TOWNSHIP OF UNION PUBLIC SCHOOLS

Honors Chemistry

Curriculum Guide 2016

Curriculum Committee

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Academic Area

Honors Chemistry

References

The following curriculum guide was adapted from the Next Generation Science Standards and the State of New Jersey Department of Education High School Chemistry Model Curriculum.

"Model Curriculum: HS Chemistry." *Model Curriculum: HS Chemistry.* State of New Jersey. 2014. Web. 26 Apr. 2016.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press. Web. 26 Apr. 2016.

Curriculum Unit Overview

Unit 1 - Structure and Properties of Matter

Unit 2b – Energy of Chemical Systems

Unit 3 - Bonding and Chemical Reactions

Unit 4 – Matter and Energy in Living Systems

Unit 5- Nuclear Chemistry

Course Proficiencies

For all units, students will understand and follow all laboratory and safety rules, understand scientific explanations, general scientific evidence through active investigations, reflection on scientific knowledge, and participate productively in science.

Unit 1: Structure and Properties of Matter

In this unit of study, students use investigations, simulations, and models to makes sense of the substructure of atoms and to provide more mechanistic explanations of the properties of substances. Chemical reactions, including rates of reactions and energy changes, can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Students are able to use the periodic table as a tool to explain and predict the properties of elements. Students are expected to communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials. The crosscutting concepts of *structure and function*, *patterns*, *energy and matter*, and *stability and change* are called out as the framework for understanding the disciplinary core ideas. Students use *developing and using models*, *planning and conducting investigations*, *using mathematical thinking*, and *constructing explanations and designing solutions*. Students are also expected to use the science and engineering practices to demonstrate proficiency with the core ideas.
HS-PS1-1, HS-PS1-2, HS-PS1-3, HS-PS2-6, HS-ETS1-3, and HS-ETS1-4.

Unit 2B: Energy of Chemical Systems

In Energy of Chemical Systems, students will understand energy as a quantitative property of a system—a property that depends on the motion and interactions of matter and radiation within that system. They will also understand that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Students develop an understanding that energy, at both the macroscopic and the atomic scales, can be accounted for as motions of particles or as energy associated with the configurations (relative positions) of particles.

Students can examine the ways that human activities cause feedback that create changes to other systems. Students are expected to demonstrate proficiency in *developing and using models*, *planning and carrying out investigations*, *analyzing and interpreting data, engaging in argument from evidence*, and using these practices to demonstrate understanding of core ideas.
HS-PS3-4.

Unit 3: Bonding and Chemical Reactions

In this unit of study, students *develop and using models*, *plan and conduct investigations, use mathematical thinking*, and *construct explanations and design solutions* as they develop an understanding of the substructure of atoms and to provide more mechanistic explanations of the properties of substances. Chemical reactions, including rates of reactions and energy changes, can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Students also apply an understanding of the process of *optimization and engineering design* to chemical reaction systems. The crosscutting concepts of *patterns, energy and matter*, and *stability and change* are the organizing concepts for these disciplinary core ideas. Students are expected to demonstrate proficiency in *developing and using models*, *planning and conducting investigations*, *using mathematical thinking*, and *constructing explanations and designing solutions.*
HS-PS1-7, HS-PS1-4, HS-PS1-5, HS-PS1-6, and HS-ETS1-2.

Unit 4: Matter and Energy in Living Systems

In this unit of study, students construct explanations for the role of energy in the cycling of matter in organisms. They apply mathematical concepts to develop evidence to support explanations of the interactions of photosynthesis and cellular respiration and develop models to communicate these explanations. The crosscutting concept of *matter and energy* provides students with insights into the structures and processes of organisms. Students are expected to *develop and use models*, *plan and conduct investigations*, *use mathematical thinking*, and *construct explanations and design solutions* as they demonstrate proficiency with the disciplinary core ideas.
HS-LS1-7 and HS-LS1-6.

Unit 5: Nuclear Chemistry

In this unit of study, energy and matter are studied further by investigating the processes of nuclear fusion and fission that govern the formation, evolution, and workings of the solar system in the universe. Some concepts studied are fundamental to science and demonstrate *scale, proportion, and quantity*, such as understanding how the matter of the world formed during the Big Bang and within the cores of stars over the cycle of their lives.

In addition, an important aspect of Earth and space sciences involves understanding the concept *of stability and change* while making inferences about events in Earth's history based on a data record that is increasingly incomplete the farther one goes back in time. A mathematical analysis of radiometric dating is used to comprehend how absolute ages are obtained for the geologic record.

The crosscutting concepts of *energy and matter*; *scale, proportion, and quantity*; and *stability and change* are called out as organizing concepts for this unit. Students are expected to demonstrate proficiency in *developing and using models*; *constructing explanations and designing solutions; using mathematical and computational thinking; and obtaining, evaluating, and communicating information*; and they are expected to use these practices to demonstrate understanding of the core ideas.

HS-PS1-8, HS-ESS1-3, HS-ESS1-1, HS-ESS1-2, and HS-ESS1-6

Course Description

This course is specifically designed for the science oriented students and those students who are contemplating the attending of a four-year college upon graduating from high school. Chemistry is a scientific discipline which is important to students because it teaches them to think abstractly, to solve mathematical problems, and to learn applicable scientific concepts necessary for success in our modern world.

Recommended Textbooks

Modern Chemistry: Holt

Unit 1 – Summary: Structure and Properties of Matter
How can the substructures of atoms explain the observable properties of substances?   In this unit of study, students use investigations, simulations, and models to makes sense of the substructure of atoms and to provide more mechanistic explanations of the properties of substances. Chemical reactions, including rates of reactions and energy changes, can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Students are able to use the periodic table as a tool to explain and predict the properties of elements. Students are expected to communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials. The crosscutting concepts of *structure and function*, *patterns*, *energy and matter*, and *stability and change* are called out as the framework for understanding the disciplinary core ideas. Students use *developing and using models*, *planning and conducting investigations*, *using mathematical thinking*, and *constructing explanations and designing solutions*. Students are also expected to use the science and engineering practices to demonstrate proficiency with the core ideas.
Student Learning Objectives
Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. *[Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.]* **(HS-PS1-1)**
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. *[Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.]* [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.] **(HS-PS1-2)**
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. *[Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite).* Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] *[Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.]* **(HS-PS1-3)**
Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* *[Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.]* [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.] **(HS-PS2-6)**
Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.(HS-ETS1-3)
Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions

within and between systems relevant to the problem. (HS-ETS1-4)

Part A: *How can a periodic table tell me about the subatomic structure of a substance?*	
Concepts	**Formative Assessment**
• Different patterns may be observed at each of the scales at which a system is studied, and these patterns can provide evidence for causality in explanations of phenomena. • Each atom has a charged substructure. • An atom's nucleus is made of protons and neutrons and is surrounded by electrons. • The periodic table orders elements horizontally by number of protons in the nucleus of each element's atoms and places elements with similar chemical properties in columns. • The repeating patterns of this table reflect patterns of outer electron states. • Patterns of electrons in the outermost energy level of atoms can provide evidence for the relative properties of elements at different scales. • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	*Students who understand the concepts are able to:* • Use the periodic table as a model to provide evidence for relative properties of elements at different scales based on the patterns of electrons in the outermost energy level of atoms in main group elements. • Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms in main group elements.

Part B: *How can I use the periodic table to predict if I need to duck before mixing two elements?*	
Concepts	**Formative Assessment**
• The periodic table orders elements horizontally by number of protons in the nucleus of each element's atoms and places elements with similar chemical properties in columns. • The repeating patterns of the periodic table reflect patterns of outer electron states. • The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. • Different patterns may be observed at each of the scales at which a system	*Students who understand the concepts are able to:* • Use valid and reliable evidence (obtained from students' own investigations, models, theories, simulations, and peer review) showing the outermost electron states of atoms, trends in the periodic table, and patterns of chemical properties to construct and revise an explanation for the outcome of a simple chemical reaction. • Use the assumption that theories and laws that describe the outcome of simple chemical reactions operate today as they did in the past and will continue to do so in the future.

is studied, and these patterns can provide evidence for causality in explanations of phenomena.	• Observe patterns in the outermost electron states of atoms, trends in the periodic table, and chemical properties. • Use the conservation of atoms and the chemical properties of the elements involved to describe and predict the outcome of a chemical reaction.

Part C: *How can I use the properties of something (in bulk quantities) to predict what is happening with the subatomic particles?*

Concepts	Formative Assessment
• The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.	*Students who understand the concepts are able to:* • Plan and conduct an investigation individually and collaboratively to produce data that can serve as the basis for evidence for comparing the structure of substances at the bulk scale to infer the strength of electrical forces between particles. In the investigation design, decide on types, how much, and accuracy of data needed to produce reliable measurements; consider limitations on the precision of the data (e.g., number of trials, cost, risk, time); and refine the design accordingly. • Use patterns in the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

Part D: I want to do the right thing, what is the greener choice for *grocery bags (paper or plastic/reusable vs. disposable); cold drink containers (plastic, glass, or aluminum); or hot drink containers (paper, Styrofoam, or ceramic)? [Clarification: Students should have the opportunity to select the product and use the Life Cycle Analysis (LCA) to make an evidence-based claim.]*

Concepts	Formative Assessment
• The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, aesthetics, and to consider social, cultural, and environmental impacts. • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of	*Students who understand the concepts are able to:* • Communicate scientific and technical information about why the molecular -level structure is important in the functioning of designed materials. • Evaluate a solution to a complex real-world problem based on scientific knowledge, student generated sources of evidence, prioritized criteria, and tradeoffs considerations to determine why the molecular level structure is important in the functioning of designed materials. • Use mathematical models and/or computer simulations to show why the molecular level structure is important in the functioning of designed materials.

purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. • Models (e.g., physical, mathematical, computer models) can be used to simulate why the molecular-level structure is important in the functioning of designed materials.	• Communicate scientific and technical information about the attractive and repulsive forces that determine the functioning of the material. • Use mathematical models and/or computer simulations to show the attractive and repulsive forces that determine the functioning of the material. • Examine in detail the properties of designed materials, the structure of the components of designed materials, and the connections of the components to reveal the function. • Use models (e.g., physical, mathematical, computer models) to simulate systems of designed materials and interactions--including energy, matter, and information flows--within and between designed materials at different scales.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Translate information from the periodic table about the patterns of electrons in the outermost energy level of atoms into words that describe the relative properties of elements.
- Write 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 of elements using well-chosen, relevant, and sufficient facts; extended definitions; and concrete details from students' own investigations, models, theories, simulations, and peer review.
- Develop and strengthen explanations for the outcome of a simple chemical reaction by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties of elements.
- Draw evidence from informational texts about the outermost electron states of atoms, trends in the periodic table, and patterns of chemical properties of elements to construct a rigorous explanation of the outcome of a simple chemical reaction.
- Cite specific textual evidence comparing the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
    - Conduct short as well as more sustained research projects to compare the structure of substances at the bulk scale and use this research to infer the strength of electrical forces between particles.
    - Gather applicable information from multiple reliable sources to support the claim that electrical forces between particles can be used to explain the structure of substances at the bulk scale.
    - Develop evidence comparing the structure of substances at the bulk scale and the strength of electrical forces between particles.

Mathematics

  - Determine a level of accuracy appropriate to limitations on measurement when reporting quantities representing periodic trends for main group elements based on patterns of electrons in the outermost energy level of atoms.
  - Considering the outermost energy level of atoms, define appropriate quantities for descriptive modeling of periodic trends for main group elements based on patterns of electrons in outermost energy levels.
  - Use units as a way to understand the outcome of a simple chemical reaction involving main group elements based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. Choose and interpret units consistently in chemical reactions.
- Determine and interpret the scale and origin in graphs and data displays representing patterns of chemical properties, outer electron states of atoms, trends in the periodic table, and patterns of chemical properties.
- Determine a level of accuracy appropriate to limitations on measurement when reporting quantities of simple chemical reactions.
- Use units as a simple way to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. Choose and interpret units comparing the structure of substances at the bulk scale to infer the strength of electrical forces between particles. Choose and interpret the scale and origin in graphs and data displays comparing the structure of substances and the bulk scale and electrical forces between particles.
  - Determine a level of accuracy appropriate to limitations on measurements of the strength of electrical forces between particles.

Suggested Learning Activities

Build an Atom: This simulation allows students to create different illustrations of atoms and provides evidence that protons determine the identity of the element.

Periodic Table Trends: This is a virtual investigation of the periodic trends.

Path to Periodic Table: This investigation provides students with the opportunity to make sense of how and why the periodic table is organized the way that it is. Students will re-create the thought process that Dmitri Mendeleev and Julius Lothar Meyer went through to devise their early periodic tables.

Castle of Mendeleev: Students engage in a fantasy world that requires them to make claims, based on evidence, regarding the identity of unknown materials.

Shall We Dance? – Classifying Types of Chemical Reactions: Students identify and differentiate between four types of chemical reactions: synthesis, decomposition, single replacement and double replacement. Students also develop models for chemical reactions and identify the limitations of the models using evidence.

Discovering Mendeleev Activity- this activity involves the students classifying the elements based on their properties, and predicting the properties of unknown elements based on their positions in the Periodic table.

Periodic Trends Lab – in this lab student investigate the reactivity of various metals to determine the pattern of reactivity going across a period and down a group of the Periodic table.

Electron Configuration Bingo- In order to understand the predictive power of the periodic table, students write electron configurations- standard, noble gas configuration, and outermost shell configuration- of both main group and transition metals, paying attention to patterns of electrons in the outermost energy level

Electron Configuration Battleship- In order to understand the predictive power of the periodic table, students write electron configurations- standard, noble gas configuration, and outermost shell configuration- of both main group and transition metals, paying attention to patterns of electrons in the outermost energy level

Getting to Know the Periodic Table Activity- Students should annotate the periodic table to determine its arrangement horizontally by number of protons in the atom's nucleus and its vertical arrangement by the placement of elements with similar chemical properties in columns.

