series. In this course, circuits are explained by the flow of electrons, and current, voltage and resistance are introduced conceptually to explain what was observed in middle school. The differences between electrical conductors and insulators can be explained by how freely the electrons flow throughout the material due to how firmly electrons are held by the nucleus.

By convention, electric current is the rate at which positive charge flows in a circuit. In reality, it is the negatively charged electrons that are actually moving. Current is measured in amperes (A), which is equal to one coulomb of charge per second (C/s). In an electric circuit, the power source supplies the electrons already in the circuit with electric potential energy by doing work to separate opposite charges. For a battery, the energy is provided by a chemical reaction that separates charges on the positive and negative sides of the battery. This separation of charge is what causes the electrons to flow in the circuit. These electrons then transfer energy to other objects and transform electrical energy into other forms (e.g., light, sound, heat) in the resistors. Current continues to flow, even after the electrons transfer their energy. Resistors oppose the rate of charge flow in the circuit. The potential difference or voltage across an energy source is a measure of potential energy in Joules supplied to each coulomb of charge. The volt (V) is the unit of potential difference and is equal to one Joule of energy per coulomb of charge (J/C). Potential difference across the circuit is a property of the energy source and does not depend upon the devices in the circuit. These concepts can be used to explain why current will increase as the potential difference increases and as the resistance decreases. Experiments, investigations and testing (3-D or virtual) must be used to construct a variety of circuits, and measure and compare the potential difference (voltage) and current. Electricity concepts are dealt with conceptually in this course. Calculations with circuits will be addressed in the physics syllabus.

Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟵	⟶	Least Complex	
Energy and Waves				
PS.EW.1 Conservation of energy ○ Quantifying kinetic energy ○ Quantifying gravitational potential energy	**PS.EW.1a** Describe the requirement(s) to change an object's energy from kinetic to potential (or potential to kinetic).	**PS.EW.1b** When a given a situation, identify if the change in energy was to kinetic or potential energy.	**PS.EW.1c** Identify a situation that demonstrates a change to the kinetic or the potential energy of an object.	HS-PS3-1 Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. HS-PS3-2 Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects). HS-PS3-3 Design, build, and refine a device that works with given constraints to convert one form of energy into another form of energy. 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.
PS.EW.2 Transfer and transformation of energy (including work)	**PS.EW.2a** Describe how heat energy can be transferred (e.g., radiation, conduction, convection).	**PS.EW.2b** Identify the transformation of energy in a given scenario (e.g., light bulb).	**PS.EW.2c** Identify that energy can be transferred (e.g., electricity is transferred to light energy in a light bulb).	HS-PS3-1 Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. HS-PS3-3 Design, build, and refine a device that works with given constraints to convert one form of energy into another form of energy.

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PS.EW.3 Waves ○ Reflection, Refraction, Diffraction, Absorption, Superposition ○ Doppler Shift				HS-PS4-3 Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations, one model is more useful than the other. HS-PS4-4 Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. 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.
PS.EW.4 Thermal energy	**PS.EW.4a1** Describe how thermal energy moves from a warmer object to a cooler object. **PS.EW.4a2** Describe how different colors of objects absorb thermal energy differently.	**PS.EW.4b1** Identify heat as thermal energy **PS.EW.4b2** Explore how thermal energy can be absorbed by objects.	**PS.EW.4c1** Identify heat as the cause of a phase change. **PS.EW.4c2** Follow the path of thermal energy transfer in a diagram.	
PS.EW.5 Electricity ○ Movement of electrons ○ Current ○ Electric potential ○ Resistors and transfer of energy				

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EVIDENCE OF LEARNING
Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

Designing technological / engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PS.EW.1 - Conservation of Energy Quantifying kinetic energy			
In the context of an engineering design project, understand how both the speed and the mass of an object is an important design consideration (e.g. ping pong ball vs bowling ball) The larger the kinetic energy of an object the more of a safety hazard it may be.	Devise a procedure to calculate the speed of an object at constant velocity using a meter stick and a stopwatch or from a frame-by-frame motion capture video that exhibits constant velocity behavior. Use measured speed and mass to calculate kinetic energy.	View objects in motion, quantitatively/qualitatively classify them as high or low kinetic energy and explain why.	Define parameters of a physical system (open and closed). Perform routine mathematical calculations of kinetic energy given an object's mass and velocity.
PS.EW.1 - Conservation of Energy Quantifying gravitational potential energy			
Design and build a roller coaster with at least 2 loops and one hill. Use the roller coaster to calculate kinetic and potential energy and identify the quantity of energy transferred out of the system during the ride. Then engineer a new design that would decrease the energy loss from the system.		Compare and explain how the gravitational potential energy of an object varies based on the position of the reference point. Calculate the drop heights of objects based on their velocity at impact.	Perform routine mathematical calculations of potential energy given an object's mass and height above a reference point. .

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PS.EW.2 - Transfer and transformation of energy (including work)			
Build an electric bicycle to run common electric items. Use energy analysis (bar graph and/or pie chart) in the context of this engineering design project. Explain how energy analysis relates to this design goal. Design, build and test a ramp system onto which a ball can be placed so that it rolls down a ramp and continues a specific distance on the table. Describe what properties of the system were important (and those not important) in the design. Provide different target distances for the launched ball to travel on the designed course and hit a given target within three trials.	Construct a pendulum and create/perform experiment to analyze the relationship between measurable variables (mass of bob, length of string, height of drop) and energy/time of motion.	Use bar and pie graph data to explain energy transformations occuring in a closed system (ex. Energy Skate Park in Phet).	Compare and contrast energy transfer and energy transformation.
PS.EW.3 - Waves **Refraction, reflection, diffraction, absorption, superposition**			
Investigate the relationship between speed, frequency and wavelength for a transverse wave traveling through a Slinky®. Make claims about what happens to the speed and the wavelength of the wave as the frequency is increased and give evidence to support any claims. Use information from the investigation to explore beneficial and harmful aspects of the use of technology (such as cell phones) for a modern convenience. Present findings and	Explore bending of light between two media with different indices of refraction using lasers and a variety of other materials such as water, air, glass, plastic, and so forth. Investigate where a person would have to sit in relation to the location of underwater life to see it through a plastic or glass barrier.	Construct a model to compare and contrast sound waves and radiant waves. Design an experiment to demonstrate how changing a medium from air to water to glass changes the bending angle. Play with prisms of different shapes and make rainbows.	Give examples and illustrate wave behaviors including reflection, refraction, absorption, diffraction, and superposition. Define medium and vacuum.

draw a conclusion using data and research in multiple formats.			
PS.EW.3 - Waves **Radiant energy and the electromagnetic spectrum**			
	Design an experiment to investigate radiant energy transmission, absorption, and reflection with a variety of materials (opaque, transparent, rough smooth, etc.). Explore the benefits of radiation and how it can be used as a tool to sustain life (sterilization and food irradiation processes, nuclear medicine). Include details about how the radiation works to accomplish the benefit and the extent (limit or range) that the benefit will continue as opposed to becoming a harm to life (plants, animals or human beings) on Earth. Draw conclusions and present an argument based on supporting data as to when radiation poses a threat as opposed to being beneficial. Present findings in multiple formats.	Using the electromagnetic spectrum, compare wave energy, frequency, and wavelength using relative position. Investigate the use of sound or radiant waves in medicine or everyday life applications (ultrasound, lasers, x-rays, etc.).	Identify the placement of each type of wave (gamma, x-ray, ultraviolet, visible, infrared, micro, radio) along the electromagnetic spectrum.
PS.EW.3 - Waves **Doppler Shift**			
Students should design and develop a procedure or device that uses doppler shift to measure speed (e.g. used by the police). Students should determine the speed of objects through data collected.	Using a doppler shift simulation, design an experiment to explain the relationship between frequency, wavelength, velocity, pitch and/or intensity.	Describe how the doppler shift effect can produce a change in pitch.	Identify how and why doppler shift occurs. SIM: http://ophysics.com/waves11.html

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PS.EW.4 - Thermal Energy			
Understand how thermal conductivity concepts can be useful in an engineering design context	Design an experiment to demonstrate the rate of thermal conductivity of various materials (various metals, black vs. white, surface area, rough vs. smooth, hot vs. cold).	Investigate the behavior of conductors and insulators for various materials.	Differentiate between a thermal insulator and thermal conductor. Provide examples of thermal conductors and thermal insulators.
PS.EW.5 - Electricity Movement of electrons			
Using the electrical properties of different materials, suggest why one material is used in engineering design over another (ex: aluminum vs. copper). Create a circuit board to illustrate electric flow in parallel and series. Explain where the two systems are used for maximum electrical output.	A plasma ball is a frequently used demo in which electrons move through a gas, in the process causing neon/xenon atoms inside the ball to emit photons. Electrons tend to move together through little channels. Touching the plasma ball affects where these channels form. Importantly, the channels light up because of electron motion and it is dark where the electrons are not flowing. Investigate the behavior of plasma balls and discuss movement of electrons through them.	Build and/or model (using schematics) series and parallel circuits.	Differentiate how electrons flow in an insulator versus a conductor. Identify examples of conductors and insulators. Differentiate between a series and parallel circuit. Define current, voltage and resistance.
PS.EW.5 - Electricity Current			
Deconstruct and judge how the maximum current in a circuit can be important in an engineering design context (ex. safety hazard, fuses).	Design and build several circuit boards where current does not flow. Hypothesize why the current is not flowing and implement a solution to resolve the problem.	Explain how current flows even after the electrons transfer their energy. Measure the current in a circuit using an ammeter or multi-meter.	Explain how a battery works. Recall that batteries work because of chemical reactions.
PS.EW.5 - Electricity Electric Potential (voltage)			
An engineering challenge where students need to configure a circuit and a few light bulbs (or LEDs) to		Use a voltmeter to measure the potential difference (in Volts) of different batteries.	Know in what units electric potential is measured in.

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produce at least certain amount of light for some application. Students will naturally find that adding bulbs in series won't produce enough light. Only adding bulbs in parallel will produce significant light.			Recall that the electric potential of a battery does not depend upon the electrical devices attached to it, it is a property of the battery itself.
PS.EW.5 - Electricity Resistors and transfer of energy			
Build and wire an electronic "bug" to complete a path through an obstacle course. Understand how resistance is an important concept in an engineering design context, for example, in determining how many light fixtures a circuit can handle, and understanding how lack of insulation can cause short circuits (which decreases the resistance of the circuit and could cause damage).	Investigate current, voltage and resistance in series verses in parallel circuits.	Determine the relationship between current, voltage and resistance given a variety of resistors and multiple batteries.	Recall that the movement of electrons through a resistor depends upon the potential difference.

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Resources

University of Colorado Phet simulations:
Energy Skate Park - This simulation allows students to study the conservation of energy with a skater. Students can built tracks and ramps for the skater and study how he moves and jumps to look at kinetic energy, potential energy, and friction. You can also study gravity and motion by studying the skater on different planets and in space.
Phet has a lesson on doppler shift as well as simulations exploring sound and waves as well as wave interference.
Phet also has a simulation exploring sound.
Ohio Energy Project: Relevant, informative, fun — that's energy education from the Ohio Energy Project. Created by teachers for teachers, OEP has been energizing classrooms with hands-on, interactive learning tools and programs since 1984. OEP brings the latest in the energy field to teachers and students in a way that makes everyone take notice by working with utilities, the State of Ohio, nonprofit organizations, energy organizations, universities, manufacturers and others.
Physics Classroom is a site that allows students to access physics tutorials, interactives, and concept builders to help clarify content.
https://serc.carleton.edu/dmvideos/videos/roller_coaster.html: View the motion of a roller coaster frame by frame and use this to determine time intervals and displacement for the coaster. Use this data to find the velocity of the roller coaster and use velocity to calculate kinetic energy.
http://go.osu.edu/waves (Wave interference interactive from the STEMcoding project, video here: http://go.osu.edu/wavesvideo)
http://go.osu.edu/conductor (Electron motion through a conductor from the STEMcoding project, press E to increase electric field, which increases the electric potential difference, for explanation see http://go.osu.edu/conductorvideo)
http://modelinginstruction.org (American Modeling Teachers Association) American Modeling Teachers Association has information on workshops offered that teach modeling instruction. There are also several units available for download in the Physical Science curriculum.

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FORCES AND MOTION

Forces and Motion

Building upon content in elementary and middle school, major concepts of motion and forces are further developed. In middle school, speed has been dealt with conceptually, mathematically and graphically. The concept that forces have both magnitude and direction can be represented with a force diagram, that forces can be added to find a net force and that forces may affect motion has been addressed in middle school. At the high school level, mathematics (including graphing) is used when describing these phenomena, moving from qualitative understanding to one that is more quantitative. For the physical science course, all motion is limited to objects moving in a straight line either horizontally, vertically, up an incline or down an incline, that can be characterized by segments of uniform motion (e.g., at rest, constant velocity, constant acceleration). Motions of two objects may be compared or addressed simultaneously (e.g., when or where would they meet).

- **Motion**

  The motion of an object depends on the observer's frame of reference and is described in terms of distance, position, displacement, speed, velocity, acceleration and time. Position, displacement, velocity and acceleration are all vector properties (magnitude and direction). All motion is relative to whatever frame of reference is chosen, for there is no motionless frame from which to judge all motion. The relative nature of motion will be addressed conceptually, not mathematically. Non- inertial reference frames are excluded. **Motion diagrams** can be drawn and interpreted to represent the position and velocity of an object. Showing the acceleration on motion diagrams will be reserved for physics.

  The displacement or change in position of an object is a vector quantity that can be calculated by subtracting the initial position from the final position ($\Delta x = x_f - x_i$). Displacement can be positive or negative depending upon the direction of motion. Displacement is not always equal to the distance travelled. Examples should be given where the distance is not the same as the displacement.

  Velocity is a vector property that represents the rate at which position changes. Average velocity can be calculated by dividing displacement (change in position) by the elapsed time ($v_{avg} = (x_f - x_i)/(t_f - t_i)$). Velocity may be positive or negative depending upon the direction of motion and is not always equal to the speed. Provide examples of when the average speed is not the same as the average velocity. Objects that move with constant velocity have the same displacement for each successive time interval. While speeding up or slowing down and/or changing direction, the velocity of an object changes continuously, from instant to instant. The speed of an object at any instant (clock reading) is called instantaneous speed. An object may not travel at this instantaneous speed for any period of time or cover any distance with that particular speed, especially if the speed is continually changing.

  Acceleration is a vector property that represents the rate at which velocity changes. Average acceleration can be calculated by dividing the change in velocity divided by elapsed time ($a_{avg} = (v_f - v_i)/(t_f - t_i)$). At this grade level, it should be noted that acceleration can be positive or negative, but specifics about what kind of motions produce positive or negative accelerations will be addressed in the physics syllabus. The word "deceleration" should not be used because students tend to associate a negative sign of acceleration only with slowing down. Objects that have no acceleration can either be standing still or be moving with constant velocity (speed and direction). Constant acceleration occurs when the change in an object's instantaneous velocity is the same for equal successive time intervals.

  Motion can be represented by position vs. time and velocity vs. time graphs. Specifics about the speed, direction and change in motion can be determined by interpreting such graphs. For physical science, graphs will be limited to positive x-values and show only uniform motion involving segments of constant velocity or constant acceleration. Motion must be investigated by collecting and analyzing data in the laboratory. Technology can enhance motion exploration and investigation through video analysis, the use of motion detectors and graphing data for analysis.

  Objects that move with constant velocity and have no acceleration form a straight line (not necessarily horizontal) on a position vs. time graph. Objects that are at rest will form a straight horizontal line on a position vs. time graph. Objects that are accelerating will show a curved line on a position vs. time graph. Velocity can be calculated by determining the slope of a position vs. time graph. Positive slopes on position vs. time graphs indicate motion in a positive direction. Negative slopes on position vs. time graphs indicate motion in a negative direction. While it is important that students can construct graphs by hand, computer graphing programs or graphing calculators also can be used so more time can be spent on graph interpretation and analysis.

  Constant acceleration is represented by a straight line (not necessarily horizontal) on a velocity vs. time graph. Objects that have no acceleration (at rest or moving at constant velocity) will have a straight horizontal line for a velocity vs. time graph. Average acceleration can be determined from the slope of a velocity vs. time graph. The details about motion graphs should not be taught as rules to memorize, but rather as generalizations that can be developed from interpreting the graphs.

- **Forces**

  Force is a vector quantity, having both magnitude and direction. The (SI) unit of force is a Newton. One Newton of net force will cause a 1 kg object to experience an acceleration of 1 m/s^2. A Newton also can be represented as $kg{\cdot}m/s^2$. The opportunity to measure force in the lab must be provided (e.g., with a spring scale or a force probe). Normal forces and tension forces are introduced conceptually at this level. These forces and other forces introduced in prior grades (friction, drag, contact, gravitational, electric and magnetic) and can be used as examples

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of forces that affect motion. Gravitational force (weight) can be calculated from mass, but all other forces will only be quantified from force diagrams that were introduced in middle school. In physical science, only forces in one dimension (positive and negative) will be addressed. The net force can be determined by one-dimensional vector addition. More quantitative study of friction forces, universal gravitational forces, elastic forces and electrical forces will be addressed in the physics syllabus.

Friction is a force that opposes sliding between two surfaces. For surfaces that are sliding relative to each other, the force on an object always points in a direction opposite to the relative motion of the object. In physical science, friction will only be calculated from force diagrams. Equations for static and kinetic friction are found in the physics syllabus.

A normal force exists between two solid objects when their surfaces are pressed together due to other forces acting on one or both objects (e.g., a solid sitting on or sliding across a table, a magnet attached to a refrigerator). A normal force is always a push directed at right angles from the surfaces of the interacting objects. A tension force occurs when a non-slack rope, wire, cord or similar device pulls on another object. The tension force always points in the direction of the pull.

In middle school, the concept of a field as a region of space that surrounds objects with the appropriate property (mass for gravitational fields, charge for electric fields, a magnetic object for magnetic fields) was introduced to explain gravitational, magnetic and electrical forces that occur over a distance. The field concept is further developed in physical science. The stronger the field, the greater the force exerted on objects placed in the field. The field of an object is always there, even if the object is not interacting with anything else. The gravitational force (weight) of an object is proportional to its mass. Weight, Fg, can be calculated from the equation $F_g = m\,g$, where g is the gravitational field strength of an object which is equal to *9.8 N/kg* (m/s^2) on the surface of Earth.

- **Dynamics**

  An object does not accelerate (remains at rest or maintains a constant speed and direction of motion) unless an unbalanced net force acts on it. The rate at which an object changes its speed or direction (acceleration) is proportional to the vector sum of the applied forces (net force, F_{net}) and inversely proportional to the mass ($a = F_{net}/m$). When the vector sum of the forces (net force) acting on an object is zero, the object does not accelerate. For an object that is moving, this means the object will remain moving without changing its speed or direction. For an object that is not moving, the object will continue to remain stationary. These laws will be applied to systems consisting of a single object upon which multiple forces act. Vector addition will be limited to one dimension (positive and negative). While both horizontal and vertical forces can be acting on an object simultaneously, one of the dimensions must have a net force of zero.

  A force is an interaction between two objects. Both objects in the interaction experience an equal amount of force, but in opposite directions. Interacting force pairs are often confused with balanced forces. Interacting force pairs can never cancel each other out because they always act on different objects. Naming the force (e.g., gravity, friction) does not identify the two objects involved in the interacting force pair. Objects involved in an interacting force pair can be easily identified by using the format "A acts on B so B acts on A." For example, the truck hits the sign therefore the sign hits the truck with an equal force in the opposite direction. Earth pulls the book down so the book pulls Earth up with an equal force. The focus of the content is to develop a conceptual understanding of the laws of motion to explain and predict changes in motion, not to name or recite a memorized definition. In the physics syllabus, all laws will be applied to systems of many objects.

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟵		⟶ Least Complex	
Forces and Motion				
PS.FM.1 Motion ○ Introduction to one-dimensional vectors ○ Displacement, velocity (constant, average and instantaneous) and acceleration. ○ Interpreting position vs. time and velocity vs. time graphs	**PS.FM.1a** Describe the motion of an object given its placement on a graph (position vs. time graph).	**PS.FM.1b** Identify the force (balanced or an unbalanced force) of a moving object.	**PS.FM.1c** Apply an unbalanced force to an object to change its motion (e.g., accelerate it, stop it, start it).	HS-PS2-1 Analyze data to support the claim that Newton's Second Law of Motion describes the mathematical relationship among the net force on a macroscopic object, its mass and its acceleration. HS-PS2-2 Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. HS-PS3-3 Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
PS.FM.2 Forces ○ Force diagrams ○ Types of forces (gravity, friction, normal, tension) ○ Field model for forces at a distance	**PS.FM.2a1** Create a force diagram by indicating the location and direction of the normal force. **PS.FM.2a2** Organize the surface types from "causes the most friction" (most difficult to push) to "causes the least amount of friction" (easiest to push).	**PS.FM.2b1** Label forces and/or directions of forces on a force diagram. **PS.FM.2b2** Investigate friction and normal force as it relates to moving an object (sliding furniture over different types of flooring).	**PS.FM.2c1** Identify a force on an object in a force diagram. **PS.FM.2c2** Recognize that diverse surface types cause friction differently.	HS-PS2-1 Analyze data to support the claim that Newton's Second Law of Motion describes the mathematical relationship among the net force on a macroscopic object, its mass and its acceleration. HS-PS2-2 Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. HS-PS3-3 Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
PS.FM.3 Dynamics (how forces affect motion) ○ Objects at rest ○ Objects moving with constant velocity ○ Accelerating objects	**PS.FM.3a** Describe a motion of an object given its position vs. time graph.	**PS.FM.3b** Apply an unbalanced force to an object to change its motion (e.g., accelerate it, stop it, start it).	**PS.FM.3c** Identify an unbalanced force.	HS-PS2-1 Analyze data to support the claim that Newton's Second Law of Motion describes the mathematical relationship among the net force on a macroscopic object, its mass and its acceleration. HS-PS2-3

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				Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

EVIDENCE OF LEARNING

Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

Designing technological / engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PS.FM.1 - Motion Activity/Example			
Introduction to one-dimensional vectors			
	Design a procedure to investigate the motion of two battery operated buggies with different constant speeds to produce motion diagrams with velocity vectors.	Provide examples of situations where the frame of reference of an observer would affect the appearance of motion. Draw motion diagrams for various one-dimensional motions. Interpret motion diagrams for various one-dimensional motions to determine starting position, direction, time change, position change, and velocity.	Identify examples of motion that are one-dimensional and two-dimensional. Identify variable examples of vector quantities and scalar quantities.
Displacement, velocity (constant, average and instantaneous) and acceleration			

Research the ranges of human reaction time and braking accelerations. Design a traffic light pattern (e.g., how long the light should stay yellow) for a particular intersection, given the speed limits. Present the design and rationale to the class. Compare the results for different speed limits. Explain any patterns and trends observed.	.	Identify and explain the relationships between displacement, velocity, acceleration using a cause-and-effect model. Describe how an object can have a distance that is not the same as the displacement and a velocity that is not the same as speed (which is always positive). Apply the calculations of speed, velocity, and/or acceleration to a "different" situation (chomps of bubble gum, bounces of a basketball, etc).	Provide examples demonstrating positive and negative displacement, positive and negative velocity, and positive and negative acceleration. Distinguish velocity from speed and provide examples . Calculate average velocity and acceleration from basic word problems. Distinguish average velocity from instantaneous velocity.
Interpreting position vs. time and velocity vs. time graphs			
	Prepare a procedure/experiment to investigate the relationship between position and time for a cart that rolls down a ramp from rest. Graph the results. Make a claim about how position and time are related and use evidence to support the claim. Present the findings to the class. Based on the presentations of other investigations in class, propose sources of error and provide suggestions for how the experiments can be improved. So-called "Direct measurement videos" can be used in this context. The "Newton's First Law" activity from Interactive Video Vignettes is a free resource that makes students click the object on the screen in each frame to chart its motion and velocity.	Calculate the slope of a position vs time or velocity vs time graph and equate it to the average velocity or average acceleration of an object.	On a position-time graph, identify when an object is showing no motion, constant velocity and constant acceleration. On a velocity-time graph, identify when an object is showing no motion, constant velocity and constant acceleration.

PS.FM.2 - Forces Activity/Example			
Force diagrams			
		Measure one dimensional forces using a spring scale (book pulled across table, hanging object, etc.) and diagram the system using force diagrams. Determine the net force acting on an object (book sitting on a table, book being pulled across a tabletop at constant velocity, book being pulled across a tabletop speeding up/slowing down) and draw the force diagram associated with it.	Recognize and explain the unit of 1 Newton of force (1 N of force will cause a 1 kg object to accelerate at 1 m/s^2).
Types of forces (gravity, friction, normal, tension)			
Construct a paper airplane and investigate design changes (using paper clips, pennies, tape, different paper, etc.) to decrease drag, increase flight time/distance, and/or improve flight performance when applying the same amount of thrust (applied force).	Investigate how forces of water (buoyant forces) behave on various objects (round, square, solid, hollow, large, small) and design an object (boat; given specific parameters) that could hold the most mass.		Provide examples of forces (normal, tension, gravitational, frictional, applied, magnetic, electrical, etc.) that affect motion and differentiate between contact and noncontact forces.
Field model for forces at a distance			
	Design an experiment to determine the relationship between weight of an object in Newtons (measured with a spring scale) and mass of an object in kilograms. Create a graph of the data collected and recognize that the slope represents the gravitational pull of Earth. Compare this graph to a graph made with data from a planet with a	Observe two objects interacting within a field (define a closed system such as an object falling to Earth, or a magnet acting on a paperclip, or two pieces of scotch tape repelling or attracting each other) and draw force vectors to show relative magnitude.	Identify the relationship between magnitude of a gravitational field and the magnitude of the force on an object placed in the field.

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	gravitational field noticeably different from Earth,e.g. the moon, Jupiter, etc.	Calculate the gravitational force on an object (weight) on earth and compare that to the calculated weights on other bodies (planets/moon).	
PS.FM.3 - Dynamics (how forces affect motion) Activity/Example			
Objects at rest			
		Paraphrase the relationship between an object's mass and its inertia. Given a cup, index card, and penny, investigate when the penny falls into the cup and when it doesn't. Explain how this works.	Calculate weight of an object given its mass. Describe Newton's three laws of motion and provide real-life examples of each. Use F=ma to calculate all three variables from basic word problems.
Objects moving with constant velocity			
	Design an experiment to investigate terminal velocity and understand that the object moves with constant velocity when no net force is acting on the object. Using cars with various masses released down a ramp, design an experiment to identify the relationship between force, mass, and acceleration.	Using the Forces and Motion simulation, explain how observations made in the simulation support Newton's First Law of Motion. Determine the velocity of a car given its oil drop pattern, the velocity of a weapon given its crime scene blood pattern, or the velocity of the wind given the raindrop pattern on concrete.	Explain how Newton's First Law of Motion applies to a basic situation (ball rolling across a floor, spinning wheel, etc.).

Accelerating objects			
Human gyroscopes, roller coasters, trampolines, ziplines, and bumper boats are all entertainments designed using the concepts of forces and motion. Suggest a new invention or an improvement to current activities such as these. Critique alternatives to current airbag design to change how objects of different masses are stopped by an airbag.	Design and implement an experiment to determine the relationship between force, mass, and acceleration (Changing masses down a ramp, variable forces applied to a constant mass on a spring, fan carts with variable mass, etc.).	Explain how observations made in the Forces and Motion simulation support Newton's Second Law of Motion. Observe fan carts that contain various masses. Relate the acceleration changes that occur to a truck or vehicle carrying various loads.	Using force diagrams, identify interacting force pairs and label magnitude and direction. Using 1 dimensional force diagrams, identify the direction of the net force and acceleration.

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THE UNIVERSE

The Universe

In early elementary school, observations of the sky and space are the foundation for developing a deeper knowledge of the solar system. In late elementary school, the parts of the solar system are introduced, including characteristics of the sun and planets, orbits and celestial bodies. At the middle school level, energy, waves, gravity and density are emphasized in the physical sciences, and characteristics and patterns within the solar system are found.

In the physical science course, the universe and galaxies are introduced, building upon the previous knowledge about space and the solar system in the earlier grades.

- **History of the Universe**

  The Big Bang Model is a broadly accepted theory for the origin and evolution of our universe. It postulates that 12 to 14 billion years ago, the portion of the universe seen today was only a few millimeters across (**NASA**).

  According to the "**big bang**" theory, the contents of the known universe expanded explosively into existence from a hot, dense state 13.7 billion years ago (NAEP 2009). After the big bang, the universe expanded quickly (and continues to expand) and then cooled down enough for atoms to form. Gravity pulled the atoms together into gas clouds that eventually became stars, which comprise young galaxies. Foundations for the big bang model can be included to introduce the supporting evidence for the expansion of the known universe (e.g., Hubble's law and red shift or cosmic microwave background radiation). A discussion of Hubble's law and red shift is found in the *Galaxy formation* section, below.

  Technology provides the basis for many new discoveries related to space and the universe. Visual, radio and x-ray telescopes collect information from across the entire electromagnetic spectrum; computers are used to manage data and complicated computations; space probes send back data and materials from remote parts of the solar system; and accelerators provide subatomic particle energies that simulate conditions in the stars and in the early history of the universe before stars formed.

- **Galaxy formation**

  A galaxy is a group of billions of individual stars, star systems, star clusters, dust and gas bound together by gravity. There are **billions of galaxies in the universe**, and they are classified by size and shape. The Milky Way is a spiral galaxy. It has more than 100 billion stars and a diameter of more than 100,000 light years. At the center of the Milky Way is a collection of stars bulging outward from the disk, from which extend spiral arms of gas, dust and most of the young stars. The solar system is part of the Milky Way galaxy.

  Hubble's law states that galaxies that are farther away have a greater red shift, so the speed at which a galaxy is moving away is proportional to its distance from the Earth. Red shift is a phenomenon due to Doppler shifting, so the shift of light from a galaxy to the red end of the spectrum indicates that the galaxy and the observer are moving farther away from one another. Doppler shifting also is found in the *Energy and Waves* section of this course.

- **Stars**

  Early in the formation of the universe, stars coalesced out of clouds of hydrogen and helium and clumped together by gravitational attraction into galaxies. When heated to a sufficiently high temperature by gravitational attraction, stars begin nuclear reactions, which convert matter to energy and fuse the lighter elements into heavier ones. These and other fusion processes in stars have led to the formation of all the other elements. (NAEP 2009). All of the elements, except for hydrogen and helium, originated from the nuclear fusion reactions of stars (College Board Standards for College Success, 2009).

  Stars are classified by their color, size, luminosity and mass. A **Hertzprung-Russell diagram** must be used to estimate the sizes of stars and predict how stars will evolve. Most stars fall on the main sequence of the H-R diagram, a diagonal band running from the bright hot stars on the upper left to the dim cool stars on the lower right.

  A star's mass determines the star's place on the main sequence and how long it will stay there. Patterns of stellar evolution are based on the mass of the star. Stars begin to collapse as the core energy dissipates. Nuclear reactions outside the core cause expansion of the star, eventually leading to the **collapse of the star**.

Note: Names of stars and naming the evolutionary stage of a star from memory will not be assessed. The emphasis is on the interpretation of data (using diagrams and charts) and the criteria and processes needed to make those determinations.

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Ohio Learning Standard	Complexity a	Complexity b	Complexity c	NGSS Alignment
Generic	Most Complex ⟵		⟶ Least Complex	
The Universe				
PS.U.1 History of the universe	**PS.U.1a** Create a model that shows how the universe is expanding (e.g., blowing up a balloon).	**PS.U.1b** Identify a model that illustrates the Big Bang theory.	**PS.U.1c** Recognize that the universe is expanding.	HS-ESS1-2 Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.
PS.U.2 Galaxies	**PS.U.2a** Classify a galaxy based on its shape (e.g., spiral, barred-spiral, elliptical, irregular).	**PS.U.2b** Match two galaxies of the same type (e.g., spiral, elliptical).	**PS.U.2c** Recognize that many stars make up a galaxy.	HS-ESS1-2 Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.
PS.U.3 Stars ○ Formation; stages of evolution ○ Fusion in stars	**PS.U.3a** Match a star of a specific relative mass (e.g., low, medium, high) with its life cycle.	**PS.U.3b** Identify "mass" as the property that determines the life cycle of a star.	**PS.U.3c** Recognize that stars form from clouds of gas.	HS-ESS1-1 Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation. HS-ESS1-3 Communicate scientific ideas about the way stars, over their life cycle, produce elements.