Reactivity of Alkaline Earth Metals Lab – Students will investigate the reactivity of the alkaline earth metals and determine the pattern. Students should also be able to translate information about patterns in the periodic table into words that describe the importance of the outermost electrons in atoms.

Ionic and Covalent Lab - Students use the ideas of attraction and repulsion (i.e., charges—cations/anions) at the atomic scale to explain the structure of matter, such as in ion formation, and to explain the properties of matter such as density, luster, melting point, boiling point, etc. Students will classify substances as either ionic, polar covalent or nonpolar covalent by the results of various tests.

Law of Conservation of Mass Activity – Students will develop a procedure and implement it to investigate the law of conservation of mass.

Chemical Reactions Lab – Students are given a list of reactants. They are to perform each reaction, determine the evidence of a reaction, predict the products of the reaction and classify the reaction according to type.

Intermolecular Forces Activity – Students will determine the type of intermolecular forces holding various substances together, and rank them according to their strength.

Types of Crystalline Solids Activity- Students will be given characteristics of different solids and need to classify them based on the characteristics.

Liquids and Solids Demo/Activity - Students investigate the physical properties of liquids such as volatility, melting point, boiling point, vapor pressure, and surface tension.

Heating/Cooling Curve Lab-Students conduct an investigation to explain at the atomic scale transformations of matter by collecting data to create cooling and heating curves.

Methods of Assessment
Do Nows,Exit Tickets, Question and Answer Techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental, Cumulative Assessments, Lab Performance and Analysis, Classwork and Homework Reinforcement Techniques, Discussion

Appendix A: NGSS and Foundations for the Unit
Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. *[Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.]* **(HS-PS1-1)**
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. *[Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.]* [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.] **(HS-PS1-2)**
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. *[Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite).* Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] *[Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.]* **(HS-PS1-3)**
Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* *[Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.]* [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.] **(HS-PS2-6)**
Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.(HS-ETS1-3)
Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. (HS-ETS1-4)

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models • Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1) **Planning and Carrying Out Investigations** • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS1-3) **Constructing Explanations and Designing Solutions** • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-PS1-2) • Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3) **Obtaining, Evaluating, and Communicating Information** • Communicate scientific and technical information (e.g. about the process of	**PS1.A: Structure and Properties of Matter** • Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1) • The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1),(HS-PS1-2) • The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (*secondary to HS-PS2-6*) **PS1.B: Chemical Reactions** • The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2) **PS2.B: Types of Interactions** • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. *(secondary to HS-PS1-1),(secondary to HS-PS1-3)* **ESS2.D: Weather and Climate** • Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6)	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-1),(HS-PS1-2),(HS-PS1-3) **Structure and Function** • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-PS2-6) **Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. (HS-ETS1-4) - ***Connections to Engineering, Technology, and Applications of Science* Influence of Science, Engineering, and Technology on Society and the Natural World** New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3)

development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS2-6) **Using Mathematics and Computational Thinking** • Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-4)	**ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)	

Embedded English Language Arts/Literacy and Mathematics Standards	
English Language Arts/Literacy	
RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-3)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-2)
WHST.9-12.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-PS1-2),(HS-ETS1-3)
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-3)
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS1-3),(HS-ETS1-3)

WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS1-3),(HS-ETS1-3)
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS1-4)
Mathematics	
MP.2	Reason abstractly and quantitatively. (HS-ETS1-3),(HS-ETS1-4)
MP.4	Model with mathematics. (HS-ETS1-3),(HS-ETS1-4)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2),(HS-PS1-3)

Unit 2 Summary – Energy and Chemical Systems

How is energy transferred within a system?

Unit 2B is used in a chemistry course when **Unit 2: The Chemistry of Abiotic Systems** is taught in the **Capstone Science Course**. In Energy of Chemical Systems, students will understand energy as a quantitative property of a system—a property that depends on the motion and interactions of matter and radiation within that system. They will also understand that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Students develop an understanding that energy, at both the macroscopic and the atomic scales, can be accounted for as motions of particles or as energy associated with the configurations (relative positions) of particles.

Students can examine the ways that human activities cause feedback that create changes to other systems. Students are expected to demonstrate proficiency in *developing and using models, planning and carrying out investigations, analyzing and interpreting data, engaging in argument from evidence*, and using these practices to demonstrate understanding of core ideas.

Student Learning Objectives

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). *[Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.]* **(HS-PS3-4)**

Part A: *Does thermal energy always transfer or transform in predictable ways?*

Concepts	Formative Assessment
• When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. • Uncontrolled systems always move toward more stable states—that is, toward a more uniform energy distribution. • Although energy cannot be destroyed, it can be converted into less useful forms—for example, to thermal energy in the surrounding environment.	*Students who understand the concepts are able to:* • Plan and conduct an investigation individually or collaboratively to produce data on transfer of thermal energy in a closed system that can serve as a basis for evidence of uniform energy distribution among components of a system when two components of different temperatures are combined. • Use models to describe a system and define its boundaries, initial conditions, inputs, and outputs. • Design an investigation to produce data on transfer of thermal energy in a closed system that can serve as a basis for evidence of uniform energy distribution among components of a system when two components of different temperatures are combined, considering types, how much, and the accuracy of data needed to produce reliable measurements. • Consider the limitations of the precision of the data collected and refine the design accordingly

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy-

- Ask and refine questions to support uniform energy distribution among the components in a system when two components of different temperature are combined, using specific textual evidence.
- Conduct short as well as more sustained research projects to determine energy distribution in a system when two components of different temperature are combined.
- Collect relevant data across a broad spectrum of sources about the distribution of energy in a system and assess the strengths and limitations of each source.

Mathematics-

- Use symbols to represent energy distribution in a system when two components of different temperature are combined, and manipulate the representing symbols. Make sense of quantities and relationships in the energy distribution in a system when two components of different temperature are combined.
- Use a mathematical model to describe energy distribution in a system when two components of different temperature are combined. Identify important quantities in energy distribution in a system when two components of different temperature are combined and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

Suggesting Learning Activities

Calorimetry –Students will create a coffee cup calorimeter to investigate and calculate heat transfer in a closed system.

PhET heat transfer simulation

Heat transfer between metals and water simulated lab-students investigate heat transfer using different materials such as metals using the specific heat for these substances.

Methods of Assessment

Do Nows, Exit Tickets, Question and Answer Techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental, Cumulative Assessments, Lab Performance and Analysis, Classwork and Homework Reinforcement Techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

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). *[Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.]* **(HS-PS3-4)**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS3-4)	**PS3.B: Conservation of Energy and Energy Transfer** • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-4) • Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (HS-PS3-4) **PS3.D: Energy in Chemical Processes** • Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-4)	**Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-PS3-4)

Embedded English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS3-4)

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-PS3-4)

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under

	investigation. (HS-PS3-4)
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS3-4)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS3-4)
Mathematics	
MP.2	Reason abstractly and quantitatively. (HS-PS3-4)
MP.4	Model with mathematics. (HS-PS3-4)

Unit 3 – Summary: Bonding and Chemical Reactions
How can one explain the structure, properties, and interactions of matter?   In this unit of study, students *develop and using models, plan and conduct investigations, use mathematical thinking,* and *construct explanations and design solutions* as they develop an understanding of the substructure of atoms and to provide more mechanistic explanations of the properties of substances. Chemical reactions, including rates of reactions and energy changes, can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Students also apply an understanding of the process of *optimization and engineering design* to chemical reaction systems. The crosscutting concepts of *patterns, energy and matter,* and *stability and change* are the organizing concepts for these disciplinary core ideas. Students are expected to demonstrate proficiency in *developing and using models, planning and conducting investigations, using mathematical thinking,* and *constructing explanations and designing solutions.*
Student Learning Objectives
Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. *[Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]* **(HS-PS1-7)**
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. *[Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]* **(HS-PS1-4)**
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. *[Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.]* **(HS-PS1-5)**
Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.* *[Clarification Statement: Emphasis is on the application of Le Chatlier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.]* **(HS-PS1-6)**
Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. (HS-ETS1-2)

Part A: *Where do the atoms go during a chemical reaction?*

Concepts	Formative Assessment
• The fact that atoms are conserved, together with the knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. • The total amount of energy and matter in closed systems is conserved. • The total amount of energy and matter in a chemical reaction system is conserved. • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. • Changes of energy and matter in a chemical reaction system can be described in terms of energy and matter flows into, out of, and within that system.	*Students who understand the concepts are able to:* • Use mathematical representations of chemical reaction systems to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. • Use mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale, using the mole as the conversion from the atomic to the macroscopic scale. • Use the fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, to describe and predict chemical reactions. • Describe changes of energy and matter in a chemical reaction system in terms of energy and matter flows into, out of, and within that system.

Part B: *What is different inside a heat pack and a cold pack?*

Concepts	Formative Assessment
• A stable molecule has less energy than the same set of atoms separated; at least this much energy must be provided in order to take the molecule apart. • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. • Changes of energy and matter in a chemical reaction system can be described in terms of collisions of molecules and the rearrangements of atoms into new molecules, with subsequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.	*Students who understand the concepts are able to:* • Explain the idea that a stable molecule has less energy than the same set of atoms separated. • Describe changes of energy and matter in a chemical reaction system in terms of energy and matter flows into, out of, and within that system. • Describe chemical processes, their rates, and whether or not they store or release energy in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.

• Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.	• Develop a model based on evidence to illustrate the relationship between the release or absorption of energy from a chemical reaction system and the changes in total bond energy.

Part C: *Is it possible to change the rate of a reaction or cause two elements to react that do not normally want to?*

Concepts	Formative Assessment
• Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. • Patterns in the effects of changing the temperature or concentration of the reacting particles can be used to provide evidence for causality in the rate at which a reaction occurs.	*Students who understand the concepts are able to:* • Use the number and energy of collisions between molecules (particles) to explain the effects of changing the temperature or concentration of the reacting articles on the rate at which a reaction occurs. • Use patterns in the effects of changing the temperature or concentration of the reactant particles to provide evidence for causality in the rate at which a reaction occurs. • Apply scientific principles and multiple and independent student-generated sources of evidence to provide an explanation of the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

Part D: *What can we do to make the products of a reaction stable?*

Concepts	Formative Assessment
• Much of science deals with constructing explanations of how things change and how they remain stable. • In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others may be needed.	*Students who understand the concepts are able to:* • Construct explanations for how chemical reaction systems change and how they remain stable. • Design a solution to specify a change in conditions that would produce increased amounts of products at equilibrium in a chemical system based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. • Break down and prioritize criteria for increasing amounts of products in a

• Explanations can be constructed explaining how chemical reaction systems can change and remain stable.	chemical system at equilibrium. • Refine the design of a solution to specify a change in conditions that would produce increased amounts of products at equilibrium in a chemical system based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Connecting with English Language Arts/Literacy

English Language Arts/Literacy

- Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations showing that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy to enhance understanding of findings, reasoning, and evidence and to add interest.
- Cite specific textual evidence to support the concept that changing the temperature or concentration of the reacting particles affects the rate at which a reaction occurs.
- Develop an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples.
- Construct short as well as more sustained research projects to answer how to increase amounts of products at equilibrium in a chemical system. Synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

Mathematics

- Represent an explanation that atoms, and therefore mass, are conserved during a chemical reaction symbolically and manipulate the representing symbols. Make sense of quantities and relationships about the conservation of atoms and mass during chemical reactions symbolically and manipulate the representing symbols.
- Use units as a way to understand the conservation of atoms and mass during chemical reactions; choose and interpret units consistently in formulas representing proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale; choose and interpret the scale and origin in graphs and data displays representing the conservation of atoms and mass in chemical reactions.
- Define appropriate quantities for the purpose of descriptive modeling of the proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale.
- Use a mathematical model to explain how the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy, and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

- Represent an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs symbolically and manipulate the representing symbols. Make sense of quantities and relationships about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs symbolically and manipulate the representing symbols.
- Use units as a way to understand an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. Choose and interpret units consistently in formulas representing the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. Choose and interpret the scale and the origin in graphs and data displays representing the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
- Use a mathematical model to explain how to increase amounts of products at equilibrium in a chemical system. Identify important quantities in the cycling of matter and flow of energy among organisms in an ecosystem, and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

Suggested Learning Activities

Endothermic/Exothermic Reaction demo – Students will be able to determine whether energy was absorbed from the surrounds or given off to the surrounds by investigating two chemical demonstrations- The Chef (exothermic) and Freezing a Beaker to Wood (endothermic). Students are also given data and asked to graph the relative energies of reactants and products to determine whether energy is released or absorbed.

Water in a Hydrate – Students calculate the percentage of water in an unknown hydrate, determine the molar ratio of anhydrate to hydrate and then use this information to identify the unknown hydrate. Students evaluate their results by performing a percent error calculation.

Interpreting Potential Energy diagrams activity- Students might be given data and asked to graph the relative energies of reactants and products to determine whether energy is released or absorbed. Students will determine whether the potential energy increases or decreases during bond formation, and whether that results in a more or less stable arrangement.

Straw Lab- Students will investigate equilibrium and the law of mass action by modeling what occurs in terms of reactant and product concentration as a reaction reaches equilibrium.

Percentage of Sugar In Gum Activity- Students will predict and then calculate the percent sugar in their favorite brand of gum.

The Mole Lab- Students will be able to calculate the molar mass of unknown elements and then based on their calculations determine the identity of each element.

Empirical formula of an Unknown Lab- Students perform a decomposition reaction and then calculate the empirical formula of the unknown substance.

Factors affecting reaction rate activity- Students will investigate what factors affect the rate of a reaction.

Counting by Weighing (Counting Large Numbers) Do Now- Students calculate how many items are in a bag without actually counting them. Students evaluate their results using a percent error calculation.

Limiting Reactant Lab/Percent Yield – Students determine the limiting reactant in a reaction, the excess reactant, amount of theoretical product and calculate how much excess reactant is left over. Students evaluate their results by performing a percent yield calculation.

Heating/Cooling Curve/Phase Diagrams (Heat of Fusion of Ice) – Students perform a simple chemical reaction and explain what is happening in terms of energy changes.

Hot or Cold? Le Chatelier's Activity – Students investigate the effect of changing the temperature and/or concentration of a reactant (Le Chatelier's principle) on the reaction.

Iodine clock reaction- Students perform the experiment and develop an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs and on equilibrium.

Ferrous cyanide complex- Students perform the reaction and develop an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs and on equilibrium.

Computer simulations located at www.harpercollege.edu/tm-ps/chm/100/dgodambe/thedisk/equil/equil.htm. - Students use results from these investigations to develop an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs and on equilibrium.

Methods of Assessment

Do Nows, Exit Tickets, Question and Answer Techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental, Cumulative Assessments, Lab Performance and Analysis, Classwork and Homework Reinforcement Techniques, Discussion

Appendix A: NGSS and Foundations for the Unit
Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. *[Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]* **(HS-PS1-7)**
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. *[Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]* **(HS-PS1-4)**
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. *[Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.]* **(HS-PS1-5)**
Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.* *[Clarification Statement: Emphasis is on the application of Le Chatlier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.]* **(HS-PS1-6)**
Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. (HS-ETS1-2)

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models • Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-4),(HS-PS1-8) • Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1) **Planning and Carrying Out Investigations** • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS1-3) **Using Mathematics and Computational Thinking** • Use mathematical representations of phenomena to support claims. (HS-PS1-7) **Constructing Explanations and Designing Solutions** • Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (HS-PS1-5) • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-PS1-2)	**PS1.A: Structure and Properties of Matter** • Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1) • The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1),(HS-PS1-2) • The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3),*(secondary to HS-PS2-6)* • A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (HS-PS1-4) **PS1.B: Chemical Reactions** • Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. (HS-PS1-4),(HS-PS1-5) • In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. (HS-PS1-6)	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-1),(HS-PS1-2),(HS-PS1-3),(HS-PS1-5) **Energy and Matter** • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8) • The total amount of energy and matter in closed systems is conserved. (HS-PS1-7) • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS1-4) **Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable. (HS-PS1-6) --------------------------------- ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS1-7)

• Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS1-6) **Asking Questions and Defining Problems** • Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1) **Using Mathematics and Computational Thinking** • Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-4) **Constructing Explanations and Designing Solutions** • Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2) • Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)	• The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2),(HS-PS1-7) **PS1.C: Nuclear Processes** • Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8) **PS2.B: Types of Interactions** • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.*(secondary to HS-PS1-1),(secondary to HS-PS1-3)* **ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS1-6) **ETS1.A: Defining and Delimiting Engineering Problems** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1) • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize	

	pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) **ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4) **ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)	

Embedded English Language Arts/Literacy and Mathematics	
English Language Arts/Literacy	
RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (HS-PS1-1)
RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-5)
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1),(HS-ETS1-3)
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-1),(HS-ETS1-3)
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1),(HS-ETS1-3)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-5)
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-6)
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS1-4)
Mathematics -	
MP.2	Reason abstractly and quantitatively. (HS-PS1-5),(HS-PS1-7),(HS-ETS1-1),(HS-ETS1-3),(HS-ETS1-4)
MP.4	Model with mathematics. (HS-PS1-4), (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)

HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),(HS-PS1-7)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-4),(HS-PS1-5),(HS-PS1-7)

Unit 4 -- Summary: Matter and Energy in Living Systems
How do organisms obtain and use the energy they need to live and grow? In this unit of study, students construct explanations for the role of energy in the cycling of matter in organisms. They apply mathematical concepts to develop evidence to support explanations of the interactions of photosynthesis and cellular respiration and develop models to communicate these explanations. The crosscutting concept of *matter and energy* provides students with insights into the structures and processes of organisms. Students are expected to *develop and use models, plan and conduct investigations, use mathematical thinking,* and *construct explanations and design solutions* as they demonstrate proficiency with the disciplinary core ideas.
Student Learning Objectives
Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. *[Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.]* **(HS-LS1-5)**
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. *[Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.]* **(HS-LS1-7)**
Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. *[Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.] [Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.]* **(HS-LS1-6)**

Part A: *How does photosynthesis transform light energy into stored chemical energy?*	
Concepts	**Formative Assessment**
• The process of photosynthesis converts light energy to stored energy by converting carbon dioxide plus water into sugars plus released oxygen. • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within a system.	*Students who understand the concepts are able to:* • Provide a mechanistic explanation for how photosynthesis transforms light energy into stored chemical energy. • Use their understanding of energy flow and conservation of energy to illustrate the inputs and outputs of matter and the transformation of energy in photosynthesis.

Part B: *How does cellular respiration result in a net transfer of energy?*

Concepts	Formative Assessment
• As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. • As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. • Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. • Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. • Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.	*Students who understand the concepts are able to:* • Construct an evidence-based 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. • Use their understanding of energy flow and conservation of energy to illustrate the inputs and outputs of the process of cellular respiration.

Part C: *How do elements of a sugar molecule combine with other elements and what molecules are formed?*

Concepts	Formative Assessment
• Sugar molecules contain carbon, hydrogen, and oxygen: Their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. • As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.	*Students who understand the concepts are able to:* • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) 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. • Construct and revise an explanation, based on valid and reliable evidence from a variety of sources (including models, theories, simulations, peer review) and on the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, 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. • Use evidence from models and simulations to support explanations 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.

Connecting with English Language Arts/Literacy

English Language Arts/Literacy

- Make strategic use of digital media in presentations to enhance understanding of how photosynthesis transforms light energy into stored chemical energy.
- Use digital media in presentations to enhance understanding of the inputs and outputs of the process of cellular respiration.
- Cite specific textual evidence to support how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large, carbon-based molecules.
- Use evidence from multiple sources to clearly communicate an explanation 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.
- Revise an explanation 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 by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant.
- Draw evidence from informational texts to describe how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large, carbon-based molecules.

Suggested Learning Activities

Model Building – Students use model kits to build the molecules involved in respiration and photosynthesis to illustrate how bonds are broken and atoms are rearranged in the process. Students also build molecules showing that carbon, hydrogen and oxygen provide the basis of hydrocarbons, illustrating their importance in biological processes.

Polymerization of sugar activity- Students research and investigate how simple sugars (made from carbon, hydrogen, and oxygen) are combined and recombined in different structures with specific functions.

Proof of CO_2 in Exhalation Activity- Students test the products of cellular respiration found in their breathe to verify that CO2 is a product of respiration.

Petri dish Toxicity testing- Students categorize each growth medium according to its acidity, basicity, polarity, etc and test to see which medium is most conducive to growth of radish seeds.

Methods of Assessment

Do Nows, Exit Tickets, Question and Answer Techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental, Cumulative Assessments, Lab Performance and Analysis, Classwork and Homework Reinforcement Techniques, Discussion

Appendix A: NGSS and Foundations for the Unit
Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. *[Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.]* **(HS-LS1-5)**
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. *[Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.]* **(HS-LS1-7)**
Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. *[Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.] [Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.]* **(HS-LS1-6)**

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models • Use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-5),(HS-LS1-7) **Constructing Explanations and Designing Solutions** • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-6)	**LS1.A: Structure and Function** • Systems of specialized cells within organisms help them perform the essential functions of life. (secondary to HS-LS1-4, HS-LS1-5, HS-LS1-6) • All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (secondary to HS-LS1-4, HS-LS1-5, HS-LS1-6) • Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (secondary to HS-LS1-4, HS-LS1-5, HS-LS1-6) • Feedback mechanisms maintain a living system's internal conditions within certain limits and	**Energy and Matter** • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-LS1-5), (HS-LS1-6) • Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS1-7)

	mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (secondary to HS-LS1-4, HS-LS1-5, HS-LS1-6) **LS1.B: Growth and Development of Organisms** • In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. (HS-LS1-4) **LS1.C: Organization for Matter and Energy Flow in Organisms** • The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS-LS1-5) • The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. (HS-LS1-6) • As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to	

	form different products. (HS-LS1-6),(HS-LS1-7) • As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. (HS-LS1-7)	

Embedded English Language Arts/Literacy and Mathematics Standards

English Language Arts/Literacy

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS1-6)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS1-6)
WHST.9-12.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS1-6)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1-6)
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-LS1-4),(HS-LS1-5),(HS-LS1-7)

Mathematics

MP.4	Model with mathematics. (HS-LS1-4)
HSF-IF.C.7	Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. (HS-LS1-4)
HSF-BF.A.1	Write a function that describes a relationship between two quantities. (HS-LS1-4)

Unit 5- Summary: Nuclear Chemistry
What happens in stars?   In this unit of study, energy and matter are studied further by investigating the processes of nuclear fusion and fission that govern the formation, evolution, and workings of the solar system in the universe. Some concepts studied are fundamental to science and demonstrate *scale, proportion, and quantity,* such as understanding how the matter of the world formed during the Big Bang and within the cores of stars over the cycle of their lives.   In addition, an important aspect of Earth and space sciences involves understanding the concept *of stability and change* while making inferences about events in Earth's history based on a data record that is increasingly incomplete the farther one goes back in time. A mathematical analysis of radiometric dating is used to comprehend how absolute ages are obtained for the geologic record.   The crosscutting concepts of *energy and matter; scale, proportion, and quantity*; and *stability and change* are called out as organizing concepts for this unit. Students are expected to demonstrate proficiency in *developing and using models; constructing explanations and designing solutions; using mathematical and computational thinking; and obtaining, evaluating, and communicating information*; and they are expected to use these practices to demonstrate understanding of the core ideas.

Student Learning Objectives
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. *[Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.]* **(HS-PS1-8)**
Communicate scientific ideas about the way stars, over their life cycle, produce elements. *[Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.]* **(HS-ESS1-3)**
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. *[Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [Assessment Boundary: Assessment does not include details of the atomic and subatomic processes involved with the sun's nuclear fusion.]* **(HS-ESS1-1)**

Part A: *Why is fusion considered the Holy Grail for the production of electricity?*

Why aren't all forms of radiation harmful to living things?

Concepts	Formative Assessment
• Nuclear processes, including fusion, fission, and radioactive decay of unstable nuclei, involve release or absorption of energy. • The total number of neutrons plus protons does not change in any nuclear process. • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.	*Students who understand the concepts are able to:* • Develop models based on evidence 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. • Use simple qualitative models based on evidence to illustrate the scale of energy released in nuclear processes relative to other kinds of transformations. • Develop models based on evidence to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of alpha, beta, and gamma radioactive decays.

Part B: *How do stars produce elements?*

Concepts	Formative Assessment
• The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.	*Students who understand the concepts are able to:* • Communicate scientific ideas in multiple formats (including orally, graphically, textually, and mathematically) about the way stars, over their life cycles, produce elements. • Communicate scientific ideas about the way nucleosynthesis, and therefore the different elements it creates, vary as a function of the mass of a star and the stage of its lifetime. • Communicate scientific ideas about how in nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Part C: *Is the life span of a star predictable?*

Concepts	Formative Assessment
• The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. • Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. • The significance of the energy transfer mechanisms that allow energy from	*Students who understand the concepts are able to:* • 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 in releasing energy that eventually reaches Earth in the form of radiation. • Develop a model based on evidence to illustrate the relationships between

nuclear fusion in the sun's core to reach Earth is dependent on the scale, proportion, and quantity at which it occurs.	nuclear fusion in the sun's core and radiation that reaches Earth.

Part D: *If there was nobody there to Tweet about it, how do we know that there was a Big Bang?*

Concepts	Formative Assessment
• The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. • Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. • Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. • Energy cannot be created or destroyed, only moved between one place and another place, between objects and/or fields, or between systems. • Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. • Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and will continue to do so in the future.	*Students who understand the concepts are able to:* • Construct an explanation based on valid and reliable evidence that energy in the universe cannot be created or destroyed, only moved between one place and another place, between objects and/or fields, or between systems.

Part E: *How can chemistry help us to figure out ancient events?*

Concepts	Formative Assessment
• Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. • Much of science deals with constructing explanations of how things change and how they remain stable.	*Students who understand the concepts are able to:* • Apply scientific reasoning to link evidence from ancient Earth materials, meteorites, and other planetary surfaces to claims about Earth's formation and early history, and assess the extent to which the reasoning and data support the explanation or conclusion.

	• Use available evidence within the solar system to construct explanations for how Earth has changed and how it remains stable.

Suggested Learning Activities

Modeling a radioactive decay series Activity- Students model radioactive decay of various substances.

PhET nuclear fission inquiry lab and graphs- Students are able to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of alpha, beta, and gamma radioactive decays.

Spectroscope/Flame Test Lab- Students use spectroscopes to analyze emission spectra given off by various gases. In addition, the flame test allows students to explore what happens in terms of electrons when metals are vaporized in a flame. Students calculate the amount of energy released using E – hv.