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EVIDENCE OF LEARNING
Students who demonstrate understanding can:

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Designing technological / engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PS.U.1 - History of the Universe			
The "wonder tube" (a.k.a. "mystery tube") is an activity that demonstrates a puzzling situation where students try to figure out how something works without seeing what is on the inside of the tube. In an engineering design context, there can be situations where we cannot directly observe or measure something in a straightforward way. For example: a rover on Mars develops a technical problem and an engineering team has to remotely diagnose and figure out what to do about it. In much the same way, we cannot simply travel to inspect stars and galaxies or even the whole universe but careful thought about the things we can observe can reveal a great deal. • Investigate features of a solid planetary body using the WorldWide Telescope. Identify features that are oldest versus those that are youngest and draw conclusions about the reasons for the	Analyze a plot of the distance versus redshift (i.e. doppler shift) of galaxies to recognize the trend for more distant galaxies to be moving faster away from our location. Construct a model to show this phenomenon (drawing dots on a balloon and blowing it up is commonly used as an illustration of the way that galaxies move apart in an expanding universe, another model is paperclips on a stretching rubber band).	Explain the premise of the "Cosmic Calendar" which describes the 14 billion year history of the universe in 365 days by constructing a cosmic calendar using a 1 year calendar. Explain the "raisin cake" analogy for the expansion of the universe and how it makes sense of the observed relationship between distance and redshift of nearby galaxies.	Recall that the universe had a beginning in the distant past (i.e the universe is not infinitely old). Recall and provide evidence that the universe is expanding (not contracting or staying the same over time).

differences using current theory to support the conclusions.			
PS.U.2 - Galaxies			
Classification can be an important strategy in an engineering design context where certain things are poorly understood. Galaxies were classified into elliptical, spiral and irregular long before scientists understood very much about how these objects formed. In an engineering design context, there can be complex situations where computer simulations are needed to understand how a proposed design might behave. Galaxies are a good example of a complex system that computer simulations help us to understand. Classroom activity: when things break we can classify the problem (ex. car won't start, internet is out) and this can help us navigate the situation. Astronomers often classify objects before they fully understand what they are (ex. short/long-duration gamma ray bursts). Research the Hubble space telescope from an engineering perspective. What were the problems encountered by this mission and how they were solved? How was the telescope upgraded over time? What scientific knowledge was gained from these technological improvements and fixes? What future improvements to	Use real-time data from the NASA Hubble Mission to research and document the history of the mission, marking the time, discoveries and impact to humans. There are links at the NASA site to connect students to astronauts and scientists to allow for primary and secondary resources in the research. Present a final product (can be an e-portfolio, presentation or formal poster session) to an authentic audience. Evaluate data analyzing the penetration ability of Gamma radiation, X-rays, UV, visible light, infrared and radio wavelengths in Earth's atmosphere. Based on the analysis and pertinent wavelength-study considerations (e.g., certain wavelengths of light are blocked from reaching Earth's surface by the atmosphere; how efficiently telescopes work at different wavelengths; telescopes in space are much more expensive to construct than Earth-based telescopes) recommend to a federal funding agency which telescope project should receive funds for construction. The two projects to consider are: • Project 1 – A UV wavelength telescope, placed high atop Mauna Kea in Hawaii at 14,000 ft. above sea level, which will be used to look at distant galaxies. • Project 2 – A visible wavelength telescope, placed on a satellite in orbit around Earth, which will be used to observe a pair of binary stars located in the constellation Ursa Major (Big	Explain that galaxies form in the early universe when gravity causes gas clouds to collapse to form stars Students should explain that we only see galaxies because of the starlight produced. Show examples of spiral, elliptical and irregular galaxies. Watch a "Powers of ten" video that starts with 1 meter on the earth and zooms out to illustrate solar system spatial scales, the scale of the Milky Way galaxy, and the scale of galaxies beyond the Milky way. There are a number of different "scales of ten" videos that exist but the basic idea is the same. Use a 3D printer to construct and print images of spiral, elliptical and irregular galaxies (https://www.thingiverse.com/TactileUniverse/designs) or print out pictures of galaxies (e.g. Messier objects that are galaxies). Have students sort these galaxies into types (elliptical, spiral and irregular). Images of Messier objects can be found here: https://www.nasa.gov/content/goddard/hubble-s-messier-catalog Note that "globular clusters" are not galaxies. Read description before printing out the image.	Recall there are three galaxy types: elliptical, spiral and irregular. Recall that our galaxy (the Milky Way) is a spiral galaxy. Recall that the solar system is part of the Milky Way galaxy.

the Hubble telescope would you make? Resource: https://www.nasa.gov/mission_pages/hubble/servicing/index.html	Dipper). (Prather, Slater, Adams, & Brissenden, 2008)		
PS.U.3 - Stars			
Formation; stages of evolution			
	Stars and planetary systems form from the collapse of gas and dust into a spinning "protoplanetary" disc. Because the inner parts of the disc spin faster than the outer parts, this can cause the disc to heat up. Because it is hot we can see these disks with infrared telescopes. Something similar happens in a blender. Use molasses or a mixture of water and cornstarch in a blender to investigate how temperature increases. Measure the temperature with a thermometer (or IR camera) and compare to a blender running for the same duration with only water in it. The water-only case is like the solar system is now. No gas extending through the solar system, thus no significant heating. Explain how this activity relates to star formation. A nearby gas cloud where stars are forming is the Orion nebula, which is easy to see with a telescope or binoculars. The bright stars at the center of the nebula are recently formed and illuminating the surrounding gas and dust. The Crab nebula is an example of the end state of a star that is easy to see with a telescope or binoculars.	Explain how stars can end up as white dwarfs, neutron stars and black holes. Explain that a gravity wave signal was detected in 2015 from two black holes that collided and merged together *without* creating a huge explosion (the light produced by this event got sucked into the resulting black hole). This could not have happened if the two objects had been stars. In this way, the gravity wave detection confirmed the existence of black holes. Explain that stars have different properties. A Hertzsprung-Russell diagram is a tool for categorizing and predicting the future evolution of stars based on their properties. Massive stars tend to be very bright and blue-ish, which place these stars in the top left part of the diagram. Less massive stars tend to be dim and red-ish. The diagonal band of stars in a Hertzsprung-Russell diagram is called the main sequence. The placement of a star on this sequence can be used to predict its evolution such as how long the star will last, and what kind of object it will end up as after it runs out of fuel.	Recall that stars form from clouds of gas that collapse due to gravity. Recall that the sun will eventually run out of fuel and collapse to form a planetary nebula with a white dwarf at the center. Recall that stars significantly more massive than the sun will eventually run out of fuel and form neutron stars and black holes. Recall that the sun is larger than a white dwarf, a white dwarf is larger than a neutron star and a neutron star is larger than a black hole

		Stars have different properties which affect how close or how far away that planets can be and still be in the right temperature range where life can flourish. This is sometimes called the "habitable zone". Have your students to choose a type of star (or stars if it is a binary or triple star system) from the main sequence and ask them to draw a sunset from the perspective of a habitable planet in that system. Students who choose a bright star should make sure that the planet is relatively far away from the star (making the star small on the horizon) and the star should be blue and bright. Students who choose a red star should make sure that the planet is relatively close to the star, meaning that the star will be large on the horizon and red (possibly with visible solar flares and starspots). In double and triple star systems the brightest star will be the most important for deciding how close the planet would be to the center of the planetary system. If the stars are the same, the planet should be further away because there is 2x or 3x as much light, so the double or triple star system would appear small on the horizon. There can be complex situations where computer simulations are needed to understand how a proposed design might behave. The formation of stars is a good example of a complex system that computer simulations help us to understand. Research how this is being done today (ex. simulations of car collisions, simulations of the stress on bridges, heat flow simulations in an engine, etc.)	

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Fusion in stars			
When there is a difficult design problem, a team may divide up aspects of the problem for smaller groups to work on even though the goal is to produce “one thing”. Our understanding of the sun developed, historically, in a heterogeneous way with different scientists focusing on different aspects of the sun. Ex. scientists studied how radiation might propagate through the sun before they knew for sure whether chemical or fusion reactions were the sun’s power source. Design a pinhole camera and refine it to project an image of the sun that has a good balance between brightness and resolution (investigate size of hole).	In The Stellar Fusion game students use the arrow keys on the keyboard to get elements to fuse, with the goal of creating Iron. A list of possible fusion reactions in stars is listed towards the bottom of the page.	Explain that fusion happens when two nuclei come together to make a larger nuclei and that this process can release significant energy. Explain that fusion only happens in objects that are massive enough and hot enough for these reactions to occur. For example, Jupiter is a large, gaseous planet with lots of hydrogen but it is not massive enough or hot enough for the hydrogen nuclei to fuse together.	Recall that stars are hot and luminous because of fusion reactions and not from chemical reactions or due to gravitational collapse. Recall that the matter in the sun is in the plasma phase. A plasma is a gas that is so hot that electrons and positively charged ions move freely.

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PHYSICS

INTRODUCTION AND SYLLABUS

COURSE DESCRIPTION

Physics is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires three one-unit courses. Each course should include inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

Physics elaborates on the study of the key concepts of motion, forces and energy as they relate to increasingly complex systems and applications that will provide a foundation for further study in science and scientific literacy.

Students engage in investigations to understand and explain motion, forces and energy in a variety of inquiry and design scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications.

Cross Curriculum connections link to ELA and Technology.

COURSE CONTENT SYLLABUS

The following information may be taught in any order; there is no ODE-recommended sequence.

P.M: MOTION

- P.M.1: Motion Graphs
    - Position vs. time
    - Velocity vs. time
    - Acceleration vs. time
- P.M.2: Problem Solving
    - Using graphs (average velocity, instantaneous velocity, acceleration, displacement, change in velocity)
    - Uniform acceleration including free fall (initial velocity, final velocity, time, displacement, acceleration, average velocity)
- P.M.3: Projectile Motion
    - Independence of horizontal and vertical motion
    - Problem-solving involving horizontally launched projectiles

P.F: FORCES, MOMENTUM AND MOTION

- P.F.1: Newton's Laws
- P.F.2: Gravitational force and fields
- P.F.3: Elastic forces
- P.F.4: Friction force (static and kinetic)
- P.F.5: Air resistance and drag
- P.F.6: Forces in two dimensions
    - Adding vector forces
    - Motion down inclines

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- Centripetal forces and circular motion
- P.F.7: Momentum, impulse and conservation of momentum

P.E: ENERGY
- P.E.1: Gravitational potential energy
- P.E.2: Energy in springs
- P.E.3: Work and power
- P.E.4: Conservation of energy
- P.E.5: Nuclear energy

P.W: WAVES
- P.W.1: Wave properties
  - Conservation of energy
  - Reflection
  - Refraction
  - Interference
  - Diffraction
- P.W.2: Light phenomena
  - Ray diagrams (propagation of light)
  - Law of reflection (equal angles)
  - Snell's law
  - Diffraction patterns
  - Wave—particle duality of light
  - Visible spectrum of color

P.EM: ELECTRICTY AND MAGNETISM
- P.EM.1: Charging objects (friction, contact and induction)
- P.EM.2: Coulomb's law
- P.EM.3: Electric fields and electric potential energy
- P.EM.4: DC circuits
  - Ohm's law
  - Series circuits
  - Parallel circuits
  - Mixed circuits
  - Applying conservation of charge and energy (junction and loop rules)
- P.EM.5: Magnetic fields
- P.EM.6: Electromagnetic interactions

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MOTION

In physical science, the concepts of position, displacement, velocity and acceleration were introduced and straight-line motion involving either uniform velocity or uniform acceleration was investigated and represented in position vs. time graphs, velocity vs. time graphs, motion diagrams and data tables. In this course, acceleration vs. time graphs are introduced and more complex graphs are considered that have both positive and negative displacement values and involve motion that occurs in stages (e.g., an object accelerates then moves with constant velocity). Symbols representing acceleration are added to motion diagrams and mathematical analysis of motion becomes increasingly more complex. Motion must be explored through investigation and experimentation. Motion detectors and computer graphing applications can be used to collect and organize data. Computer simulations and video analysis can be used to analyze motion with greater precision.

PM.1- Motion Graphs

Instantaneous velocity for an accelerating object can be determined by calculating the slope of the tangent line for some specific instant on a position vs. time graph. Instantaneous velocity will be the same as average velocity for conditions of constant velocity, but this is rarely the case for accelerating objects. The position vs. time graph for objects increasing in speed will become steeper as they progress and the position vs. time graph for objects decreasing in speed will become less steep.

On a velocity vs. time graph, objects increasing in speed will slope away from the x-axis and objects decreasing in speed will slope toward the x-axis. The slope of a velocity vs. time graph indicates the acceleration so the graph will be a straight line (not necessarily horizontal) when the acceleration is constant. Acceleration is positive for objects speeding up in a positive direction or objects slowing down in a negative direction. Acceleration is negative for objects slowing down in a positive direction or speeding up in a negative direction. These are not concepts that should be memorized, but can be developed from analyzing the definition of acceleration and the conditions under which acceleration would have these signs. The word “deceleration” should not be used since it provides confusion between slowing down and negative acceleration. The area under the curve for a velocity vs. time graph gives the change in position (displacement) but the absolute position cannot be determined from a velocity vs. time graph. Objects moving with uniform acceleration will have a horizontal line on an acceleration vs. time graph. This line will be at the x-axis for objects that are either standing still or moving with constant velocity. The area under the curve of an acceleration vs. time graph gives the change in velocity for the object, but the displacement, position and the absolute velocity cannot be determined from an acceleration vs. time graph. The details about motion graphs should not be taught as rules to memorize, but rather as generalizations that can be developed from interpreting the graphs.

PM.2- Problem Solving

Many problems can be solved from interpreting graphs and charts as detailed in the motion graphs section. In addition, when acceleration is constant, average velocity can be calculated by taking the average of the initial and final instantaneous velocities ($v_{avg} = (v_f - v_i)/2$). This relationship does not hold true when the acceleration changes. The equation can be used in conjunction with other kinematics equations to solve increasingly complex problems, including those involving free fall with negligible air resistance in which objects fall with uniform acceleration. Near the surface of Earth, in the absence of other forces, the acceleration of freely falling objects is 9.81 m/s^2. Assessments of motion problems, including projectile motion, will not include problems that require the quadratic equation to solve.

PM.3- Projectiles

When an object has both horizontal and vertical components of motion, as in a projectile, the components act independently of each other. For a projectile in the absence of air resistance, this means that horizontally, the projectile will continue to travel at constant speed just like it would if there were no vertical motion. Likewise, vertically the object will accelerate just as it would without any horizontal motion. Problem solving will be limited to solving for the range, time, initial height, initial velocity or final velocity of horizontally launched projectiles with negligible air resistance. While it is not inappropriate to explore more complex projectile problems, it must not be done at the expense of other parts of the curriculum.

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟷		Least Complex	
Motion				
P.M.1 Motion Graphs ○ Position vs. time ○ Velocity vs. time ○ Acceleration vs. time	**P.M.1a** Complete a motion graph by indicating the sections where the object is speeding up, moving at constant speed, and slowing down.	**P.M.1b** Label areas of different motion on a motion graph.	**P.M.1c** Identify the motion of an object in a motion graph.	
P.M.2 Problem Solving ○ Using graphs (average velocity, instantaneous velocity, acceleration, displacement, change in velocity) ○ Uniform acceleration including free fall (initial velocity, final velocity, time, displacement, acceleration, average velocity)	**P.M.2a** Use graphs to show that the free fall acceleration rate of varying objects, with negligible air resistance, is the same.	**P.M.2b** Make a prediction of the fall rate of two objects that have significantly different mass and surface area.	**P.M.2c** Drop two objects that have significantly different mass and surface area (e.g., a bowling ball and a feather) and make observations.	HS-PS2-3 Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
P.M.3 Projectile Motion ○ Independence of horizontal and vertical motion ○ Problem-solving involving horizontally launched projectiles	**P.M.3a** Determine whether a ball needs to be thrown higher (vertical) or farther (horizontal) for it to land in a designated area (e.g., in a hoop or on an "x" on the ground).	**P.M.3b** Identify the horizontal and vertical motions of a projectile.	**P.M.3c** Recognize that projectiles have movement in both horizontal and vertical directions.	

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EVIDENCE OF LEARNING

Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

Designing technological / engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.M.1- Motion Graphs			
	Determine the position at which two carts will collide: a buggy moving at constant velocity released from the top of a ramp and a cart released 1.0 second later that starts from rest and accelerates down the ramp. Construct a method to measure the changing velocity of an object falling from a height of at least 5.0 m and that of an object rising into the air for at least 5.0 m. Determine the position at which two constant velocity buggies moving towards each will collide if they have different velocities.	Given a position time graph or velocity time graph write a driving scenario that fits the graph given. Given a position time graph, sketch the velocity time graph (and acceleration time graph). Vary which type of graph is given and have them draw the other. Using a timing motor, pull a strip of data from a constant motion car. Students cut strips into 6-dot(1/10th second) lengths, numbering them to keep them in order. Glue the strips onto graph paper to construct a position time graph. Recognizing the equal bar lengths corresponds to constant velocity. Repeat the same process with an accelerating car constructing a position time graph with the stripes. Recognize the increasing bars corresponds to increasing velocity. Measure the distance between consecutive strips and interpret what that says about acceleration. Create a position vs time graph from given data and determine the velocity of an object at two different times. Use that data to determine the average acceleration of the object during that interval of time.	Construct a position-time graph and determine the velocity at two different points, and then use that data to find average acceleration during that interval. Given a velocity-time graph showing quadrants I and IV, label portions of the graph where acceleration is positive or negative, and describe the motion of the object as increasing or decreasing by relating slope of the line to sign of acceleration. This clarifies the misconception of negative acceleration always indicating that an object is slowing down. Given unlabeled graphs with a variety of shapes, e.g. constant positive slope, increasing positive slope, zero slope, come up with an example for an object that would produce a graph for each of the relevant motion graphs.

P.M.2- Problem Solving			
	A buggy moving at constant velocity is released from the top of a ramp 1.0 second before a cart that starts from rest and accelerates down the ramp. At what position on the ramp will the buggy and the cart collide? All data, graphs, calculations and explanations must be clearly represented and annotated to explain how the answer was determined. The cart and the buggy may be checked out one at a time to collect data, but may not be used together until the prediction is ready to be tested. An alternative to the activity above is to determine where the cart that starts from rest should be released so that the two cars reach the bottom of the ramp at the same time. Investigate the motion of a freely falling body using either a ticker timer or a motion detector. Use mathematical analysis to determine a value for "g." Compare the experimental value to known values of "g." Suggest sources of error and possible improvements to the experiment.	Using kinematic equations, solve simultaneous equations to determine when an accelerating object will overtake an object moving at constant velocity, e.g. the police officer and speeder problem. Constraints such as the maximum velocity the officer may drive and the reaction time of the officer provide a chance for the student to consider the effect that time passing will have on the problem's solution. Have students determine their reaction time and the velocity they are able to jump with experimentally using kinematic equations and data collected in class. By measuring the distance a meter stick falls before they catch it, a student can determine the time it fell and hence, the reaction time. By measuring the vertical height the student can jump or the time in the air, the student can determine the velocity of his or her jump.	Use the kinematic equations to solve for unknown quantities regarding an accelerated body in one dimension when provided with a sufficient amount of information, e.g. only one unknown variable of a four variable equation. Solve for information in one part of the problem and use it to solve for information in subsequent parts, e.g. solving for the final velocity at the end of a period of acceleration that is the initial velocity for a period of time during which the object decreases its speed.

P.M.3- Projectiles			
	Design an experiment to collect data that will determine the launch velocity of a projectile launcher. Use the data to predict the range of the projectile at a given angle and attempt to hit a target with a projectile. Then, describe any assumptions made in the written procedures, e.g. neglecting air resistance, and account for any uncertainty in the measurements. Note: a projectile launcher is not necessary. Aluminum C-channel can be purchased from a hardware store and bent to create a marble ramp which will serve the same purpose.	Predict the range of a ball rolling off of a table by measuring the speed of the ball on the table and determining the time the ball will take to fall by measuring the height of the table. Using a target placed on the floor, determine how accurate student predictions were. Then, identify sources of uncertainty in measurements and explain the effect it had on experimental results.	Solve problems involving horizontal projectiles and recognize that the horizontal velocity does not affect the time that a horizontal projectile will spend in the air.

Resources

Graphs

- Phet Simulations, an example would be the "Moving man", which allows students to set position, velocity and acceleration, watch the motion of the man and see the position vs. time, velocity vs. time and acceleration vs. time graphs.
- Argumentative-Driven Inquiry consist of lab investigations guided by an 8-stage process where students are required to used all cognitive demand levels.
- Modeling workshops are available nationally that help teachers develop a framework for using guided inquiry in their instruction.
- Ranking tasks are designed to draw out common misconceptions in physics, weed out extraneous information and defend their answers with simple math . Examples can be found online including some posted by the University of Virginia . Published works with good ranking exercises include TIPERs: Sensemaking Tasks for Introductory Physics (Pearson ISBN-13: 978-0132854580)
- Mechanical Universe is a series of 52 videos produced by Caltech and now housed on a YouTube channel. Most topics in the physics standards are addressed. Each video is roughly 30 minutes in length.
- Physics Classroom

Problem Solving

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Projectiles

- "Motion in 2-D" is an interactive simulation from PhET that shows the magnitude and direction of the velocity and accelerations for different types of motion.
- "Motion Diagrams" is a tutorial from Western Kentucky University that shows how to draw motion diagrams for a variety of motions. It includes an animated physlet.
- "Projectile Motion" is a physlet from High Point University that illustrates the independence of horizontal and vertical motion in projectile motion. The projectile motion is shown in slow motion so the horizontal and vertical positions of the ball can be clearly tracked and analyzed. While it shows a projectile launched at an angle, it emphasizes the conceptual aspects of projectile motion that are appropriate for physics students.
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FORCES, MOMENTUM AND MOTION

In earlier grades, Newton's laws of motion were introduced; gravitational forces and fields were described conceptually; the gravitational force (weight) acting on objects near Earth's surface was calculated; friction forces and drag were addressed conceptually and quantified from force diagrams; and forces required for circular motion were introduced conceptually. In this course, Newton's laws of motion are applied to mathematically describe and predict the effects of forces on more complex systems of objects and to analyze falling objects that experience significant air resistance. Gravitational forces are studied as a universal phenomenon and gravitational field strength is quantified. Elastic forces and a more detailed look at friction are included. At the atomic level, "contact" forces are actually due to the forces between the charged particles of the objects that appear to be touching. These electric forces are responsible for friction forces, normal forces and other "contact" forces. Air resistance and drag are explained using the particle nature of matter. Projectile motion is introduced and circular motion is quantified. The vector properties of momentum and impulse are introduced and used to analyze elastic and inelastic collisions between objects. Analysis of experimental data collected in laboratory investigations must be used to study forces and momentum. This can include the use of force probes and computer software to collect and analyze data.

P.F.1- Newton's Laws

Newton's laws of motion, especially the third law, can be used to solve complex problems that involve systems of many objects that move together as one (e.g., an Atwood's machine). The equation a = Fnet/m that was introduced in physical science can be used to solve more complex problems involving systems of objects and situations involving forces that must themselves be quantified (e.g., gravitational forces, elastic forces, friction forces).

P.F.2- Gravitational Force and Fields

Gravitational interactions are very weak compared to other interactions and are difficult to observe unless one of the objects is extremely massive (e.g., the sun, planets, moons). The force law for gravitational interaction states that the strength of the gravitational force is proportional to the product of the two masses and inversely proportional to the square of the distance between the centers of the masses, $Fg = (G \cdot m_1 \cdot m_2)/r^2$). The proportionality constant, G, is called the universal gravitational constant. Problem solving may involve calculating the net force for an object between two massive objects (e.g., Earth-moon system, planet-sun system) or calculating the position of such an object given the net force.

The strength of an object's (i.e., the source's) gravitational field at a certain location, g, is given by the gravitational force per unit of mass experienced by another object placed at that location, $g = F_g / m$. Comparing this equation to Newton's second law can be used to explain why all objects on Earth's surface accelerate at the same rate in the absence of air resistance. While the gravitational force from another object can be used to determine the field strength at a particular location, the field of the object is always there, even if the object is not interacting with anything else. The field direction is toward the center of the source. Given the gravitational field strength at a certain location, the gravitational force between the source of that field and any object at that location can be calculated. Greater gravitational field strengths result in larger gravitational forces on masses placed in the field. Gravitational fields can be represented by field diagrams obtained by plotting field arrows at a series of locations. Field line diagrams are excluded from this course. Distinctions between gravitational and inertial masses are excluded.

P.F.3- Elastic Forces

Elastic materials stretch or compress in proportion to the load they support. The mathematical model for the force that a linearly elastic object exerts on another object is Felastic = kΔx, where Δx is the displacement of the object from its relaxed position. The direction of the elastic force is always toward the relaxed position of the elastic object. The constant of proportionality, k, is the same for compression and extension and depends on the "stiffness" of the elastic object.

P.F.4- Friction Forces (Static and Kinetic)

The amount of kinetic friction between two objects depends on the electric forces between the atoms of the two surfaces sliding past each other. It also depends upon the magnitude of the normal force that pushes the two surfaces together. This can be represented mathematically as $F_k = \mu_k F_N$, where μ_k is the coefficient of kinetic friction that depends upon the materials of which the two surfaces are made. Sometimes friction forces can prevent objects from sliding past each other, even when an external force is applied parallel to the two surfaces that are in contact. This is called static friction, which is mathematically represented by $F_s \leq \mu_s F_N$. The maximum amount of static friction possible depends on the types of materials that make up the two surfaces and the magnitude of the normal force pushing the objects together, $F_{smax} = \mu_s F_N$. As long as the external net force is less than or equal to the maximum force of static friction, the objects will not move relative to one another. In this case, the actual static friction force acting on the object will be equal to the net external force acting on the object, but in the opposite direction. If the external net force exceeds the maximum static friction force for the object, the objects will move relative to each other and the friction between them will no longer be static friction, but will be kinetic friction.

P.F.5- Air Resistance and Drag

Liquids have more drag than gases like air. When an object pushes on the particles in a fluid, the fluid particles can push back on the object according to Newton's third law and cause a change in motion of the object. This is how helicopters experience lift and how swimmers propel themselves forward. Forces from fluids will only be quantified using Newton's second law and force diagrams.

P.F.6- Forces in 2-Dimensions

Net forces will be calculated for force vectors with directions between 0° and 360° or a certain angle from a reference (e.g., 37° above the horizontal). Vector addition can be done with trigonometry or by drawing scaled diagrams. Problems can be solved for objects sliding down inclines. The net force, final velocity, time, displacement and acceleration can be calculated. Inclines will either be frictionless or the force of friction will already be quantified. Calculations of friction forces down inclines from the coefficients of friction and the normal force will not be addressed in this course.

An object moves at constant speed in a circular path when there is a constant net force that is always directed at right angles to the direction of motion toward the center of the circle. In this case, the net force causes an acceleration that shows up as a change in direction. If the force is removed, the object will continue in a straight-line path. The nearly circular orbits of planets and satellites result from the force of gravity. Centripetal acceleration is directed toward the center of the circle and can be calculated by the equation $a_c = v^2/r$, where v is the speed of the object and r is the radius of the circle. This expression for acceleration can be substituted into Newton's second law to calculate the centripetal force. Since the centripetal force is a net force, it can be equated to friction (unbanked curves), gravity, elastic force, etc., to perform more complex calculations.

P.F.7- Momentum, Impulse and Conservation of Momentum

Momentum, p, is a vector quantity that is directly proportional to the mass, m, and the velocity, v, of the object. Momentum is in the same direction the object is moving and can be mathematically represented by the equation $p = mv$. The conservation of linear momentum states that the total (net) momentum before an interaction in a closed system is equal to the total momentum after the interaction. In a closed system, linear momentum is always conserved for elastic, inelastic and totally inelastic collisions. While total energy is conserved for any collision, in an elastic collision, the kinetic energy also is conserved. Given the initial motions of two objects, qualitative predictions about the change in motion of the objects due to a collision can be made. Problems can be solved for the initial or final velocities of objects involved in inelastic and totally inelastic collisions. Momentum may be dealt with in two dimensions conceptually, but at this level calculations should be limited to only one dimension. Coefficients of restitution are beyond the scope of this course.

Impulse, Δp, is the total momentum transfer into or out of a system. Any momentum transfer is the result of interactions with objects outside the system and is directly proportional to both the average net external force acting on the system, F_{avg}, and the time interval of the interaction, t. It can mathematically be represented by $\Delta p = p_f - p_i = F_{avg}\,\Delta t$. This equation can be used to justify why momentum changes due to the external force of friction can be ignored when the time of interaction is extremely short. Average force, initial or final velocity, mass or time interval can be calculated in multi-step word problems. For objects that experience a given impulse (e.g., a truck coming to a stop), a variety of force/time combinations are possible. The time could be small, which would require a large force (e.g., the truck crashing into a brick wall to a sudden stop). Conversely, the time could be extended which would result in a much smaller force (e.g., the truck applying the brakes for a long period of time).

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟷		Least Complex	
Forces, Momentum and Motion				
P.F.1 Newton's Laws Applied to Complex Problems	**P.F.1a** Recognize that momentum is conserved in a collision.	**P.F.1b** Demonstrate Newton's Third Law: for every action, there is an equal and opposite reaction.	**P.F.1c** Identify the direction of an object's motion after it collides with another moving object.	HS-PS2-1 Analyze data to support the claim that Newton's Second Law of Motion describes the mathematical relationship among the net force on a macroscopic object, its mass and its acceleration.
P.F.2 Gravitational Force and Fields	**P.F.2a** Explain the relationship between mass and gravitational pull.	**P.F.2b** Recognize that gravity is the force that keeps planets and satellites in circular orbits	**P.F.2c** Identify gravity as a force.	**HS-PS2-4** Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
P.F.3 Elastic Forces	**P.F.3a** Design a device that would propel an object using elastic materials (e.g., rubber band cars).	**P.F.3b** Make a prediction of the elasticity of two significantly different elastic materials.	**P.F.3c** Manipulate a variety of elastic bands and other elastic materials and make observations (e.g., rubber bands, hair bands).	
P.F.4 Friction Forces (Static and Kinetic)	**P.F.4a** Organize the surface types from "causes the most friction" (most difficult to push) to "causes the least amount of friction" (easiest to push).	**P.F.4b** Investigate friction as it relates to moving an object (e.g., sliding furniture over different types of flooring).	**P.F.4c** Recognize that diverse surface types cause friction differently.	
P.F.5 Air Resistance and Drag	**P.F.5a** Through investigation, determine the rate of fall of an object in air and a variety of liquids.	**P.F.5b** When given an object, make a prediction of its motion and rate of fall when dropped in the air and a variety of liquids.	**P.F.5c** Drop the same object in air and into a variety of liquids with different viscosity and make observations (e.g., oil, honey, and water).	
P.F.6 Forces in Two Dimensions	**P.F.6-7a** Identify the force that, if removed from an object moving in a circular	**P.F.6-7b** Indicate the direction of the centripetal force of an object moving in	**P.F.6-7c** Recognize that gravity is the force that creates motion down an	HS-PS2-1 Analyze data to support the claim that Newton's Second Law of Motion describes the mathematical

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○ Adding vector forces AND **P.F.7 Momentum, Impulse, and Conservation of Momentum** ○ Motion down inclines ○ Centripetal forces and circular motion	motion, would cause the object to move in a straight line.	a circular motion (e.g., ball being swung on a string).	incline.	relationship among the net force on a macroscopic object, its mass and its acceleration.

EVIDENCE OF LEARNING
Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

Designing technological / engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.F.1- Newton's Laws			
Design a demonstration for one of Newton's Laws and present the demonstration to the class. The demonstration should provide clear evidence for the law and be supported with mathematical data for their claims. Sufficient data should be collected to support the demonstration is valid. Critiques are conducted about the demonstration and provide improvements to the creator of the demonstration.	Plan and conduct an investigation using an Atwood Machine. Vary one of the masses to determine the effect it has on the acceleration of the system. This can be accomplished by measuring the time for one mass to fall a known distance and using kinematics equations to solve for the acceleration or by measuring the acceleration using smart pulleys and computer data logging if it is available. Then, state the relationship mathematically and verify the numerical values from their data.	Draw free body diagrams for objects and use them to apply Newton's 2nd Law to solve for the acceleration of a mass. Solve problems for both horizontal and vertical acceleration. (Note: Once friction and elastic forces are introduced, these concepts should be integrated into students learning experiences.)	Solve for the acceleration of a mass that is acted upon by multiple forces acting in one dimension. Solve problems for both horizontal and vertical acceleration. (Note: Once friction and elastic forces are introduced, these concepts should be integrated into students learning experiences.)

P.F.2- Gravitational Force and Fields			
Place students in charge of a space exploration mission to find a planet that could be inhabited by humans. Ignoring the difficulties inherent with deep space travel and the other biological needs for humans to explore and survive on distant planets, their job is simply to come up with an method of verifying that a planet meets the gravitational criteria for people to live there. Students research the biological implications of high and low gravitational fields on human beings and determine their criteria for an acceptable range for gravitational field strength, along with justification for their criteria. Determine a planet that meets their criteria using data from NASA at exoplanets.nasa.gov and present how their planet meets the criteria of being habitable	Plan and conduct an investigation into a vertical acceleration using force plates and computer data collection or analog scales and video recording equipment, such as a phone camera. State any assumptions made in the investigation and where possible, compare findings to accepted known values. Using an elevator at the school or at a nearby public building would provide sufficient data for analysis.	Provided a graph of a reading from an object on a scale as it ascends or descends, determine the acceleration of the elevator as it begins and ends its motion, the distance travelled by the elevator, and the mass of the object. Construct the graph of the elevator's motion in the opposite direction, stating what assumptions they needed to make in order to create the graph as well as what a real vs. ideal graph of this motion would look like.	Solve problems using the equation for Universal Gravitation. For example, use the equation to determine the net force on a mass at a point between the Earth and another stellar object and to determine why the gravitational force between two people is negligible. Then, determine the value for g from the equation and Newton's 2nd Law.
P.F.3- Elastic Forces			
Construct a bungee jump apparatus to safely drop a fragile object (ex. flour bag) to within a specified distance of the ground from an appropriate height, using calculations alone to determine length and strength of bungee cord required. After construction students should be able to compare elastic force and gravitational force on the object and use data to critique designs and propose changes for reconstruction.	Plan and conduct a scientific investigation to determine the relationship between the force exerted on a spring and the amount it stretches. Represent the data graphically. Analyze the data to determine patterns and trends and model the relationship with a mathematical equation. Describe the relationship in words and support the conclusion with experimental evidence.	Draw a free body diagram that shows the forces acting on a mass that is hanging from a spring. Draw the forces acting on a mass that is attached to an ideal spring that is unstretched in the vertical direction and then released. Diagrams can be drawn at the initial position, the equilibrium position, the maximum stretched distance, and at the points halfway between equilibrium and the ends of the motion. The forces and the motion of the spring should only be discussed qualitatively at this point.	Calculate the force on a mass that is hanging in equilibrium by relating the force of gravity and the force applied by the spring

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P.F.4- Friction Force (Static and Kinetic)			
	Plan and conduct an investigation to determine the coefficient of kinetic friction between two surfaces. Collect sufficient relevant data and analyze the data graphically to determine the value for the coefficient of kinetic friction. Then, compare the value to either the accepted value of kinetic friction when possible or to the results of other students and discuss any differences and sources of uncertainty in their measurements. There is a misconception that the speed of an object or the surface area affects the value for the force of friction between two surfaces. At low speeds (where air resistance is negligible) between two dry surfaces, this is not the case. Design an investigation to prove or disprove student beliefs about one of these two factors and the effect it has on the force of friction between two surfaces. Students present their experimental designs and results to the class and allow for other students to question the design and the validity of the results. The focus should be on critiquing the experimental design and validity of the results obtained, not on whether the students were successful at "proving" their hypothesis or not. Students then improve upon their design and conduct their experiment with revisions or improvements and re-present their findings when applicable.	Conduct an investigation to measure the coefficient of static friction between two surfaces by changing variables such as mass, incline, and types of surfaces.	Solve problems involving calculations of the force of kinetic friction between two surfaces. This calculation should be used in conjunction with applications of Newton's Laws. Problems should include objects moving at constant velocity, objects that are accelerating due to an external force other than friction, and situations where friction is the only force acting on an object to slow it to a stop. Kinematics equations may be included to allow students to determine stopping distance or time for an object to slide to a stop. Draw free body diagrams in conjunction with these problems.