Radiometric dating simulation- Students use examples of spontaneous radioactive decay as a tool to determine the ages of rocks or other materials (K-39 to Ar-40). Students also construct graphs showing data on the absolute ages and composition of Earth's rocks, lunar rocks, and meteorites.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS1-1)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS1-3),(HS-ESS1-2)
SL.11-12.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (HS-ESS1-3)

Mathematics

MP.2	Reason abstractly and quantitatively. (HS-ESS1-1), (HS-ESS1-2) ,(HS-ESS1-3) ,(HS-PS1-8)
MP.4	Model with mathematics. (HS-ESS1-1)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS1-1),(HS-ESS1-2)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS1-1), (HS-ESS1-2)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-1), (HS-ESS1-2)
HSA-SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-ESS1-1)

HSA-CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-ESS1-1), (HS-ESS1-2)
HSA-CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-ESS1-1),(HS-ESS1-2)

Methods of Assessment
Do Nows, Exit Tickets, Question and Answer Techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental, Cumulative Assessments, Lab Performance and Analysis, Classwork and Homework Reinforcement Techniques, Discussion

Appendix A: NGSS and Foundations for the Unit
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. *[Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.]* **(HS-PS1-8)**
Communicate scientific ideas about the way stars, over their life cycle, produce elements. *[Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.]* **(HS-ESS1-3)**
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. *[Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [Assessment Boundary: Assessment does not include details of the atomic and subatomic processes involved with the sun's nuclear fusion.]* **(HS-ESS1-1)**
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. *[Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).]* **(HS-ESS1-2)**
Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. *[Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.]* **(HS-ESS1-6)**

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and	**PS1.C: Nuclear Processes** • Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not	**Energy and Matter** • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-ESS1-3), (HS-PS1-8), (HS-ESS1-1)

designed worlds.

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8),(HS-ESS1-1)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS1-2)
- Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-ESS1-6)

Using Mathematical and Computational Thinking

Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical or computational

change in any nuclear process. (HS-PS1-8)

- Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.(secondary (HS-ESS1-6)

ESS1.A: The Universe and Its Stars

- The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (HS-ESS1-1)
- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-2),(HS-ESS1-3)
- The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (HS-ESS1-2)
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (HS-ESS1-2),(HS-ESS1-3)

PS3.D: Energy in Chemical Processes and Everyday Life

- Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (secondary) (HS-ESS1-1)

PS4.B: Electromagnetic Radiation

- Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems. (HS-ESS1-2)

Scale, Proportion, and Quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-ESS1-1)
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-ESS1-4)
- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS1-6)

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Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-2),(HS-ESS1-4)

- -

representations of phenomena to describe explanations. (HS-ESS1-4) **Obtaining, Evaluating, and Communicating Information** • Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. (HS-ESS1-6) • Communicate scientific ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-ESS1-3)	• Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.*(secondary)*HS-ESS1-2) **ESS1.B: Earth and the Solar System** • Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS-ESS1-4) **ESS1.C: The History of Planet Earth** • Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.	***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • 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. (HS-ESS1-2) • Science assumes the universe is a vast single system in which basic laws are consistent. (HS-ESS1-2) **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-ESS1-2)

Embedded English Language Arts/Literacy and Mathematics	
English Language Arts/Literacy -	
RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS1-1)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS1-3),(HS-ESS1-2)
SL.11-12.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (HS-ESS1-3)

Mathematics -	
MP.2	Reason abstractly and quantitatively. (HS-ESS1-1), (HS-ESS1-2) ,(HS-ESS1-3) ,(HS-PS1-8)
MP.4	Model with mathematics. (HS-ESS1-1)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS1-1),(HS-ESS1-2)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS1-1), (HS-ESS1-2)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-1), (HS-ESS1-2)
HSA-SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-ESS1-1)
HSA-CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-ESS1-1), (HS-ESS1-2)
HSA-CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-ESS1-1),(HS-ESS1-2)

TOWNSHIP OF UNION PUBLIC SCHOOLS

SC 211 Honors Biology

Curriculum Guide 2016

Curriculum Committee

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Academic Area

Honors Biology

References

The following curriculum guide was adapted from the Next Generation Science Standards and the State of New Jersey Department of Education High School Biology Model Curriculum.

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Curriculum Unit Overview

Unit 1- Interdependent Relationships in Ecosystems & Population Dynamics

Unit 2- Structure & Function

Unit 3- Matter and Energy in Organisms and Ecosystems

Unit 4- Inheritance and Variation of Traits

Unit 5- Natural Selection and Mechanisms of Evolution

Unit 6- Evidence of Evolution, Relationships and Common Ancestry

Curriculum Pacing Guide – Honors Biology

Unit Name	Estimated Number of Days
Unit 1- Interdependent Relationships in Ecosystems & Population Dynamics	30
Unit 2- Structure & Function	30
Unit 3- Matter and Energy in Organisms and Ecosystems	30
Unit 4- Inheritance and Variation of Traits	45
Unit 5- Natural Selection and Mechanisms of Evolution	20
Unit 6- Evidence of Evolution, Relationships and Common Ancestry	25

Honors Biology Course Description

The Honors Biology course is specifically designed for the student who has demonstrated exceptional ability in the sciences. The course challenges the student with a rigorous, in-depth study of Biology, stressing higher-level learning skills and critical thinking. Emphasis is on developing skills such as: designing experiments and investigative procedures, hypothesizing, observing, interpreting, data analysis, graphing, and inferring. Extensive open-ended laboratory and computer-based investigations are utilized, to foster inquiry and discovery skills.

Course Proficiencies

For all units, students will understand and follow all laboratory and safety rules, understand scientific explanations, generate scientific evidence through active investigations, reflect on scientific knowledge and participate productively in science.

The honors biology student will explore the following unit topics that are aligned with the NGSS Disciplinary Core Ideas/ NJ Biology Model Curriculum Standards:

Unit 1- Interdependent Relationships in Ecosystems & Population Dynamics

In this unit of study, students formulate answers to the question *"how and why do organisms interact with each other (biotic factors) and their environment (abiotic factors), and what affects these interactions?"* Secondary ideas include the interdependent relationships in ecosystems; dynamics of ecosystems; and functioning, resilience, and social interactions, including group behavior. Students use *mathematical reasoning* and *models* to make sense of carrying capacity, factors affecting biodiversity and populations, the cycling of matter and flow of energy through systems. Additionally, in this unit of study, *mathematical models* provide support for students' conceptual understanding of systems and students' ability to *design, evaluate, and refine solutions* for reducing the impact of human activities on the environment and maintaining biodiversity. The crosscutting concepts of *scale, proportion, and quantity* and *stability and change* are called out as organizing concepts for the disciplinary core ideas. Students are expected to use *mathematical reasoning* and *models* to demonstrate proficiency with the disciplinary core ideas.

Unit 2- Structure & Function

Students formulate an answer to the question "*How do the structures of organisms enable life's functions?*" Students investigate explanations for the structure and functions of cells as the basic unit of life, of hierarchical organization of interacting organ systems, and of the role of specialized cells for maintenance and growth. The crosscutting concepts of *structure and function*, *matter and energy*, and *systems and system models* are called out as organizing concepts for the disciplinary core ideas. Students use *critical reading*, *modeling*, and *conducting investigations*. Students also use the science and engineering practices to demonstrate understanding of the disciplinary core ideas.

Unit 3- Matter and Energy in Organisms and Ecosystems

In this unit of study, students *construct explanations* for the role of energy in the cycling of matter in organisms and ecosystems. They *apply mathematical concepts* to *develop evidence to support explanations* of the interactions of photosynthesis and cellular respiration, and they will *develop models to communicate these explanations*. Students also understand organisms' interactions with each other and their physical environment and how organisms obtain resources. Students utilize the crosscutting concepts of *matter and energy* and *systems, and system models* to make sense of ecosystem dynamics. Students are expected to use students *construct explanations* for the role of energy in the cycling of matter in organisms and ecosystems. They *apply mathematical concepts* to *develop evidence to support explanations* as they demonstrate their understanding of the disciplinary core ideas.

Unit 4- Inheritance and Variation of Traits

Students analyze data develop models to make sense of the relationship between DNA and chromosomes in the process of cellular division, which passes traits from one generation to the next. Students determine why individuals of the same species vary in how they look, function, and behave. Students develop *conceptual models* of the role of DNA in the unity of life on Earth and *use statistical models* to explain the importance of variation within populations for the survival and evolution of species. Ethical issues related to genetic modification of organisms and the nature of science are described. Students explain the mechanisms of genetic inheritance and describe the environmental and genetic causes of gene mutation and the alteration of gene expressions. The crosscutting concepts of *structure and function*, *patterns,* and *cause and effect* are used as organizing concepts for the disciplinary core ideas. Students also use the science and engineering practices to demonstrate understanding of the disciplinary core ideas.

Unit 5- Natural Selection and Mechanisms of Evolution

Students *constructing explanations* and *designing solutions*, *analyzing and interpreting data*, and *engaging in argument from evidence investigate* to make sense of the relationship between the environment and natural selection. Students also develop an understanding of the factors causing natural selection of species over time. They also demonstrate and understandings of how multiple lines of evidence contribute to the strength of scientific theories of natural selection. The crosscutting concepts of *patterns* and *cause and effect* serve as a organizing concepts for the disciplinary core ideas. Students also use the science and engineering practices to demonstrate understanding of the disciplinary core ideas.

Unit 6- Evidence of Evolution, Relationships and Common Ancestry

Students construct explanations for the processes of natural selection and evolution and then communicate how multiple lines of evidence support these explanations. Students evaluate evidence of the conditions that may result in new species and understand the role of genetic variation in natural selection. Additionally, students can apply concepts of probability to explain trends in population as those trends relate to advantageous heritable traits in a specific environment. Students demonstrate an understanding of these concepts by obtaining, evaluating, and communicating information and constructing explanations and designing solutions. The crosscutting concepts of patterns and cause and effect support the development of a deeper understanding.

Unit 1 Summary

Interdependent Relationships in Ecosystems & Population Dynamics

How do organisms interact with the living and nonliving environments to obtain matter and energy?

In this unit of study, students formulate answers to the question "how and why do organisms interact with each other (biotic factors) and their environment (abiotic factors), and what affects these interactions?" Secondary ideas include the interdependent relationships in ecosystems; dynamics of ecosystems; and functioning, resilience, and social interactions, including group behavior. Students use mathematical reasoning and models to make sense of carrying capacity, factors affecting biodiversity and populations, the cycling of matter and flow of energy through systems. The crosscutting concepts of scale, proportion, and quantity and stability and change are called out as organizing concepts for the disciplinary core ideas. Students are expected to use mathematical reasoning and models to demonstrate proficiency with the disciplinary core ideas.

Student Learning Objectives

Illustrate how interactions among living systems and with their environment result in the movement of matter and energy. LS2.A

Graph real or simulated populations and analyze the trends to understand consumption patterns and resource availability, and make predictions as to what will happen to the population in the future. LS2.A

Provide evidence that the growth of populations are limited by access to resources, and how selective pressures may reduce the number of organisms or eliminate whole populations of organisms. LS2.A

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

Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. *[Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [Assessment Boundary: Assessment is limited to provided data.]* (HS-LS2-2)

Evaluate the 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. *[Clarification Statement: 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.]* (HS-LS2-6)

Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. *[Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]* **(HS-LS2-7)**

Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.[Clarification Statement: Emphasis is on: (1)

distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming. **(HS-LS2-8)**	
Unit Sequence	
Part A: *When they relocate bears, wolves, or other predators, how do they know that they will survive?*	
Concepts	**Formative Assessment**
• Ecosystems have carrying capacities, which are limits to the number of organisms and populations they can support. • These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, completion, and disease. • Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (the number of individuals) of species in any given ecosystem. • The significance of carrying capacity in ecosystems is dependent on the scale proportion and quantity at which it occurs. • Quantitative analysis can be used to compare and determine relationships among interdependent factors that affect the carrying capacity of ecosystems at different scales.	*Students who understand the concepts are able to:* • Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. • Use quantitative analysis to compare relationships among interdependent factors and represent their effects on the carrying capacity of ecosystems at different scales.
Unit Sequence	
Part B: *What limits the number and types of different organisms that live in one place?*	
Concepts	**Formative Assessment**
• Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. • Ecosystems have carrying capacities, which are limits to the number of organisms and populations they can support. • These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, completion, and disease. • Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. • This fundamental tension affects the abundance (number of individuals) of	*Students who understand the concepts are able to:* • Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. • Use the concept of orders of magnitude to represent how factors affecting biodiversity and populations in ecosystems at one scale relate to those factors at another scale.

species in any given ecosystem.

- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions.
- If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem.
- Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.
- Using the concept of orders of magnitude allows one to understand how a model of factors affecting biodiversity and populations in ecosystems at one scale relates to a model at another scale.

Unit Sequence

Part C: *How can a one or two inch rise in sea level devastate an ecosystem?*

Concepts	**Formative Assessment**
• Much of science deals with constructing explanations of how things change and how they remain stable. • A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. • If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem) as opposed to becoming a very different ecosystem. • Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. • Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.	*Students who understand the concepts are able to:* • Evaluate the claims, evidence, and reasoning that support the contention that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. • Construct explanations of how modest biological or physical changes versus extreme changes affect stability and change in ecosystems.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support analysis of science and technical texts supporting explanations of factors that affect carrying capacity of ecosystems at different scales, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

- Develop and write explanations of factors that affect carrying capacity of ecosystems at different scales by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.
- Cite specific textual evidence to support how factors affect biodiversity and populations in ecosystems of different scale, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Write explanatory texts based on scientific procedures/experiments to explain how different factors affect biodiversity and populations in ecosystems at different scales.
- Assess the extent to which the claim that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem, is supported by reasoning and evidence.
- Cite specific textual evidence to support claims that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Integrate and evaluate multiple sources of information presented in diverse formats and media in order to address claims that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- Evaluate the validity of evidence and reasoning that support claims that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Mathematics

- Represent the factors that affect carrying capacity of ecosystems at different scales symbolically and manipulate the representing symbols. Make sense of quantities and relationships between different factors that affect carrying capacity of ecosystems at different scales.
- Use a mathematical model to describe factors that affect carrying capacity of ecosystems at different scales. Identify important quantities in factors that affect carrying capacity of ecosystems at different scales and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand how factors affect the carrying capacity of ecosystems at different scales. Choose and interpret units consistently in formulas to determine carrying capacity. Choose and interpret the scale and origin in graphs and data displays showing factors that affect carrying capacity of ecosystems at different scales.
- Define appropriate quantities for the purpose of descriptive modeling of factors that affect carrying capacity of ecosystems at different scales.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing factors that affect carrying capacity of ecosystems at different scales.
- Represent the factors that affect biodiversity and populations in ecosystems symbolically and manipulate the representing symbols. Make sense of quantities and relationships between different factors and their effects on biodiversity and populations in ecosystems.
- Use a mathematical model to describe the factors that affect biodiversity and populations in ecosystems. Identify important quantities in factors that affect biodiversity and populations in ecosystems and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting

on the results and improving the model if it has not served its purpose.

- Use units as a way to understand factors that affect biodiversity and populations in ecosystems.
- Choose and interpret units consistently in formulas to determine effects on biodiversity and populations in ecosystems. Choose and interpret the scale and the origin in graphs and data displays representing the factors that affect biodiversity and populations in ecosystems.
- Define appropriate quantities for the purpose of descriptive modeling of the factors that affect biodiversity and populations in ecosystems.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities of the factors that affect biodiversity and populations in ecosystems.
- Represent claims that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem symbolically and manipulate the representing symbols. Make sense of quantities and relationships between complex interactions in ecosystems and ways in which ecosystems remain stable and ways in which they change.
- Represent data relating to complex interactions in ecosystems and their effects on stability and change in ecosystems with plots on the real number line (graph).
- Understand statistics as a process for making inferences about complex interactions in ecosystems and organism population parameters based on a random sample from that population.
- Evaluate reports of complex interactions and their effects on stability and change in ecosystems based on data showing numbers and types of organisms in stable conditions and in changing conditions.

Suggested Learning Activities

Predator/Prey Relationships: Students will construct and interpret graphs to correlate relationships between population sizes of predator and prey.

Infectious Disease Lab: Students will model spread of disease (density dependent factor) and the exponential growth of bacterial populations.

Human Population Age Structure Study: Students will compare age structure histograms to predict future trends for developing and developed countries.

Live and Let Live Group Project: Students will work in cooperative learning groups to develop a plan to accommodate an increase in human population while having a minimal impact on surrounding ecosystem.

The Bean Game: Exploring Human Interactions with Natural Resources: This activity explores the various influences of human consumption of natural resources over time. (use this as a primer for making a computational model).

World In Balance Film: Students will view film that reviews age structure trends within various countries.

Population Growth – Exponential and Logistic Models vs. Complex Realities: This analysis and discussion activity is designed to help students develop a solid understanding of the exponential and logistic models of population growth, including the biological processes that result in exponential or logistic population growth. Students learn about the simplifying assumptions built into the exponential and logistic models and explore how deviations from these assumptions can result in discrepancies between the predictions of these models and the actual trends in population size for natural populations.

Changing Biological Communities – Disturbance and Succession: Students use their understanding of the processes involved in succession to construct and evaluate models of succession in abandoned farm fields. Students also analyze the effects on succession of climate and non-native invasive plants.

Bye Bye Birdie: Students will develop criteria that ecologists, wildlife managers, and public officials might use to make decisions about protecting endangered species, conduct research on an endangered species through the Internet and other sources, and then present their findings, showing how their species measures up against the chosen decision criteria.

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

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

Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. *[Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [Assessment Boundary: Assessment is limited to provided data.]* (HS-LS2-2)

Evaluate the 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. *[Clarification Statement: 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.]* (HS-LS2-6)

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking • Use mathematical and/or computational representations of phenomena or design solutions to support explanations. (HS-LS2-1) • Use mathematical representations of	LS2.A: Interdependent Relationships in Ecosystems • Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and	Scale, Proportion, and Quantity • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-LS2-1) • Using the concept of orders of magnitude allows

phenomena or design solutions to support and revise explanations. (HS-LS2-2) Engaging in Argument from Evidence • Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS2-6)	nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-1),(HS-LS2-2) LS2.C: Ecosystem Dynamics, Functioning, and Resilience • A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-2),(HS-LS2-6)	one to understand how a model at one scale relates to a model at another scale. (HS-LS2-2) Stability and Change • Much of science deals with constructing explanations of how things change and how they remain stable. (HS-LS2-6)

Unit 2 Summary Structure and Function
How do the structures of organisms enable life's functions? Students formulate an answer to the question *"How do the structures of organisms enable life's functions?"* Students investigate explanations for the structure and functions of cells as the basic unit of life, of hierarchical organization of interacting organ systems, and of the role of specialized cells for maintenance and growth. The crosscutting concepts of *structure and function, matter and energy*, and *systems and system models* are called out as organizing concepts for the disciplinary core ideas. Students use *critical reading, modeling*, and *conducting investigations.* Students also use the science and engineering practices to demonstrate understanding of the disciplinary core ideas.
Student Learning Objectives
Explain the connection between the sequence and the subcomponents of a biomolecule and its properties. *[Clarification Statement: Emphasis is on the general structural properties that define molecules. Examples include r-groups of amino acids, protein shapes, the nucleotide monomers of DNA and RNA, hydrophilic and hydrophobic regions.] [Assessment Boundary: Assessment does not include identification or the molecular sequence and structure of specific molecules]* (LS1.A)
Create representations that explain how genetic information flows from a sequence of nucleotides in a gene to a sequence of amino acids in a protein. (LS1.A)
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. *[Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.]* **(HS-LS1-1)**
Construct models that explain the movement of molecules across membranes with membrane structure and function. *[Clarification Statement: Emphasis is on the structure of cell membranes, which results in selective permeability; the movement of molecules across them via osmosis, diffusion and active transport maintains dynamic homeostasis.]* (LS1.A)
Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. *[Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.] [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.]* **(HS-LS1-2)**
Provide examples and explain how organisms use feedback systems to maintain their internal environments. (LS1.A)
Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. *[Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] [Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.]* **(HS-LS1-3)**
Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. *[Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]* **(HS-LS1-4)**

Unit Sequence	
Part A: *How does the structure of DNA determine the structure of proteins, and what is the function of proteins?*	
Concepts	**Formative Assessment**
• Systems of specialized cells within organisms help them perform the essential functions of life. • All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal their functions and/or solve a problem.	*Students who understand the concepts are able to:* • Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells. • Construct an explanation, based on the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells. • Conduct a detailed examination of the structure and function of DNA.
Unit Sequence	
Part B: *What do you mean they say that people are made of a system of systems?*	
Concepts	**Formative Assessment**
• Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales.	*Students who understand the concepts are able to:* • Develop and use a model based on evidence to illustrate hierarchical organization of interacting systems that provide specific functions within multicellular organism. • Develop and use a model based on evidence to illustrate the interaction of functions at the organism system level. • Develop and use a model based on evidence to illustrate the flow of matter and energy within and between systems of an organism at different scales.
Unit Sequence	
Part C: *How do feedback mechanisms maintain homeostasis?*	

Concepts	Formative Assessment
• All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. • Feedback mechanisms maintain a living system's internal conditions within certain limits, and they mediate behaviors, allowing the system to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. • Feedback (negative or positive) can stabilize or destabilize a system.	*Students who understand the concepts are able to:* • Plan and conduct an investigation individually and collaboratively to produce evidence that feedback mechanisms (negative and positive) maintain homeostasis. • In the planning of the investigation, decide on the types, amount, and accuracy of the data needed to produce reliable measurements, consider limitations on the precision of the data, and refine the design accordingly.

Unit Sequence

Part D: *Why aren't all elephants the same size?*

Concepts	Formative Assessment
• In multicellular organisms, individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. • The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. • Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. • Models (e.g., physical, mathematical, and computer models) can be used to simulate systems and interactions, including energy, matter, and information flows, within and between systems at different scales.	*Students who understand the concepts are able to:* • Use a model based on evidence to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. • Use a model to illustrate the role of cellular division and differentiation in terms of energy, matter, and information flows within and between systems of cells/organisms.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence that supports how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Write an explanation that supports how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Draw evidence from informational texts to support how the structure of DNA determines the structure of proteins, which carry out the essential functions of life

through systems of specialized cells.

- Make strategic use of digital media in presentations to enhance understanding of the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- Conduct short as well as more sustained research to determine how feedback mechanisms maintain homeostasis. Synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- Gather applicable information from multiple reliable sources to support claims that feedback mechanisms maintain homeostasis. Use advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
- Make strategic use of digital media in presentations to enhance understanding of the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

Mathematics

- Use a mathematical model to illustrate the role of cellular division and differentiation in producing and maintaining complex organisms. Identify important quantities in the role of cellular division and differentiation in producing and maintaining complex organisms and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Graph functions expressed symbolically showing the role of cellular division and differentiation in producing and maintaining complex organisms and show key features of the graph, by hand in simple cases and using technology for more complicated cases.
- Write a function that describes a relationship between the role of cellular division and differentiation and the production and maintenance of complex organisms.

Suggested Learning Activities

Building Macromolecules from Monomers: Students will combine paper models of monomers for various macromolecules using knowledge of dehydration synthesis to create macromolecules.

Understanding the Functions of Proteins and DNA: Students learn about the functions of proteins and how different versions of a protein can result in a characteristic such as albinism or sickle cell anemia.

Model of phospholipid bilayer: Students will recognize structural components of fluid mosaic model.

Introduction to Osmosis- **Osmosis Egg Demonstration:** Students will predict cell response to a change in osmotic conditions.

Osmosis in Onion Cell Lab: Students will utilize microscope techniques to observe cell structures that regulate osmotic pressure to maintain homeostasis.

Design your own dialysis diffusion lab?/ **Diffusion Across a Selectively Permeable Membrane:** Students will design their own investigation using dialysis tubing, sugar and starch solutions to predict and observe the diffusion of water and other substances through the a selectively permeable membrane.

Osmosis & Diffusion "In and Out of Cells" Web quest: Students will use internet simulations to study active and passive transport.

Modeling endocytosis and exocytosis: Students will investigate the types of active transport in cells.

Enzyme Liver Lab (Chemical Reactions and Catalysts in Living Organisms): Students will observe the impact of temperature and pH on enzyme activity via. analysis of data.

Enzymes Help Us Digest Food: Students also analyze how lactase functions in the digestive system and how the digestive and circulatory systems cooperate to provide cells all over the body with molecules that provide the energy for cellular processes

Structure and Function of Molecules and Cells: Students analyze multiple examples of the relationship between structure and function in diverse proteins and eukaryotic cells. In addition, students learn that cells are dynamic structures with constant activity, students learn about emergent properties, and students engage in argument from evidence to evaluate three alternative claims concerning the relationship between structure and function.

Amylase cracker demonstration: Students will use sense of taste in recognizing specificity of digestive enzymes in the body.

Murder Food Lab (macromolecule identification): Students will apply various chemical tests to determine presence or absence of macromolecules of unknown sample.

Cell Cycle and Mitosis Internet Activity: Students will use an online web quest to identify stages of the cell cycle

Ideal Cell Size Lab Investigation: Students will use potato cubes to predict the rate of diffusion for a small and large cell. Students will measure the depth and rate of diffusion for a small and large cell (potato cube)

Mitosis vs. Meiosis Pipe Cleaner Modeling Activity: Students will use pipe cleaner chromosomes to model the processes of mitosis and meiosis

Structure and Function of Cells, Organs and Organ Systems: Students analyze multiple examples of the relationship between structure and function in diverse eukaryotic cells and in the digestive system. In addition, students learn that cells are dynamic structures with constant activity and they learn how body systems interact to accomplish important functions.

Mitosis – How Each New Cell Gets a Complete Set of Genes: students learn about the basic process of mitosis and use model chromosomes to simulate mitosis. Throughout, students respond to analysis and discussion questions to further develop their understanding of mitosis.

Homeostasis and Negative Feedback – Concepts and Breathing Experiments: Students carry out and analyze an experiment which investigates how rate and depth of breathing are affected by negative feedback regulation of blood levels of CO2 and O2. Finally, students formulate a question concerning effects of exercise on breathing, design and carry out a relevant experiment, analyze and interpret their data, and relate their results to homeostasis during exercise

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab

performance and analysis, Classwork & Homework reinforcement techniques, Discussion
Appendix A: NGSS and Foundations for the Unit
Explain the connection between the sequence and the subcomponents of a biomolecule and its properties. *[Clarification Statement: Emphasis is on the general structural properties that define molecules. Examples include r-groups of amino acids, protein shapes, the nucleotide monomers of DNA and RNA, hydrophilic and hydrophobic regions.] [Assessment Boundary: Assessment does not include identification or the molecular sequence and structure of specific molecules]* (LS1.A)
Create representations that explain how genetic information flows from a sequence of nucleotides in a gene to a sequence of amino acids in a protein. (LS1.A)
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. *[Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.]* **(HS-LS1-1)**
Construct models that explain the movement of molecules across membranes with membrane structure and function. *[Clarification Statement: Emphasis is on the structure of cell membranes, which results in selective permeability; the movement of molecules across them via osmosis, diffusion and active transport maintains dynamic homeostasis.]* (LS1.A)
Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. *[Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.] [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.]* **(HS-LS1-2)**
Provide examples and explain how organisms use feedback systems to maintain their internal environments. (LS1.A)
Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. *[Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] [Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.]* **(HS-LS1-3)**
Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. *[Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]* **(HS-LS1-4)**

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions • Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-1) **Developing and Using Models** • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-2) **Planning and Carrying Out Investigations** • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-LS1-3)	**LS1.A: Structure and Function** • Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (HS-LS1-2) • Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (HS-LS1-3) • Regions of DNA called genes determine the structure of proteins, which carry out the essential functions of life through systems of specialized cells. The sequence of genes contains instructions that code for proteins. (LS1.A) • Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS1-1) • Groups of specialized cells (tissues) use proteins to carry out functions that are essential to the organism. (LS1.A)	**Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-LS1-2) **Stability and Change** • Feedback (negative or positive) can stabilize or destabilize a system. (HS-LS1-3)

Unit 3 Summary
Matter and Energy in Organisms and Ecosystems

How do matter and energy cycle through ecosystems?