Design a shoe, based on student experimental results.	Determine what factors to investigate for the shoe material and plan and conduct an investigation based on these factors. Prior to beginning any data collection, students should present their experimental designs to the class and receive feedback and criticism regarding their experimental design. After the experiment is complete, students will present their experimental design with any modifications based on the feedback from other students and the results of the investigation.	Next- Compare and contrast different material options that could be used for soles on shoes.	Students have been asked to help the high school basketball team select the material for the soles of the shoes that the team will wear this season. First - Identify the factors that affect the coefficient of friction between the sole of a shoe and the surface.
P.F.5- Air Resistance and Drag			
	Design and conduct an investigation that determines how the surface area of a parachute affects the force due to air resistance as an object falls toward the ground. Students decide what data should be collected and interpret their findings to others using evidence and justification.	By dropping different quantities of coffee filters, students analyze experimental data to calculate the drag force (air resistance) and determine the factors that affect terminal velocity.	Determine the magnitude of the air resistance or drag acting on an object moving at a constant velocity when given the acceleration at an instant and draw the force of air resistance in free body diagrams.
P.F.6- Forces in 2-Dimensions			
	Plan and conduct an investigation into the acceleration of an object down an incline. Investigate the relationship between the acceleration and the angle of the incline in the absence of friction. (The use of a low friction cart is necessary if the angle is to be varied.) Investigate the effect that increasing the mass of an object has on the acceleration. This can be done with a fixed angle with or	Draw a free-body diagram for an object that is accelerating along a horizontal surface under the influence of a force that acts at a known angle to the horizontal. The free-body diagram should in turn be used to solve for the acceleration of the object. The object may be acted upon by friction and subject to more than one external force. Students must be able to successfully resolve forces into horizontal and vertical force components to be able to complete this successfully. If trigonometry is not being used, fewer	Solve for the components of a force that lies at an angle to a known reference and add force components that act at right angles. Both of these can be done using either trigonometry or by drawing scale diagrams. Solve problems involving an object accelerating down an incline with a known force of friction. Use of kinematics equations to solve for

	without the presence of frictional force. This opportunity to determine that no relationship exists may provide some interesting discussion regarding misconceptions of this phenomenon.	forces should be given to draw due to the time needed to construct scale diagrams for solving such problems. Use a free body diagram and trigonometry or scale diagrams to determine the acceleration of an object accelerating down a frictionless incline. Make use of kinematics equations to solve for the time to slide down the incline, the final velocity, or the length of the incline when the appropriate information is provided. Conduct an investigation into the relationship between the speed of an object moving in a circular path and the force needed to keep the object moving in a circular path. A spring scale or force sensor may be mounted to dowel or meter stick with an eye hook at the end of the rod or stick. A string of known length can be attached from the end of the string, run through the eye hook, and then attached to a small rubber stopper. The mass of the stopper and the radius can be measured and the period of rotation can be used to determine the velocity of the rotating mass. Students can plot a graph of force vs. velocity and analyze the relationship to verify that the force is proportional to the square of the velocity.	the time to slide down the incline, the final velocity, or the length of the incline when the appropriate information is provided. Solve problems involving objects moving in circular motion, including satellites orbiting planets, cars driving around horizontal curves, and planes flying in horizontal and vertical circles. Identify what force is providing the necessary centripetal force for each situation and should not just calculate a value for the centripetal force given the speed and the radius of the path.
Research a stretch of road where there are many accidents. Evaluate potential causes and propose a design change to the road to reduce the number of accidents.	Design an investigation to test a variety of road surfaces and conditions that can affect the coefficient of friction between the tires and the road in order to determine the best surface for a variety of conditions.	Research the effect of snow, rain, and ice on the coefficients of friction between tires and the road and use this knowledge to create a presentation for other students on the importance of driving appropriately for the road conditions. Present data using posters to display in the school to increase awareness among the students about the effects that changes in weather conditions can have on driving.	Identify factors that can affect the amount of friction felt between car tires and the surface of the road.

		Take measurements of curves on local roads and use the research to determine safe speeds of travel.	
P.F.7- Momentum, Impulse and Conservation of Momentum			
	Given two spring-loaded dynamic carts with different masses that are located on a table between two wooden blocks, determine where the carts must be placed so that they hit the blocks simultaneously. Measurements may be taken of the model set up at the front of the room, but the carts may not be released prior to determination. Clearly justify the answer and state any assumptions that were made. Test your prediction with the model set up at the front of the room.	Relate the impulse on an object to changes in its momentum and determine relevant information about the impulse applied to the object.	Solve problems involving inelastic, totally inelastic, and elastic collisions using the conservation of momentum and the principles associated with each type of collision. Then, calculate the final velocity of one mass if the collision is inelastic, one or both masses if the collision is elastic or totally inelastic, the initial velocity of one of the masses, or the mass of one of the objects in the collision.
Solve problems involving inelastic, totally inelastic, and elastic collisions using the conservation of momentum and the principles associated with each type of collision. Then, calculate the final velocity of one mass if the collision is inelastic, one or both masses if the collision is elastic or totally inelastic, the initial velocity of one of the masses, or the mass of one of the objects in the collision.	Provide evidence for design decisions through the calculations of the data collected throughout testing and revision or through research so that the class may provide feedback and ask questions about these choices	Present models to the class and provide a demonstration or a walkthrough of the theoretical method using sketches or diagrams.	Show all calculations that were made prior to design and how data from trials were used in calculations to improve the design if the students are using a working model. Students using a theoretical model should be able to show how researched data was used in calculations to provide validity to their model.

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Resources

P.F.1- Newton's Laws

- "Forces and Motion" is an interactive simulation that allows students to explore the forces present when a filing cabinet is pushed. Students can create an applied force and see the resulting friction force and total force acting on the cabinet. Graphs show forces vs. time, position vs. time, velocity vs. time, and acceleration vs. time. A force diagram of all the forces (including gravitational and normal forces) is shown.
- Phet Simulations, and example would be "Motion in 2-D" that shows the magnitude and direction of the velocity and accelerations for different types of motion.
- Argumentative-Driven Inquiry consist of lab investigations guided by an 8-stage process where students are required to used all cognitive demand levels.

- "Motion Diagrams" is a tutorial from Western Kentucky University that shows how to draw motion diagrams for a variety of motions. It includes an animated physlet.
- "Projectile Motion" is a physlet from High Point University that illustrates the independence of horizontal and vertical motion in projectile motion. The projectile motion is shown in slow motion so the horizontal and vertical positions of the ball can be clearly tracked and analyzed. While it shows a projectile launched at an angle, it emphasizes the conceptual aspects of projectile motion that are appropriate for physics students.
- Modeling workshops are available nationally that help teachers develop a framework for using guided inquiry in their instruction.
- Ranking tasks are designed to draw out common misconceptions in physics, weed out extraneous information and defend their answers with simple math . Examples can be found online including some posted by the University of Virginia . Published works with good ranking exercises include TIPERs: Sensemaking Tasks for Introductory Physics (Pearson ISBN-13: 978-0132854580
- Mechanical Universe is a series of 52 videos produced by Caltech and now housed on a YouTube channel. Most topics in the physics standards are addressed. Each video is roughly 30 minutes in length.
- Physics Classroom

P.F.2- Gravitational Force and Fields

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P.F.4- Friction Force

- Phet Simulations, an example would be "Forces and Motion" which allows students to explore the forces present when a filing cabinet is pushed. Students can create an applied force and see the resulting friction force and total force acting on the cabinet. Graphs show forces vs. time, position vs. time, velocity vs. time, and acceleration vs. time. A force diagram of all the forces (including gravitational and normal forces) is shown.
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P.F.6- Forces in 2-Dimensions

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P.F.7- Momentum

- Phet Simulations, an example would be the "Collision Lab" that allows students to investigate collisions on an air hockey table. Students can vary the number of discs, masses, elasticity and initial conditions to see if momentum and kinetic energy are conserved.
- Modeling workshops are available nationally that help teachers develop a framework for using guided inquiry in their instruction.
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ENERGY

In Physical Science, the role of strong nuclear forces in radioactive decay, half-lives, fission and fusion, and mathematical problem solving involving kinetic energy, gravitational potential energy, energy conservation and work (when the force and displacement were in the same direction) were introduced. In this course, the concept of gravitational potential energy is understood from the perspective of a field, elastic potential energy is introduced and quantified, nuclear processes are explored further, the concept of mass-energy equivalence is introduced, the concept of work is expanded, power is introduced, and the principle of conservation of energy is applied to increasingly complex situations. Energy must be explored by analyzing data gathered in scientific investigations. Computers and probes can be used to collect and analyze data.

P.E.1- Gravitational Potential Energy

When two attracting masses interact, the kinetic energies of both objects change but neither is acting as the energy source or the receiver. Instead, the energy is transferred into or out of the gravitational field around the system as gravitational potential energy. A single mass does not have gravitational potential energy. Only the system of attracting masses can have gravitational potential energy. When two masses are moved farther apart, energy is transferred into the field as gravitational potential energy. When two masses are moved closer together, gravitational potential energy is transferred out of the field.

P.E.2- Energy in Springs

The approximation for the change in the potential elastic energy of an elastic object (e.g., a spring) is $\Delta E_{elastic} = \frac{1}{2} k \Delta x^2$ where Δx is the distance the elastic object is stretched or compressed from its relaxed length.

P.E.3- Work and Power

Work can be calculated for situations in which the force and the displacement are at angles to one another using the equation $W = F\Delta x(\cos\theta)$ where W is the work, F is the force, Δx is the displacement, and θ is the angle between the force and the displacement. This means when the force and the displacement are at right angles, no work is done and no energy is transferred between the objects. Such is the case for circular motion.

The rate of energy change or transfer is called power (P) and can be mathematically represented by $P = \Delta E / \Delta t$ or $P = W / \Delta t$. Power is a scalar property. The unit of power is the watt (W), which is equivalent to one joule of energy transferred in one second (J/s).

P.E.4- Conservation of Energy

The total initial energy of the system and the energy entering the system are equal to the total final energy of the system and the energy leaving the system. Although the various forms of energy appear very different, each can be measured in a way that makes it possible to keep track of how much of one form is converted into another. Situations involving energy transformations can be represented with verbal or written descriptions, energy diagrams and mathematical equations. Translations can be made between these representations. The conservation of energy principle applies to any defined system and time interval within a situation or event in which there are no nuclear changes that involve mass-energy equivalency. The system and time interval may be defined to focus on one particular aspect of the event. The defined system and time interval may then be changed to obtain information about different aspects of the same event.

P.E.5- Nuclear Energy

Alpha, beta, gamma and positron emission each have different properties and result in different changes to the nucleus. The identity of new elements can be predicted for radioisotopes that undergo alpha or beta decay. Nuclear reactions, such as fission and fusion, are accompanied by large energy changes that are much greater than those that accompany chemical reactions. Nuclear fission reactions are used as a controlled source of energy in nuclear power plants. There are advantages and disadvantages of generating electricity from fission and fusion. During nuclear interactions, the transfer of energy out of a system is directly proportional to the change in mass of the system as expressed by $E = mc^2$, which is known as the equation for mass-energy equivalence. A very small loss in mass is accompanied by a release of a large amount of energy. In nuclear processes such as nuclear decay, fission and fusion, the mass of the product is less than the mass of the original nuclei. The missing mass appears as energy. This energy can be calculated for fission and fusion when given the masses of the particle(s) formed and the masses of the particle(s) that interacted to produce them.

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟵	⟶	Least Complex	
Energy				
P.E.1 Gravitational Potential Energy	**P.E.1a** Explain that when two attracting objects are at a distance from each other there is gravitational potential energy present.	**P.E.1b** Describe that the gravitational force between two objects depends on the distance between them and their masses.	**P.E.1c** Identify ways people use energy	HS-PS3-2 Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).
P.E.2 Energy in Springs	**P.E.2a1** Given a spring stretched various amounts, identify when it has the most potential energy. AND **P.E.2a2** Identify a real-world scenario where the use of a spring might improve the efficiency or performance of a tool.	**P.E.2b1** Compare the distance that two different springs can stretch or can be compressed. AND **P.E.2b2** Investigate how the use of a spring can improve the efficiency of a tool (e.g., a shock absorber in a car or a ball point pen).	**P.E.2c1** Manipulate a variety of springs and make observations (e.g., from inside of a ball point pen, from toys). AND **P.E.2c2** Identify where springs are used in everyday life.	
P.E.3 Work and Power	**P.E.3a** Chart the relationship between work and power.	**P.E.3b** Describe the relationship between work and power (pedaling a bicycle, lifting different weights). More work in a shorter period of time equals more power.	**P.E.3c** Identify work being done.	
P.E.4 Conservation of Energy	**P.E.4a**.Given situation, describe where the energy has gone (e.g., a car rolling down hill has energy changing from potential to kinetic).	**P.E.4b** Explain that energy changes forms but the total amount is the same before and after a transfer.	**P.E.4c** Identify that energy cannot be created or destroyed.	HS-PS3-1 Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

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P.E.5 Nuclear Energy	**P.E.5a** Identify types of nuclear energy (e.g., fission and fusion).	**P.E.5b** Describe ways people use nuclear energy.	**P.E.5c** Identify nuclear energy as a type of energy.	

EVIDENCE OF LEARNING
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Designing technological / engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.E.1- Gravitational Potential Energy			
Design a gravity feed water system, connecting concepts of rise/fall to gravitational potential energy. Evaluate the systems real-world function compared to performance as designed, considering factors affecting performance (effects of pipe diameter etc.) vs. linear gravitational potential energy calculations. Use data to critique designs and propose changes for reconstruction.		Measure and graph mass vs. weight. Students should get a slope of $9.8 m/s^2$.	Solve problems involving gravitational potential energy. These problems involve objects near the surface of the Earth as well as objects that have a large distance between their centers of mass, such as a satellite orbiting the Earth.
P.E.2- Energy in Springs			
Attempt to measure/calculate k values for a variety of bungee shock cords. Then construct a bungee jump apparatus to safely drop a fragile object (ex. flour bag, egg) to within a specified distance of the		Referring to a force vs. distance graph from a Hooke's Law lab, interpret what the slope of the line represents (the spring constant, k, measured in N/m) and what the area under the line represents (the energy stored in the spring in Joules).	Calculate the amount of energy stored in a spring that is stretched or compressed a certain distance. Referring to a force vs. distance graph, recognize that the force of a

ground from an appropriate height, using calculations alone to determine length and strength of bungee cord required. After construction, compare elastic force and gravitational force on the object and use data to critique designs and propose changes for reconstruction.			spring is changing as a spring oscillates.
P.E.3- Work and Power			
	Plan an investigation into the rate at which work can be done by a student. Determine tasks that allow them to do work on a system and then measure the amount of work done by the student and the time to calculate each student's average power. Students tasks may include running up a flight of stairs, raising a mass a certain distance, changing their kinetic energy, or any other tasks they deem measurable. Then, compare the values for the power and discuss possible reasons for differences in values obtained by similar tasks performed by different students.	Compare the use of a horizontal force, the use of a force angled above the horizontal, and a force at the same angle below the horizontal to determine which situation transfers the greatest total amount of energy to the system, both with and without friction present.	Solve problems determining the work done on an object by a force that acts at an angle to the displacement of the object. The use of free body diagrams and solving for unknown forces, such as the Normal Force, using Newton's Laws should be encouraged. Solve problems determining the rate at which energy is added or removed from an object or a system of objects. Calculations should be limited to calculations involving the average power or the instantaneous power delivered to an object moving at a constant velocity.
P.E.4- Conservation of Energy			
Investigate a system that transforms mechanical energy to determine the average force of friction on the system and refine the system to improve its efficiency. Measurements should be made to allow for the comparison of	Plan and conduct an investigation into an existing system that transforms mechanical energy from one form into another. Determine an unknown quantity or value associated with the system, such as the spring constant of a rubber band or a mass of an	Solve problems using the principle of energy conservation to determine information about a system, such as the final velocity of a mass or the height an object travels to. These problems should require the use of free body diagrams and the	Draw diagrams or graphs to represent energy flow into or out of a system. This skill was developed in Physical Science and should be refreshed and expanded upon in Physics. Students can use energy

the efficiency of the system before and after student refinements.	unknown object, and make measurements to calculate the unknown quantity. The value for the unknown quantity can be measured directly and compared to the experimentally determined value. Uncertainties in measurement and assumptions made by the students should be included. Predict where an object sliding down a ramp onto a flat surface will stop. Design multiple experiments to determine what would need to be measured and calculated in order to make predictions.	application of Newton's Laws to solve for unknown forces and may include multiple forms of energy transformations, i.e. initial elastic potential energy transformed into kinetic and gravitational potential energy. External forces, such as friction, should be included in problems.	diagrams to provide a visual scaffold to begin complex problems.
Design a system that must complete a task, such as raising a mass a certain distance or compressing a spring or a spring-loaded lever. Use the smallest amount of initial energy to complete the task and test and refine their design to minimize energy transferred out of the system. Students refine their process to minimize the energy transferred out of the system. provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.	Each stage of the energy transformation should be investigated and measurements taken to provide data to calculate the amount of energy present	Students must have a minimum of five transformations from one form of mechanical energy and should be able to describe the type of mechanical energy and show how they arrived at their values for the energy present, lost and remaining at each step in the process.	Identify the energy present before and after each transformation in the system and accurately calculate the amount of energy present at each step in the process. Estimates for energy lost at each transformation should be recorded throughout the design process and students should make an effort to reduce the amount of energy transferred out of the system.
P.E.5- Nuclear Energy			
		Correctly predict the products of a given decay process and identify the decay process given the reactants and products of a decay process.	From given reactions, calculate the masses of the reactants and the products to find the mass defect and hence the energy released in fission and fusion reactions.
Students should research benefits and drawbacks to nuclear energy as a	Students should research concepts such as nuclear waste storage, decay	Students will present and explain their scientific evidence as support for their	Students should relate the scientific principles associated with electrical

source of electrical energy production. From their research, students should choose to support or oppose the construction of a nuclear power plant and debate the issue.	series, energy production from fossil fuels, and other related concepts to provide scientific evidence for their argument for or against the construction of a nuclear power plant.	argument for or against the construction of a nuclear power plant.	energy production through nuclear fission to their argument.

Resources

P.E.1- Gravitational Potential Energy

- Energy Skate Park Phet Simulation This simulation allows students to learn about conservation of energy with a skater. Students can build tracks, ramps and jumps for the skater and view the kinetic energy, potential energy and friction as he moves. You can also take the skater to different planets or even space.
- Modeling workshops are available nationally that help teachers develop a framework for using guided inquiry in their instruction.
- Ranking tasks are designed to draw out common misconceptions in physics, weed out extraneous information and defend their answers with simple math . Examples can be found online including some posted by the University of Virginia . Published works with good ranking exercises include TIPERs: Sensemaking Tasks for Introductory Physics (Pearson ISBN-13: 978-0132854580)
- Mechanical Universe is a series of 52 videos produced by Caltech and now housed on a YouTube channel. Most topics in the physics standards are addressed. Each video is roughly 30 minutes in length.
- Physics Classroom

P.E.2- Energy in Springs

- Phet Simulations (including Hooke's Law simulation)
- Modeling workshops are available nationally that help teachers develop a framework for using guided inquiry in their instruction.
- Ranking tasks are designed to draw out common misconceptions in physics, weed out extraneous information and defend their answers with simple math . Examples can be found online including some posted by the University of Virginia . Published works with good ranking exercises include TIPERs: Sensemaking Tasks for Introductory Physics (Pearson ISBN-13: 978-0132854580)
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- Physics Classroom

P.E.3- Work and Power

- The Ramp Phet Simulation Students can explore forces, energy and work as they push household objects up and down a ramp. They can lower and raise the ramp to see how the angle of inclination affects the parallel forces acting on the file cabinet. Graphs show forces, energy and work.

- Modeling workshops are available nationally that help teachers develop a framework for using guided inquiry in their instruction.
- Ranking tasks are designed to draw out common misconceptions in physics, weed out extraneous information and defend their answers with simple math . Examples can be found online including some posted by the University of Virginia . Published works with good ranking exercises include TIPERs: Sensemaking Tasks for Introductory Physics (Pearson ISBN-13: 978-0132854580)
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- Physics Classroom

P.E.4- Conservation of Energy

- Energy Skate Park Phet Simulation This simulation allows students to learn about conservation of energy with a skater. Students can build tracks, ramps and jumps for the skater and view the kinetic energy, potential energy and friction as he moves. You can also take the skater to different planets or even space.
- Modeling workshops are available nationally that help teachers develop a framework for using guided inquiry in their instruction.
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P.E.5- Nuclear Energy

- Nuclear Fission Phet Simulation Students can start a chain reaction, or introduce non-radioactive isotopes to prevent one. Students can control energy production in a nuclear reactor.
- Modeling workshops are available nationally that help teachers develop a framework for using guided inquiry in their instruction.
- Ranking tasks are designed to draw out common misconceptions in physics, weed out extraneous information and defend their answers with simple math . Examples can be found online including some posted by the University of Virginia . Published works with good ranking exercises include TIPERs: Sensemaking Tasks for Introductory Physics (Pearson ISBN-13: 978-0132854580)
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WAVES

In earlier grades, the electromagnetic spectrum and basic properties (wavelength, frequency, amplitude) and behaviors of waves (absorption, reflection, transmission, refraction, interference, and diffraction) were introduced. In this course, conservation of energy is applied to waves and the measurable properties of waves (wavelength, frequency, amplitude) are used to mathematically describe the behavior of waves (index of refraction, law of reflection, single- and double-slit diffraction). The wavelet model of wave propagation and interactions is not addressed in this course. Waves must be explored experimentally in the laboratory. This may include, but is not limited to, water waves, waves in springs, the interaction of light with mirrors, lenses, barriers with one or two slits, and diffraction gratings.

P.W.1- Wave Properties

When a wave reaches a barrier or a new medium, a portion of its energy is reflected at the boundary and a portion of the energy passes into the new medium. Some of the energy that passes to the new medium may be absorbed by the medium and transformed to other forms of energy, usually thermal energy, and some continues as a wave in the new medium. Some of the energy also may be dissipated, no longer part of the wave since it has been transformed into thermal energy or transferred out of the system due to the interaction of the system with surrounding objects. Usually all of these processes occur simultaneously, but the total amount of energy must remain constant. When waves bounce off barriers (reflection), the angle at which a wave approaches the barrier (angle of incidence) equals the angle at which the wave reflects off the barrier (angle of reflection). When a wave travels from a two dimensional (e.g., surface water, seismic waves) or three- dimensional (e.g., sound, electromagnetic waves) medium into another medium in which the wave travels at a different speed, both the speed and the wavelength of the transferred wave change. Depending on the angle between the wave and the boundary, the direction of the wave also can change resulting in refraction. The amount of bending of waves around barriers or small openings (diffraction) increases with decreasing wavelength. When the wavelength is smaller than the obstacle or opening, no noticeable diffraction occurs. Standing waves and interference patterns between two sources are included in this topic. As waves pass through a single or double slit, diffraction patterns are created with alternating lines of constructive and destructive interference. The diffraction patterns demonstrate predictable changes as the width of the slits spacing between the slits and/or the wavelength of waves passing through the slits changes.

P.W.2- Light phenomena

The path of light waves can be represented with ray diagrams to show reflection and refraction through converging lenses, diverging lenses and plane mirrors. Since light is a wave, the law of reflection applies. Snell's law, $n_1 \sin\theta_1 = n_2 \sin\theta_2$, quantifies refraction in which n is the index of refraction of the medium and θ is the angle the wave enters or leaves the medium, when measured from the normal line. The index of refraction of a material can be calculated by the equation $n = c/v$, where n is the index of refraction of a material, v is the speed of light through the material, and c is the speed of light in a vacuum. Diffraction patterns of light must be addressed, including patterns from diffraction gratings. There are two models of how radiant energy travels through space at the speed of light. One model is that the radiation travels in discrete packets of energy called photons that are continuously emitted from an object in all directions. The energy of these photons is directly proportional to the frequency of the electromagnetic radiation. This particle-like model is called the photon model of light energy transfer. A second model is that radiant energy travels like a wave that spreads out in all directions from a source. This wave-like model is called the electromagnetic wave model of light energy transfer. Strong scientific evidence supports both the particle-like model and wave-like model. Depending on the problem scientists are trying to solve, either the particle- like model or the wave-like model of radiant energy transfer is used. Students are not required to know the details of the evidence that supports either model at this level. Humans can only perceive a very narrow portion of the electromagnetic spectrum. Radiant energy from the sun or a light bulb filament is a mixture of all the colors of light (visible light spectrum). The different colors correspond to different radiant energies. When white light hits an object, the pigments in the object reflect one or more colors in all directions and absorb the other colors.

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟷		Least Complex	
Waves				
P.W.1 Wave Properties ○ Conservation of energy ○ Reflection ○ Refraction ○ Interference ○ Diffraction	**P.W.1a** Compare the speeds at which light waves travel in different mediums.	**P.W.1b** Identify what results from light traveling into a different medium (e.g., dispersion into colors – prism, apparent location of a pencil is different from actual location - water).	**P.W.1c** Identify the reflection of light in a mirror.	HS-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. 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.
P.W.2 Light Phenomena ○ Ray diagrams (propagation of light) ○ Law of reflection (equal angles) ○ Snell's law ○ Diffraction patterns ○ Wave – particle duality of light ○ Visible spectrum and color	**P.W.2a** Create a ray diagram showing the path of a light wave.	**P.W.2b** Complete a simple ray diagram to show at what angle a wave is reflected off a surface.	**P.W.2c** Identify a ray diagram.	HS-PS4-3 Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations, one model is more useful than the other. 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.

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EVIDENCE OF LEARNING
Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

Designing technological / engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.W.1- Wave Properties			
	Plan and conduct an investigation into diffraction of waves. Students use single or double slit diffraction to experimentally investigate diffraction of light waves. Find the resonance lengths of a particular frequency using a large graduated cylinder of water, a piece of pipe, and a tuning fork. Calculate the speed of sound. Repeat using two nested cardboard tubes to make an open ended pipe.	Solve problems related to the distance between two sources and locations of constructive and destructive interference. Graphically represent the places where constructive and destructive interference are occurring based on the path difference of the waves from each source as well as calculate the distances mathematically from an equation.	Solve problems involving standing waves on strings and in open and closed pipes. Be familiar with the conditions for standing waves to occur and be able to calculate the frequency of the standing wave of a given harmonic.
Design a laser maze using the laws of reflection. Students can use mirrors to direct a beam of light or a laser through a maze or around a target. Students can present their mazes and challenge other students to solve their maze.	Plan and conduct an investigation into reflection of waves using ray tracing and a plane mirror.	Calculate and create a display of the solution path using a diagram prior to constructing the actual maze. This diagram will serve as the basis for the students' maze and should be refined and updated as the students test their design	Accurately apply the law of reflection to correctly predict the path of light.
P.W.2- Light Phenomena			
Design a parabolic cooker using principles of ray reflection to design the apparatus. After construction	Investigate the image formed by a lens. Experimentally determine the focal length of the lens and then	Draw ray diagrams for light reflecting off of plane,concave,and convex mirrors to determine the location of the image formed	Solve problems using the equation for mirrors and lenses to determine the location and properties of an

and testing evaluate the success of the design and examine where performance departs from plan.	investigate the images formed by a lens using a candle placed at different distances from the lens, e.g. inside the focal length, outside the focal length, twice the focal length. Experimentally determine the wavelength of a laser using diffraction through a single slit, a double slit, or a diffraction grating.	and describe the properties of the image that is formed using the diagrams and calculations. Draw ray diagrams for light refracting through a boundary of two translucent media and through converging and diverging lenses to determine the location of the image formed and describe the properties of the image that is formed from the diagrams and from calculations.	image formed by various mirrors and lenses. Identify the features of the wave and the particle model of light to compare both models.
	Plan and conduct an investigation to determine the index of refraction of a substance. Determine a procedure to collect sufficient and relevant data that can be used to determine the index of refraction of a substance.	Analyze the data collected to determine the index of refraction of the material.	Use the phenomenon of refraction to be able to determine relevant data that can be collected to determine the index of refraction of a substance. Solve refraction problems using Snell's Law to find the index of of refraction for a medium.

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Resources

P.W.1- Wave Properties

- Phet Simulations - Waves on a String is helpful for exploring reflection in open and closed end situations.
- Modeling workshops are available nationally that help teachers develop a framework for using guided inquiry in their instruction.
- Ranking tasks are designed to draw out common misconceptions in physics, weed out extraneous information and defend their answers with simple math . Examples can be found online including some posted by the University of Virginia . Published works with good ranking exercises include TIPERs: Sensemaking Tasks for Introductory Physics (Pearson ISBN-13: 978-0132854580)
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- Physics Classroom

P.W.2- Light Phenomena

- Phet Simulations - Waves on a String is helpful for exploring reflection in open and closed end situations.
- Modeling workshops are available nationally that help teachers develop a framework for using guided inquiry in their instruction.
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ELECTRICITY AND MAGNETISM

In earlier grades, the following concepts were addressed: conceptual treatment of electric and magnetic potential energy; the relative number of subatomic particles present in charged and neutral objects; attraction and repulsion between electrical charges, and attraction and repulsion between magnetic poles; the concept of fields to conceptually explain forces at a distance; the concepts of current, potential difference (voltage) and resistance to explain circuits conceptually; and connections between electricity and magnetism as observed in electromagnets, motors and generators. In this course, the details of electrical and magnetic forces and energy are further explored and can be used as further examples of energy and forces affecting motion.

P.EM.1- Charging Objects

For all methods of charging neutral objects, one object/system ends up with a surplus of positive charge and the other object/system ends up with the same amount of surplus of negative charge. This supports the law of conservation of charge that states that charges cannot be created or destroyed. Tracing the movement of electrons for each step in different ways of charging objects (rubbing together two neutral materials to charge by friction; charging by contact and by induction) can explain the differences between them. When an electrical conductor is charged, the charge "spreads out" over the surface. When an electrical insulator is charged, the excess or deficit of electrons on the surface is localized to a small area of the insulator. There can be electrical interactions between charged and neutral objects. Metal conductors have a lattice of fixed positively charged metal ions surrounded by a "sea" of negatively charged electrons that flow freely within the lattice. If the neutral object is a metal conductor, the free electrons in the metal are attracted toward or repelled away from the charged object. As a result, one side of the conductor has an excess of electrons and the opposite side has an electron deficit. This separation of charges on the neutral conductor can result in a net attractive force between the neutral conductor and the charged object. When a charged object is near a neutral insulator, the electron cloud of each insulator atom shifts position slightly so it is no longer centered on the nucleus. The separation of charge is very small, much less than the diameter of the atom. Still, this small separation of charges for billions of neutral insulator particles can result in a net attractive force between the neutral insulator and the charged object.

P.EM.2- Coulomb's Law

Two charged objects, which are small compared to the distance between them, can be modeled as point charges. The forces between point charges are proportional to the product of the charges and inversely proportional to the square of the distance between the point charges [$F_e = (k_e\ q_1\ q_2) / r^2$]. Problems may be solved for the electric force, the amount of charge on one of the two objects or the distance between the two objects. Problems also may be solved for three- or four-point charges in a line if the vector sum of the forces is zero. This can be explored experimentally through computer simulations. Electric forces acting within and between atoms are vastly stronger than the gravitational forces acting between the atoms. However, gravitational forces are only attractive and can accumulate in massive objects to produce a large and noticeable effect whereas electric forces are both attractive and repulsive and tend to cancel each other out.

P.EM.3- Electric Fields and Electric Potential Energy

The strength of the electrical field of a charged object at a certain location is given by the electric force per unit charge experienced by another charged object placed at that location, $E = F_e / q$. This equation can be used to calculate the electric field strength, the electric force or the electric charge. However, the electric field is always there, even if the object is not interacting with anything else. The direction of the electric field at a certain location is parallel to the direction of the electrical force on a positively charged object at that location. The electric field caused by a collection of charges is equal to the vector sum of the electric fields caused by the individual charges (superposition of charge). This topic can be explored experimentally through computer simulations. Greater electric field strengths result in larger electric forces on electrically charged objects placed in the field. Electric fields can be represented by field diagrams obtained by plotting field arrows at a series of locations. Electric field diagrams for a dipole, two-point charges (both positive, both negative, one positive and one negative) and parallel capacitor plates are included. Field line diagrams are excluded from this course.

The concept of electric potential energy can be understood from the perspective of an electric field. When two attracting or repelling charges interact, the kinetic energies of both objects change but neither is acting as the energy source or the receiver. Instead, the energy is transferred into or out of the electric field around the system as electric potential energy. A single charge does not have electric potential energy. Only the system of attracting or repelling charges can have electric potential energy. When the distance between the attracting or repelling charges changes, there is a change in the electric potential energy of the system. When two opposite charges are moved farther apart or two like charges are moved close together, energy is transferred into the field as electric potential energy. When two opposite charges are moved closer together or two like charges are moved far apart, electric potential energy is transferred out of the field. When a charge is transferred from one object to another, work is required to separate the positive and negative charges. If there is no change in kinetic energy and no energy is transferred out of the system, the work increases the electric potential energy of the system.