In this unit of study, students *construct explanations* for the role of energy in the cycling of matter in organisms and ecosystems. They *apply mathematical concepts* to *develop evidence to support explanations* of the interactions of photosynthesis and cellular respiration, and they will *develop models to communicate these explanations*. Students also understand organisms' interactions with each other and their physical environment and how organisms obtain resources. Students utilize the crosscutting concepts of *matter and energy* and *systems, and system models* to make sense of ecosystem dynamics. Students are expected to use students *construct explanations* for the role of energy in the cycling of matter in organisms and ecosystems. They *apply mathematical concepts* to *develop evidence to support explanations* as they demonstrate their understanding of the disciplinary core ideas.

This unit is based on HS-LS1-5, HS-LS2-3, HS-LS2-4, and HS-LS2-5.

Student Learning Objectives

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

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

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

Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. *[Clarification Statement: Examples of models could include simulations and mathematical models.] [Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.]* **(HS-LS2-5)**

Unit Sequence

Part A: *Why do astrobiologists look for water on planets and not oxygen when they search for life on other planets?*

Concepts	Formative Assessment
• Energy drives the cycling of matter within and between systems. • Energy drives the cycling of matter within and between systems in aerobic and anaerobic conditions. • Photosynthesis and cellular respiration (including anaerobic processes)	*Students who understand the concepts are able to:* • Construct and revise an explanation for the cycling of matter and flow of energy in aerobic and anaerobic conditions, based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the

provide most of the energy for life processes.	assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. • Construct and revise an explanation for the cycling of matter and flow of energy in aerobic and anaerobic conditions, considering that most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.
Unit Sequence	
Part B: *Why is there no such thing as a food chain?*	
Concepts	**Formative Assessment**
• Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. • At each link in an ecosystem, matter and energy are conserved. • Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward to produce growth and release energy in cellular respiration at the higher level. • Given this inefficiency, there are generally fewer organisms at higher levels of a food web. • Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. • The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways.	*Students who understand the concepts are able to:* • Support claims for the cycling of matter and flow of energy among organisms in an ecosystem using conceptual thinking and mathematical representations of phenomena. • Use a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and to show how matter and energy are conserved as matter cycles and energy flows through ecosystems. • Use a mathematical model to describe the conservation of atoms and molecules as they move through an ecosystem. • Use proportional reasoning to describe the cycling of matter and flow of energy through an ecosystem.
Unit Sequence	
Part C: *How can the process of photosynthesis and respiration in a cell impact ALL of Earth's systems?*	
Concepts	**Formative Assessment**
• Models (e.g., physical, mathematical, computer) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. • Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere,	*Students who understand the concepts are able to:* • Develop a model, based on evidence, to illustrate the roles of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere, showing

atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. • The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.	the relationships among variables in systems and their components in the natural and designed world. • Develop a model, based on evidence, to illustrate the roles of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere at different scales.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support an explanation for the cycling of matter and flow of energy in aerobic and anaerobic conditions, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Develop and write an explanation, based on evidence, for the cycling of matter and flow of energy in aerobic and anaerobic conditions by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples.
- Develop and strengthen an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

Mathematics

- Represent the cycling of matter and flow of energy among organisms in an ecosystem symbolically and manipulate the representing symbols. Make sense of quantities of and relationships between matter and energy as they cycle and flow through an ecosystem.
- Use a mathematical model to describe the cycling of matter and flow of energy among organisms in an ecosystem. Identify important quantities in the cycling of matter and flow of energy among organisms in an ecosystem and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand the cycling of matter and flow of energy among organisms in an ecosystem. Choose and interpret units consistently in formulas to determine the cycling of matter and flow of energy among organisms in an ecosystem. Choose and interpret the scale and the origin in graphs and data displays representing the cycling of matter and flow of energy among organisms in an ecosystem.
- Define appropriate quantities to represent matter and energy for the purpose of descriptive modeling of their cycling and flow among organisms in ecosystems.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing matter cycles and energy flows among organisms in ecosystems.

Suggested Learning Activities

Experiments in Photosynthesis Film: Students will make predictions on plant response to various conditions pertaining to the reactants and products of photosynthesis.

Photosynthesis Web- Quest: Students will utilize internet resources to observe and make predictions on factors that affect the process of photosynthesis including light intensity, water availability and gas exchange.

Photosynthesis Modeling Activity: Students learn the chemical formula for photosynthesis by acting out plant's photosynthetic process including photosystem 2, photosystem 1, and the Calvin cycle. Great visual and kinesthetic activity.

Where does a plant's mass come from? This analysis and discussion activity helps students to understand that a large part of a plant's mass consists of water, most of the biomass comes from carbon dioxide, and minerals from the soil contribute only a tiny amount of the plant's mass. For example, students engage in analyzing and interpreting data and arguing from evidence.

Plant Growth Puzzle: This analysis and discussion activity presents a structured sequence of questions to challenge students to explain why a plant that sprouts and grows in the light has a greater biomass than the seed it came from, whereas a plant that sprouts and grows in the dark has less biomass than the seed it came from.

Build a Paper Ecosystem: Using biotic and abiotic factors, students will build a food web and energy pyramid using examples of producers, consumers, and decomposers.

Surviving Winter in the Dust Bowl (Food Chains and Trophic Levels): The lesson engages students in an argumentation cycle based on an engaging scenario in which their group is a farm family trying to survive a dust bowl winter with limited food and water resources. The family has a bull, a cow, and limited amounts of water and wheat. Students are presented with four options that include various combinations of eating or keeping the animals alive and eating the wheat. Within this scenario, the lesson provides data on nutritional requirements of cows and humans, along with nutritional contents of wheat, milk, and beef. Students then use this data to construct an argument for the best strategy to allow their family to survive. As they construct this argument, students build and apply knowledge of food chains, trophic levels, interdependence among organisms, and energy transfers within ecosystems.

How does Energy Flow Through an Ecosystem? Virtual lab: Model Ecosystems: **Students** will model the transfer of energy up a food chain via online simulation.

Link: http://www.mhhe.com/biosci/genbio/virtual_labs/BL_02/BL_02.html

Food Webs, Energy Flow, Carbon Cycles and Trophic Pyramids: Students construct a food web for Yellowstone National Park, including producers, primary consumers, secondary consumers, decomposers, and trophic omnivores. Then, students analyze a trophic cascade that resulted when wolves were re-introduced to Yellowstone.

Cellular Respiration Activity: Students will model the biochemistry behind cellular respiration by acting out the steps of cellular respiration.

Exercise & Cellular Respiration Lab: Students will compare rate of aerobic cellular respiration before and after physical activity to confirm the production of CO_2 during aerobic respiration.

Lactic Acid Fermentation in Human Muscle Cells Investigation: Students will investigate the relationship between aerobic respiration, anaerobic respiration and muscle fatigue in living organisms.

Of Microbes and Men: Students will develop a model to show the relationships among nitrogen and the ecosystem including parts that are not observable but predict observable phenomena. They will then construct an explanation of the effects of the environmental and human factors on this cycle.

How do Biological Organisms Use Energy? This analysis and discussion activity helps students understand the basic principles of how biological organisms use energy, with a focus on the roles of ATP and cellular respiration. In addition, students apply the principles of conservation of energy and conservation of matter to avoid common errors and correct common misconceptions.

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

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

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

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

Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. *[Clarification Statement: Examples of models could include simulations and mathematical models.] [Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.]* **(HS-LS2-5)**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today	LS1.C: Organization for Matter and Energy Flow in Organisms • The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS-LS1-1) LS2.B: Cycles of Matter and Energy Transfer in Ecosystems	Energy and Matter • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-LS1-1) • Energy drives the cycling of matter within and between systems. (HS-LS2-3)

as they did in the past and will continue to do so in the future. (HS-LS2-3) **<u>Using Mathematics and Computational Thinking</u>** • Use mathematical representations of phenomena or design solutions to support claims. (HS-LS2-4) **<u>Developing and Using Models</u>** • Develop a model based on evidence to illustrate the relationships between systems or components of a system. (HS-LS1-5),(HS-LS2-5)	• Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (HS-LS2-3) • Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. (HS-LS2-4) • Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (HS-LS2-5)	• Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS2-4) **<u>Systems and System Models</u>** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-LS2-5) - ***Connections to Nature of Science*** **Scientific Knowledge is Open to Revision in Light of New Evidence** • Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. (HS-LS2-3)

Unit 4 Summary
Inheritance and Variation of Traits

How are characteristics from one generation related to the previous generation?

Students analyze data develop models to make sense of the relationship between DNA and chromosomes in the process of cellular division, which passes traits from one generation to the next. Students determine why individuals of the same species vary in how they look, function, and behave. Students develop *conceptual models* of the role of DNA in the unity of life on Earth and *use statistical models* to explain the importance of variation within populations for the survival and evolution of species. Ethical issues related to genetic modification of organisms and the nature of science are described. Students explain the mechanisms of genetic inheritance and describe the environmental and genetic causes of gene mutation and the alteration of gene expressions. The crosscutting concepts of *structure and function, patterns,* and *cause and effect* are used as organizing concepts for the disciplinary core ideas. Students also use the science and engineering practices to demonstrate understanding of the disciplinary core ideas.

Student Learning Objectives

Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. *[Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]* **(HS-LS1-4)**

Explain *how* the process of meiosis results in the passage of traits from parent to offspring, and how that results in increased genetic diversity necessary for evolution. [*Clarification Statement: The emphasis is on how meiosis results in genetic diversity, not the rote memorization of the steps of meiosis.]* (LS1.B)

Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. *[Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]* **(HS-LS3-1)**

Create a visual representation to illustrate how changes in a DNA nucleotide sequence can result in a change in the polypeptide produced. (LS3.B)

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. *[Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]* **(HS-LS3-2)**

Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. *[Clarification Statement: Emphasis on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.]* **(HS-LS3-3)**

Unit Sequence

Part A: *Why can't two roses ever be identical?*

Concepts	Formative Assessment

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- All cells contain genetic information in the form of DNA molecules.
- Genes are regions in the DNA that contain the instructions that code for the formation of proteins.
- Each chromosome consists of a single, very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA.
- The instructions for forming species' characteristics are carried in the DNA.
- All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways.
- Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have, as yet, no known function.
- Empirical evidence is required to differentiate between cause and correlation and to make claims about the role of DNA and chromosomes in coding the instructions for the characteristic traits passed from parents to offspring.

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Students who understand the concepts are able to:

- Ask questions that arise from examining models or a theory to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parent to offspring.
- Use empirical evidence to differentiate between cause and correlation and make claims about the role of DNA and chromosomes in coding the instructions for characteristics passed from parents to offspring.

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<tr><td colspan="2">Unit Sequence</td></tr>
<tr><td colspan="2">Part B: How does inheritable genetic variation occur?</td></tr>
<tr><td>Concepts</td><td>Formative Assessment</td></tr>
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- In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation.
- Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation.
- Environmental factors can also cause mutations in genes, and viable mutations are inherited.
- Environmental factors also affect expression of traits, and hence affect the probability of occurrence of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.
- Empirical evidence is required to differentiate between cause and correlation and to make claims about inheritable genetic variations resulting

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Students who understand the concepts are able to:

- Make and defend a claim based on evidence that inheritable genetic variations may result from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors.
- Use data to support arguments for the ways inheritable genetic variation occurs.
- Use empirical evidence to differentiate between cause and correlation and make claims about the ways inheritable genetic variation occurs.

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from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors.	

Unit Sequence

Part C: *Can a zoologist predict the distribution of expressed traits in a population?*

Concepts	Formative Assessment
• Environmental factors affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variations and distributions of traits observed depend on both genetic and environmental factors. • Algebraic thinking is used to examine scientific data and predict the distribution of traits in a population as they relate to the genetic and environmental factors (e.g., linear growth vs. exponential growth). • Technological advances have influenced the progress of science, and science has influenced advances in technology. • Science and engineering are influenced by society, and society is influenced by science and engineering.	*Students who understand the concepts are able to:* • Apply concepts of statistics and probability (including determining function fits to data, slope, intercepts, and correlation coefficient for linear fits) to explain the variation and distribution of expressed traits in a population. • Use mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits. • Use algebraic thinking to examine scientific data on the variation and distribution of traits in a population and predict the effect of a change in probability of traits as it relates to genetic and environmental factors.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support analysis of science and technical texts describing the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring, resolving conflicting information when possible.
- Cite specific textual evidence to support analysis of science and technical texts describing the ways that inheritable genetic variation occurs, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Write arguments, based on evidence, that inheritable genetic variations may result from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors.

Mathematics

- Represent symbolically evidence that inheritable genetic variations may result from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors, and manipulate the representing symbols. Make sense of quantities and relationships to describe and predict the ways in which inheritable genetic variation occurs.
- Represent the variation and distribution of expressed traits in a population symbolically and manipulate the representing symbols. Make sense of quantities and

relationships to describe and predict the variation and distribution of expressed traits in a population.

Suggested Learning Resources

Structure and Function: Stem Cell: Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.

DNA Structure, Function and Replication: To introduce students to key concepts about the structure, function and replication of DNA or to review these topics. This activity includes hands-on modeling of DNA replication.

Modeling DNA Replication, Transcription and Translation Activities: Model the process of protein synthesis utilizing the genetic codon chart to show how DNA determines the structure of proteins which determine physical characteristics in organisms.

From Gene to Protein – Transcription and Translation: Students also analyze how lactase functions in the digestive system and how the digestive and circulatory systems cooperate to provide cells all over the body with molecules that provide the energy for cellular processes

DNA Mutations and Consequences Activity: Students will witness the change a single point mutation in the DNA can have on a resulting protein.

DNA Extraction Lab: Through active investigation of extraction human cheek cells, students will understand the technique and applications of DNA extraction.

Determining Structure of DNA Investigation: Students will analyze given set of data to construct an argument about the molecular structure of DNA. Students will compare synthesized models to determine the validity of their argument.

Karyotype & Pedigree STEM project: Students will explore, explain, elaborate and evaluate karyotypes and pedigrees of human chromosomal disorder case studies.

Probability Lab: Students will be introduced to concepts of probability and inheritance by applying concepts of statistics to bead models.

Genetics Activity: Students will complete a coin toss genetics activity and an analysis of student data on the sex makeup of sibships, both of which help students understand the probabilistic nature of inheritance and Punnett square predictions

Soap Opera Genetics – Genetics to Resolve Family Arguments: Students explain the relevant biology to answer the probing questions of a skeptical father who wants to know how his baby could be albino when neither he nor his wife are albino. Students also analyze sex-linked inheritance.

Genetic Engineering Challenge - How can scientists develop a type of Rice that could prevent vitamin A deficiency? To challenge students to design a basic plan that could produce a genetically engineered rice plant that makes rice grains that contain pro-vitamin A

Investigating Corn Genetics: Students will collect and analyze data of corn kernel population and apply test cross methods in determining genotypes of P generation. Students will additionally complete a test cross based on two-trait (dihybrid) corn kernel analysis.

Using Blood Tests to Identify Babies and Criminals: Students will use knowledge of non-mendelian genetics and multiple alleles to determine identities of unknown individuals.

Meiosis and Fertilization – Understanding How Genes Are Inherited: Students use model chromosomes to simulate the processes of meiosis and fertilization. As they model meiosis and fertilization, students follow the alleles of three human genes from the parents' body cells through gametes to zygotes.

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. [*Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.*] **(HS-LS1-4)**

Explain *how* the process of meiosis results in the passage of traits from parent to offspring, and how that results in increased genetic diversity necessary for evolution. [*Clarification Statement: The emphasis is on how meiosis results in genetic diversity, not the rote memorization of the steps of meiosis.*](LS1.B)

Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*] **(HS-LS3-1)**

Create a visual representation to illustrate how changes in a DNA nucleotide sequence can result in a change in the polypeptide produced. (LS3.B)

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. [*Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.*] [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*] **(HS-LS3-2)**

Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. [*Clarification Statement: Emphasis on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.*] [*Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.*] **(HS-LS3-3)**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems • Ask questions that arise from examining models or a theory to clarify relationships. (HS-LS3-1) **Constructing Explanations and Designing Solutions**	LS1.A: Structure and Function • All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. (secondary to HS-LS3-1)	Cause and Effect • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HSLS3-1; HSLS3-2)

• Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-1) **Engaging in Argument from Evidence** • Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. (HS-LS3-2) • Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon. (MS-LS1-3) • Use an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS-LS1-4)	**LS3.A: Inheritance of Traits** • Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. • Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. (HS-LS3-1) **LS3.B: Variation of Traits** • In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (HS-LS3-2) • Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (HS-LS3-2; HS-LS3-3)	**Scale, Proportion, and Quantity** • Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-LS3-3)

Unit 5 Summary

Natural Selection and Mechanisms of Evolution

How can there be so many similarities among organisms yet so many different plants, animals, and microorganisms?

Students *constructing explanations* and *designing solutions, analyzing and interpreting data*, and *engaging in argument from evidence investigate* to make sense of the relationship between the environment and natural selection. Students also develop an understanding of the factors causing natural selection of species over time. They also demonstrate and understandings of how multiple lines of evidence contribute to the strength of scientific theories of natural selection. The crosscutting concepts of *patterns* and *cause and effect* serve as organizing concepts for the disciplinary core ideas. Students also use the science and engineering practices to demonstrate understanding of the disciplinary core ideas.

This unit is based on Disciplinary Core Idea LS4.C (Adaptation), HS-LS4-4, HS-LS4-3, HS-LS4-5, and HS-LS2-8.

Student Learning Objectives

Make predictions about the effects of artificial selection on the genetic makeup of a population over time. (LS4.C)

Construct an explanation based on evidence for how natural selection leads to adaptation of populations. *[Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]* **(HS-LS4-4)**

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. *[Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.]* **(HS-LS4-3)**

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. *[Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]* **(HS-LS4-5)**

Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. *[Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.]* **(HS-LS2-8)**

Unit Sequence

Part A: *How does natural selection lead to adaptations of populations?*

Concepts	Formative Assessment
• Natural selection leads to adaptation, that is, to a population dominated by	*Students who understand the concepts are able to:*

organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. • Empirical evidence is required to differentiate between cause and correlation and make claims about how natural selection leads to adaptation of populations. • Empirical evidence is required to differentiate between cause and correlation and make claims about how specific biotic and abiotic differences in ecosystems contribute to change in gene frequency over time, leading to adaptation of populations. • Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and will continue to do so in the future.	• Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review), and on the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, for how natural selection leads to adaptation of populations. • Use data to differentiate between cause and correlation and to make claims about how specific biotic and abiotic differences in ecosystems contribute to change in gene frequency over time, leading to adaptation of populations.

Unit Sequence

Part B: *Why is it so important to take all of the antibiotics in a prescription if I feel better?*

Concepts	Formative Assessment
• Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. • The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. • Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. • Adaptation also means that the distribution of traits in a population can change when conditions change. • Different patterns may be observed at each of the scales at which a system is	*Students who understand the concepts are able to:* • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. • Analyze shifts in numerical distribution of traits and, using these shifts as evidence, support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. • Observe patterns at each of the scales at which a system is studied to provide evidence for causality in explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.

studied and can provide evidence for causality in explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.	

Unit Sequence

Part C: *How are species affected by changing environmental conditions?*

Concepts	Formative Assessment
• Changes in the physical environment, whether naturally occurring or human induced, have contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline, and sometimes the extinction, of some species. • Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. • Empirical evidence is required to differentiate between cause and correlation and make 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.	*Students who understand the concepts are able to:* • 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. • Determine cause-and-effect relationships for how changes to the environment affect distribution or disappearance of traits in species. • Use empirical evidence to differentiate between cause and correlation and to make 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.

Unit Sequence

Part D: *Why do some species live in groups and others are solitary?*

Concepts	Formative Assessment
• Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. • Empirical evidence is required to differentiate between cause and correlation and to make claims about the role of group behavior in individual and species' chances to survive and reproduce. • Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in the revision of an explanation about the role of group behavior on individual and species' chances to survive and reproduce.	*Students who understand the concepts are able to:* • Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. • Distinguish between group and individual behavior. • Identify evidence supporting the outcome of group behavior. • Develop logical and reasonable arguments based on evidence to evaluate the role of group behavior on individual and species' chances to survive and reproduce. • Use empirical evidence to differentiate between cause and correlation and to make claims about the role of group behavior on individual and species'

	chances to survive and reproduce.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support analysis of science and technical texts describing how natural selection leads to adaptation of populations, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Write informative/explanatory texts describing how natural selection leads to adaptation of populations, including the narration of historical events, scientific procedures/experiments, or technical processes.
- Draw evidence from informational texts to support analysis, reflection, and research about how natural selection leads to adaptation of populations.
- Cite specific textual evidence to support analysis of science and technical texts that provide explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Write informative/explanatory texts about explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait, including the narration of historical events, scientific procedures/experiments, or technical processes.
- Draw evidence from information texts to support analysis, reflection, and research about organisms with an advantageous heritable trait and their proportional increase as compared to organisms lacking this trait.
- Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text 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, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
- Draw evidence from information texts making 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 to support analysis, reflection, and research.
- Assess the extent to which the reasoning and evidence in a text support the author's claim about the role of group behavior on individual and species' chances to survive and reproduce.
- Cite specific textual evidence to support analysis of science and technical texts about the role of group behavior on individual and species' chances to survive and reproduce.
- Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address the role of group behavior on individual and species' chances to survive and reproduce.
- Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text about the role of group behavior on individual and species' chances to survive and reproduce, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Mathematics

- Represent how natural selection leads to adaptation of populations symbolically, and manipulate the representing symbols. Make sense of quantities and relationships between specific biotic and abiotic differences in ecosystems and their contributions to a change in gene frequency over time that leads to adaptation of populations.

- Represent symbolically the proportional increase in organisms with an advantageous heritable trait as compared with organisms lacking this trait, and manipulate the representing symbols. Make sense of quantities and relationships between the proportional increase in organisms with an advantageous heritable trait as compared with the numbers of organisms lacking this trait.

Suggested Learning Activities

Peppered Moth Evolution: Students explain how variation, selection, and time drive the process of evolution by collecting and analyzing data within peppered moth population. Students will construct graphical representations to visualize trend of change over time within population of moths.

Evolution by Natural Selection: Students develop their understanding of natural selection by analyzing specific examples and carrying out a simulation

Using Molecular and Evolutionary Biology to Understand HIV/AIDS and Treatment: To challenge students to apply their understanding of basic molecular and cellular biology and natural selection and interpret information presented in prose and diagrams in order to understand multiple aspects of the biology of HIV/AIDS and treatment.

Evolution and Adaptations Lesson: Students will analyze how the balance between the advantages and disadvantages of a characteristic (e.g. an animal's color) can vary in different circumstances, how phenotypic plasticity can be a heritable trait that can optimize fitness in a variable environment, and how natural selection can influence the amount of phenotypic plasticity in a population. This activity is designed to help high school students meet the Next Generation Science Standards and the Common

The Ecology of Lyme Disease: Students will analyze when and where human risk of Lyme disease is greatest, why rates of Lyme disease have increased in recent decades in the US, and ecological approaches to preventing Lyme disease.

Desert Snakes (Mechanics of Evolution): Students will generate argument using multiple lines of evidence presented via. text, data tables and photos to defend claim about physical similarities between snakes. Students will present and justify their claim to classmates.

Monstrous Mutation Lab: Students will simulate how mutations in DNA impact the fitness of an organism due to natural selection.

Modeling the Process of Natural Selection: Class will act as a varied population of living organisms that over time will change due to external and internal factors.

Genetic Drift Activity: Students will analyze shifts in numerical distribution of traits due to density independent factors.

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

Make predictions about the effects of artificial selection on the genetic makeup of a population over time. (LS4.C)

Construct an explanation based on evidence for how natural selection leads to adaptation of populations. *[Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]* **(HS-LS4-4)**

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. *[Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.]* **(HS-LS4-3)**

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. *[Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]* **(HS-LS4-5)**

Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. *[Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.]* **(HS-LS2-8)**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data • Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS4-3) **Constructing Explanations and Designing Solutions** • Construct an explanation based on valid and	**LS1.A: Structure and Function** • Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (HS-LS1-2) **LS4.B: Natural Selection** • Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. (HS-LS4-3) • The traits that positively affect survival are more likely to be reproduced, and thus are more	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-4) **Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-LS4-3)

<table>
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<td>reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS4-4)

Engaging in Argument from Evidence

• Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS4-5)</td>
<td>common in the population. (HSLS4-3)

• Adaptation also means that the distribution of traits in a population can change when conditions change. (HS-LS4-3)

LS4.C: Adaptation

• Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. (HS-LS4-4)

LS2.D: Social Interactions and Group Behavior

• Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. (HSLS2-8)</td>
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Unit 6 Summary
Evidence of Evolution, Relationships and Common Ancestry

What evidence shows that different species are related?

Students construct explanations for the processes of natural selection and evolution and then communicate how multiple lines of evidence support these explanations. Students evaluate evidence of the conditions that may result in new species and understand the role of genetic variation in natural selection. Additionally, students can apply concepts of probability to explain trends in population as those trends relate to advantageous heritable traits in a specific environment. Students demonstrate an understanding of these concepts by *obtaining, evaluating, and communicating information* and *constructing explanations and designing solutions.* The crosscutting concepts of patterns and cause and effect support the development of a deeper understanding.

Student Learning Objectives

Examine a group of related organisms using a phylogenic tree or cladogram in order to (1) identify shared characteristics, (2) make inferences about the evolutionary history of the group, and (3) identify character data that could extend or improve the phylogenetic tree. (LS4.A)

Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. *[Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]* **(HS-LS4-1)**

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 (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. *[Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.]* **(HS-LS4-2)**

Unit Sequence

Part A: *How can someone prove that birds and dinosaurs are related?*

Concepts	Formative Assessment
• A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. • Genetic information provides evidence of evolution. DNA sequences vary	*Students who understand the concepts are able to:* • Communicate scientific information in multiple forms that common ancestry and biological evolution are supported by multiple lines of empirical evidence. • Understand the role each line of evidence has relating to common ancestry and biological evolution. • Observe patterns in multiple lines of empirical evidence at different scales

among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. • Different patterns in multiple lines of empirical evidence may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of common ancestry and biological evolution.	and provide evidence for causality in explanations of common ancestry and biological evolution.

Unit Sequence

Part B: *What is the relationship between natural selection and evolution?*

Concepts	Formative Assessment
• Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information— that is, trait variation—that leads to differences in performance among individuals. • Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. • Empirical evidence is required to differentiate between cause and correlation and make claims about the process of evolution.	*Students who understand the concepts are able to:* • Construct an explanation, based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, 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 (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. • Use empirical evidence to explain the influences of: (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 (4) the proliferation of those organisms that are better able to survive and reproduce in the environment, on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support analysis of science and technical texts describing common ancestry and biological evolution, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

- Write informative/explanatory texts describing common ancestry and biological evolution, including the narration of historical events, scientific procedures/experiments, or technical processes.
- Draw evidence from informational texts describing common ancestry and biological evolution to support analysis, reflection, and research.
- Present claims and findings about common ancestry and biological evolution, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics

- Represent evidence that common ancestry and biological evolution are supported by multiple lines of empirical evidence symbolically, and manipulate the representing symbols. Make sense of quantities and relationships to describe and predict common ancestry and biological evolution.