P.EM.4- DC Circuits

Once a circuit is switched on, the current and potential difference are experienced almost instantaneously in all parts of the circuit even though the electrons are only moving at speeds of a few centimeters per hour in a current-carrying wire. It is the electric field that travels instantaneously through all parts of the circuit, moving the electrons that are already present in the wire. Since electrical charge is conserved, in a closed system such as a circuit, the current flowing into a branch point junction must equal the total current flowing out of the junction (junction rule).

Resistance is measured in ohms and has different cumulative effects when added to series and parallel circuits. The potential difference, or voltage (ΔV), across an energy source is the potential energy difference (ΔE) supplied by the energy source per unit charge (q) ($\Delta V = \Delta E/q$). The electric potential difference across a resistor is the product of the current and the resistance ($\Delta V = I R$). In this course, only ohmic resistors will be studied. When potential difference vs. current is plotted for an ohmic resistor, the graph will be a straight line and the value of the slope will be the resistance. Since energy is conserved for any closed loop, the energy put into the system by the battery must equal the energy that is transformed by the resistors. For circuits with resistors in series, this means that $V_{battery} = \Delta V_1 + \Delta V_2 + \Delta V_3 + \ldots$. The rate of energy transfer (power) across each resistor is equal to the product of the current through and the voltage drop across each resistor ($P = \Delta V I$) and $P_{battery} = I \Delta V_1 + I \Delta V_2 + I \Delta V_3 + \ldots = I\Delta V_{battery}$. Equations should be understood conceptually and used to calculate the current or potential difference at different locations of a parallel, series or mixed circuit. However, the names of the laws (e.g., Ohm's law,) are not the focus. Measuring and analyzing current, voltage and resistance in parallel, series and mixed circuits must be provided. This can be done with traditional laboratory equipment and through computer simulations.

P.EM.5- Magnetic Fields

The direction of the magnetic field at any point in space is the equilibrium direction of the north end of a compass placed at that point. Magnetic fields can be represented by field diagrams obtained by plotting field arrows at a series of locations. Field line diagrams are excluded from this course. Calculations for the magnetic field strength are not required at this grade level, but it is important to note that greater magnetic fields result in larger magnetic forces on magnetic objects or moving charges placed in the field. In this course, the concept of magnetic fields will not be addressed mathematically.

P.EM.6- Electromagnetic Interactions

Magnetic forces are very closely related to electric forces. Even though they appear to be distinct from each other, they are thought of as different aspects of a single electromagnetic force. A flow of charged particles (including an electric current) creates a magnetic field around the moving particles or the current carrying wire. Motion in a nearby magnet is evidence of this field. Electric currents in Earth's interior give Earth an extensive magnetic field, which is detected from the orientation of compass needles. The motion of electrically charged particles in atoms produces magnetic fields. Usually these magnetic fields in an atom are randomly oriented and therefore cancel each other out. In magnetic materials, the subatomic magnetic fields are aligned, adding to give a macroscopic magnetic field. A moving charged particle interacts with a magnetic field. The magnetic force that acts on a moving charged particle in a magnetic field is perpendicular to both the magnetic field and to the direction of motion of the charged particle. The magnitude of the magnetic force depends on the speed of the moving particle, the magnitude of the charge of the particle, the strength of the magnetic field, and the angle between the velocity and the magnetic field. There is no magnetic force on a particle moving parallel to the magnetic field. Calculations of the magnetic force acting on moving particles are not required at this grade level. Moving charged particles in magnetic fields typically follow spiral trajectories since the force is perpendicular to the motion.

A changing magnetic field creates an electric field. If a closed conducting path, such as a wire, is in the vicinity of a changing magnetic field, a current may flow through the wire. A changing magnetic field can be created in a closed loop of wire if the magnet and the wire move relative to one another. This can cause a current to be induced in the wire. The strength of the current depends upon the strength of the magnetic field, the velocity of the relative motion and the number of loops in the wire. Calculations for current induced in a wire or coil of wire is not required at this level. A changing electric field creates a magnetic field and a changing magnetic field creates an electric field. Thus, radiant energy travels in electromagnetic waves produced by changing the motion of charges or by changing magnetic fields. Therefore, electromagnetic radiation is a pattern of changing electric and magnetic fields that travel at the speed of light.

The interplay of electric and magnetic forces is the basis for many modern technologies that convert mechanical energy to electrical energy (generators) or electrical energy to mechanical energy (electric motors) as well as devices that produce or receive electromagnetic waves. Therefore, coils of wire and magnets are found in many electronic devices including speakers, microphones, generators and electric motors. The interactions between electricity and magnetism must be explored in the laboratory setting. Experiments with the inner workings of motors, generators and electromagnets can be conducted. Current technologies using these principles can be explored.

Ohio Learning Standard	Complexity a	Complexity b	Complexity c	NGSS Alignment
Generic	Most Complex ⟵	⟶	Least Complex	
Electricity and Magnetism				
P.EM.1 Charging Objects (Friction, Contact, and Induction)	**P.EM.1a** Recognize that charges can transfer from one object to another in different ways.	**P.EM.1b** Understand that objects can have charges which can be either negative or postitive.	**P.EM.1c** Relate the symbols (+, -) to their corresponding charge.	
P.EM.2 Coulomb's Law	Complex and advanced learning standards in Ohio's New Learning Standards are not included in the extended standards.			HS-PS2-4 Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
P.EM.3 Electric Fields and Electric Potential Energy	**P.EM.3a** Recognize the effect of an electric field around a positively or negatively charged object	**P.EM.3b** Label a model or picture indicating an electric field.	**P.EM.3c** Identify a field as an area around an object.	**HS-PS2-5** Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
P.EM.4 DC Circuits ○ Ohm's law ○ Series circuits ○ Parallel circuits ○ Mixed circuits ○ Applying conservation of charge and energy (junction and loop rules)	**P.EM.4a** Construct a direct current circuit.	**P.EM.4b** Identify the required parts of a circuit.	**P.EM.4c** Complete a direct current circuit (e.g., closing a switch to initiate flow).	HS-PS3-3 Design, build, and refine a device that works with given constraints to convert one form of energy into another form of energy.
P.EM.5 Magnetic Fields	**P.EM.5a** Apply a real-life example demonstrating the strength of magnetic fields (e.g., explore how many paper clips a weak magnet can hold up versus a strong	**P.EM.5b** Demonstrate that different magnets have different sized magnetic fields.	**P.EM.5c** Manipulate two objects displaying magnetism.	**HS-PS3-5** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

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	magnet).			
P.EM.6 Electromagnetic Interactions	Complex and advanced learning standards in Ohio's New Learning Standards are not included in the extended standards.			**HS-PS3-5** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. HS-PS4-3 Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations, one model is more useful than the other. HS-PS4-4 Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.

EVIDENCE OF LEARNING
Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

Designing technological / engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.EM.1- Charging Objects			
Investigate alternative solutions to reduce static electricity in clothing tossed in a dryer.		Describe and draw diagrams to explain the process of polarization and the attraction of a charged object and a neutral object in terms of the movement of electrons. Examples: Balloon sticking to a wall, balance a meter stick on a golf ball and cause rotation with a charged balloon.	State the differences between conductors and insulators in terms of electron movement through the materials. Describe how electrons move in an electroscope and indicate charge.

	Investigate the charging of objects through friction, conduction, and induction. Students are not expected to quantify the interaction, but should record observations to create a general pattern of rules that apply to these interactions. Use an electroscope to investigate charging by conduction and induction.	Represent the types of charging in a graphic organizer, chart or drawing. Draw diagrams that represent the distribution of charges and movement of electrons throughout the investigation.	Explain how the law of conservation of charge applies to the movement of electrons in charging by friction, conduction, and induction.
P.EM.2- Coulomb's Law			
	Use a computer simulation to investigate electrostatic repulsion and attraction of charges. Devise two procedures to investigate the effects charge and distance have on the magnitude and direction of the force.	Solve problems using Coulomb's Law to determine the net force on a charge due to two charges that are not collinear. Explain the relationship between force and distance using a graphical representation.	Cite the similarities and differences between the equation for gravitational and for electrical force (Coulomb's Law). • Both follow inverse square law • Gravity only attracts, Electric forces attract and repel • Comparing the magnitude of the two constants shows electrical forces are much stronger than gravitational forces.
P.EM.3- Electric Fields and Electric Potential Energy			
	Use a computer simulation to investigate the effect of charges on the electric field at a point in space and the effect of an external field on a charged particle. Use a computer simulation to explore the Millikan Oil Drop Experiment. Apply the idea of equilibrium to electrical and gravitational forces.	Draw the field lines for a positive charge, a negative charge, a dipole, and two parallel plates of charge. Compare and contrast the earth's gravitational field with an electric field in terms of when potential energy is increasing and decreasing.	Solve problems involving a constant electric field in a region and the force on a charged particle. Newton's Laws, kinematics equations, and equations for work and kinetic energy can be used to calculate the acceleration of the particle, the final velocity of the particle, and the change in energy of the particle. These concepts can be further used to introduce the

			relationship between potential energy and electric fields.
P.EM.4- DC Circuits			
	Plan and conduct an investigation of series and parallel arrangements of resistors to experimentally determine the similarities and differences between the two types of arrangements.	Solve problems involving complex arrangements of resistors in both parallel and series in one circuit to determine the equivalent resistance of the entire circuit as well as the current, the potential difference, or rate of energy dissipated in individual resistors in the circuit. Compare different types of string lights and explore what type of circuits are involved, how blinker bulbs work, how bulbs that are unlit complete a circuit.	Solve problems involving resistors in series and in parallel to determine the current, potential difference, or rate of energy dissipated in individual resistors in the circuit Build a series circuit adding one bulb at a time. Observe what happens to the brightness of the bulb and total current as bulbs are added. Build a parallel circuit adding bulb branches one at a time and make brightness and current observations. Discuss the advantages and disadvantages of each type of circuits.
	Plan and conduct an investigation to determine the resistance of an unknown resistor. Unanticipated effects on measurements should be accounted for, i.e. internal resistance of the battery or power supply, and assumptions made by the students should be explained, i.e. assuming that the resistance of the wires can be ignored or that a voltmeter has an infinite impedance. Plan and conduct an investigation to determine the resistance of an unknown resistor. Experimental	Draw a circuit diagram of the experimental design before conducting the experiment, labeling the elements of the circuit.	Calculate the resistance of the resistor, using either an average of the data or by graphing the data and analyzing it.

	design should be checked for safety before conducting the experiment.		
P.EM.5- Magnetic Fields			
		Use a small compass to map the magnetic field around a bar magnet, horseshoe magnet and circular magnet.	
P.EM.6- Electromagnetic Interactions			
	Plan and conduct an investigation into the production of a magnetic field by a current carrying wire. Develop a hypothesis between a dependent and an independent variable of their choosing and investigate the relationship qualitatively or quantitatively. Build a simple electromagnet with wire wrapped around a straw. What variables in an electromagnetic affects the strength of the magnetic field. Examples: number of turnings, core material and strength of current. Using a galvanometer connected to a solenoid and a magnetic, design and conduct an investigation to determine when current is induced and what variables affect the strength of the current.	Apply Newton's Laws to predict the shape of the path followed by a charged particle moving in a magnetic field. Draw the path and predict the shape for heavier and lighter particles as well as particles with different charge. Use a solenoid and permanent magnet to launch the magnet. Take apart so students can view a simple doorbell, electric motor or power door locks diagrams and compare the fundamental parts of these systems and how they work. Predict the direction of a magnetic field in a current carrying wire. Use a compass and wire demonstration device to check the prediction.	State the factors that affect the force on a moving charged particle in a magnetic field and determine the path taken by the charged particle. Explore using the right hand rules to determine the direction of a charged particle in a magnetic field. Discuss the benefits and origins of earth's magnetic field.
Design an electromagnetic motor with a limitation on the amount of materials used in construction. Students are given a budget that they can use to "purchase" materials from the	Plan and conduct an investigation to determine the rate of rotation of an electromagnetic motor.	Present the model for the design including a materials list and "budget" for the supplies.	Design and construct a working circuit that interacts with an external magnetic field.

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teacher so that they cannot simply use an unlimited supply of wire and batteries to provide the potential difference. Test the design and redesign the motor based on the findings from the testing process.			

Resources

P.EM.1- Charging Objects

- The Van De Graaff generator allows students to see attractive and repulsive forces with charges
- Raging Planet video https://www.youtube.com/watch?v=3D0BRSJ5nIs
- Mechanical Universe is a series of 52 videos produced by Caltech and now housed on a YouTube channel. Most topics in the physics standards are addressed. Each video is roughly 30 minutes in length.
- CASTLE physics has many great activities to address these topics.
- There are multiple examples and activities at www.physicsclassroom.com.
- Phet Simulations
- Modeling workshops are available nationally that help teachers develop a framework for using guided inquiry in their instruction.
- Ranking tasks are designed to draw out common misconceptions in physics, weed out extraneous information and defend their answers with simple math . Examples can be found online including some posted by the University of Virginia . Published works with good ranking exercises include TIPERs: Sensemaking Tasks for Introductory Physics (Pearson ISBN-13: 978-0132854580)
- Physics Classroom
- Video: Raging Planet:Lightning (NOVA)

P.EM.2- Coulomb's Law

- The "Charges and Fields" PhET (phet.colorado.edu) allows students to explore and measure the interactions between point charges.
- Ranking tasks are designed to draw out common misconceptions in physics, weed out extraneous information and defend their answers with simple math . Examples can be found online including some posted by the University of Virginia . Published works with good ranking exercises include TIPERs: Sensemaking Tasks for Introductory Physics (Pearson ISBN-13: 978-0132854580)
- There are multiple examples and activities at www.physicsclassroom.com.

P.EM.3- Electric Fields and Potential Energy

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- Ranking tasks are designed to draw out common misconceptions in physics, weed out extraneous information and defend their answers with simple math . Examples can be found online including some posted by the University of Virginia . Published works with good ranking exercises include TIPERs: Sensemaking Tasks for Introductory Physics (Pearson ISBN-13: 978-0132854580)
- Mechanical Universe is a series of 52 videos produced by Caltech and now housed on a YouTube channel. Most topics in the physics standards are addressed. Each video is roughly 30 minutes in length.
- Physics Classroom
- Millikan Oil Drop Simulation, https://www.youtube.com/watch?v=nwnjYERS66U

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P.EM.4- DC Circuits

- Phet Simulations
- Modeling workshops are available nationally that help teachers develop a framework for using guided inquiry in their instruction.
- Ranking tasks are designed to draw out common misconceptions in physics, weed out extraneous information and defend their answers with simple math . Examples can be found online including some posted by the University of Virginia . Published works with good ranking exercises include TIPERs: Sensemaking Tasks for Introductory Physics (Pearson ISBN-13: 978-0132854580)
- Mechanical Universe is a series of 52 videos produced by Caltech and now housed on a YouTube channel. Most topics in the physics standards are addressed. Each video is roughly 30 minutes in length.
- Physics Classroom
- The STEMcoding youtube channel has a number of videos and interactive simulations, including an electric current interactive and explanatory video

P.EM.5- Magnetic Fields

- Phet Simulations
- Modeling workshops are available nationally that help teachers develop a framework for using guided inquiry in their instruction.
- Ranking tasks are designed to draw out common misconceptions in physics, weed out extraneous information and defend their answers with simple math . Examples can be found online including some posted by the University of Virginia . Published works with good ranking exercises include TIPERs: Sensemaking Tasks for Introductory Physics (Pearson ISBN-13: 978-0132854580)
- Mechanical Universe is a series of 52 videos produced by Caltech and now housed on a YouTube channel. Most topics in the physics standards are addressed. Each video is roughly 30 minutes in length.
- Physics Classroom

P.EM.6- Electromagnetic Interactions

- Phet Simulations
- Modeling workshops are available nationally that help teachers develop a framework for using guided inquiry in their instruction.
- Ranking tasks are designed to draw out common misconceptions in physics, weed out extraneous information and defend their answers with simple math . Examples can be found online including some posted by the University of Virginia . Published works with good ranking exercises include TIPERs: Sensemaking Tasks for Introductory Physics (Pearson ISBN-13: 978-0132854580)
- Mechanical Universe is a series of 52 videos produced by Caltech and now housed on a YouTube channel. Most topics in the physics standards are addressed. Each video is roughly 30 minutes in length.
- Physics Classroom
- Cosmos: A Spacetime Odyssey (2014) The Electric Boy (Episode 10)

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ANATOMY AND PHYSIOLOGY

INTRODUCTION AND SYLLABUS

COURSE DESCRIPTION

Human Anatomy and Physiology is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires three one-unit courses. Each course should include inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

Human Anatomy and Physiology comprises a systematic study in which students will examine human anatomy and physical functions, as well as homeostatic imbalances. They will analyze descriptive results of abnormal physiology and evaluate clinical consequences. A workable knowledge of medical terminology will be demonstrated.

Investigations are used to understand and explain the human body in a variety of investigative scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

Cross Curriculum connections link to ELA and Technology.

COURSE CONTENT SYLLABUS

The following information may be taught in any order; there is no ODE recommended sequence.

AP.LO: LEVELS OF ORGANIZATION
- AP.LO.1: Hierarchy of Organization
- AP.LO.2: Types of Tissues
- AP.LO.3: Homeostasis
- AP.LO.4: Anatomical Terminology

AP.SM: SUPPORT AND MOTION
- AP.SM.1: Integumentary System
- AP.SM.2: Skeletal System
- AP.SM.3: Muscular System

AP.IC: INTEGRATION AND COORDINATION
- AP.IC.1: Nervous System
- AP.IC.2: Special Senses
    - Sense of Sight
    - Senses of Hearing and Balance
    - Senses of Taste and Smell
- AP.IC.3: Endocrine System

AP.T: TRANSPORT
- AP.T.1: Blood
- AP.T.2: Cardiovascular System
- AP.T.3: Lymphatic and Immune Systems

AP.AE: ABSORPTION AND EXCRETION
- AP.AE.1: Digestive System

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- AP.AE.2: Respiratory System
- AP.AE.3: Urinary System

AP.R: REPRODUCTION
- AP.R.1: Reproductive System

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LEVELS OF ORGANIZATION

AP.LO.1- Hierarchy of Organization

Building on knowledge from middle school and Biology on cell structures and processes, this topic focuses on the increasing complexity of cells as they are organized into tissues. Several tissue types make up an organ. Several organs working together make up an organ system. All the organ systems interact and form the human body.

AP.LO.2: Types of Tissues

The human body is comprised of four types of tissues: epithelial, connective, muscle, and nervous. This topic includes a broad overview of the structure, function, and location of each tissue type. Tissues can be studied as an independent unit or as they are encountered within each organ system. Investigations are used to understand and explain types of tissues in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications..

AP.LO.3: Homeostasis

Homeostasis is a theme that is explored throughout the course. Homeostasis requires the body to continuously monitor and adjust its internal conditions through positive and negative feedback mechanisms. Examples can include temperature regulation, pH, hormone regulation, blood pressure, and hemostasis.

AP.LO.4: Anatomical Terminology

Standard anatomical position is to be used as a reference point. Each area of the human body is identified by region. The features and structures of the body, relative to each other, are described by directional terms. The body and its organs can be divided by planes. The organs are located in cavities.

Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟷		Least Complex	
Levels of Organization				
AP.LO.1 Hierarchy of Organization	**AP.LO.1a** Describe the function of organ systems (e.g., muscular, skeletal, digestive, nervous, respiratory, reproductive, digestive).	**AP.LO.1b** Recognize the hierarchy of cellular organization (i.e., cells make tissues, tissues make organs, etc.).	**AP.LO.1c** Identify a cell.	HS-LS1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
AP.LO.2 Types of Tissues	**AP.LO.2a** Describe the function of a particular type of tissue (e.g., muscle tissue).	**AP.LO.2b** Recognize that there are different types of tissues with different functions.	**AP.LO.2c** Identify that tissues are made of cells.	
AP.LO.3 Homeostasis	**AP.LO.3a** Describe how the body works to maintain	**AP.LO.3b** Recognize that the body's systems interact	**AP.LO.3c** Identify that the body has many systems that	HS-LS1-3 Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟷		Least Complex	
	homeostasis (e.g., sweating when the body is hot).	to maintain balance.	work together.	
AP.LO.4 Anatomical Terminology	**AP.LO.4a** Label organs on a model or image of a body.	**AP.LO.4b** Match organ names to a model or image.	**AP.LO.4c** Locate a body part on a model or image of a body.	

EVIDENCE OF LEARNING
Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

Designing technological / engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
AP.LO.1- Hierarchy of Organization			
		Analyze data about various human cell types and hypothesize the relationships between structure and function. Develop an analogy that relates levels of organization to a real world example (e.g.: machine, factory, etc.) Create a model that illustrates at least three levels of organization.	Identify all levels of organization from cellular to organism.

AP.LO.2: Types of Tissues			
Simulate tissue engineering using a variety of materials (e.g.: gelatin, agar, yeast, etc.). Critique the characteristics of each tissue simulation to rate as a possible replacement in tissue grafting.		Create labeled illustrations or models of the four types of human tissues.	Identify the four types of human tissues. Using microscopes, micrographs, models or illustrations, analyze samples of each of the four types of tissue. Interpret how the function of each tissue type relates to its structure.
AP.LO.3: Homeostasis			
Design or critique a device used to maintain or monitor homeostasis for a human body process (e.g.: heart rate, glucose, oxygen level)	Investigate homeostasis by measuring changes in heart rate. Compare resting heart rate to the rate after changing a variable. Present data and hypothesize ways to improve heart rates in stressed individuals (e.g. yoga, deep breathing, etc.).	After using a simulation or another data source, discuss how the data are similar to and different than the self-regulation that goes on in an actual human body.	Identify examples of how the body uses homeostasis to maintain balance. Differentiate between positive and negative feedback mechanisms.
AP.LO.4: Anatomical Terminology			
		Demonstrate knowledge of anatomical directional terminology through the dissection of a three-dimensional object, such as a clay model, cucumber, or gummy bear. Design an educational tool or game to help others learn correct anatomical terminology.	Label a diagram of a human body with directional terms, planes, and cavities.

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Resources

Real Cell Videos is a collection of video clips and images of living cells from humans and other species, organized by the University of Utah Genetic Science Learning Center.

Structural Organization of the Human Body is a short section of an Oregon State open source textbook that can be used as a resource to learn the levels of organization from cellular to organism.

The goal of this Wake Forest School of Medicine activity is to experience a simulation of tissue engineering. Since it is not feasible to grow cells or make biopolymers in a classroom, this activity simulates the process by making various types of gels to use as scaffolding and hydrogels.

This Body Control Center simulation from PBS LearningMedia virtually manipulates heart rate, respiration rate, blood vessel dilation, amount of perspiration and blood sugar levels in an attempt to maintain a homeostatic balance in a human.

In this Wisc-Online by Fox Valley Technical College interactive learning activity, review the terms used to describe relative position of body parts in order to have a common set of words to describe their position.

This Boston Children's Hospital Stem Cell Virtual Lab determines the effects of different coaxing agents on virtual embryonic stem cells.

Build-A-Body is a drag and drop game with the goal of assembling an organ system from a set of organs. The site also includes case studies where a functional problem with a system must be linked to the organ affected.

In this activity, design and build a museum display for a new exhibit at The Tech Museum of Innovation in San Jose, California. The exhibit will explore anatomy, physiology, and development. This process will include: researching a selected body system; developing exhibit text, diagrams, charts, and graphs; and designing and building an analogous model.

This CK-12 PLIX interactive activity virtually diagrams the organization of living things. Create a free account to access this resource.

This CK-12 lesson summarizes information about the organization of the human body. Create a free account to access this resource.

This CTE Online activity is the hands-on dissection of gummy bears to demonstrate knowledge of the body planes. Create a free account to access this resource.

The following links include information about devices used to monitor or maintain homeostasis in the human body:

Artificial Pancreas (FDA)
Cardiac Event Recorder (American Heart Association)
Pulse Oximeter (American Thoracic Society)

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SUPPORT AND MOVEMENT

AP.SM.1: Integumentary System

The integumentary system consists of skin and accessory structures. The skin is composed of three layers: the epidermis, the dermis, and the hypodermis (subcutaneous layer). The accessory structures can include sweat glands, sebaceous glands, arrector pili muscles, hair follicles, and nails. Skin functions include protection, temperature regulation, excretion, and sensory perception through the processes of perspiration, skin production and shedding, pigmentation, vitamin D synthesis, healing, and repair. Homeostatic imbalances are also explored, including, but are not limited to, burns, skin cancer, anhidrosis, acne, eczema or scleroderma. Tissues can be studied as an independent unit or as they are encountered within each organ system. Investigations are used to understand and explain the integumentary system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.SM.2: Skeletal System

The skeletal system is composed of bones, cartilage, joints, and ligaments. Bones make up most of the skeleton. There are four main cell types, each with a specific function, that compose bone tissue: osteogenic cells, osteocytes, osteoblasts, and osteoclasts. The microscopic anatomy of compact bone includes osteons. Bones are classified by their shape. The structure of a typical long bone can be explored. Specific bones of the skeleton can be studied by their subdivisions: the axial skeleton and the appendicular skeleton. Cartilage is found in areas of the nose, ears, ribs, and joints. Joints can be classified by structure or by function. The general structure of synovial joints may be explored. Ligaments connect bone to bone stabilizing joints.

The skeletal system functions to provide support of the body, protect soft organs, allow for movement due to attachment of muscles, store minerals and fat, and form blood cells. Processes of the skeletal system include hematopoiesis, ossification, and bone growth and remodeling. A comparison of male to female and of juvenile to adult skeletons may be explored. In addition to normal functions, homeostatic imbalances can be explored. These can include, but are not limited to osteoporosis, malnutrition, fractures, ACL injuries, and arthritis. Investigations are used to understand and explain the skeletal system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.SM.3: Muscular System

The muscular system consists of three types of muscle cells: skeletal, smooth, and cardiac. The primary function of the muscular system is to contract; thereby, moving the body and internal fluids, maintaining posture, generating heat, and stabilizing joints. Muscles are controlled voluntarily and/or involuntarily.

Cardiac muscle cells, found in the heart, are uninucleated, branched, and striated. Intercalated disks are characteristic of cardiac muscle and aid in communication between cardiac muscle cells. Smooth muscle cells, found in the hollow organs and blood vessels, are uninucleated, spindle-shaped, and nonstriated. Skeletal muscle cells, found attached to bones and skin, are multinucleated, cylindrical, and striated. The structure of skeletal muscle should be studied in detail. The muscles of the body can be studied by group, which include the muscles of the head, face, and neck, the trunk, and the upper and lower limbs.

Processes of the muscular system include gross body movements produced by skeletal muscles as they interact with the skeletal system, and muscle contraction. The connection between the nervous system and the skeletal system should be explored through the study of action potentials and the resulting contraction of sarcomeres, as described by the sliding filament theory. Energy processing and muscle responses to stimuli can also be studied along with building muscle tissue through exercise. The effects of steroids can also be investigated. Homeostatic imbalances can be explored. These include, but are not limited to, muscular dystrophy, atrophy, and aging. Investigations are used to understand and explain the muscular system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟷		Least Complex	
Support and Motion				
AP.SM.1 Integumentary System	**AP.SM.1a** Identify the accessories of the skin system (e.g., nails, hair follicles, sweat glands).	**AP.SM.1b** Identify the functions of skin (e.g., protection, temperature regulation).	**AP.SM.1c** Identify skin as a form of protection.	
AP.SM.2 Skeletal System	**AP.SM.2a** Describe the functions of the skeletal system	**AP.SM.2b** Complete a model of a skeleton using the major bones of the body.	**AP.SM.2c** Match major bones with a diagram of a body (e.g., skull=head).	
AP.SM.3 Muscular System	**AP.SM.3a** Describe how muscles are needed for movement.	**AP.SM.3b** Recognize that some muscle movements are voluntary (e.g., walking) and some are involuntary.	**AP.SM.3c** Identify a muscle.	

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EVIDENCE OF LEARNING

Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

	Designing technological/engineering solutions	**Demonstrating science knowledge**	**Interpreting and communicating science concepts**	**Recalling accurate science**
AP.SM.1: Integumentary System				
Skin Cell ID			Create labeled illustrations or models of skin cells.	Use microscopes, micrographs, models or illustrations to identify types of skin cells.
Accessory Structures ID			Create labeled illustrations or models of accessory structures	Use microscopes, micrographs, models or illustrations to identify accessory structures and functions
Integ-Sensory Connections Investigation		Design an investigation to explore the connection between types of cells, accessory structures, and the ability to sense temperature and pressure.	Identify and communicate the connection between types of cells, accessory structures, and ability to sense temperature and pressure.	List sensory structures involved in the integumentary system
Layers of Skin			Create foldable or other illustration listing information about the layers of the human skin	Label a diagram of the layers of the skin
Skin Cancer-UV Connection	Design a method to eliminate sun exposure in a common problem area/job	Design an investigation to test varying sunscreens and other homeopathic methods	Investigate and present data on the connection between UV/Sun exposure	List potential risks of UV exposure and connection to skin cancer risk

	area or propose a plan to lower the incidence of skin cancer in a given population	using UV sensitive paper/UV sensitive yeast strains/etc	and increased incidence of skin cancer. Create a presentation to inform audience about the risks of and dispel common myths about UV exposure	
Homeostatic Imbalances		Design an investigation to dispel common myths about acne and/or other skin disorders	Investigate and present information on conditions involving homeostatic imbalances (Burns, Skin Cancers, Anhidrosis, Acne, Eczema, Scleroderma)	List and describe common homeostatic imbalances in the integumentary system
Tissue Engineering and Tissue Donation	Analyze and interpret technological and engineering problems with tissue engineering and tissue donation.		Communicating scientific arguments about tissue engineering and tissue donation Create a pamphlet to persuade audience to become tissue donors	Describe the process of tissue engineering and tissue donation List pro's and con's of being a tissue donor
AP.SM.2: Skeletal System				
Structure of a long bone	Design and create a model of a Prosthetic limb that can a perform a functional task (lift or carry an object)	Design a bone with cardstock and tape and specific parameters. Test the strength of the bone with weights across two chairs.	Create an illustration of a long bone and label all structures	Label structures of a long bone using pictures, diagrams Identify anatomical structures in chicken leg focusing on bone structure
Bone Classification			Create a model of each type of bone and identify important features	Identify, label, and describe the types of bones using graphics, images,X-ray images or lab bone specimens
Bone Life Cycle	Design a better cast for fractures identifying the materials, type of fixation, etc.	Research gender and age data for common fractures and develop reasoning for	Create mnemonic device, song, or other memory device to remember stages	Create illustration of different stages of bone development and destruction including fracture repair

		common injuries for given age/gender classifications	of bone development, repair, and destruction	
Bones of the skeleton	Given environmental parameters, design the ideal bone and skeletal structure for organism survival	Measure femur length and perform associated calculations to find height. Graph class data and compare genders and ages. Can include younger age child data from siblings at home, parents, etc	Create mnemonic device, song, or other memory device to remember the bones of the skeleton	Use models or illustrations to identify and name bones of the human skeleton and important bony features on models.
Bone Density	Research and develop an action plan to help elderly prevent bone density loss	Investigate bone density using chicken bones and vinegar/bleach		List and describe factors that affect bone density
Terms of Anatomical Movement	Design system to analyze movement/joint stability in specified movements.		Record common athletic movements and identify bones and joints involved and anatomical movement represented	Using images, models, or videos, identify terms of anatomical movement Demonstrate terms of movement by moving specified joints and naming the movement.
Joints	Design a rehab plan/exercise program to promote ROM return after selected joint surgery	Design, plan, and conduct an investigation to compare range of motion between types of joints.	Use a goniometer to measure joint range of motion and degrees of motion and present a comparative analysis by gender, age, height, activity level, etc	Identify types of joints and give examples and locations from the human body Use a goniometer to measure joint range of motion and degrees of motion
AP.SM.3: Muscular System				
Muscle Fatigue		Design, plan, and conduct a lab on muscle fatigue using basic exercise equipment (tennis ball, clothespin, textbook, etc.) Collect data and analyze.	Investigate muscle fatigue comparing handedness, gender, height, and other factors	Describe the physiology behind muscle fatigue

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Identification of Muscle Tissue Types			Create presentation describing and differentiating between muscle tissue types.	Use microscopes, micrographs, models or illustrations to identify muscle tissue types
Identification of muscles of the body by name and action			Create a rap, mnemonic, song, or other memory device to remember muscle name, origin, insertion, and action	Name and recognize muscles of the body by their name and action using pictures and performance/dissection labs, online dissection tutorials, online virtual lab, matching games, and/or clay models. Identify muscles and connective tissue structures in preserved cat/fetal pig
Sliding Filament Theory and Muscle Contraction		Choose opposing major muscle groups and design an investigation to compare contraction length and/or force	Build a model using household items to demonstrate the steps of the sliding filament theory Manual muscle testing lab, determine the strength of a muscle by muscle grading parameters	Measure the circumference of a muscle as it contracts/relaxes
Tendons, Connective Tissue, & Muscle Attachment	Design and create a "Helping Hand" (hand made from common household items where the fingers flex and extend)			Define and describe the types of connective tissue Understand how muscles, bones, and tendons work together to move a joint by dissecting a chicken wing
Steroids - Effects and Risks	Design a 'perfect' steroid. Focus on recognizing and eliminating negative impacts and maximizing positive impacts of typical steroid use		Research and present findings over the uses for steroids, risks of use, and alternative treatment options	Define anabolic steroids and describe risk factors of their use

			Create skit/product to inform public of risks of anabolic steroid abuse	
Homeostatic Imbalances in Muscles	Design action plan to reduce risks and prevent muscle atrophy associated with common muscle disorders		Create product describing symptoms, treatments, and prognosis for varying muscle disorders	Identify common muscle disorders and give common symptoms and treatments

Resources

- Anatomy in Clay : Anatomically correct, hand-crafted, human and animal skeletal models. Cost involved.
- Getting Comfortable In My Own Skin : Investigate the layers of the skin and make connections to tattoos and their impact on the skin.
- Skin Deep Project : List of lesson plans over a variety of topics related to human skin.
- Skin Size Lab : Investigate body surface area/skin size using newspaper and measuring devices.
- Skin Sensory Receptor Lab : Explore pressure and temperature receptors in the skin and demonstrate adaptation of sensory receptors.
- Protect the Skin You're In : Explore the connection between sun exposure and skin cancer and test the effectiveness of sunscreen products.
- Sun Smart U: Rays Awareness : Introduce the importance of sun protection and provide the tools needed to prevent skin cancer (free registration is required).
- Biology of Skin Color : Anthropologist led discussion of the connection between skin color and the intensity of UV light exposure in different parts of the world.
- Chicken Long Bone Dissection Lab : Investigate the muscle, joint, and bone structures of a leg by dissecting a chicken leg.
- Bone Density and Fracture Data Investigation : Recognize changes in skeletal development and bone health (including bone density) across the life span, along with the roles of genetics and healthy choices in preserving our bones.
- NASA Bone Density Loss Investigation : 5E Lesson Plan to work through a mathematical analysis of bone density loss in astronauts on the International Space Station.
- No Bones About It : Forensic anthropology investigation into the connection between long bone lengths and height.
- Skeletal Remains and Determining a Victim's Height: Measuring bone length to determine height and using the humerus and pelvis to determine gender.
- Bone Crusher Activity : Investigation of bone fractures and design best treatment practices for bones/fractures.
- Soft and Brittle Bone Lab Investigations : Investigate the effects of soft or brittle bones on the ability to withstand forces.
- X-Rayed Web Investigation : Investigate bone abnormalities and fractures using x-rays.
- Design Your Own Cast Lab : Research and design effective casting and repair devices for turkey leg bones.
- Prosthetic Limb Engineering Investigation : Design, evaluate, and test the effectiveness of prosthetic limbs.
- COSI Interactive Videoconferencing Total Knee Replacement Surgery : Video conference viewing of total knee replacement surgery offered at a cost.
- Cat Dissection Online : Virtual cat dissection photo collection.
- Indiana University Virtual Anatomy Collection : Investigate and review anatomical structures and systems.
- Yale Histology Muscles Collection : Histology slides for muscles and muscle cells.
- Chicken Wing Dissection Lab : Investigate bone and joint structures through dissection of a chicken wing.

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- Burn Baby Burn - Muscle Fatigue Lab : Investigate muscle function and the impact of muscle fatigue on performance.
- Muscle Station Lab : Investigate muscle structure and function in this multi-station lab.
- Build a Helping Hand : Design and construct a prosthetic hand using common household items.
- Manual Muscle Testing: Manual muscle testing, key to muscle grading, and testing order of muscle groups.
- How to Build a Beating Heart : National Geographic video investigation into the process of building a working heart.
- Role of Steroids: Create a skit on the role of steroids in society and positive and negative impacts.
- Build a Steroid: Online interactive activity that covers the molecular structure of a steroid.
- HASPI A&P Lesson Resources : Collection of lesson plan resources for variety of anatomy & physiology topics. Free registration required.
- Anatomy Review Games : Games and activities to review muscles and bones.
- Essential Skeleton 4 : I-pad app to visualize and investigate anatomical structures.

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INTEGRATION AND COORDINATION

AP.IC.1: Nervous System

The nervous system consists of neurons and supporting cells that combine to form nerves, the spinal cord, and the brain. The primary functions of the nervous system are sensation, integration, and response. A comparison of the structures and functions of the central and peripheral nervous systems should be explored. The central nervous system is composed of the brain and spinal cord. The peripheral nervous system includes the remaining nervous tissue.

A neuron consists of dendrites, a cell body, and an axon. The function of a neuron is to communicate through electrical impulses at synapses. Neuroglia cells help to support neural function.

The brain consists of three major parts: the cerebrum, cerebellum, and brainstem. The cerebrum is divided into lobes and hemispheres. Functions of the cerebrum that may be explored include voluntary muscle control, memory, sensory perception, emotions, and speech. The cerebellum is primarily responsible for balance and coordination. The brainstem, a part of the autonomic nervous system, includes structural divisions that are responsible for basic life functions such as breathing and heart rate.

The spinal cord is a continuation of the brainstem. The spinal cord is a bundle of nerve tracts that function to communicate between the brain and the body through electrical impulses.

Nerves are bundles of neurons that transmit impulses between the peripheral and central nervous systems. The study of nerves can include sciatic, cranial, and spinal nerves. Supporting structures of the central nervous system include the meninges and cerebrospinal fluid which function to provide protection.

Processes of the nervous system are action potential propagation, simple nerve pathways (reflex arc) and neurotransmitter function, Homeostatic imbalances can be explored, including but not limited to, the effects of drugs, mental illnesses, spinal injuries, concussions, meningitis, and multiple sclerosis. Investigations are used to understand and explain the nervous system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.IC.2: The Special Senses

The special senses consist of sight, hearing, balance, smell, and taste. Each sense involves a network of feedback processes and consists of distinct structures.

Sense of Sight

The eye provides visual environmental feedback and includes primary and accessory structures. Light enters through the pupil and is then focused by the lens onto the retina at the visual axis. The optic nerve transmits the electrical impulses to the brain for translation. The accessory structures provide lubrication, protection, and support to the eye.

Processes include stimulation of the photoreceptors by light and the comparison of rods and cones. Homeostatic imbalances can be explored, including but not limited to, blindness, conjunctivitis, glaucoma, astigmatism, hyperopia, myopia, cataracts, and color blindness. Investigations are used to understand and explain the sense of sight in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

Senses of Hearing and Balance

The ears collect a range of sounds and provide a sense of equilibrium. The structures include those of the outer, middle and inner ear. Processes of hearing and balance should be explored including the perception of sound and spatial awareness. Homeostatic imbalances can be explored, including but not limited to, deafness, otitis media, imbalance, tinnitus, auditory processing, motion sickness and Meniere’s syndrome. Investigations are used to understand and explain the senses of hearing and balance in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

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Senses of Taste and Smell
The senses of taste and smell emanate primarily in the oral and nasal cavities. The structure of taste buds and olfactory cells are the foundation of taste and smell. The location, structure and afferent pathways of taste and smell receptors should be addressed.

Processes include activation of chemoreceptors and transmission of electrical impulses to the brain for integration. Homeostatic imbalances can be explored, including but not limited to, age related sensitivities, taste preferences, anosmias, and olfactory auras. Investigations are used to understand and explain the senses of taste and smell in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.IC.3: Endocrine System
The endocrine system is comprised of glands that secrete hormones resulting in a response in a target cell or organ. Glands with their associated hormones may include pituitary, hypothalamus, thyroid, thymus, parathyroid, pineal, pancreas, adrenal, ovaries, and testes. The functions of the endocrine system include regulating metabolism, maintaining homeostasis, growth and development, and controlling reproduction through chemical communication.

The processes involved in the endocrine system should include a comparison of negative and positive feedback systems. Negative feedback examples can include regulation of blood glucose levels, calcium levels, blood pressure, and temperature. Positive feedback examples can include oxytocin in childbirth and hemostasis. Homeostatic imbalances can be explored, including but not limited to hyper- and hypo- functions of glands, diabetes (type I and type II), gigantism, and dwarfism. Investigations are used to understand and explain the endocrine system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟷		Least Complex	
Integration and Coordination				
AP.IC.1 Nervous System	**AP.IC.1a** Explain how the nervous system controls all of the functions of the body and that it is made up of the brain, spinal cord, and nerves of the body.	**AP.IC.1b** Identify a function of the nervous system (e.g., muscle control, memory, sensory perception, emotions, speech, balance, and basic life functions like breathing).	**AP.IC.1c** Identify that the nervous system consists of the brain, spinal cord, and nerves.	
AP.IC.2 Special Senses (Sense of Sight, Senses of Hearing and Balance, Senses of Taste and Smell)	**AP.IC.2a** Explain the connection between the senses and involuntary reactions.	**AP.IC.2b** Match each of the five senses to descriptions or images of activities that involve the senses.	**AP.IC.2c** Identify each of the 5 senses using diagrams or pictures (e.g., sight = eyes).	
AP.IC.3 Endocrine System	**AP.IC.3a** Recognize that imbalances in the body can lead to diseases (e.g., high blood pressure, diabetes).	**AP.IC.3b** Identify functions of hormones (maintains blood glucose levels, stable blood pressure, body temperature, reproduction).	**AP.IC.3c** Identify that the body produces substances to help bodies grow and develop.	**HS-LS1-3** Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

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EVIDENCE OF LEARNING
Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

	Designing technological / engineering solutions	**Demonstrating science knowledge**	**Interpreting and communicating science concepts**	**Recalling accurate science**
AP.IC.1: Nervous System				
CNS / PNS		Design and implement an experiment to measure muscular response to stimuli. Evaluate the validity of the scientific claims made by both proponents and opponents of using environmental toxins/neurotoxins. Provide peer-reviewed scientific evidence to support your claims.	Compare the structures and functions of the central nervous system with the structures and functions of peripheral nervous system.	Identify the main structures and functions of the central nervous system and the peripheral nervous system.
Neurons		Critique the current treatment(s) available for a neurological disease. (Examples: Parkinson's, MS, Huntington's)	Construct a 3D model of a neuron that can be used to illustrate anatomy, action potential propagation, simple nerve pathways (reflex arc), and neurotransmitter function. Construct a labeled model of each type of neuron and provide evidence, an explanation, and scientific reasoning behind your construction.	Using microscopes, micrographs, models or illustrations to identify the cells of the nervous tissue. Construct a model of a neuron including dendrites, cell body, axon, synaptic terminal.

Brain Structure / Function	Dissect a tumor from a model brain using basic techniques and equipment -- ex. Knife, spoon, forceps. (Cutting out the Tumor Lab) Analyze the tumor extraction methods and experiences from the tumor dissection lab in order to propose new techniques and/or construct instrumentation remove a brain tumor.	Explore some of the difficulties of investigating brain function, and critique the limitations in treating damage and disease in the brain and other parts of the nervous system. Analyze the myth of “Left brain / Right brain” dominance. Conclude the validity of the myth and provide support or alternative explanations for your results. Using scientific evidence, support the claim that the structure and function of the nervous system is similar to the operating system of a computer. Evaluate the evidence that supports / refutes the claim that high school athletes are more susceptible to brain damage than their peers. Suggest a possible way to reduce CTE (Chronic Traumatic Encephalopathy) in high school athletes	Create labeled illustrations or models of the human brain including structure and function Predict the outcome of tumor growth in different regions of the brain. Relate the development of the brain to decision making skills Justify the relationship between a brain injury, occurring in a specific region, and the expressed symptoms.	Using microscopes, micrographs, models or illustrations to identify the main structures of the brain. Recall the functions of the cerebrum, cerebellum, and brainstem. Compare the structure of another vertebrate brain (eg. sheep) to the human brain.
Spinal Cord		Design an experiment to compare reaction times and reflex times.	Through scientific investigation, measure reaction and reflex times, and explain the differences in your recorded data.	Using microscopes, micrographs, models or illustrations to identify the main structures of the spinal cord.

Nerves		Design a new test that can be used to identify malfunction in cranial nerves	Differentiate between spinal and cranial nerves Explain how the density of nerve endings in different body areas and the ability of nerves to adapt to stimuli relate to human physiology.	Using microscopes, micrographs, models or illustrations identify the main structures of a nerve. Create a matching game to reinforce the structure and function of nerves.
Processes	Design a prototype of a new medical device for an amputee, including the transfer of electrical impulses to neurons. Critique the current treatments for paralysis disorders and evaluate the pros / cons of each. (ie	Design and test an experiment to measure the effect of a depressant or stimulant on an organism's nervous system of a model organism (eg. *C.elegans,* Daphnia*)*	Choose a neurologic disorder and demonstrate or model how this disorder results in the symptoms presented. Predict how drugs interfere with chemical communication in the brain. Predict how a change in membrane potential would impact action potential propagation in an axon.	Create a Model of action potential propagation and/or neurotransmitter function Using graphs of membrane potential vs time, distinguish between depolarization, repolarization,and hyperpolarization.
AP.IC.2: The Special Senses				
Sight	Choose a disease causing a homeostatic imbalance to one's vision. Use a picture as a control, and modify the picture to show how the	Design a scientific investigation to examine binocular vision by performing various eye tests. (Ex. astigmatism, color blindness)	Identify common defects of the eye and their common treatments. Investigate a specific neurological effect of aging, and explain how this leads to a homeostatic imbalance. Present the findings to the class. Example: glaucoma,	Trace the pathway of light through the eye. Using microscopes, micrographs, models or illustrations to identify the main structures of the eye, and their functions.

	picture would be seen by an individual with the chosen visual disease. Design a possible medical devices that could alleviate the symptoms			Relate the structures of the eye to their associated functions. Complete a cow eye or virtual eye dissection. *Instructional resource - include a note to go to a butcher shop
Hearing / Balance	Choose a disease causing a homeostatic imbalance to one's hearing. Modify a sound file to illustrate the damage and suggest possible medical devices that could alleviate the symptoms		Perform a scientific investigation to examine equilibrium and balance. Perform a scientific investigation to examine sensorineural and conductive hearing pathways. Investigate a specific neurological effect of aging, and explain how this leads to a homeostatic imbalance. Present the findings to the class. Example: tinnitus	Using models or illustrations identify the main structures in the inner, outer, and middle ear Listen to different tones and identify patterns of hearing ability in the population.
Taste / Smell		Design and carry out an investigation to determine how smell and taste are related in the body and how sensory messages to the brain contribute to flavor perception	Research and explain why chemoreceptor function is blocked by a chemical such as miraculin or by the *Gymnema sylvestre* tea	Using models illustrations, or slides, identify the anatomical structures related to taste and smell (taste buds, gustatory cells, papillae, cilia, etc.)
AP.IC.3: Endocrine System				
Glands / Structures		Recall a time when they were threatened or stressed. Analyze the physiological reactions that were experienced during the	Perform a scientific investigation to examine endocrine system and stress responses.	Using models illustrations, identify the main structures associated with glands and their associated target cells / organs.

		situation, and what aspects of the endocrine system created those reactions.		
Processes	Critique the medical devices used by diabetics to monitor or treat blood sugar and propose solutions to address the identified flaws	Propose a treatment plan for a hypothetical patient who is experiencing a hormonal imbalance.	Analyze patient data to diagnose a hormone imbalance and provide suggestions for treatment.	Draw examples of negative and positive feedback loops. Predict the effect of changes in hormone levels.

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Resources

Nervous System

- BrainU This resource includes a wide variety of activities that relate to neuroscience activities
- Cutting out the Tumor Lab - This activity provides the opportunity to practice removing a tumor from a gelatin brain and can then design a more appropriate tool for tumor removal.
- Construct a model of a neuron - This site includes a "game" to construct a model of a neuron and label basic anatomy
- Model the brain - This activity can be used to build a model of a brain and investigate the major anatomical structures, and also to build an imaginary brain for a fictitious animal.
- damage and disease in the brain - The FINR Interactive Brain models both normal brain structure and function and allows students to manipulate the model brain to illustrate various diseases and damages.
- "Left brain / Right brain" - This article can be used as a conversation starter to get students prepared to investigate the validity of the concept that students learn best when following a particular learning style
- human brain This activity provides instructions to make a "wearable" model of the human brain and map out structures and functions.
- effect of a depressant or stimulant on an organism's nervous system This activity utilizes a model organism to study the effects of a drug on the nervous system.
- chemical communication This resource simulates the effect of various drugs on the chemical communication system of the brain.
- Sample Cranial Nerve Lab - this activity demonstrates some of the typical noninvasive tests that can be used to investigate cranial nerve function.
- BrainFacts.org This resource is an interactive model of the human brain.
- Neurotransmitter function This tutorial illustrates neurotransmitter function
- structure of another vertebrate brain This activity provides the opportunity to compare the structure of the human brain to that of a variety of other vertebrates.
- density of nerve endings This activity provides the opportunity to test the density of nerve endings in different regions of the body

Special Senses

- Trace the pathway - This resource provides the opportunity to trace the pathway of light as it goes through the eye, and also manipulate factors to observe how the eye adjusts to maintain clear vision as the environment changes.
- inner, outer, and middle ear - This interactive model of the human ear provides the opportunity to study internal anatomy of the ear and the physiology of hearing.
- tones This online tone generator can be manipulated to produce a variety of frequencies and waveforms to test the threshold of human hearing.

Endocrine System

- suggestions for treatment. This simulation allows for investigation into the endocrine system, hormones, glands, feedback loops, negative feedback, insulin, glucagon, melatonin, adrenaline, and growth hormone. This "Virtual Rat" activity is appropriate to use for patient diagnosis if human data is not available

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TRANSPORT

AP.T.1: Blood

Blood is composed of plasma and the formed elements: red blood cells (erythrocytes), white blood cells (leukocytes), and platelets (thrombocytes). The primary functions of blood are transportation, protection, and regulation. Plasma, the most abundant component of blood, is the liquid portion that transports dissolved nutrients, waste, hormones, antibodies, and proteins throughout the body. Red blood cells deliver oxygen throughout the body for use during cellular processes. White blood cells identify and protect the body against infectious disease and foreign invaders. Platelets bind together when they recognize a damaged blood vessel and assist in blood clot formation.

The major ABO blood types, A, B, AB, and O, are determined by the presence or absence of antigens on the surface of red blood cells. An additional antigen is present or absent on the surface of red blood cells determining Rh factor. Blood type antibodies are found in plasma. Processes related to blood include hematopoiesis, agglutination, and hemostasis. Homeostatic imbalances can be explored, including but are not limited to, sickle cell anemia, hemophilia, deep vein thrombosis, leukemia, and lymphoma. Investigations are used to understand and explain blood in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.T.2: Cardiovascular System

The cardiovascular system consists of the heart and blood vessels. The heart is mostly comprised of cardiac muscle which is supplied with oxygenated blood by coronary arteries.

The structure of the heart includes four chambers, four valves, and major vessels leading to and from the heart. The flow of blood through the heart, pulmonary and systemic circuits should be explored. Blood flows from arteries, to arterioles, to capillaries, to venules, then to veins. In the capillaries, oxygen, nutrients, and chemical messengers leave and carbon dioxide and other waste products enter. Veins have valves that keep the blood flowing toward the heart.

The primary function of the cardiovascular system is the transport of oxygen, carbon dioxide, hormones, nutrients, waste products, and chemical messengers.

Processes involved in the cardiovascular system include the cardiac cycle and cardiac and conductive pathway which is measured by electrocardiograms and blood pressure.
Homeostatic imbalances can be explored, including but are not limited to a variety of cardiovascular diseases and structural imperfections of the heart, valves, and vessels. Examples include, but are not limited to, myocardial infarction, aneurysm, atherosclerosis, hypertrophic cardiomyopathy, Tetralogy of Fallot, hypo/hypertension, and arrhythmias. Investigations are used to understand and explain the cardiovascular system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.T.3: Lymphatic and Immune System

The lymphatic system includes lymphatic vessels, lymph nodes, and the immune system. The lymphatic system has multiple, interrelated functions. They include the removal of fluid from tissues, absorption of large fatty acids in small intestines, and transport of white blood cells to the lymph nodes. The immune system consists of white blood cells whose main function is to defend the body against foreign antigens. Lymph is formed from the tissue fluid that has entered into lymphatic capillaries. These lymphatic capillaries join to form lymphatic vessels. As lymph circulates through the body, it passes through multiple lymph nodes. These lymph nodes contain lymphocytes which can help destroy foreign antigens.

Processes of the lymphatic system include defense through nonspecific and specific resistance. Examples of nonspecific resistance include mechanical barriers such as the skin, enzymes, species resistance, and mucus membranes. In specific resistance, antibodies are produced to defend the body against foreign antigens. Memory cells are produced following an infection to allow for possible immunity against a specific antigen upon re-exposure. A comparison of primary versus secondary immune responses can be explored. Homeostatic imbalances can be explored. These include, but are not

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limited to, autoimmune disorders, parasitic diseases, allergies, bacterial versus viral infections, and ringworm. Vaccinations provide the body with either long-term protection or short-term protection against many pathogens. Investigations are used to understand and explain the lymphatic system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

Ohio Learning Standard	***Complexity a***	***Complexity b***	***Complexity c***	***NGSS Alignment***
Generic	Most Complex ↔		Least Complex	
Transport				
AP.T.1 Blood	**AP.T.1a** Describe the specific functions of red blood cells and white blood cells.	**AP.T.1b** Describe the function of blood in the human body (e.g., transportation, protection, and regulation).	**AP.T.1c** Identify the two types of blood cells (e.g., red and white blood cells).	
AP.T.2 Cardiovascular System	**AP.T.2a** Describe the structure and function of the heart.	**AP.T.2b** Identify the heart as a muscle that pumps blood throughout the body.	**AP.T.2c** Locate the heart on a diagram/picture.	
AP.T.3 Lymphatic and Immune Systems	**AP.T.3a** Describe the role of the immune system in fighting disease.	**AP.T.3b** Identify white blood cells as part of the immune system.	**AP.T.3c** Identify a white blood cell.	

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EVIDENCE OF LEARNING
Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

	Designing technological / engineering solutions	**Demonstrating science knowledge**	**Interpreting and communicating science concepts**	**Recalling accurate science**
AP.T.1: Blood				
Blood Histology			Explain the function of blood and each of the components of whole blood. Describe the process of hemostasis. Create labeled illustrations or models of the components of whole blood. Create a graphic organizer to illustrate the differentiation of stem cells into white blood cells, red blood cells and lymphocytes.	Identify the components of whole blood. Identify the structure and function of red blood cells (erythrocytes). Describe the steps of hemostasis.
Blood Typing	Critique available artificial blood products.	Design a scientific process to determine unknown blood types to determine transfusion compatibility or paternity.	Create labeled illustration or model of blood to explain the relationship between antigens, antibodies and blood type (ABO/ Rh).	Identify ABO phenotypes and genotypes.

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	Design artificial blood products.		Explain the inheritance of blood types through the use of Punnett squares. Investigate the process of agglutination and describe its consequences.	Identify Rh phenotypes and genotypes.
Homeostatic Imbalances		Diagnose a genetic blood disorder (sickle cell, thalassemia, hemophilia) using patient symptoms, family history, and laboratory data. Construct a pedigree of the family history, and create a genetic counseling plan to advise the patient and family.	Diagnose homeostatic imbalances (anemia, sickle cell, leukemia, sepsis) by analyzing laboratory data from a blood sample.	
AP.T.2: Cardiovascular System				
Gross Anatomy	Critique available artificial heart and valve products. Design an artificial heart and/or components. Redesign, build, and test a new cardiovascular syst em	Investigate the structures and function of the heart through comparative anatomy by dissecting a sheep heart and tracing the flow of blood through the vessels, valves and chambers of the heart and role the organ plays in the propulsion of blood through the pulmonary and systemic circuits.	Create labeled illustrations or models to describe the pathway of blood through the valves, chambers and major vessels of the heart. Create labeled illustrations or models to describe the pathway of blood through the pulmonary and systemic circuits.	Identify the valves, chambers, coronary arteries, and major vessels of the heart. Identify the functions of the cardiovascular system.
Cardiac Histology			Describe the relationship between the structure and specialized function of cardiac muscle cells. Create labeled illustrations,models, or written descriptions to differentiate	Identify cells and tissues of the cardiovascular system.

			between arteries,arterioles, capillaries, venules and veins in terms of structure and function.	
Cardiac Output	Design a device or protocol to reduce syncopal events in at risk populations. Propose counter-measures to minimize effects of microgravity and describe how microgravity can be applied on Earth to treat or prevent circulatory diseases.	Design an experiment to manipulate and measure cardiac output in order to investigate the relationship between heart rate, stroke volume, and cardiac output. Analyze data to explain why long term exposure to microgravity can be dangerous to the cardiovascular system.	Explain the relationship between heart rate, stroke volume, and cardiac output.	Identify the components of cardiac output.
Cardiac Conduction Pathway			Describe the features of an electrocardiogram (ECG/EKG) used to identify homeostatic imbalances. Diagnose an individual by analyzing an electrocardiogram.	Match electrocardiogram (ECG/EKG) waves to events in the cardiac cycle.
Cardiovascular Imbalance	Design a device to clear an occluded artery	Design a method to diagnose homeostatic imbalances and propose solutions. Diagnose homeostatic imbalances by analyzing signs and symptoms, laboratory data, ECG/EKGs, and	Diagnose homeostatic imbalances and propose solutions based on patient information. Create labeled illustrations or models of congenital cardiovascular defects.	Identify homeostatic imbalances of the cardiovascular system

		imaging studies and create a evidence-based treatment plan.		
AP.T.3: Lymphatic and Immune System				
Immune System			Using games or models, demonstrate immune responses. Create labeled illustrations or models of the cells of the immune system. Debate the risks and benefits of vaccines and antibiotics.	Identify the structure and functions of the immune system. Compare the treatment of bacterial and viral infections. Compare nonspecific and specific resistance. Conduct an ELISA test
Gross Anatomy and Histology			Create a flowchart to demonstrate the circulation of lymph throughout the body. Create labeled illustrations or models of the components of the lymphatic system.	Identify and describe the structures and functions of the lymphatic system.

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Homeostatic Imbalances	Critique the effectiveness of tonsil removal on infection rates. Design an interactive app or a game to educate users about allergies.	Design a simulation to demonstrate the spread of a pathogen throughout a population. Design an experiment to test the effectiveness of antibacterial products. Design an experiment to identify common allergens.	Diagnose an autoimmune disease using laboratory data in a case study. Diagnose allergic reactions by analyzing laboratory data in a case study Create a community education campaign to increase awareness about the meningitis vaccine.	Identify the mechanisms of autoimmune responses.

Resources

AP.T.1: Blood

- Get Body Smart -- General resource about blood composition, function, ABO blood typing, and blood tests.
- American Society of Hematology -- “Explore the Mystery of Blood” Curriculum that includes the following: teaching guide, PowerPoint slides of blood smears, and short videos about hematology and blood diseases.
- Virtual Blood Pathology Slides -- Blood histology and pathology slides
- World Federation of Hemophilia - Resource provides graphic and description of the clotting process. Links to information about bleeding disorders such as hemophilia, von Willebrand Disease, inherited platelet disorders, and treatments are also provided.
- Stem cell differentiation -- Activity to show the differentiation of stem cells in response to a coaxing agent. Students are presented with a population of stem cells and will then choose a coaxing agent to expose to the stem cells. Ultimately, the students are tasked with “creating” eight cell types by exposing stem cells to different combinations of coaxing agents.
- Virtual Blood Typing Lab and Game -- Virtual blood typing activity where students determine the unknown blood type of a patient using antibodies and the presence or absence of agglutination. Students will then select an appropriate donor for a blood transfusion.
- Erythroblastic Anemia Case Study and Sickle Cell Anemia Case Study -- Two of many case studies from the University of Buffalo. These two cases present information in a gradual progression to allow for the diagnosis of homeostatic imbalances and for exploration of their corresponding abnormal physiology.
- KidsHealth -- Anemia is an informative site educating users about anemia and why teens are susceptible becoming anemic.
- FDA -- Normal blood serum chemistry values and normal hematology values in PDF format.
- Normal laboratory values for blood from the U.S. National Library of Medicine. This includes a description of what might be the cause of abnormal results. Blood smear images are also available.
- US National Library of Medicine: Artificial Blood Substitutes -- Article summarizes the progress made in artificial blood substitutes, focusing on red blood cells substitutes.

AP.T.2: Cardiovascular System

- Sheep Heart Dissection Video -- This is a resource for previewing dissection procedure and/or as a substitute for physical dissection.

- Atlas of Human Cardiac Anatomy -- This is a resource containing in vivo videos and pictures. MRI imaging, diagrams, and computer models of the heart are also available. Comparative anatomy can also be explored through a comparative anatomy tutorial. Compare and contrast normal anatomy with abnormal anatomy due to homeostatic imbalances.
- Engineering Heart Model -- Lesson on designing an artificial heart to test properties of heart valves.
- Re-engineering the Cardiovascular System -- Redesign the Cardiovascular system to build a more efficient system.
- Histology Slides -- Cardiac histology slides.
- Effects of Exercise on Cardiovascular Physiology-- Activity measures heart rate and blood pressure changes as a result of exercise. Cardiac output will then be calculated and graphed.
- Microgravity Effects on Cardiovascular Physiology -- An activity from NASA that introduces microgravity and provides data from astronauts for analysis in order to describe the changes in blood pressure and cardiac output, explain why long term exposure to microgravity can be dangerous, propose counter-measures to minimize effects of microgravity, and describe how microgravity can be applied on Earth to treat or prevent circulatory diseases.
- ECG Library of Examples -- A library of normal and abnormal electrocardiograms (ECG/EKG) to study cardiac conduction and identify homeostatic imbalances of the heart.
- Virtual ECG -- Virtual activity provides the opportunity to administer an electrocardiogram (ECG/EKG) and diagnose patients based on the results of the ECG/EKG.
- Virtual Cardiology Lab -- Play the role of a virtual intern and diagnose homeostatic imbalances of the cardiovascular system and propose solutions based on patient information and diagnostic test results.
- Virtual Bypass Surgery -- Examine actual pathology of homeostatic imbalances
- Unblocking arteries activity -- Design a device to clear an occluded artery.
- Evolutionary Origin of Cardiac Chambers -- A scientific article about the evolution of the four chambered heart that discusses evolutionary relationships using cladograms.
- Comparative anatomy: Circulatory system in vertebrates: Slides discussing the evolution of the circulatory system in vertebrates.

AP.T.3: Lymphatic and Immune System

- Microbes and the Human Body **:** Exploration of various microbes (pathogens, bacteria, and antibodies) and the effects on a human body. This includes structures and functions of the immune system and microbes.
- Ready, Set, Infect! --Role-playing game where students act as either antigens, antibodies, or white blood cells. The game can be used to introduce the immune system or as a follow up activity.
- Using Balloons to Teach Immunology -- This demonstration is designed to model what an antibody is and how antibodies combine with foreign materials to help eliminate them from the body.
- Viral Attack Coloring Book**:** This is a downloadable pdf that is similar to a comic book which can be read and colored about a viral attack on the human body.
- Cells of the Immune System -- Howard Hughes Medical Institute Biointeractive provides a note taking guide, and presentation with embedded videos that provides a comparison of innate immune response and adaptive immune response.
- Immunology Virtual Lab (ELISA test)**:** The virtual lab to perform a test and record data to determine if a specific antibody is present in the blood samples. The lab walks the user through each step in the test with descriptions of why each step is important to the test. It also familiarizes the user with lab equipment and procedures.
- Histology Slides**:** Images of lymph nodes, mucosa- associated lymphoid tissue, tonsils, spleen and tonsils under a microscope. These images can be used to assist in identifying the structures of the lymphatic system.

- Viral Hijackers**:** A predesigned lesson about viral infections, the structure of viruses and the human response to a virus in the body. There is background information about viruses that is needed for the understanding of autoimmune response to a viral infection. There are multiple suggested activities that would help with the understanding of how viruses infect the body and the body's response to the pathogen.
- PBS: Vaccine Wars **:** Frontline-The vaccines war video :The first link is to classroom activities, discussion topics and further exploration. This can be an introductory to a campaign project or support for another lesson associated with a current medical issue.
- Allergy Case Study**:** Using a case study, diagnose an allergic reaction by analyzing laboratory data
- Autoimmune Case Study**:** Using a case study with gradual release of information, develop a differential diagnosis for autoimmune diseases, diagnose a patient, and develop a treatment plan for lupus.
- PubMed Health Immune System**:** A general resource to learn about the immune system, its functions, and associated conditions.

ABSORPTION AND EXCRETION

AP.AE.1: Digestion System

The digestive system consists of the gastrointestinal tract (alimentary canal) as well as various accessory organs including the teeth, tongue, salivary glands, liver, gallbladder, and pancreas.

The digestive system functions to process and supply the molecules needed to sustain the living tissues within the body through the absorption of nutrients. Six major functions of the digestive system include ingestion, mechanical processing, digestion, secretion, absorption, and excretion. The lining of the digestive system also functions to protect surrounding tissues from the mechanical and enzymatic stresses of the digestive process.

Processes of the digestive system include the mechanical and chemical breakdown of food into small molecules which are then absorbed by the digestive tract. Specific actions within the digestive system include mastication, peristalsis, segmentation, and the release of hormones and enzymes necessary for digestion. The metabolic functions of the accessory organs play strategic roles in the breakdown of food products, the maintenance of glucose levels within the blood, and the regulation of homeostasis in the body. Indigestible material is excreted as waste. Homeostatic imbalances can be explored. These include, but are not limited to, conditions such as gallstones, heartburn, ulcers, dehydration, diarrhea, cirrhosis, and cancers of the digestive system. Investigations are used to understand and explain the digestive system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.AE.2: Respiratory System

The respiratory system is comprised of the airways, lungs, and diaphragm. The airways include the nasal and oral cavities, pharynx, larynx, trachea, bronchi, bronchioles, and alveoli. The respiratory system functions to transport and exchange gases including oxygen and carbon dioxide.

Processes involved in the respiratory system include respiration mechanics, gas exchange, and lung volumes and capacity. Respiration mechanics is the process by which humans breathe and includes the movement of the diaphragm and pressure-volume relationships. Gas exchange refers to the transfer of gas across the alveolar epithelium in the respiratory system and capillary endothelium of the cardiovascular system. Lung volumes and capacities can be measured using spirometry. Homeostatic imbalances can be explored. These include, but are not limited to, asthma, COPD, tuberculosis, cystic fibrosis, and the effects of smoking and pollution. Investigations are used to understand and explain the respiratory system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.AE.3: Urinary System

The urinary system is a regulatory system that helps maintain homeostasis. The structures of the urinary system include the kidneys, ureters, bladder and urethra. The kidney consists of the renal cortex, medulla, and renal pyramids. The functional unit of the kidney is the nephron. The renal pelvis is a funnel-shaped chamber that is connected to the ureter.

The primary functions of the urinary system are excretion, elimination, and regulation of blood volume and pressure. Processes of the urinary system include filtration, reabsorption and secretion which occurs in the nephrons. Urine is normally a clear, yellow, sterile solution but the composition can vary slightly between individuals. Urinalysis is a diagnostic tool for detecting infections and diseases. Antidiuretic hormone (ADH) and aldosterone hormones influence the volume and concentration of urine. Caffeine and alcohol act as diuretics and can lead to short or long term kidney issues. Homeostatic imbalances can be explored. These include, but are not limited to, urinary tract infections, kidney stones, nephritis, and acute and chronic kidney disease. Investigations are used to understand and explain the urinary system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟷		Least Complex	
Absorption and Excretion				
AP.AE.1 Digestive System	**AP.AE.1a** Explain how the digestive system functions to allow humans to receive nutrients needed to survive.	**AP.AE.1b** Identify structures used in digestion (e.g., mouth, teeth, tongue, esophagus, stomach, small intestine, large intestine, and rectum).	**AP.AE.1c** Identify a digestive organ in a model or diagram of the body.	
AP.AE.2 Respiratory System	**AP.AE.2a** Describe how the respiratory system can be damaged by disease or pollutants.	**AP.AE.2b** Identify that breathing is the act of taking in oxygen and expelling carbon dioxide.	**AP.AE.2c** Identify the lungs in a model or diagram of the body.	
AP.AE.3 Urinary System	**AP.AE.3a** Describe the main function of the urinary system (e.g., to excrete liquid waste).	**AP.AE.3b** Identify structures of the urinary system (kidneys, bladder, and urethra).	**AP.AE.3c** Identify the kidneys in a model or diagram of the body.	

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EVIDENCE OF LEARNING

Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

	Designing technological / engineering solutions	**Demonstrating science knowledge**	**Interpreting and communicating science concepts**	**Recalling accurate science**
AP.AE.1: Digestion System				
	Propose a redesign of an alimentary canal segment and/or accessory digestive organ: What I know about structure; Description of the structure's design (anatomy); Description of the structure's job (physiology); Redesign idea; Redesign improves function by _____; Anatomical change(s) necessary; Physiological change(s) necessary and projected; Roadblocks to application of redesign		Homeostatic Imbalance Inquiry:Relate Esophageal Cancer and Tissue Engineering: "Wash" cells from chicken heart using sodium dodecyl(lauryl) sulfate to acquire scaffold of heart to demonstrate technique basic to tissue engineering used to create replacement for damaged esophagus	Define major digestive functions. e.g. absorption, excretion, ingestion, secretion, mechanical processing, chemical digestion Explain which major digestive function(s) occur in each anatomical region: Structure / function match game: *Place cards that list digestive functions along appropriate place in alimentary canal (using model or drawing of canal), Or "race against the clock" or "what's missing" game* Identify major sections and layering of alimentary canal

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				Describe structure and function of accessory digestive organs
		Design Models of mechanical and chemical digestion using varied materials provided Argue the efficiency of human digestion vs. ruminant digestion		Distinguish mechanical from chemical digestion using appropriate terminology Compare and Contrast: saliva/chyme acids/enzymes absorption/secretion excretion/secretion peristalsis/segmentation digestive hormones/digestive enzymes Identify where canal receives contributions from saliva, acid, bile, and enzymes
	Propose a procedure as a potential cure for cirrhosis or ulcers using tissue engineering techniques Demonstrate knowledge of the digestive system in arguments for or against surgery as a weight-loss solution	Investigate the processes and implications of the various types of bariatric surgery: *Students will explore the types of bariatric surgeries and compare their safety and effectiveness to determine whether this is an effective weight-loss solution* Hypothesize functional changes using Loss of Tissue Projections (see resources)		Identify the anatomical and functional regions of the stomach

			How do you Know This Is/Is Not...Activity showing micrographs of digestive organ sections with a(n) proper/improper function described	Histology Lab: Identify tissue and cell types in digestive and accessory organs using microscopes, slides, micrographs, models or illustrations
AP.AE.2: Respiratory System				
			• Interpret description using knowledge and terminology of the respiratory system: *Describe a structure / function of the respiratory system and partner guesses what is described - class game / competition* (See $10,000 Pyramid Game)	• Define respiratory functions • Identify major respiratory structures •Explain the structures and functions of the respiratory system to a partner
	Propose a redesign of a respiratory organ or structure with anticipated benefits and drawbacks (see resources)			
		Hypothesize and design an experiment to determine factors which alter respiratory volumes, Compare individual data to classroom data	• Interpret lab values (respiratory volumes) as above or below normal: *collect or view sample spirometry test results and match them to the appropriate "patients": normal, asthmatic, smoker, athlete* • Graph data	• List the normal respiratory volumes • Explain what alters respiratory volumes
			• Collect data on respiratory volumes during each scenario (using tape measure to measure thoracic cavity as estimate of volume) • Communicate which of the two scenarios (belt / straw) reflect an obstructive vs. restrictive disease	• Name muscles used for inspiration and expiration • List how respiratory functions (volumes / capacities) are impaired in obstructive versus restrictive disease:

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			(using data of how their breathing was impacted by each manipulation)	Obstructive vs. restrictive respiratory disorders: *(1) wrap belts around chest and appropriately tighten, attempt to breathe, and (2) purse lips around a straw and attempt to breathe*
			• Explain how the structure in each portion of the respiratory tree supports its function	• Identify sections of the respiratory tree by histological slides / images
	• Design an action plan to improve the air quality in a low-quality area	Demonstrate knowledge of how pollutants impact respiratory system: Investigate local air quality and asthma (or other pulmonary disease) rates: Respiratory health & the Environment: *formulate an argument for how the air quality in area impacts local respiratory health. Things to explore include asthma rates, pollution levels, ozone activity*		
	• Design a device that would improve the respiratory function in athletes	• Explain how the observed respiratory changes support “fitness” • Design an experiment to show how cold / flu impact respiratory function	• Interpret changes between pre- & post- exercise data	• Define tidal volume and breathing rate • Explain how to determine breathing rate and depth • Measure breathing rate, depth, and tidal volume: Respiratory adaptations during Exercise: *collect data on breathing rate, depth, and tidal volume, pre- & post- exercise*

AP.AE.3: Urinary System				
Basic nephron physiology "get up and move" game *"Play" the role of an ion or molecule and move in/out of the blood / nephron for "secretion, reabsorption, filtration"*	Design a model using dialysis tubing and some common solute (such as NaCl, KCl, or baking soda to represent the waste product) to demonstrate the movement of wastes from interstitial fluid to renal tube		Create labeled illustrations or models to describe the filtration, secretion, and reabsorption of ions/molecules.	• Make a basic layout of the nephron segments and show how it relates to the blood - Move in the proper direction when asked to demonstrate "filtration, secretion, reabsorption" of the various ions/molecules
Redesign	Propose a redesign of a nephron or entire kidney with anticipated benefits and drawbacks: What I know about structure; Description of the structure's design (anatomy); Description of the structure's job (physiology); Redesign idea; Redesign improves function by _____; Anatomical change(s) necessary; Physiological change(s) necessary and projected; Roadblocks to application of redesign		Explain to each other the process of filtration, reabsorption and secretion in the nephron	• List parts of the nephron • Describe the basic physiological processes accomplished by the nephron (filtration, reabsorption, secretion)
Diagnosis: Urine *"Play doctor" as they work to match representative urine lab values (concentrations) with mock patient scenario: high ADH, dehydration, excess coffee,*	Treatment plan adds this level	Integrating multiple lab result to do a differential diagnosis	• Interpret lab values (urine concentration) as above or below normal	• List the normal urine concentrations • Explain what you would expect in various patient scenarios (infection, dehydration, etc.)

urinary tract infection, diuretics				
Dangers of overhydration (hyponatremia): Read a news story related to the death of a woman due to overhydration & explain possible mechanisms		Illustrate or describe the roles of osmosis and diffusion in the process of urine formation	• Explain the interplay between the renal system and other organ systems	• Name chemicals/ hormones that influence the body's hydration status • Describe the process by which the body eliminates excess fluids Identify what body chemicals might be impacted by too much body water (i.e. plasma sodium)
Making dialysis mobile: Investigate the possibility of inventing a hemodialysis machine that patients could use on their own (outside of the clinic setting or outside of their home)	• Design a device that serves as a "mini dialysis" machine to be used in patients with renal failure; list and discuss the limitations		• Interpret lab values to determine what ions / proteins need to be altered during dialysis • Create a pamphlet that explains the impact of diet on blood chemistry and and how that likely affects kidney function especially in those on dialysis Research and compare current hemodialysis machines to how the actual kidney functions	• Identify normal functions of the kidney • List complications of renal failure -List the components of normal urine Explain the interplay between the renal and vascular systems
<u>General Kidney Function:</u> elimination and excretion of metabolic wastes Explore what constitutes metabolic wastes			Ask the question: 'when you eat a slice of pizza, what happens to it? What products of its breakdown might be eliminated by way of the urinary system?" do think-pair-share; construct a list of responses from the share and use it to help them create a flowchart showing the ingestion,	

			digestion, absorption of the nutrients and the elimination of the metabolic wastes created by the breakdown of proteins; use internet resources to determine the effects of not eliminating these wastes; infer from this the role of kidneys in maintaining homeostasis	
Nephron structure - Relate the structure of the nephron to its appearance in histological slides				Study labeled illustrations of nephron structure and then compare the illustrations to labeled histological slides of the kidney showing the basic components of a nephron; will see the cellular composition and arrangement of the tubules in cross sectional view.
Physiology **-***Formation of urine through osmosis and diffusion*		Use a limited supply of material to mimic the process urine formation using dialysis tubing.		
Physiology *-How do we protect the health of our kidneys?* *What are risk factors for kidney disease?*			Use information from the National Kidney Foundation website to create an informational flyer that gives basic information about the structure and function of the urinary system and how to prevent kidney disease. These could then be distributed at school open house events or as take home information for families.	
Urinary bladder - structure and function go hand in hand		Create a circuit board to illustrate the flow of nerve impulses involved in the involuntary phase of micturition (urination)	Work in small groups to discuss how the urinary and nervous systems act together to regulate the elimination of urine from the bladder. Include the structures that are involved. Share the work with the larger group.	Describe the gross and histological structure of the urinary bladder Explain how the structure and function of the urinary bladder complement each other

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Resources

AP.AE.1: Digestion System

- Redesign Proposal: Students describe: What I know about structure; Description of the structure's design (anatomy); Description of the structure's job (physiology); Redesign idea; Redesign improves function by _____; Anatomical change(s) necessary; Physiological change(s) necessary and projected; Roadblocks to application of redesign
- Structure / function match game: Place cards that list the system functions along their appropriate place in the organ system (using a model or drawing of the system); "race against the clock";"what's missing" game
- $10,000 Pyramid Game-*Students describe a structure / function of the system and their partner has to guess what they're describing - class game / competition*
- Loss of Tissue Projections: Tissue(s) analyzed, Function(s) of Tissue(s) analyzed, Projected Loss of function(s) if tissue(s) are removed/damaged, and Projected effect(s) on associated tissue(s)
- Demonstrating biology video clips It Takes Guts Video
- Indigestible cellulose resource for ruminant digestion
- Background for use with esophageal cancer and organ scaffolds
- Digestive Histology slides

AP.AE.2: Respiratory System

- *Physiology of Exercise -start on p. 16*
- Respiratory Histological Slides
- Test Lung Capacity at Home
- Monitor Lung Health Using Smartphone
- Air Pollution Data
- *Measure Lung Capacity*- video
- *Balloon to Measure Respiratory Volume*

AP.AE.3: Urinary System

- Redesign Proposal: Describe what I know about structure, description of the structure's design (anatomy), description of the structure's job (physiology), redesign idea, redesign improves function by, anatomical change(s) necessary, physiological change(s) necessary, and projected roadblocks in application of redesign
- Structure / function match game: Place cards that list the system functions along their appropriate place in the organ system (using a model or drawing of the system); "race against the clock"; "what's missing" game
- $10,000 Pyramid Game: Describe a structure / function of the system and their partner has to guess what they're describing - class game / competition
- Loss of Tissue Projections: Tissue(s) analyzed, Function(s) of Tissue(s) analyzed, Projected Loss of function(s) if tissue(s) are removed/damaged, and Projected effect(s) on associated tissue(s)
- Basic Nephron animation Animation linked to the Raven Biology textbook showing the basic processes of filtration, absorption, and secretion in a nephron
- Virtual Urinalysis Lab This is a slide show that walks the students through a complete laboratory experience in which they complete an urinalysis and write and submit responses to analysis of data
- Drinking too much water A woman dies after participating in a water-drinking contest
- Kidney histology Interactive virtual side of kidney
- Descriptive Kidney Histology Set of interactive micrographs of kidney

- Normal urine concentration and composition This is a tutorial on urinalysis that gives information regarding urine concentration and how to measure it and how to measure the composition of urine
- Protecting kidney health The National Kidney Foundation provides tips on protecting kidney health and there is a video, “Your Kidneys and You”, that provides information about kidney function and kidney health
- Carnegie Mellon Open Learning Initiative- tutorials for all systems
- Comprehensive Resource List for Human Anatomy and Physiology-see resource list page 13
- General Anatomy Histological Slides
- Review Games
- Virtual Autopsy
- Anatomy and Physiology Animations by System
- Labeling Practice by System
- Engineering and Design: University Of Cincinnati-STEM Design challenge- Design a device that removes impurities from a solution
- The National Kidney Foundation: speaker’s bureau and the information that may be useful as hooks for teaching about the urinary system
- General Science Portal: provides tools and resources for life science, physical science, earth and space science, science and technology, science and society, and the history and nature of science.
- Open Access Anatomy and Physiology Text: designed for the typical year-long anatomy and physiology course taught at community and other two-year colleges; 29 chapters arranged by organ systems and is written in an accessible language

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REPRODUCTION

AP.R.1: Reproductive System

The reproductive system is comprised of internal and external organs and hormones. The ovaries and testes are the primary organs and are responsible for gamete production. A comparison of male and female anatomy should be explored. The function of the reproductive system is for continuation of the species. The female body has the additional function of providing protection and nourishment for the developing fetus until birth.

The processes of the reproductive system should include oogenesis, spermatogenesis, and fertilization. Additional processes can include lactation and menstruation. Homeostatic imbalances can be explored. These include, but are not limited to, infertility, chromosomal disorders, endometriosis, menopause, cancer, HPV, and STD's. Investigations are used to understand and explain the reproductive system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

Note: At this level, a detailed description of embryological development is not required. The focus is on the structure and function of the reproductive organs.

Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟷		Least Complex	
Reproduction				
AP.R.1 Reproductive System	**AP.R.1a** Describe the function of the reproductive system (e.g., producing offspring).	**AP.R.1b** Identify structures of the reproductive system in a model or visual representation.	**AP.R.1c** Identify male and female differences.	**HS-LS3-1** Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. **HS-LS3-2** Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

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EVIDENCE OF LEARNING
Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

Designing technological / engineering solutions using science concepts	**Demonstrating science knowledge**	**Interpreting and communicating science concepts**	**Recalling accurate science**
Structure and Function			
Design an artificial womb (ectogenesis) that could support embryonic life.			Identify the structures of the male reproductive system and functions of each structure. Identify the structures of the female reproductive system and functions of each structure. Draw a labeled illustration that compares the male and female reproductive systems. Explain the pathway of a gamete through each reproductive system.
Processes			
.	Examine how environmental variables can impact sea urchin fertilization.	Interpret information from a case study to discuss the misconception that all menstrual cycles last 28 days.	Compare the processes of oogenesis and spermatogenesis. Create a diagram or model of gamete production and fertilization.

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Homeostatic Imbalances			
Consider the consequences and alternatives of removing female reproductive organs based upon genetic testing before cancer is diagnosed	Design an investigation to critique sperm quality.	Create a visual representation of the relationship between symptoms, possible causes, and possible treatments of homeostatic imbalances related to the reproductive system. Analyze karyotypes in order to diagnose chromosomal disorders.	Describe the relationship between HPV and cervical cancer.

Resources

- "What Happened to 28 Days?"- Case study with clicker questions investigating the human female menstrual cycle including the organs, hormones and the menstruation cycle. Additional resources for the case study.
- "And Baby Makes Four"- This case study is based on stories reported in the media and is used to examine biological and ethical dimensions of assisted reproductive technologies, specifically egg donation and gestational surrogacy.
- Voluntary Reproductive Organ Removal
    - An article that describes options if you test positive for a $BRCA_1$, $BRCA_2$, or $PALB_2$ gene mutation.
    - An article about ways surgery can reduce the risk of breast cancer.
    - An article about prophylactic ovary removal to prevent ovarian cancer
- Sea Urchin Embryology Lab: Basics of how to collect gametes, fertilize and observe embryos of live sea urchins.
- Endometriosis and hormones. An article that describes what endometriosis is and possible treatments. It shows a relationship to hormones and the growth of endometrium outside of the uterus.
- Designing an artificial womb.
    - background information on building a womb
    - successful womb design
- Karyotype Activity:This exercise is a simulation of human karyotyping using digital images of chromosomes from actual human genetic studies and diagnosing chromosomal disorders..
- HPV and Cervical Cancer: A six lesson unit that investigates HPV and its link to cervical cancer. This content includes, but is not limited to, topics such as immune responses to pathogens and vaccines, virus life cycle, the Pap test, clinical testing for cancer, and the ethical, legal, and social implications of mandatory vaccination policies for the HPV vaccine. Each part can be used alone or with other parts to explore HPV and cervical cancer.

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ENVIRONMENTAL SCIENCE

INTRODUCTION AND SYLLABUS

COURSE DESCRIPTION

Environmental science is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires three one-unit courses. Each course should include inquiry-based laboratory experience that engages students in asking valid scientific questions.

Environmental science incorporates biology, chemistry, physics and physical geology and introduces students to key concepts, principles and theories within environmental science.

Investigations are used to understand and explain the behavior of nature in a variety of inquiry and design scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications. It should be noted that there are classroom examples in the model curriculum that can be developed to meet multiple sections of the syllabus, so one well-planned long-term project can be used to teach multiple topics.

Cross Curriculum connections link to ELA and Technology.

COURSE CONTENT AND SYLLABUS

The following information may be taught in any order; there is no ODE-recommended sequence.

EARTH SYSTEMS: INTERCONNECTED SPHERES OF EARTH

- ENV.ES.1: Biosphere
  - Evolution and adaptation in populations
  - Biodiversity
  - Ecosystems (equilibrium, species interactions, stability)
  - Population dynamics
- ENV.ES.2: Atmosphere
  - Atmospheric properties and currents
- ENV.ES.3: Lithosphere
  - Geologic events and processes
- ENV.ES.4: Hydrosphere
  - Oceanic currents and patterns (as they relate to climate)
  - Surface and ground water flow patterns and movement
  - Cryosphere
- ENV.ES.5: Movement of matter and energy through the hydrosphere, lithosphere, atmosphere and biosphere
  - Energy transformation on global, regional and local scales
  - Biogeochemical cycles
  - Ecosystems
  - Weather
  - Climate

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EARTH'S RESOURCES

- ENV.ER.1: Energy resources
  - Renewable and nonrenewable energy sources and efficiency
  - Alternate energy sources and efficiency
  - Resource availability
  - Mining and resource extraction
- ENV.ER.2: Air and air pollution
  - Primary and secondary contaminants
  - Greenhouse gases
  - Clean Air Act
- ENV.ER.3: Water and water pollution
  - Potable water and water quality
  - Hypoxia, eutrophication
  - Clean Water Act
  - Point source and non-point source contamination
- ENV.ER.4: Soil and land
  - Desertification
  - Mass movement and erosion
  - Sediment contamination
  - Land use and land management (including food production, agriculture and zoning)
  - Solid and hazardous waste
- ENV.ER.5: Wildlife and wilderness
  - Wildlife and wilderness management
  - Endangered species
  - Invasive Species
  - Introduced Species

GLOBAL ENVIRONMENTAL PROBLEMS AND ISSUES

- ENV.GP.1: Human Population
- ENV.GP.2: Potable water quality, use and availability
- ENV.GP.3: Climate change
- ENV.GP.4: Sustainability
- ENV.GP.5: Species depletion and extinction
- ENV.GP.6: Air quality
- ENV.GP.7: Food production and availability
- ENV.GP.8: Deforestation and loss of biodiversity
- ENV.GP.9: Waste management (solid and hazardous)

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EARTH SYSTEMS: INTERCONNECTED SPHERES OF EARTH

This topic builds upon both the physical science and biology courses as they relate to energy transfer and transformation, conservation of energy and matter, evolution, adaptation, biodiversity, population studies, and ecosystem composition and dynamics. In grades 6-8, geologic processes, biogeochemical cycles, climate, the composition and properties of the atmosphere, lithosphere and hydrosphere (including the hydrologic cycle) are studied.

The focus for this topic is on the connections and interactions between Earth's spheres (the hydrosphere, atmosphere, biosphere and lithosphere). Both natural and human-made interactions must be studied. This includes an understanding of causes and effects of climate, global climate (including el Niño/la Niña patterns and trends) and changes in climate through Earth's history, geologic events (e.g., a volcanic eruption or mass wasting) that impact Earth's spheres, biogeochemical cycles and patterns, the effect of abiotic and biotic factors within an ecosystem, and the understanding that each of Earth's spheres is part of the dynamic Earth system. Ground water and surface water velocities and patterns are included as the movement of water (either at the surface, in the atmosphere or beneath the surface) can be a mode of transmission of contamination. This builds upon previous hydrologic cycle studies in earlier grades. Geomorphology and topography are helpful in determining flow patterns and pathways for contamination.

Ohio Learning Standard	***Complexity a***	***Complexity b***	***Complexity c***	***NGSS Alignment***
Generic	Most Complex ⟷		Least Complex	
ENV.ES.1 Biosphere ○ Evolution and adaptation in populations ○ Biodiversity ○ Ecosystems (equilibrium, species interactions, stability) ○ Population dynamics	**ENV.ES.1a** Predict the effects on the biosphere based on changes in a given population.	**ENV.ES.1b** Identify cause and effect of population change(s) within the biosphere.	**ENV.ES.1c** Recognize that the biosphere is occupied by living organisms.	HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. HS-LS1-1 Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. HS-LS1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organism HS-LS2-6 Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

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ENV.ES.2 Atmosphere ○ Atmospheric properties and currents	**ENV.ES.2a** Analyze how greenhouse gases affect atmospheric properties**.**	**ENV.ES.2b** Identify atmospheric properties (e.g., temperature, humidity, density and pressure).	**ENV.ES.2c** Recognize air currents on a map.	HS-PS1-5 Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. HS-PS3-4 Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
ENV.ES.3 Lithosphere ○ Geologic events and processes	**ENV.ES.3a** Describe how a geologic event can impact the other spheres (e.g., volcano eruption into the air, mudslide into water, etc.).	**ENV.ES.3b** List events that can occur within the lithosphere.	**ENV.ES.3c** Recognize that the lithosphere is the outer most layer (crust) of the surface of the Earth.	HS-ESS2-1 Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. HS-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
ENV.ES.4 Hydrosphere ○ Oceanic currents and patterns (as they relate to climate) ○ Surface and ground water flow patterns and movement ○ Cryosphere	**ENV.ES.4a** Describe how ocean currents and patterns relate to climate.	**ENV.ES.4b** Follow surface and ground water flow patterns and movement.	**ENV.ES.4c** Recognize that the hydrosphere is the water portion of Earth.	HS-ESS2-5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.
ENV.ES.5 Movement of matter and energy ○ Energy transformations on global, regional, and				HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

local scales ○ Biogeochemical cycles ○ Ecosystems ○ Weather Climate				HS-ESS2-3 Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection. HS-ESS2-4 Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. HS-ESS2-6 Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. HS-PS3-1 Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. HS-LS1-5 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. HS-LS1-6 Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. HS-LS2-5 Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

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EVIDENCE OF LEARNING

Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

	Designing technological / engineering solutions using science concepts (T)	Demonstrating science knowledge (D)	Interpreting and communicating science concepts (C)	Recalling accurate science (R)
ENV.ES.1: Biosphere				
Biomagnification or Bioaccumulation	Present the process, results and possible solutions of an investigation on biomagnification or bioaccumulation within a specific ecosystem to an authentic audience and/or verbally or in writing.	Plan and implement an investigation to explore biomagnification or bioaccumulation within a specific Ohio ecosystem (existing public case studies can be used, such as a local Brownfields case – see resource listed below). Document the steps and process to collect or research, evaluate or test and analyze the data. Research should include the possible impact to humans. Present the process and results to the class verbally or in writing.	Conduct a pond study, calculate biodiversity index, and construct a sustainable food web. Present research and findings on biomagnification and bioaccumulation impacts on specific Ohio ecosystems. Explain the process and results to the class verbally or in writing. Perhaps addressing "Ohio's Sportfish Consumption Advisory" published annually by the Ohio EPA.	Research how biomagnification or bioaccumulation impacts specific Ohio ecosystems.. Research should include the possible impact to humans.
Climate Impact	Evaluate and critique current trends in reclaiming former industrial sites. Taking economics, government regulations, and current technology into consideration, design a new method to reclaim a former Brownfield in the Great Lakes Region.	Plan and implement a population study of a specific area (over a period of time) or critique/analyze an existing population study. Document changes in weather, food availability and any change to the population. Prepare a scientific analysis and conclusion (in writing) for the study.	Graph survivorship curves to make judgements about environmental and health conditions in various habitats/ecosystems.	Determine the carrying capacity of an ecosystem using historical or up to date data (ex: Moose on Isle Royale, Kaibab Deer in Arizona).
Endangered Species	Evaluate current protection and management laws pertaining to endangered species and their habitats. Research an endangered species and develop a solution involving all of the stakeholders/parties of interest to	Research or conduct a field investigation for a specific invasive species or species that has been introduced into the local community or into Ohio. Examples of research questions include: How did the organism get into Ohio? What is	Choose two accessible habitats and take a field trip. Choose a level and type of taxa (i.e. birds, insects, spiders, trees, herbaceous plants, etc.) Collect data on species diversity and abundance. Compare and contrast data using Simpson's Diversity Index	Using a food web, identify the different relationships and trophic levels. Describe consequences of removing an organism or

	conserve the species. List the advantages and disadvantages to conservation.	being done to control the spread of the species? What is the impact of the species on the ecosystem? Use quantifiable data to draw conclusions and present research results in writing or orally.	or Shannon-Weiner Index to measure species diversity/abundance and compare the relative health of the two habitats.	enduring an environmental change.
ENV.ES.2- Atmosphere				
	Research an actual contamination event (that has quantitative data available). Use a computer-modeling program to model and predict the movement of the contamination through Earth's spheres. Develop and evaluate solutions for the cleanup, containment or reduction of the contamination. Include consequences and/or alternatives for the proposed solution. Present findings to the class or an authentic audience.	Using authentic data from a credible source, explain the effects and causes of el Nino/la Nina weather patterns on Earth's spheres, biogeochemical cycles and biodiversity. Include regional comparisons of the effects of these events.	Draw the biogeochemical cycles (e.g.: Water, carbon and nitrogen) onto a large sheet of paper, in order to illustrate the role the atmosphere plays with the various biogeochemical cycles.	Complete a foldable or other manipulative on the layers of the Earth's atmosphere, complete with description and chemical composition.
ENV.ES.3- Lithosphere				
	Develop a risk assessment for a specific company. Research one particular toxin or hazardous chemical used by the company (e.g., diesel fuel) to determine possible risks and pathways to the environment and humans. The assessment should include: nature of the toxin/chemical (e.g., is the material flammable, does it react when wet), on-site use and handling (including existing safety practices) of the toxin/chemical, by-products (e.g., vapors or dilution processes), storage, transportation of the toxin/chemical, required documentation, emergency plans/ guidelines, topography and geology of the area. Use a computer-modeling program (many are available through freeware sites) to model and predict the movement of the possible pathways of the toxin/chemical and recommendations of methods to contain the release of the toxin/chemical. Present	Examine the human impact on the lithosphere and hypothesize possible consequences. Examples may include hydraulic fracturing, surface mining, and urbanization.	Research and analyze an event (ex: natural or anthropogenically caused such as an Icelandic volcano eruption or the BP Oil spill) and make a connection model to demonstrate how the different spheres (atmosphere, biosphere, lithosphere, and hydrosphere) are impacted.	Build a model of the layers of the Earth in order to identify and describe the components and their role in geologic events and the Earth's dynamic transformation.

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	the findings to the class or an authentic audience.			
			Find a large tract of property for sale in your community. Using knowledge of the lithosphere through data found on USDA's site, make recommendations on how this property could be used in the future.	Explore soil composition through ground truthing data: Each student brings a topsoil sample from their home or nearby area for comparison to others. Analyze soil properties using the soil triangle through texturing. Use soil settling jars to confirm, then create a map of your community by soil texture.
ENV.ES.4- Hydrosphere				
	Construct a functioning shower using only 4 gallons of water and household materials provided by the teacher that would allow someone to wash their body and their hair effectively and capture the gray water produced. The shower construction must be tested by students (e.g. can wear bathing suits to test at school).	Plan and implement an experiment or demonstration to illustrate the factors that lead to changing oceanic currents (both deep and shallow, can be 3-D or virtual). Document all steps and prepare a presentation or a poster session for the class. Defend the process and the results.	Create a map of your local watershed and include boundaries of adjoining watersheds. The map must demonstrate movement of water within the watershed.	Create an illustration or animation of the water cycle. Include at a basic level, plant & animal use, and anthropogenic impacts of water in your story.
	Using a model of an oil spill, students can use various methods to clean up the spill and evaluate its effects without allowing further damage to the ecosystem. At the completion of the clean-up process, each team will assess the effectiveness of the methods and make suggestions for improvement.	Design methods to transport potable water to arid areas. Students should consider availability of materials, cost and efficiency.	Research a water resource disaster and describe various ways the disaster has altered the ecosystem of the region. Explain the stability of that ecosystem, as well as how has it changed over time. Ohio EPA well water data can be used to compare water composition of the contaminated site with groundwater from your own community. Students can present their research in a multimedia format.	Using a regional map, Identify local water sources and their proximity to schools, neighborhoods and shopping centers. Indicate how those areas may infringe upon the health of the those waterways.
ENV.ES.5- Movement of Matter and Energy through the hydrosphere, lithosphere, atmosphere, and biosphere				
	Research, design, create, and maintain a tabletop sustainable biosphere (e.g.: eco columns) using aquarium gravel, live aquatic plants, and aquatic organisms (eg: fish, ghost shrimp, Sea Monkeys ®). Students can study nutrient cycling,	Research or investigate an actual environmental/geologic event (e.g., a specific release of a toxin/contaminant, hurricane, earthquake, flood, fire or landslide) and determine how each of Earth's	Model and describe how toxins enter and accumulate in a food chain . Find and paraphrase laws/regulations which attempt to regulate use of potential contaminants (for example DDT, BPA, pharmaceuticals, lead, etc).	Given a list of terms students determine if they are abiotic or biotic and defend their choice and/or explain the significance.

	limiting factors, decomposition, water quality, and eutrophication.	spheres was impacted. Long-term and short term impacts must be included. Provide scientific evidence and data to support conclusions and trace movement of contamination or energy through each sphere. Use a multimedia presentation to share findings with the class. .		
	Students can use Google Earth to explore global temperature changes and to determine how the temperature of the Earth has changed during a recent 50 - 58 year period. They will also explore, analyze, and interpret climate patterns of 10 different cities, and analyze differences between weather and climate patterns. Using their research, students will participate in a debate on whether climate change is real or fake news.	Investigate and/or research (using quantifiable data and evidence) the relationship between deforestation and changing weather or, in some cases, climate, at a specific location (e.g. the Amazon region of South America). Analyze the data and draw a conclusion based upon the analysis. Discuss the conclusion with the class.	Through historical data research (using NOAA database), students will describe the relationship between ocean surface temperature and hurricane intensity. Students can then create a map of the most vulnerable and highly populated areas that could be affected.	Given definitions of weather and climate, write an article explaining the difference as well as the importance of the difference between the two concepts.

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Resources

ENV.ES.1: Biosphere

- The Ohio EPA provides a map of all regional Brownfields projects, a resource to provide data and documentation for local case studies involving a variety of hazardous releases into the environment and quantifiable data and monitoring data at http://www.epa.state.oh.us/derr/SABR/brown_dtb/browndtb.aspx.
- The College Board provides enduring understandings recommended for AP environmental science, which can help to form discussion questions and research for this topic at https://apcentral.collegeboard.org/ap-2019 Appendix A (page 175) of this document contains the environmental science information.
- The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies and other scientific agencies. Resources are searchable by grade level and standards at http://www.dlese.org/lib/index.html
- The Ohio Environmental Protection Agency's' Project WET program offers training and resources for K-12 teachers that promote deep understanding about all aspects of water and the interconnectedness of all of Earth's spheres (Earth Systems). Training and workshop opportunities can be found at http://epa.ohio.gov/oeef/ProjectWET.aspx
- Project WET's Healthy Water, Healthy People water quality educators guide offers ideas and resources for teaching all aspects of water and water contamination issues. Ideas for field monitoring, research projects and student investigations as well as teacher training are available at http://epa.ohio.gov/oeef/ProjectWET.aspx
- Project WILD helps students learn basic concepts about wild animals, their needs and importance and their relationships to people and the environment. These activities can be helpful for introducing or reinforcing concepts with students. The activity guides are available to educators at low cost or free of charge when they attend a workshop. Information about upcoming workshops are available on the ODNR Website at http://wildlife.ohiodnr.gov/education-and-outdoor-discovery/conservation-education-project-wild
    - The activity *Hazardous Links, Possible Solutions* can effectively introduce the concepts of bioaccumulation and biomagnification within a food chain. Students will (I) give examples of ways in which pesticides enter food chains, (2) describe possible consequences of pesticides entering food chains, and (3) describe how regulations attempt to control pesticide use.
- Project Learning Tree helps students learn basic concepts about trees and forest ecosystems and the kinds of ecological services they provide. The activity guides are available to educators when they attend a workshop (either in person or online). Information about upcoming workshops are available on the ODNR Division of Forestry website at http://forestry.ohiodnr.gov/plt. Specific information about high school level curriculum modules is available at https://www.plt.org/curriculum-offerings/high-school/
    - The PLT activity *Monitoring Forest Health* in the Secondary Module "Focus on Forests," Students conduct an extensive forest health survey of a local forest area, will collect biotic and abiotic data, conduct a species inventory, and will evaluate the ecological services provided by trees and forests.

- The Association of Fish and Wildlife Agencies has a Conservation Toolkit that includes guides on conducting field investigations with students, schoolyard habitat investigations, technology for field investigations, and more. https://www.fishwildlife.org/afwa-informs/ce-strategy/north-american-conservation-education-strategy
- ODNR-Division of Wildlife's WILD School Sites program provides resources, grants, and workshops to help schools create habitat projects on their school grounds. http://wildlife.ohiodnr.gov/education-and-outdoor-discovery/conservation-education-project-wild#tabr4
- Misconceptions regarding all aspects of environmental science must be addressed through scientific data analysis, investigation and research. Discussing the conclusions and findings through a professional "gallery walk" can be a very useful way to determine possible misconceptions that exist for the class and address them. Carleton College offers a gallery walk website at http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html

ENV.ES.2- Atmosphere

- Intellicast.com offers real-time data for the jet stream (updated daily), including velocities and patterns on an isometric map at http://www.intellicast.com/National/Wind/JetStream.aspx

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- Project Wet's Healthy Water, Healthy People water quality educators guide offers ideas and resources for teaching all aspects of water and water contamination issues. Ideas for field monitoring, research projects and student investigations as well as teacher training are available at http://epa.ohio.gov/oeef/ProjectWET.aspx
- EarthComm offers a program that uses many different strategies to reach students of all learning levels at http://www.agiweb.org/earthcomm/ The teaching of environmental science through relating the classroom to the real world is essential for many learners.
- The Ohio EPA's air quality database can be used to explore comparison between different areas of Ohio, including your own community, found here: http://www.epa.ohio.gov/dapc/airohio/index.aspx
- Misconceptions regarding all aspects of environmental science must be addressed through scientific data analysis, investigation and research. Discussing the conclusions and findings through a professional "gallery walk" can be a very useful way to determine possible misconceptions that exist for the class and address them. Carleton College offers a gallery walk website at http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html

ENV.ES.3- Lithosphere

- The College Board provides enduring understandings recommended for AP environmental science, which can help to form discussion questions and research for this topic at https://apcentral.collegeboard.org/ap-2019 Appendix A (page 175) of this document contains the environmental science information.
- The Ohio Environmental Protection Agency's' Project WET program offers training and resources for K-12 teachers that promote deep understanding about all aspects of water and the interconnectedness of all of Earth's spheres (Earth Systems). Training and workshop opportunities can be found at http://epa.ohio.gov/oeef/ProjectWET.aspx
- The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies and other scientific agencies. Resources are searchable by grade level and standards at http://www.dlese.org/lib/index.html
- NOAA provides real-time data for many of its projects and research missions at http://www.noaa.gov/sciencemissions/bpoilspill.html
- Project WET's Healthy Water, Healthy People water quality educators guide offers ideas and resources for teaching all aspects of water and water contamination issues. Ideas for field monitoring, research projects and student investigations as well as teacher training are available at http://epa.ohio.gov/oeef/ProjectWET.aspx
- EarthComm offers a program that uses many different strategies to reach students of all learning levels at http://www.agiweb.org/earthcomm/. The teaching of environmental science through relating the classroom to the real world is essential for many learners.
- Your county's Soil and Water Conservation District can offer a wealth of advice and resources, and can often supply models and even classroom visits. Get your local office's contact information through this web tool: http://www.agri.ohio.gov/divs/SWC/SearchLocalSWCD.aspx
- The United StatesDepartment of Agriculture has soil type data throughout Ohio, with considerations for human use, through the use of an interactive mapping webtool found here: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
- The United States Department of Agriculture offers a variety of lesson plans and classroom ideas, including the soil triangle, found here: https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/edu/7thru12/
- Ohio Corn and Wheat offers a variety of classroom activities exploring the balance of farming and maintaining soil for a sustainable world, found here: http://ohiocorneducation.org/curriculum/soil-and-sustainability

- The Soil Science Society of America has a plethora of resources and activities for exploring concepts of soil, found here: http://www.soils4teachers.org/resources
- The NSTA offers a position paper which is helpful in addressing concerns and misconceptions from students regarding evolution at http://www.nsta.org/about/positions/evolution.aspx
- The EPA provides support for teachers that are teaching about climate change. To address student misconceptions regarding this issue, it is important to use realtime data and research, which can be found through the EPA at http://www.epa.gov/students/teachers.html#epaclimate
- Nutrients for Life has resources for soil investigations and lessons https://www.nutrientsforlife.org/for-teachers
- Students may have difficulty separating science from non-science factors as they relate to the different parts of the environment. It is important to distinguish "what is science" and therefore, what will be included in an environmental science class, especially as it relates to climate change and evolution. Identifying and understanding personal bias and ethical issues are an important step in recognizing science. Wheaton College offers Teaching Ethical Analysis in Environmental Management Decisions: A Process-Oriented Approach at http://www.wheaton.edu/~/media/Files/Academics/Departments/Biology/Van Dyke files/Teachingethical.pdf

ENV.ES.4- Hydrosphere

- The North Carolina Department of Environment and Natural Resources offers basic hydrology background information, including ways to calculate ground water velocity and outlining different types of aquifers, to help in teaching about ground water at http://www.ncwater.org/Education_and_Technical_Assistance/Ground_Water/Hydrogeology/
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- The Globe Program collects data from a variety of protocols from every facet of our biosphere, through a collaborative effort of Citizen Scientists, predominantly educators and their classrooms. Data can be downloaded here: https://datasearch.globe.gov/
- The EPA has data for water wells throughout Ohio, enabling your class to zoom in to your community on a map, choose a well, and see its composition history, found here: https://oepa.maps.arcgis.com/apps/webappviewer/index.html?id=b39b9cbeb3834e9ca598d968d16333ce Complete datasets can also be downloaded in a large Excel file here: http://www.epa.state.oh.us/ddagw/gwqcp.aspx#115414902-access-data
- The NSTA offers a position paper which is helpful in addressing concerns and misconceptions from students regarding evolution at http://www.nsta.org/about/positions/evolution.aspx
- The EPA provides support for teachers that are teaching about climate change. To address student misconceptions regarding this issue, it is important to use realtime data and research, which can be found through the EPA at http://www.epa.gov/students/teachers.html#epaclimate

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- EarthEcho International facilitates a water quality assessment involving students across the globe from more than 140 countries. Students can upload their water quality data, while seeing the work of countless others, allowing for vast comparisons to be made. Visit http://www.worldwatermonitoringday.org/ to learn more.

ENV.ES.5- Movement of Matter and Energy through the hydrosphere, lithosphere, atmosphere, and biosphere

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- National Oceanic Atmospheric Association http://www.ospo.noaa.gov/Products/ocean/sst.html
- The Byrd Polar and Climate Research center at Ohio State offers comprehensive classroom resources on climate science, available at https://bpcrc.osu.edu/create-classroom-ice-cores. Additionally, PBS's NOVA Teachers offers a great lesson interpreting ice core data, available here: http://www.pbs.org/wgbh/nova/education/activities/3005_vinson.html
- Project WILD and Aquatic WILD help students learn science concepts while learning about wildlife, their needs and importance and their relationships to people and the environment. The activity guides are available to educators free of charge when they attend a workshop. Information about upcoming workshops are available on the ODNR Website at http://wildlife.ohiodnr.gov/education-and-outdoor-discovery/conservation-education-project-wild
    - The Project WILD activity *Hazardous Links, Possible Solutions* can effectively introduce the concepts of bioaccumulation and biomagnification within a food web.
    - The Aquatic WILD activity *Glass Menagerie*, students observe and describe changes in the physical characteristics of several different experimental aquatic habitats they create.
- The NSTA offers a position paper which is helpful in addressing concerns and misconceptions from students regarding evolution at http://www.nsta.org/about/positions/evolution.aspx
- The EPA provides support for teachers that are teaching about climate change. To address student misconceptions regarding this issue, it is important to use realtime data and research, which can be found through the EPA at http://www.epa.gov/students/teachers.html#epaclimate
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EARTH RESOURCES

This topic explores the availability of Earth's resources, extraction of the resources, contamination problems, remediation techniques and the storage/disposal of the resources or by-products. Conservation, protection and sustainability of Earth's resources also are included. This builds upon grades 6-8 within the Earth and Space Science strand (sections pertaining to energy and Earth's resources) and the biology and physical science (in particular chemistry and energy topics) courses at the high school level.

To understand the effects that certain contaminants may have on the environment, scientific investigations and research must be conducted on a local, national and global level. Water, air, land, and biotic field and lab sampling/testing equipment and methods must be utilized with real-world application. Quantifiable field and/or lab data must be used to analyze and draw conclusions regarding air, water or land quality. Examples of types of water-quality testing include: hydraulic conductivity, suspended and dissolved solids, dissolved oxygen, biochemical oxygen demand, temperature, pH, fecal coliform and macro-invertebrate studies. Wetland or woodland delineations and analysis, land use analysis and air monitoring (e.g., particulate matter sizes/amount) are all appropriate field study investigations. Comparative analysis of scientific field or lab data should be used to quantify the environmental quality or conditions. Local data also can be compared to national and international data.

The study of relevant, local problems can be a way to connect the classroom to the real world. Within Ohio, there are numerous environmental topics that can be investigated. Examples include wetland loss or mitigation, surface or ground water contamination (including sediment, chemical or thermal contamination), acid rain, septic system or sewage overflows/failures, landfill seepage, underground storage tank/pipe releases, deforestation, invasive species, air pollution (e.g., photochemical smog or particulate matter), soil loss/erosion or acid mine drainage.

At the advanced science level, renewable and nonrenewable energy resources topics investigate the effectiveness, risk and efficiency for differing types of energy resources at a local, state, national and global level. This builds upon grades 6-8 within both Earth and Space Science, and physical science at the high school level. Nuclear and geothermal energy are included in this topic.

Feasibility, availability, remediation and environmental cost are included in the extraction, storage, use and disposal of both abiotic and biotic resources. Environmental impact must be evaluated as it pertains to both the environmental and human risk. Examples include chemical hazards, radiation, biological hazards, toxicology and risk analysis studies. Learning about conservation and protection of the environment also requires an understanding of laws and regulations that exist to preserve resources and reduce and/or remediate contamination, but the emphasis should be on the science behind the laws and regulations.

Relating Earth's resources to a global scale and using technology to collect global resource data for comparative classroom study is recommended. In addition, it is important to connect the industry and the scientific community to the classroom to increase the depth of understanding. Critical thinking and problem-solving skills are important in evaluating resource use, management and conservation. New discoveries and research are important parts of this topic.

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Ohio Learning Standard	***Complexity a***	***Complexity b***	***Complexity c***	***NGSS Alignment***
Generic	Most Complex ⟷		Least Complex	
Earth's Resources				
ENV.ER.1 Energy resources ○ Renewable and nonrenewable energy sources and efficiency ○ Alternate energy sources and efficiency ○ Resource availability ○ Mining and resource extraction	**ENV.ER.1a** Describe the source and benefit of renewable and nonrenewable energy as it relates to resources.	**ENV.ER.1b** Compare renewable and nonrenewable sources of energy (e.g., effectiveness, cost to produce).	**ENV.ER.1c** Sort sources of energy as renewable and nonrenewable.	HS-PS3-3 Design, build, and refine a device that works with given constraints to convert one form of energy into another form of energy. HS-ESS3-1 Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. HS-ESS3-2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. HS-ESS3-3 Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.
ENV.ER.2 Air and air pollution ○ Primary and secondary contaminants ○ Greenhouse gases ○ Clean Air Act	**ENV.ER.2a** Identify a consequence and solution to air pollution (e.g., Clean Air Act).	**ENV.ER.2b** Identify a greenhouse gas and how humans have impacted the level of greenhouse gases.	**ENV.ER.2c** Identify types of air pollution.	HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
ENV.ER.3 Water and water pollution ○ Potable water and water quality ○ Hypoxia, eutrophication ○ Clean Water Act ○ Point source and non-point source contamination	**ENV.ER.3a** Identify a consequence and solution to water pollution (e.g., Clean Water Act).	**ENV.ER.3b** Identify ways that humans have changed the global water supply (e.g., water quality).	**ENV.ER.3c** Identify types of water pollution.	HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

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ENV.ER.4 Soil and land ○ Desertification ○ Mass movement and erosion ○ Sediment contamination ○ Land use and land management (including food production, agriculture, and zoning) ○ Solid and hazardous waste	**ENV.ER.4a** Identify a consequence and solution of soil pollution (e.g., land use, zoning).	**ENV.ER.4b** Identify ways that humans have contributed to changes in the land (e.g., deforestation, strip mining, waste, etc.).	**ENV.ER.4c** Identify types of soil pollution.	HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
ENV.ER.5 Wildlife and wilderness ○ Wildlife and wilderness management ▪ Endangered species ○ Invasive species ○ Introduced species	**ENV.ER.5a** Explain how a species can become endangered (e.g., deforestation, invasive species).	**ENV.ER.5b** Categorize species as "endangered" or "non-endangered."	**ENV.ER.5c** Identify the meaning of "endangered." species.	

EVIDENCE OF LEARNING
Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

	Designing technological / engineering solutions using science concepts (T)	**Demonstrating science knowledge (D)**	**Interpreting and communicating science concepts (C)**	**Recalling accurate science (R)**
ENV.ER.1- Energy Resources				
	Research an actual contamination event (that has quantitative data available). Use a computer-modeling program (many are available through freeware sites, fate and transport modeling) to model and predict the movement of the contamination through Earth's	Design an energy efficient, clean, renewable community based upon real data and models of other cities, communities. Include explanations of the benefits and consequences associated with the model.	Compose a letter to a local politician or school board outlining the need for renewable energy/alternative energy exploration and incorporation into your city. Think about taxes, resources and infrastructure.	Identify the primary resources used in your community for energy. Create a brochure explaining and comparing the sources.

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	spheres. Develop and evaluate solutions for the cleanup, containment or reduction of the contamination. Include consequences and/or alternatives for the proposed solution. Present findings to the class or an authentic audience.			
	Design and conduct a field investigation that concentrates on a specific environmental problem (e.g., sediment contamination or acid mine drainage) and how the problem can be remediated. Compare results to similar communities, recommended limits, permit requirements or other published results. Analyze the data and make specific recommendations to limit, remediate, reduce or prevent the problem. Present findings to an authentic audience from the community.	Using existing alternative energy sources as a model generate a new alternate energy source of improve an existing energy source. Test your design and your hypothesis. ("build a better mousetrap")	Compare energy usage of the United States to energy usage of a developing nation. Parse it down to a "typical" family in America and a "typical" family in the developing country.	Research a widely used and/or controversial energy source (Nuclear, oil, gas, wind, solar…) and create a detailed poster to be used as a teaching tool for younger grades.
	Develop a risk assessment for a specific company. Research one particular toxin or hazardous chemical used by the company (e.g., diesel fuel) to determine possible risks and pathways to the environment and humans. The assessment should include: nature of the toxin/chemical (e.g., is the material flammable, does is react when wet), on-site use and handling (including existing safety practices) of the toxin/chemical, by-products (e.g., vapors or dilution processes), storage, transportation of the toxin/chemical, required documentation, emergency plans/ guidelines, topography and geology	Contact your local energy provider and conduct an energy audit of your school. Identify areas where energy can be conserved. Generate a plan to decrease energy footprint.	Create a PSA explaining the importance of energy conservation in your community, home and school. Include methods for conservation.	Record energy usage in your home for a 24-48 hour period. With parental permission, review an electric bill for your home and identify adoptable strategies to reduce your home's energy usage.

	of the area. Use a computer-modeling program (many are available through freeware sites) to model and predict the movement of the possible pathways of the toxin/chemical and recommendations of methods to contain the release of the toxin/chemical. Present the findings to the class or an authentic audience.			
ENV.ER.2- Air and Air Pollution				
	Research an actual contamination event such as Donora, PA or Bhopal, India (that has quantitative data available). Use a computer-modeling program (many are available through freeware sites, fate and transport modeling) to model and predict the movement of the contamination through Earth's spheres. Develop and evaluate solutions for the cleanup, containment or reduction of the contamination. Include consequences and/or alternatives for the proposed solution. Present findings to the class or an authentic audience.	Conduct tests for air quality in and around your school then investigate the sources of any pollutants and design a plan to remove or reduce the pollutants.	Construct a model of your home or school explaining the internal air pollutants. Determine the relationships between the pollutants and human activities in or near your home/school.	Create a presentation on the major types and sources of air pollution. Compare the main types and illustrate how to prevent air pollution.
	Design and conduct a field investigation that concentrates on a specific environmental problem (e.g., sediment contamination or acid mine drainage) and how the problem can be remediated. Compare results to similar communities, recommended limits, permit requirements or other published results. Analyze the data and make specific recommendations to limit, remediate, reduce or prevent the problem. Present findings to an authentic audience from the community.	Prepare to debate your classmates on issues surrounding the controversy of global warming. Prepare for both sides-teams will be decided at time of debate.	Looking at the data for the US EPA and clean air outline a plan for Ohio/Great Lake States to improve the air by 2025 OR Using ice core models and/or datasets, make a graph showing how elements in the atmosphere can change over time. Interpret, and extrapolate into the future.	Design and create a poster/graphic organizer/infographic illustrating the difference between primary and secondary contaminants

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	Develop a risk assessment for a specific company. Research one particular toxin or hazardous chemical used by the company (e.g., diesel fuel) to determine possible risks and pathways to the environment and humans. The assessment should include: nature of the toxin/chemical (e.g., is the material flammable, does is react when wet), on-site use and handling (including existing safety practices) of the toxin/chemical, by-products (e.g., vapors or dilution processes), storage, transportation of the toxin/chemical, required documentation, emergency plans/ guidelines, topography and geology of the area. Use a computer-modeling program (many are available through freeware sites) to model and predict the movement of the possible pathways of the toxin/chemical and recommendations of methods to contain the release of the toxin/chemical. Present the findings to the class or an authentic audience.	Design a “city makeover” for a city near you. Your new city must be “Air friendly”. Consider mass transit, industry, infrastructure, homes, education and technology.	Students can rewrite the Clean Air act for 2020, being sure to consider technology and demographics.	Read the Clean Air Act and create a timeline demonstrating major events that led up to it and major events which occurred after it. (also include results of those events)

ENV.ER.3- Water and water pollution				
	Design and build a water filter with commonly available materials for either waste water or drinking water, taking into account cost and efficiency. Students must test their water filter, analyze the data collected, and brainstorm ideas on how to improve their design.	Take a field trip to visit a water treatment facility or watch the drilling of a water well. Document observations, including information about how water is treated prior to and after use, specific issues that may impact the source, the location of the original water source, specific tests conducted (materials and	Conduct a water quality field test of various local bodies of water, and determine how the results (e.g.: dissolved oxygen content, phosphates, nitrates/nitrites, pH, fecal coliform, etc.) could impact aquatic ecosystems.	Examine and report on your town’s or city’s water delivery system. Include where your drinking water comes from and where your waste water goes.

		methods needed to test and how the tests are conducted, results of the tests), and the steps taken to monitor the water at the source and throughout the process (including from the facility/well into the residence). Discuss with the class.		
	Design and conduct a field investigation that concentrates on a specific water problem (e.g., sediment contamination or acid mine drainage) and how the problem can be remediated. Compare results to similar communities, recommended limits, permit requirements or other published results. Analyze the data and make specific recommendations to limit, remediate, reduce or prevent the problem. Present findings to an authentic audience from the community.	Plan and implement an investigation to determine the water quality of a section of a local stream. This includes researching and conducting standard water-quality tests and how to analyze the results. Compare the results to known data from a different country (with a similar setting). Compare and contrast the data and analyze the results. Example research questions include: What are the reasons for any statistically significant differences? What comparisons can be made about the topography or geomorphology of the location? What testing methods, materials and/or equipment are used? What are the testing dates/ times/locations? What are the existing, applicable, environmental laws or requirements? Document all results and present to an authentic audience.	Outline a water conservation plan for your school. Base your plan on a water assessment which you performed on your home. Explain where water can be conserved at school and at home. Model how small changes can have large effects.	Research and report out on water as a resource. Identify areas of concern and classify various sources. (fresh, salt, ground, surface, glacier, etc)
	Develop a risk assessment for a specific company. Research one particular toxin or hazardous chemical used by the company (e.g., diesel fuel) to determine possible risks and pathways to the environment and humans. The	Identify two small waterways in your town: one in a human-developed area, and another in a natural area. Develop an experiment to find correlations between the differences of human impact	Read the clean water act and rewrite it to address the increases in populations and changes to ecosystems.	Read excerpts or summaries of Rachel Carson's *Silent Spring* and conduct experiments which model the effects of toxins introduced into a water system.

	assessment should include: nature of the toxin/chemical (e.g., is the material flammable, does is react when wet), on-site use and handling (including existing safety practices) of the toxin/chemical, by-products (e.g., vapors or dilution processes), storage, transportation of the toxin/chemical, required documentation, emergency plans/ guidelines, topography and geology of the area. Use a computer-modeling program (many are available through freeware sites) to model and predict the movement of the possible pathways of the toxin/chemical and recommendations of methods to contain the release of the toxin/chemical. Present the findings to the class or an authentic audience.	around these waterways using biotic indicators and chemical composition. (this could be demonstrating scientific practice, or interpreting data)		
ENV.ER.4- Soil and Land				
	Design and conduct a field investigation that concentrates on a specific soil problem (e.g., sediment contamination or acid mine drainage) and how the problem can be remediated. Compare results to similar communities, recommended limits, permit requirements or other published results. Analyze the data and make specific recommendations to limit, remediate, reduce or prevent the problem. Present findings to an authentic audience from the community .	Research and analyze quantifiable scientific data pertaining to food availability, reproductive requirements and changes, adaptations or population changes to draw conclusions. Students present data and conclusions to the class.	Research current FDA laws pertaining to food safety for agriculture and write a user-friendly version of the laws for the public to access on the FDA website.	Design a community garden which could supplement the diet of the student population of your school. Consider soil types, precipitation, and yield.
	Develop a risk assessment for a specific company. Research one particular toxin or hazardous	Research and document land-use planning or management in the	Create a plan to revitalize a brownfield site in one of the Great Lake States. Be sure	Conduct soil tests, including sampling on various sites around school campus. Present findings with implications.

	chemical used by the company (e.g., diesel fuel) to determine possible risks and pathways to the environment and humans. The assessment should include: nature of the toxin/chemical (e.g., is the material flammable, does is react when wet), on-site use and handling (including existing safety practices) of the toxin/chemical, by-products (e.g., vapors or dilution processes), storage, transportation of the toxin/chemical, required documentation, emergency plans/ guidelines, topography and geology of the area. Use a computer-modeling program (many are available through freeware sites) to model and predict the movement of the possible pathways of the toxin/chemical and recommendations of methods to contain the release of the toxin/chemical. Present the findings to the class or an authentic audience.	community or at a specific location. Attend community meetings pertaining to land-use, land management or zoning plans. Research questions should include: What factors are used in determining use? What data is collected and analyzed? What changes are on the horizon? Discuss in class	to include an explanation of how it became a brownfield.	
	Deconstruct an area affected by a mass wasting, desertification or erosion event and write a detailed explanation with data. Write a “brief” for a law firm to explain the disaster and assign blame for purposes of restitution and remediation.	Research and collect specific data for a mass wasting or desertification event (can be present day or historical). Research questions should include: What factors led to the event? What was the result of the event (how was each of Earth’s spheres impacted)? What data is present (analyze the data and draw conclusions)? What laws are related to the event? How can this be prevented in the future? Record the results graphically or in a scientific report.	Write a letter to a company which historically violated EPA laws outlining their violations and the impact on the environment.	Identify and report out at least 2 examples of modern desertification in the. One in the United States and one in another country.

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ENV.ER.5- Wildlife and wilderness				
	Design and conduct a field investigation that concentrates on a specific environmental problem (e.g., sediment contamination or acid mine drainage) and how the problem can be remediated. Compare results to similar communities, recommended limits, permit requirements or other published results. Analyze the data and make specific recommendations to limit, remediate, reduce or prevent the problem. Present findings to an authentic audience from the community.	Choose a specific living species. Using scientific data, trace the history of that species. Show existing, proven evolutionary relationships, environmental (both biotic and abiotic) requirements, global locations, ecosystem characteristics and sustainability predictions. Use quantifiable data to support findings and present findings to the class orally, through demonstration/explanation or a poster session.	Design a plan to preserve/conserve a wilderness or waterway in Ohio. Be specific and defend your rationale with data. Include biological and ecological relationships within the system	Create sustainable food web for an Ohio wilderness or water ecosystem, being sure to involve humans. Include information on threats to each species. Discuss the process of biomagnification and the ramifications if a primary consumer/producer is removed or too many consumers/producers are introduced.
	Develop a risk assessment for a specific company. Research one particular toxin or hazardous chemical used by the company (e.g., diesel fuel) to determine possible risks and pathways to the environment and humans. The assessment should include: nature of the toxin/chemical (e.g., is the material flammable, does is react when wet), on-site use and handling (including existing safety practices) of the toxin/chemical, by-products (e.g., vapors or dilution processes), storage, transportation of the toxin/chemical, required documentation, emergency plans/ guidelines, topography and geology of the area. Use a computer-modeling program (many are available through freeware sites) to model and predict the movement of the possible pathways of the toxin/chemical and recommendations of methods to contain the release of the toxin/chemical. Present the findings to the class or an authentic audience.	Research or conduct a field investigation for a specific invasive species that is present in the local community or in Ohio. Examples of research questions include: Is the species native or non-native? If not native, how did the organism get into Ohio? What is being done to control the spread of the species? What is the impact of the species on the native population? Use quantifiable data to draw conclusions and present research results in writing or orally	Write a bill to be presented at the Ohio State House (to Ohio Congress) restricting, preventing, eliminating invasive species in Ohio.	Create a presentation for local stakeholders on the hazards of invasive species.

	Collect data on a local system/species and share with a national/state/county agency. Maintain population data on your local system from year to year to make predictions about population fluctuations and climate impacts on local populations.	Evaluate current practices to preserve and recover native species. Make assessments about the introduction of species that could boost endangered species populations, or could become invasive.	Construct an experiment to compare the biodiversity of two natural areas, including richness and evenness. Draw conclusions and present results orally. Facilitate classroom discussion around results, and how they are relevant towards mitigating invasive species impact.	Students can identify invasive species in their community and describe their impacts on the food web. Students report their findings in a lab report format.

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Resources

ENV.ER.1- Energy Systems

- The College Board provides enduring understandings recommended for AP environmental science, which can help to form discussion questions and research for this topic at https://apcentral.collegeboard.org/ap-2019 Appendix A (page 175) of this document contains the environmental science information.
- The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies and other scientific agencies. Resources are searchable by grade level and standards at http://www.dlese.org/lib/index.html
- NOAA provides real-time data for many of its projects and research missions at http://www.noaa.gov/sciencemissions/bpoilspill.html
- http://www.cbf.org/ the Chesapeake Bay Foundation has a multitude of resources which can easily be adapted for anyone teaching in Ohio
- The NSTA offers a position paper which is helpful in addressing concerns and misconceptions from students regarding evolution at http://www.nsta.org/about/positions/evolution.aspx
- Students may have difficulty separating science from non-science factors as they relate to the different parts of the environment. It is important to distinguish "what is science" and therefore, what will be included in an environmental science class, especially as it relates to climate change and evolution. Identifying and understanding personal bias and ethical issues are an important step in recognizing science. Wheaton College offers Teaching Ethical Analysis in Environmental Management Decisions: A Process-Oriented Approach at http://www.wheaton.edu/~/media/Files/Academics/Departments/Biology/Van Dyke files/Teachingethical.pdf
- The EPA provides support for teachers that are teaching about climate change. To address student misconceptions regarding this issue, it is important to use realtime data and research, which can be found through the EPA at http://www.epa.gov/students/teachers.html#epaclimate
- Misconceptions regarding all aspects of environmental science must be addressed through scientific data analysis, investigation and research. Discussing the conclusions and findings through a professional "gallery walk" can be a very useful way to determine possible misconceptions that exist for the class and address them. Carleton College offers a gallery walk website at http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html

ENV.ER.2- Air and Air pollution

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ENV.ER.3- Water and Water Pollution

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- The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies and other scientific agencies. Resources are searchable by grade level and standards at http://www.dlese.org/lib/index.html
- NOAA provides real-time data for many of its projects and research missions at http://www.noaa.gov/sciencemissions/bpoilspill.html
- The Ohio Environmental Protection Agency's' Project WET program offers training and resources for K-12 teachers that promote deep understanding about all aspects of water and the interconnectedness of all of Earth's spheres (Earth Systems). Training and workshop opportunities can be found at http://epa.ohio.gov/oeef/ProjectWET.aspx
- Project WET's Healthy Water, Healthy People water quality educators guide offers ideas and resources for teaching all aspects of water and water contamination issues. Ideas for field monitoring, research projects and student investigations as well as teacher training are available at http://epa.ohio.gov/oeef/ProjectWET.aspx
- Wiki Watershed allows students to make computer-simulated model changes within their own watershed. Students can make changes to their hometown landscape by developing land and paving areas, then see how this changes natural waterflow. https://wikiwatershed.org/
- The Ohio EPA's air quality database can be used to explore comparison between different areas of Ohio, including your own community, found here: http://www.epa.ohio.gov/dapc/airohio/index.aspx
- Project Learning Tree helps students learn basic concepts about trees and forest ecosystems and the kinds of ecological services they provide. The activity guides are available to educators when they attend a workshop (either in person or online). Information about upcoming workshops are available on the ODNR Division of Forestry website at http://forestry.ohiodnr.gov/plt. Specific information about high school level curriculum modules is available at https://www.plt.org/curriculum-offerings/high-school/
  - The PLT activity *Forest to Faucet* in the Focus on Forests Secondary Module students will identify local watersheds and their forest cover, will analyze a specific watershed in Maine (adaptable to Ohio), and will evaluate the extent to which their own community's water supply is affected by forests and forest management.
- The Association of Fish and Wildlife Agencies has a Conservation Toolkit that includes guides on conducting field investigations with students, schoolyard habitat investigations, technology for field investigations, and more. https://www.fishwildlife.org/afwa-informs/ce-strategy/north-american-conservation-education-strategy
- ODNR-Division of Wildlife's WILD School Sites program provides resources, grants, and workshops to help schools create habitat projects on their school grounds. http://wildlife.ohiodnr.gov/education-and-outdoor-discovery/conservation-education-project-wild#tabr4
- The NSTA offers a position paper which is helpful in addressing concerns and misconceptions from students regarding evolution at http://www.nsta.org/about/positions/evolution.aspx
- Students may have difficulty separating science from non-science factors as they relate to the different parts of the environment. It is important to distinguish "what is science" and therefore, what will be included in an environmental science class, especially as it relates to climate change and evolution. Identifying and understanding personal bias and ethical issues are an important step in recognizing science. Wheaton College offers Teaching Ethical Analysis in Environmental Management Decisions: A Process-Oriented Approach at http://www.wheaton.edu/~/media/Files/Academics/Departments/Biology/Van Dyke files/Teachingethical.pdf
- The EPA provides support for teachers that are teaching about climate change. To address student misconceptions regarding this issue, it is important to use realtime data and research, which can be found through the EPA at http://www.epa.gov/students/teachers.html#epaclimate
- Misconceptions regarding all aspects of environmental science must be addressed through scientific data analysis, investigation and research. Discussing the conclusions and findings through a professional "gallery walk" can be a very useful way to determine possible misconceptions that exist for the class and address them. Carleton College offers a gallery walk website at http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html

ENV.ER.4- Soil and land

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- Your county's Soil and Water Conservation District can offer a wealth of advice and resources, and can often supply models and even classroom visits. Get your local office's contact information through this web tool: http://www.agri.ohio.gov/divs/SWC/SearchLocalSWCD.aspx
- The United StatesDepartment of Agriculture has soil type data throughout Ohio, with considerations for human use, through the use of an interactive mapping webtool found here: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
- The College Board provides enduring understandings recommended for AP environmental science, which can help to form discussion questions and research for this topic at https://apcentral.collegeboard.org/ap-2019 Appendix A (page 175) of this document contains the environmental science information.
- The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies and other scientific agencies. Resources are searchable by grade level and standards at http://www.dlese.org/lib/index.html
- Project Learning Tree helps students learn basic concepts about trees and forest ecosystems and the kinds of ecological services they provide. The activity guides are available to educators when they attend a workshop (either in person or online). Information about upcoming workshops are available on the ODNR Division of Forestry website at http://forestry.ohiodnr.gov/plt. Specific information about high school level curriculum modules is available at https://www.plt.org/curriculum-offerings/high-school/
    - In the PLT activity *Seeking Sustainability: A Global Response* in the Forests of the World Secondary Module, students explore how forests and timber is being managed sustainably locally and globally.
- The NSTA offers a position paper which is helpful in addressing concerns and misconceptions from students regarding evolution at http://www.nsta.org/about/positions/evolution.aspx
- Students may have difficulty separating science from non-science factors as they relate to the different parts of the environment. It is important to distinguish "what is science" and therefore, what will be included in an environmental science class, especially as it relates to climate change and evolution. Identifying and understanding personal bias and ethical issues are an important step in recognizing science. Wheaton College offers Teaching Ethical Analysis in Environmental Management Decisions: A Process-Oriented Approach at http://www.wheaton.edu/~/media/Files/Academics/Departments/Biology/Van Dyke files/Teachingethical.pdf
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ENV.ER.5- Wildlife and Wilderness

- The College Board provides enduring understandings recommended for AP environmental science, which can help to form discussion questions and research for this topic at https://apcentral.collegeboard.org/ap-2019 Appendix A (page 175) of this document contains the environmental science information.
- The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies and other scientific agencies. Resources are searchable by grade level and standards at http://www.dlese.org/lib/index.html
- Invasive plant species information can be found at the ODNR
- Project WILD helps students learn basic concepts about wildlife, their habitat needs and importance, and their relationships to people and the environment. The activity guides are available to educators free of charge when they attend a workshop. Information about upcoming workshops are available on the ODNR Website at http://wildlife.ohiodnr.gov/education-and-outdoor-discovery/conservation-education-project-wild
    - The activity *Hazardous Links, Possible Solutions* can effectively introduce the concepts of bioaccumulation and biomagnification within a food web.
    - The activity *Birds of Prey* students interpret a graph of animal populations, noting changes over time; hypothesize the relationship among temperature, ground squirrel behavior, and falcon populations; and describe the importance of interdependence to the functioning of an ecosystem.

  - The activity *Back from the Brink* students will explain the reasons for the decline of certain wildlife species and describe methods used in species recovery, describe the effects of the decline and recovery of wildlife on people and the environment, analyze issues surrounding the decline and recovery of wildlife species and examine strategies to resolve those issues, and describe the importance of an environmentally literate citizen base to the success of the recovery project.
- The Association of Fish and Wildlife Agencies has a Conservation Toolkit that includes guides on conducting field investigations with students, schoolyard habitat investigations, technology for field investigations, and more. https://www.fishwildlife.org/afwa-informs/ce-strategy/north-american-conservation-education-strategy
- Project Learning Tree helps students learn basic concepts about trees and forest ecosystems and the kinds of ecological services they provide. The activity guides are available to educators when they attend a workshop (either in person or online). Information about upcoming workshops are available on the ODNR Division of Forestry website at http://forestry.ohiodnr.gov/plt. Specific information about high school level curriculum modules is available at https://www.plt.org/curriculum-offerings/high-school/
  - In the PLT activity *Monitoring Forest Health* in the Focus on Forest Secondary Module, students conduct a forest health checkup of a local forest area, will take forestry measurements, and will evaluate the ecological services provided by trees and forests. Data may be collected for a longitudinal study.
  - In the PLT activity *Forest Invaders* in the Focus on Forest Secondary Module, students consider what makes invasive species a problem for forest ecosystems, will work in teams to present different methods of controlling an invasive species, and will conduct research to find out how invasive species may affect their local forest.
- The NSTA offers a position paper which is helpful in addressing concerns and misconceptions from students regarding evolution at http://www.nsta.org/about/positions/evolution.aspx
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GLOBAL ENVIRONMENTAL PROBLEM AND ISSUES

This topic is a culminating section that incorporates the previous topics and applies them to a global or international scale. Case studies, developing and using models, collecting and analyzing water and/or air quality data, conducting or researching population studies and methods of connecting to the real world must be emphasized for this topic. Technology can be used for comparative studies to share local data internationally so that specific, quantifiable data can be compared and used in understanding the impact of some of the environmental problems that exist on a global scale. Researching and investigating environmental factors on a global level contributes to the depth of understanding by applying the environmental science concepts to problem solving and design. Examples of global topics that can be explored include building water or air filtration models, investigating climate change data, monitoring endangered or invasive species, and studying the environmental effects of increasing human population. Researching contemporary discoveries, new technology and new discoveries can lead to improvement in environmental management.

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Ohio Learning Standard	*Complexity a*	*Complexity b*	*Complexity c*	*NGSS Alignment*
Generic	Most Complex ⟷		Least Complex	
Global Environment Problems and Issues				
ENV.GP.1 Human population	**ENV.GP.1a** Describe how the size of the human population can have harmful effects on the environment.	**ENV.GP.1b** Identify how the human population has changed over time.	**ENV.GP.1c** Recognize that humans can change their environment globally.	HS-ESS3-5 Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems. HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. HS-LS4-6 Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
ENV.GP.2 Potable water quality, use, and availability	**ENV.GP.1a** Describe a way to preserve potable water on Earth.	**ENV.GP.1b** Identify a way humans have changed the global water quality.	**ENV.GP.1c** Identify a fresh water source.	
ENV.GP.3 Climate change	**ENV.GP.3a** Describe a way to preserve our global climates.	**ENV.GP.3b** Identify a possible factor of climate change.	**ENV.GP.3c** Recognize the characteristics of a climate change (e.g., melting glaciers).	
ENV.GP.4 Sustainability	**ENV.GP.4a** Explain how resources can be sustained to reduce the impact on Earth (e.g., planting new trees after chopping down others).	**ENV.GP.4b** Identify a resource that should be sustained to positively affect Earth.	**ENV.GP.4c** Sort resources into renewable or non-renewable categories.	
ENV.GP.5 Species depletion and extinction	**ENV.GP.4a** Describe why species extinction is harmful to Earth.	**ENV.GP.4b** Identify the cause of a species extinction.	**ENV.GP.4c** Identify a species that has become extinct.	
ENV.GP.6 Air quality	**ENV.GP.6a** Describe the effect of air quality on humans.	**ENV.GP.6b** Describe the effect of a pollutant on air quality.	**ENV.GP.6c** Identify a type of air pollution.	
ENV.GP.7 Food production and availability	**ENV.GP.7a** Describe how a factor could limit the availability of food.	**ENV.GP.7b** Describe a factor that can affect food production (e.g., early frost, drought, etc.).	**ENV.GP.7c** Identify oane food production method (e.g., farming, manufacturing).	

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ENV.GP.8 Deforestation and loss of biodiversity	**ENV.GP.8a** Identify an effect of deforestation on an ecosystem.	**ENV.GP.8b** Describe the importance of a forest ecosystem.	**ENV.GP.8c** Recognize that having many different organisms in an ecosystem generally leads to a healthier ecosystem.	
ENV.GP.9 Waste management (solid and hazardous)	**ENV.GP.9a** Describe a way to reduce solid and hazardous waste.	**ENV.GP.9b** Describe an effect of waste on the environment.	**ENV.GP.9c** Sort types of waste into solid or hazardous waste.	

EVIDENCE OF LEARNING
Students who demonstrate understanding can:

This section provides examples of tasks that students may perform to show evidence of learning. These can be used for guidance in developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas. It is divided into Cognitive Demands: **Recall** (Bloom's Remembering, Webb's DOK 1), **Interpreting and Communicating** (Bloom's Applying and Understanding, Webb's DOK 2), **Demonstrating** (Bloom's Analyzing and Evaluating, Webb's DOK 3) and **Designing** (Bloom's Create, Webb's DOK 4).

	Designing technological / engineering solutions using science concepts (T)	**Demonstrating science knowledge (D)**	**Interpreting and communicating science concepts (C)**	**Recalling accurate science (R)**
ENV.GP.1- Human population				
	Working in teams, students can work together as a planning committee to develop a parcel of undeveloped rural land or to revitalize an urban neighborhood that had been blighted. Solutions must address housing, transportation, business and industrial, green space and recreation land uses as well as food, water, waste and energy systems. Teams will present their solutions to the	Plan and implement a population study of a specific area (over a period of time) or critique/analyze an existing population study. Document changes in weather, food availability and any change to the population. Prepare a scientific analysis and conclusion (in writing) for the study.	Interpret population demographic curves/graphs/pyramids (from US Census Bureau or the UN Census) and discuss differences in population growth rates among several different countries (developing vs developed).	Students can perform a simulation using beans/beads to demonstrate population doubling time over the course of 10 generations. Students can then graph their results to illustrate exponential growth.

	class via a gallery walk. Extension could limit funds available, and then require planning committees must choose just one solution.			
	Students create their own survey tool to investigate and predict fertility rates within their home community and extrapolate that out to the nation at large. This would be best conducted as a collaborative/interdisciplinary exercise with social sciences and mathematics.	Students can be provided a data table with birth rates, death rates, life expectancy, average income, and literacy rates of various countries (from Unicef) to develop a plan that could contribute to a change in the fertility and death rates.	Relative to resource availability and rates of consumption, assess the scope of human population growth and potential limits to its growth (eg: Tragedy of the Commons, Hans Rosling and Gapminder Foundation)	Students can compare and contrast developing vs developed countries, and identify the factors that separate the two types of countries.
ENV.GP.2- Potable water quality, use and availability				
	Students can design a water treatment system or process that can be implemented at a low cost and without the need for electricity to be used in areas that do not have access to potable water.	Using real-time data, research the most severe environmental problems (and the root causes for the problems) that face the local community, Ohio, the United States or the world. Present evidence (quantitative data) and conclusions orally, through a poster session or in written form (scientific research paper).	Students will investigate the their local water source and test for contaminants in comparison to the released water quality reports. If school/community has surface water one may study the relationship of distance from water distribution facilities and the amount of chlorine in their drinking water. Students will examine the water quality report from their municipality to determine the health of their water. (Disinfection By Products-DPS's breakdown	Students investigate the source of various 'bottled water'. For example *Dasani* comes from the City Of Akron's water supply. Record each water source on a map.

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			over time and are harmful- DBPs are often a result of the breaking down of chlorine which is added to surface water)	
	Design and build an irrigation system using household materials that will move 400mL of water 1 meter and deliver it to only 2 containers.	"Your water footprint" Conduct a water survey in your home/school. How much water do you use on a daily basis and how much does it cost? Identify areas where water can be saved.	Investigate sources of drinking water pollutants and design a plan to lower/restrict/prevent those pollutants.	Define potable water and identify the largest sources in the world in comparison to access.
ENV.GP.3- Climate Change				
	Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems	Choose a specific location in the United States. Research and analyze the patterns of climate change throughout the geologic record, historic data (human records) and present-day data for the location. Be able to explain the interpretation and analysis of the data. Create a graphical representation of the pattern and discuss with the class.	Students will research monthly average precipitation data in different areas to strengthen conclusions about periods of drought or abnormal rainfall as they relate to climate change.	Students can compare the effects of El Nino and La Nina at two different longitudinal locations, but at the same latitude, using sea surface temperature and precipitation from real satellite data.
	Research and examine the current political/social feelings on climate change and prepare a debate for the national stage to convince the federal government to spend money on research. Students must prepare for both sides of the debate.	Investigate and research the effect that climate change is having or has had on a specific living or extinct species, such as the harp seal or elkhorn coral, or on an ecosystem, such as the Great Barrier Reef or the Arctic Circle. Additionally, investigate the history of local habitats exploring change, particularly the Great Lakes.	Create a timeline of climate science and policy initiatives over the past two centuries in developing and non-developing countries. Students must include global data-and compare different nations.	Students will interpret historical carbon dioxide concentration data and compare to historical global temperature data in order to determine if there is a correlation.

ENV.GP.4- Sustainability				
	Students are charged with the challenge to redesign a city/village/town to be more sustainable. Divide groups to look at concepts such as waste treatment, water resources, pollution, transportation, energy resources, and maintaining biodiversity. Groups will share out and critique the recommendations to make a final proposal for the city/village/town.	Students research and design a sustainable home in regards to energy efficiency, using resources mindfully, alternative transportation, diet, and outdoor space(s). Students can present designs orally, through a model, or in written form.	Students will create a pie chart graph displaying the breakdown of components of their ecological footprint (ex: shelter, food, energy, transportation), and construct a plan to reduce their carbon footprint.	Using an online ecological footprint calculator, students (ex: Earth Day Network), students can calculate how many Earth's it would take to sustain their lifestyle.
			Expanding on the Tragedy of the Commons simulation activity, students can list and explain potential strategies to prevent the destruction of the common resource.	Students can perform a simulation allowing them to explore the Tragedy of the Commons (common usage of limited resource inevitably leads to exploitation).
ENV.GP.5- Species depletion and extinction				
	Investigate and research the effect that climate change is having or has had on a specific living or extinct species, such as the harp seal or elkhorn coral, or on an ecosystem, such as the Great Barrier Reef or the Arctic Circle. Determine future outcomes if nothing is done to address climate change.	Plan and implement an investigation to explore biomagnification or bioaccumulation within a specific Ohio ecosystem (existing public case studies can be used, such as a local Brownfields case – see resource listed below). Document the steps and process to collect or research, evaluate or test and analyze the data. Research should include the possible impact to humans. Present the process and results to the class verbally or in writing.	Analyze a conservation case study (ex: osprey, bald eagle, black bears in Ohio) and write an analysis and a recommendation for solutions.	Create an Infographic on an endangered species (could be just in Ohio, or the United States, or globally), including information on the organism's ecosystem and its role within the ecosystem, its value (ecologically and commercially), reasons for endangerment, and possible solutions or interventions.
	Using phenological protocols, collect information on the local	Research or conduct a field investigation for a specific invasive	The National Audubon Society has been collecting data on	Research the requirements for listing a species as a species of

	plants and wildlife as the seasons progress and contribute and track for comparison from year to year, and location to location. Identify trends in phenological changes and design solutions to local climate impacts.	species that is present in the local community or in Ohio. Examples of research questions include: How did the organism get into Ohio? What is being done to control the spread of the species? What is the impact of the species on the native population? Use quantifiable data to draw conclusions and present research results in writing or orally	avian population and movements for over a century, through the annual Christmas Bird Count. Download a dataset of the history of birds for your locality, and have students choose a species represented in the count. Have each student present on the population status of their species, then as a class, discuss overall trends.	concern, threatened, or endangered. Have each student identify a species on either of these lists, and research its life history, specifically the impacts leading to its decline. Share and discuss.
ENV.GP.6- Air Quality				
	Design and construct a scrubber for cleaning the sulfur emissions from burning coal. Students can assess how well their scrubbers works by collecting calcium sulfate or sulfite, and checking the amount against the known sample of sulfur content.	Using real-time data, research air pollution issues (and the root causes for the problems) that face the local community, Ohio, the United States or the world. Present evidence (quantitative data) and conclusions orally, through a poster session or in written form (scientific research paper).	Complete a lab activity demonstrating the effects of acid rain (with a range of pH) on seed sprouting.	Illustrate the process of how acid rain is created and describe its effects on each component of the environment.
	Generate a plan to improve the air quality in your school/community. Use real data from the EPA.	Students can complete a case study on a fictitious city that has historically experienced air pollution (teachers can utilize data/information on air quality from: Donora, Pittsburgh, Delhi, Kolkata, Beijing). Students will analyze the situation and identify issues/actions described in the case which may be problematic.	Conduct a lab determining the concentration of tropospheric ozone in various locations outside of school, and compare results to determine the cause(s) for the difference in concentration.	Identify indoor/human-made pollutants and explain their impacts.
	ENV.GP.7- Food Production and availability			
	Design and conduct an LD50 laboratory experiment to	Research and analyze quantifiable scientific data pertaining to food	Research and write a persuasive essay on	Construct an energy pyramid (with a human at the top) and

	determine whether or not a fertilizer or pesticide is toxic to an organism such as brine shrimp or radish seeds.	availability, reproductive requirements and changes, adaptations or population changes to draw conclusions. Students present data and conclusions to the class.	Genetically Modified Organisms used in agriculture.	defend the position that eating lower on the food chain is better for the environment.
	Construct a plan for a sustainable garden that could provide food for your school/community. Share your plan with stakeholders	Research availability of fresh food in your community- is your community a food dessert? (if not find the closest community which is) Write a proposal to the local government to provide that community with better food resources.	Research food production in developing and underdeveloped nations, compare land use vs. crop yield. Present your findings.	Using the National Geographic website What the World Eats, students can explore and compare the pie graphs to determine which country consumes the most/least daily calories, the most/least grains, the most/least meat, etc.
ENV.GP.8- Deforestation and loss of biodiversity				
	Students write a proposal for the state setting limits/regulations for housing/commercial development. Students must consider Federal Laws.	Students design a community of the future that demonstrates responsible practices for preservation of biodiversity and forested areas.	Students can use satellite mapping resources to investigate the connection between urbanization, population growth and deforestation (NASA Forest Changes in Rondonia Brazil).	Students identify areas where urban sprawl has impacted their community.
	Students can develop a PSA on commercial products that contribute to deforestation (ex: palm oil), and how deforestation contributes to the loss of biodiversity.	Engage in a classroom debate on the rationale and methods to reduce the deer population in an Ohio community.	Using either simulations or actual collection, students collect and sample from various locations on school grounds to examine biodiversity and determine the health of an ecosystem.	Complete a graphic organizer on various tree harvesting practices (clear cutting, seed tree cutting, selective cutting, slash & burn), including a description on each with advantages and disadvantages (economic and ecological).

ENV.GP.9- Waste Management (solid and hazardous)				
	Develop a risk assessment for a specific company. Research one particular toxin or hazardous chemical used by the company (e.g., diesel fuel) to determine possible risks and pathways to the environment and humans. The assessment should include: nature of the toxin/chemical (e.g., is the material flammable, does is react when wet), on-site use and handling (including existing safety practices) of the toxin/chemical, by-products (e.g., vapors or dilution processes), storage, transportation of the toxin/chemical, required documentation, emergency plans/ guidelines, topography and geology of the area. Use a computer-modeling program (many are available through freeware sites) to model and predict the movement of the possible pathways of the toxin/chemical and recommendations of methods to contain the release of the toxin/chemical. Present the findings to the class or an authentic audience.	Plan and implement an investigation to explore human health issues related to the disposal of hazardous waste materials (biomagnification or bioaccumulation within a specific Ohio ecosystem, existing public case studies can be used, such as a local Brownfields case). Document the steps and process to collect or research, evaluate or test and analyze the data. Research should include the possible impact to humans. Present the process and results to the class verbally or in writing.	Students can conduct a landfill decomposition study over an 8 week period to determine the rate at which typical materials found in landfills decompose.	Students can document the amount of waste they produce throughout a 24 hr period, and identify the materials that are non-recyclable and recyclable. Students can then describe the benefits of recycling (ex: saves landfill space, saves money, saves energy, saves natural resources, reduces air and water pollution).
	Construct and maintain a composting site on school grounds after researching methods and procedures to manage a healthy compost bin. Students can conduct	Using real-time data, research the most severe waste management issues (and the root causes for the problems) that face the local community, Ohio, the United States or the world. Present evidence	Collect research information on various waste management types, and specifically compare and contrast the practices of waste management of developed and developing	Students can draw a diagram of a modern landfill, and label the various components that are required or used in landfills today to prevent them from polluting the air and water.

	population sampling on insects that may be involved in the degradation process.	(quantitative data) and conclusions orally, through a poster session or in written form (scientific research paper).	nations. Compare methods of at least two different nations and identify the best practices.	

Resources

ENV.GP.1- Human population

- The College Board provides enduring understandings recommended for AP environmental science, which can help to form discussion questions and research for this topic at https://apcentral.collegeboard.org/ap-2019 Appendix A (page 175) of this document contains the environmental science information.
- The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies and other scientific agencies. Resources are searchable by grade level and standards at http://www.dlese.org/lib/index.html
- NOAA provides real-time data for many of its projects and research missions at http://www.noaa.gov/sciencemissions/bpoilspill.html
- The world of 7 Billion has resources for a variety of human population topics at different learning levels. This site is run by Population Education. https://www.worldof7billion.org/teacher-resources/high-school-activities/ You can find Population Education at this site http://populationeducation.org/
- The Census Bureau provides real time data for both the United States and the World. The site can be accessed at https://www.census.gov/popclock/ In addition, there are many map and graph resources that can be used.

- Students may have misinformation and misconceptions that pertain to climate change. To address this, it is important to provide evidence of climate change throughout Earth's history and current data to document temperature changes (surface and oceanic). Data and other resources to help with teaching climate change can be found at http://www.epa.gov/climatechange/index.html
- Misconceptions regarding all aspects of environmental science must be addressed through scientific data analysis, investigation and research. Discussing the conclusions and findings through a professional "gallery walk" can be a very useful way to determine possible misconceptions that exist for the class and address them. Carleton College offers a gallery walk website at http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html

ENV.GP.2- Potable water quality, use and availability

- The College Board provides enduring understandings recommended for AP environmental science, which can help to form discussion questions and research for this topic at https://apcentral.collegeboard.org/ap-2019 Appendix A (page 175) of this document contains the environmental science information.
- The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies and other scientific agencies. Resources are searchable by grade level and standards at http://www.dlese.org/lib/index.html
- NOAA provides real-time data for many of its projects and research missions at http://www.noaa.gov/sciencemissions/bpoilspill.html
- The Ohio Environmental Protection Agency's' Project Wet program offers training and resources for K-12 teachers that promote deep understanding about all aspects of water and the interconnectedness of all of Earth's spheres (Earth Systems). Training and workshop opportunities can be found at http://epa.ohio.gov/oeef/ProjectWET.aspx

- Project Wet's Healthy Water, Healthy People water quality educators guide offers ideas and resources for teaching all aspects of water and water contamination issues. Ideas for field monitoring, research projects and student investigations as well as teacher training are available at http://epa.ohio.gov/oeef/ProjectWET.aspx
- Take a field trip to visit the water treatment facility or watch the drilling of a water well. Document observations, including information about how water is treated prior to and after use, specific issues that may impact the source, the location of the original water source, specific tests conducted (materials and methods needed to test and how the tests are conducted, results of the tests), and the steps taken to monitor the water at the source and throughout the process (including from the facility/well into the residence). Discuss with the class.
- The U. S. National Library of Medicine provides data information, articles for drinking water. https://medlineplus.gov/drinkingwater.html
- Students may have misinformation and misconceptions that pertain to climate change. To address this, it is important to provide evidence of climate change throughout Earth's history and current data to document temperature changes (surface and oceanic). Data and other resources to help with teaching climate change can be found at http://www.epa.gov/climatechange/index.html
- Misconceptions regarding all aspects of environmental science must be addressed through scientific data analysis, investigation and research. Discussing the conclusions and findings through a professional "gallery walk" can be a very useful way to determine possible misconceptions that exist for the class and address them. Carleton College offers a gallery walk website at http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html
- The EPA provides many resources including activities for drinking water activities https://www.epa.gov/ground-water-and-drinking-water/drinking-water-activities-students-and-teachers

ENV.GP.3- Climate Change

- The College Board provides enduring understandings recommended for AP environmental science, which can help to form discussion questions and research for this topic at https://apcentral.collegeboard.org/ap-2019 Appendix A (page 175) of this document contains the environmental science information.
- The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies and other scientific agencies. Resources are searchable by grade level and standards at http://www.dlese.org/lib/index.html
- Nasa resources provide data maps including sea surface temperature, snow-ice temperature along with corresponding lesson ideas. https://mynasadata.larc.nasa.gov/lesson-plans/climate-change-lessons/
- Project Learning Tree helps students learn basic concepts about trees and forest ecosystems and the kinds of ecological services they provide. The activity guides are available to educators when they attend a workshop (either in person or online). Information about upcoming workshops are available on the ODNR Division of Forestry website at http://forestry.ohiodnr.gov/plt. Specific information about high school level curriculum modules is available at https://www.plt.org/curriculum-offerings/high-school/
    - The PLT activity *Climate Change and Forests* in the Focus on Forests Secondary Module students use a carbon footprint calculator to analyze their personal effect on carbon dioxide (CO_2) levels in the atmosphere, will calculate the amount of carbon stored in a single tree, and will explore how carbon sequestration can affect CO_2 levels.
- Students may have misinformation and misconceptions that pertain to climate change. To address this, it is important to provide evidence of climate change throughout Earth's history and current data to document temperature changes (surface and oceanic). Data and other resources to help with teaching climate change can be found at http://www.epa.gov/climatechange/index.html
- The Ohio Sea Grant's climate change activity through evidence seen in the Great Lakes can be found here: http://www.cgll.org/wp-content/uploads/2017/10/2012edu_CurriculaVisualizingV6.pdf
- Misconceptions regarding all aspects of environmental science must be addressed through scientific data analysis, investigation and research. Discussing the conclusions and findings through a professional "gallery walk" can be a very useful way to determine possible

misconceptions that exist for the class and address them. Carleton College offers a gallery walk website at http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html

ENV.GP.4- Sustainability

- The College Board provides enduring understandings recommended for AP environmental science, which can help to form discussion questions and research for this topic at https://apcentral.collegeboard.org/ap-2019 Appendix A (page 175) of this document contains the environmental science information.
- The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies and other scientific agencies. Resources are searchable by grade level and standards at http://www.dlese.org/lib/index.html
- NOAA provides real-time data for many of its projects and research missions at http://www.noaa.gov/sciencemissions/bpoilspill.html
- The Ohio Environmental Protection Agency's' Project WET program offers training and resources for K-12 teachers that promote deep understanding about all aspects of water and the interconnectedness of all of Earth's spheres (Earth Systems). Training and workshop opportunities can be found at http://epa.ohio.gov/oeef/ProjectWET.aspx
- Project WET's Healthy Water, Healthy People water quality educators guide offers ideas and resources for teaching all aspects of water and water contamination issues. Ideas for field monitoring, research projects and student investigations as well as teacher training are available at http://epa.ohio.gov/oeef/ProjectWET.aspx
- Ecological footprint calculator can be found at https://www.earthday.org/take-action/footprint-calculator/
- Students may have misinformation a stand misconceptions that pertain to climate change. To address this, it is important to provide evidence of climate change throughout Earth's history and current data to document temperature changes (surface and oceanic). Data and other resources to help with teaching climate change can be found at http://www.epa.gov/climatechange/index.html
- Misconceptions regarding all aspects of environmental science must be addressed through scientific data analysis, investigation and research. Discussing the conclusions and findings through a professional "gallery walk" can be a very useful way to determine possible misconceptions that exist for the class and address them. Carleton College offers a gallery walk website at http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html

ENV.GP.5- Species depletion and extinction

- The College Board provides enduring understandings recommended for AP environmental science, which can help to form discussion questions and research for this topic at https://apcentral.collegeboard.org/ap-2019 Appendix A (page 175) of this document contains the environmental science information.
- The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies and other scientific agencies. Resources are searchable by grade level and standards at http://www.dlese.org/lib/index.html
- NOAA provides real-time data for many of its projects and research missions at http://www.noaa.gov/sciencemissions/bpoilspill.html
- The ODNR-Division of Wildlife maintains a current listing of species native to Ohio that are designated as state and federally-endangered, threatened, species of concern, and species of interest for review. This list is updated every five years. http://wildlife.ohiodnr.gov/species-and-habitats/state-listed-
- species
- The National Audubon Society's Christmas Bird Count is one of the longest Citizen Science efforts of the planet, and is employed by researchers to monitor trends. Datasets can be downloaded for classroom analysis here: http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx#

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- The USA National Phenology Network's program Nature's Notebook helps classes design phenology studies on local flora and fauna and contribute their data to the national database of phenological changes. This information is used to track the impacts of climate change on plants and animals.https://www.usanpn.org/usa-national-phenology-network
- Project Learning Tree helps students learn basic concepts about trees and forest ecosystems and the kinds of ecological services they provide. The activity guides are available to educators when they attend a workshop (either in person or online). Information about upcoming workshops are available on the ODNR Division of Forestry website at http://forestry.ohiodnr.gov/plt. Specific information about high school level curriculum modules is available at https://www.plt.org/curriculum-offerings/high-school/
    - In the PLT activity *Global Invaders* in the Secondary Module "Biodiversity" students will research invasive species in the United States and then investigate the presence and effects of invasive species in their own community.
- Misconceptions regarding all aspects of environmental science must be addressed through scientific data analysis, investigation and research. Discussing the conclusions and findings through a professional "gallery walk" can be a very useful way to determine possible misconceptions that exist for the class and address them. Carleton College offers a gallery walk website at http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html

ENV.GP.6- Air quality

- The College Board provides enduring understandings recommended for AP environmental science, which can help to form discussion questions and research for this topic at https://apcentral.collegeboard.org/ap-2019 Appendix A (page 175) of this document contains the environmental science information.
- The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies and other scientific agencies. Resources are searchable by grade level and standards at http://www.dlese.org/lib/index.html

- Students may have misinformation and misconceptions that pertain to climate change. To address this, it is important to provide evidence of climate change throughout Earth's history and current data to document temperature changes (surface and oceanic). Data and other resources to help with teaching climate change can be found at ttp://www.epa.gov/climatechange/index.html
- Misconceptions regarding all aspects of environmental science must be addressed through scientific data analysis, investigation and research. Discussing the conclusions and findings through a professional "gallery walk" can be a very useful way to determine possible misconceptions that exist for the class and address them. Carleton College offers a gallery walk website at http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html

ENV.GP.7- Food production and availability

- The College Board provides enduring understandings recommended for AP environmental science, which can help to form discussion questions and research for this topic at https://apcentral.collegeboard.org/ap-2019 Appendix A (page 175) of this document contains the environmental science information.
- The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies and other scientific agencies. Resources are searchable by grade level and standards at http://www.dlese.org/lib/index.html
- What the World Eats ttps://www.nationalgeographic.com/what-the-world-eats/
- Students may have misinformation and misconceptions that pertain to climate change. To address this, it is important to provide evidence of climate change throughout Earth's history and current data to document temperature changes (surface and oceanic). Data and other resources to help with teaching climate change can be found at ttp://www.epa.gov/climatechange/index.html

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- Food, Land, and People is a nationally-recognized curricula that helps classrooms discover the relationships between food production, land and resource use, and human populations through hands-on activities, demonstrations, and experiments, and can be downloaded here: http://www.foodlandpeople.org/
- Misconceptions regarding all aspects of environmental science must be addressed through scientific data analysis, investigation and research. Discussing the conclusions and findings through a professional "gallery walk" can be a very useful way to determine possible misconceptions that exist for the class and address them. Carleton College offers a gallery walk website at http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html

ENV.GP.8- Deforestation and loss of biodiversity

- The College Board provides enduring understandings recommended for AP environmental science, which can help to form discussion questions and research for this topic at https://apcentral.collegeboard.org/ap-2019 Appendix A (page 175) of this document contains the environmental science information.
- The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies and other scientific agencies. Resources are searchable by grade level and standards at http://www.dlese.org/lib/index.html
- Science Education Resource Center at Carleton College - Earth Labs https://serc.carleton.edu/eslabs/carbon/lab4.html
- Project WILD helps students learn basic concepts about wild animals, their needs and importance and their relationships to people and the environment. The activity guides are available to educators free of charge when they attend a workshop. Information about upcoming workshops are available on the ODNR Website at http://wildlife.ohiodnr.gov/education-and-outdoor-discovery/conservation-education-project-wild
    - In the activity *Bird Song Survey* students will identify and describe the importance of bird counting as one means of inventorying wildlife populations.
- Project Learning Tree helps students learn basic concepts about trees and forest ecosystems and the kinds of ecological services they provide. The activity guides are available to educators when they attend a workshop (either in person or online). Information about upcoming workshops are available on the ODNR Division of Forestry website at http://forestry.ohiodnr.gov/plt. Specific information about high school level curriculum modules is available at https://www.plt.org/curriculum-offerings/high-school/
    - The PLT activity *Protected Areas: Issues and Analysis* in the Secondary Module "BIodiversity" module students analyze case studies and describe some of the challenges and conflicts, students will learn about the importance to biodiversity of protected areas.
- The Association of Fish and Wildlife Agencies has a Conservation Toolkit that includes guides on conducting field investigations with students, schoolyard habitat investigations, technology for field investigations, and more. https://www.fishwildlife.org/afwa-informs/ce-strategy/north-american-conservation-education-strategy
- Students may have misinformation and misconceptions that pertain to climate change. To address this, it is important to provide evidence of climate change throughout Earth's history and current data to document temperature changes (surface and oceanic). Data and other resources to help with teaching climate change can be found at ttp://www.epa.gov/climatechange/index.html
- Misconceptions regarding all aspects of environmental science must be addressed through scientific data analysis, investigation and research. Discussing the conclusions and findings through a professional "gallery walk" can be a very useful way to determine possible misconceptions that exist for the class and address them. Carleton College offers a gallery walk website at http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html

ENV.GP.9- Waste management (solid and hazardous)

- The College Board provides enduring understandings recommended for AP environmental science, which can help to form discussion questions and research for this topic at https://apcentral.collegeboard.org/ap-2019   Appendix A (page 175) of this document contains the environmental science information.
- The Ohio Sea Grant's litter activity helps students understand the scope of impact of solid pollutants in the Great Lakes, and can be found here: http://www.cgll.org/wp-content/uploads/2017/10/beach-litter-v3.pdf
- The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies and other scientific agencies. Resources are searchable by grade level and standards at http://www.dlese.org/lib/index.html
- NOAA provides real-time data for many of its projects and research missions at http://www.noaa.gov/sciencemissions/bpoilspill.html
- The Ohio Environmental Protection Agency's' Project WET program offers training and resources for K-12 teachers that promote deep understanding about all aspects of water and the interconnectedness of all of Earth's spheres (Earth Systems). Training and workshop opportunities can be found at http://epa.ohio.gov/oeef/ProjectWET.aspx
- The Association of Fish and Wildlife Agencies has a Conservation Toolkit that includes guides on conducting field investigations with students, schoolyard habitat investigations, technology for field investigations, and more. https://www.fishwildlife.org/afwa-informs/ce-strategy/north-american-conservation-education-strategy
- Project Learning Tree helps students learn basic concepts about trees and forest ecosystems and the kinds of ecological services they provide. The activity guides are available to educators when they attend a workshop (either in person or online). Information about upcoming workshops are available on the ODNR Division of Forestry website at http://forestry.ohiodnr.gov/plt. Specific information about high school level curriculum modules is available at https://www.plt.org/curriculum-offerings/high-school/
    - The PLT activity *The Waste Stream* in the Secondary Module "Municipal Solid Waste" students develop an understanding of municipal solid waste management, its importance and the role it plays in their community. Students will be introduced to their school's solid waste management system and investigate it by collecting, analyzing, and graphing data.