Suggested Learning Activities

Anatomical Evidence of Evolution Investigation: Students investigate evidence for evolution by analyzing fossil evidence, structural evidence, and genetic evidence in support of common ancestry among living things.

How could complex eyes have evolved? Students analyze evidence from comparative anatomy, mathematical modeling, and molecular biology. This evidence suggests a likely sequence of steps in the evolution of the human eye and the octopus eye.

Construction of Cladograms: Students will interpret cladograms and synthesize cladograms to identify shared characteristics and make inferences about the evolutionary history of the group.

Geologic Time Web Quest: Students will use various online sources to study the history of life on Earth and major life forms that existed during each era.

Evolutionary Relationships in Mammals: Students will compare amino acid sequences, homologous structures and photographs of various animals to make a claim that incorporates phylogeny between mammal species.

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. *[Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of* *evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]* (HS-LS4-1)

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 (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. *[Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.]* (HS-LS4-2)

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information • Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-LS4-1) **Constructing Explanations and Designing Solutions** • Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS4-2)	**LS4.A: Evidence of Common Ancestry and Diversity** • Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. (HS-LS4-1) **LS4.B: Natural Selection** • Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. (HS-LS4-2) **LS4.C: Adaptation** • Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-LS4-1) **Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-2)

	that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-2)	

HONORS BIOLOGY CURRICULUM ACTIVITIES - ALIGNED WITH NGSS STANDARDS

Units 1 and 3 Activities – Ecology, Ecosystems, and Biodiversity

Cellular Respiration Activity
Students will model the biochemistry behind cellular respiration by acting out the steps of cellular respiration.
HS-LS1.C: Organization for Matter and Energy Flow in Organisms
Published by NGSS Life Science

Build a Paper Ecosystem
Using biotic and abiotic factors, students will build a food web and energy pyramid using examples of producers, consumers, and decomposers.
HS-LS1.C: Organization for Matter and Energy Flow in Organisms

Photosynthesis Activity
Students learn the chemical formula for photosynthesis by acting out plant's photosynthetic process including photosystem 2, photosystem 1, and the Calvin cycle. Great visual and kinesthetic activity.
HS-LS2.B: Cycles of Matter and Energy Transfer in Organisms

How does Energy Flow Through an Ecosystem?
Virtual lab: Model Ecosystems
http://www.mhhe.com/biosci/genbio/virtual_labs/BL_02/BL_02.html
HS-LS2.B: Cycles of Matter and Energy Transfer in Organisms

These activities help to prepare students to meet **Performance Expectations** (PE)

(from http://serendip.brynmawr.edu/exchange/bioactivities/NGSS)

- HS-LS1-5, "Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy."
- 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."
- HS-LS2-5. "Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere..."

Activity	Scientific Practices[1]					Crosscutting Concepts[2]		
	Model	Investigation	Data	Explain	Argue	Mechanism	Models	Energy
How do biological organisms use energy? (DCI: LS1.C; PE: HS-LS1-7)				+		+		+
Using Models to Understand Photosynthesis (DCI: LS1.C, LS 2.B; PE: HS-LS1-5, HS-LS1-7, HS-LS2-5)	+			+			+	+
Photosynthesis Investigation (DCI: LS1.C; PE: HS-LS1-5)		+	+	+				+
Where does a plant's mass come from? (DCI: LS1.C; PE: HS-LS1-5)			+		+			+
Plant Growth Puzzle (DCI: LS1.C; PE: HS-LS1-5 and HS-LS1-7)			+	+		+		+

How do muscles get the energy they need for athletic activity? (DCI: LS1.C; PE: HS-LS1-7)				+	+			+
Food, Energy and Body Weight (DCI: LS1.C; PE: HS-LS1-7)				+				+

[1] Model = Developing and Using Models; Investigation = Planning and Carrying out Investigations; Data = Analyzing and Interpreting Data; Explain = Constructing Explanations and Designing Solutions; Argue = Engaging in Argument from Evidence

[2] Mechanism = Cause and effect: Mechanism and explanation; Models = Systems and System Models; Energy = Energy and Matter: Flows, Cycles and Conservation

Learning Activities for Disciplinary Core Idea (DCI) **LS1.C - Organization for Matter and Energy Flow in Organisms**

LS2.B - Photosynthesis and Cellular Respiration – Carbon Cycle

(from http://serendip.brynmawr.edu/exchange/bioactivities/NGSS)

These activities help to prepare students to meet **Performance Expectations** (PE)

- HS-LS1-5, "Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy."
- 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."
- HS-LS2-5. "Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere…"

[1] Model = Developing and Using Models; Investigation = Planning and Carrying out Investigations; Data = Analyzing and Interpreting Data; Explain = Constructing Explanations and Designing Solutions; Argue = Engaging in Argument from Evidence

[2] Mechanism = Cause and effect: Mechanism and explanation; Models = Systems and System Models; Energy = Energy and Matter: Flows, Cycles and Conservation

Learning Activities for Disciplinary Core Ideas (DCI) **LS2.A – Interdependent Relationships in Ecosystems**

LS2.B – Cycles of Matter and Energy Transfer in Ecosystems

LS2.C – Ecosystem Dynamics, Functioning and Resilience

(from http://serendip.brynmawr.edu/exchange/bioactivities/NGSS)

These activities prepare students to meet **Performance Expectations** (PE)

- MS-LS2-3. "Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem."
- HS-LS2-1,"Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems…"
- HS-LS2-2, "Use mathematical representations to support and revise explanations based on evidence about factors affecting... populations in ecosystems..."
- HS-LS2-4. "Use a mathematical representation to support claims for the cycling of matter and flow of energy among organisms in an ecosystem."
- 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."
- HS-LS2-6, "Evaluate the 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."

Activity	Scientific Practices[1]					Crosscutting concepts[2]			
	Model	Math	Data	Explain	Argue	Mechanism	Models	Stability/ Change	Energy/ Matter
Population Growth - Exponential and Logistic Models vs.	+	+	+	+			+	+	

Complex Realities (DCI: LS2.A, LS2.C; PE: HS-LS2-1, HS-LS2-2)									
Food Webs, Energy Flow, Carbon Cycles and Trophic Pyramids (DCI: LS2.B; PE: MS-LS2-3, HS-LS2-4, HS-LS2-5	+	+	+	+					+
Changing Biological Communities - Disturbance and Succession (DCI: LS2.C)	+		+	+	+	+	+	+	

[1] Model = Developing and Using Models; Math = Using Mathematics and Computational Thinking; Data = Analyzing and Interpreting Data; Explain = Constructing Explanations; Argue = Engaging in Argument from Evidence

[2] Mechanism = Cause and effect: Mechanism and explanation; Models = Systems and system models; Stability/Change = Stability and Change; Energy/Matter= Energy and Matter: Flows, Cycles and Conservation

NGS Standard: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity (HS-LS2-7).

Culminating Showcase Lesson: Bye, Bye Birdie

https://www.populationeducation.org/sites/default/files/activity-bye_bye_birdie.pdf

Curriculum CD: Earth Matters,Biodiversity (Earth Matters Unit)

Grade Level: High School

Subjects: biology, environmental science, language arts, civics

Lesson Objectives: In this lesson students will be able to:

- Develop criteria that ecologists, wildlife managers, and public officials might use to make decisions about protecting endangered species.
- Conduct research on an endangered species through the Internet and other sources.
- Present their findings, showing how their species measures up against the chosen decision criteria.

Many human activities have adverse effects on the environment. Human induced climate change, deforestation, land use conversion, and pollution are causing a great loss in species biodiversity across the planet. Scientists estimate that as much as species could go extinct by the year 2020, and some argue humans are the primary driver behind a sixth mass extinction. High species biodiversity provides many valuable ecosystem services that keep our planet in equilibrium. With the rate of wildlife endangerment increasing, difficult decisions are required in order to prioritize efforts to save endangered species. In Bye, Bye Birdie students determine which factors should be considered in species conservation and conduct research on an endangered species to justify it preservation.

Note: This lesson is targeted to meet NGS Standard HS-LS2-7 –however– it is most closely aligned to its supporting Disciplinary Core Idea LS4.D (by grade 12), which examines the ways in which humans adversely impact biodiversity. This activity should be used to supplement a series of lessons aimed at meeting standard HS-LS2-7.

Units 2 and 4 Activities- Cell Specialization, Homeostasis, and DNA/Inheritance

Learning Activities for Disciplinary Core Idea (DCI) **LS1.A - Structure and Function (Part 1)**

(from http://serendip.brynmawr.edu/exchange/bioactivities/NGSS)

These activities help to prepare students to meet **Performance Expectations** (PE):

- MS-LS1-2, "Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function."

- MS-LS1-3, "Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells."

Activity[1]	Scientific Practices[2]						Crosscutting Concepts[3]		
	Model	Investigation	Data	Explain	Argue	Info	Mechanism	Models	Structure/Function
Structure and Function of Cells, Organs and Organ Systems (DCI: LS1.A; PE: MS-LS1-2, MS-LS1-3)[4]				+	+	+			+
Diffusion Across a Selectively Permeable Membrane (DCI: LS1.A; PE: MS-LS1-2)	+	+	+	+			+	+	+
Introduction to Osmosis (DCI: LS1.A; PE: MS-LS1-2)		+	+	+			+		+

[1]For each activity, Student Handouts and Teacher Notes with instructional suggestions and background information are available at the link given.

[2]Model = Developing and Using Models; Investigation = Planning and Carrying out Investigations; Data = Analyzing and Interpreting Data; Explain = Constructing

Explanations and Designing Solutions; Argue = Engaging in Argument from Evidence; Info = Obtaining, Evaluating and Communicating Information

[3]Mechanism = Cause and effect: Mechanism and explanation; Models = Systems and system models; Structure/Function = Structure and function

[4]DCI = Disciplinary Core Idea; PE = Performance Expectation. Additional information is provided in the Teacher Notes (see footnote 1) and the Next Generation Science Standards website where you can use the search function to find more specifics.

Learning Activities for Disciplinary Core Ideas (DCI) **LS1.A - Structure and Function (Part 2) and**

LS1.B - Growth and Development of Organisms

(from http://serendip.brynmawr.edu/exchange/bioactivities/NGSS)

These activities help to prepare students to meet **Performance Expectations** (PE)

- 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 organisms."
- HS-LS1-3, "Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis."
- HS-LS1-4, "Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms."

Activity	Scientific Practices[1]						Crosscutting Concepts[2]		
	Ask	Model	Investigation	Data	Explain	Argue	Models	Structure and function	Stability/ change
Understanding the Functions of Proteins and DNA (DCI: LS1.A, LS3.A; PE: HS-LS1-1, HS-LS3-1)			+		+			+	

Enzymes Help Us Digest Food (DCI: LS1.A; PE: HS-LS1-1, HS-LS1-2)			+	+	+			+	
Structure and Function of Molecules and Cells (DCI: LS1.A; PE: HS-LS1-1)					+	+		+	
DNA (DCI: LS1.A, LS3.A; PE: HS-LS1-1, MS-LS3-1, HS-LS3-1)		+			+			+	
DNA Structure, Function and Replication (DCI: LS1.A, LS3.A; PE: HS-LS1-1, MS-LS3-1, HS-LS3-1)		+			+			+	
From Gene to Protein - Transcription and Translation (DCI: LS1.A,		+					+	+	

LS3.A, LS3.B; PE: HS-LS1-1, HS-LS3-1)									
Mitosis - How Each New Cell Gets a Complete Set of Genes (DCI: LS1.A, LS1.B, LS3.A; PE: MS-LS3-2, HS-LS1-4, HS-LS3-1)		+			+		+	+	
Meiosis and Fertilization - Understanding How Genes Are Inherited (DCI: LS1.A, LS1.B, LS3.A, LS3.B; PE: MS-LS3-2, HS-LS3-1, HS-LS3-2)		+			+		+		
Homeostasis and Negative Feedback - Concepts and Breathing Experiments (DCI: LS1.A; PE: HS-LS1-3)	+		+	+	+				+

[1] Ask = Asking Questions; Model = Developing and Using Models; Investigation = Planning and Carrying out Investigations; Data = Analyzing and Interpreting Data; Explain = Constructing Explanations; Argue = Engaging in Argument from Evidence

[2] Models = Systems and system models; Structure/Function = Structure and function; Stability/Change = Stability and Change

Learning Activities for Disciplinary Core Idea (DCI) **LS3A – Inheritance of Traits**

(from http://serendip.brynmawr.edu/exchange/bioactivities/NGSS)

These activities help to prepare students to meet **Performance Expectations** (PE)

- MS-LS3-1, "Develop and use a model to describe why structural changes to genes located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism."
- 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."

Activity	Scientific and Engineering Practices[1]					Crosscutting Concepts[2]		
	Model	Investigation	Data	Explain	Argue	Mechanism	Models	Structure/ Function
Mitosis - How Each New Cell Gets a Complete Set of Genes (DCI: LS1.A, LS1.B, LS3.A; PE: MS-LS3-2, HS-LS1-4, HS-LS3-1)	+			+			+	+
Meiosis and Fertilization - Understanding	+			+			+	

How Genes Are Inherited (DCI: LS1.A, LS1.B, LS3.A, LS3.B; PE: MS-LS3-2, HS-LS3-1, HS-LS3-2)								
Genetics (DCI: LS1.A, LS3.A, LS3.B; PE: HS-LS3-1, HS-LS3-2, HS-LS3-3)	+		+	+	+		+	
Soap Opera Genetics - Genetics to Resolve Family Arguments (DCI: LS1.A, LS3.A, LS3.B; PE: HS-LS3-1, HS-LS3-2, HS-LS3-3)	+			+	+		+	
Understanding the Functions of Proteins and DNA (DCI: LS1.A, LS3.A; PE: HS-LS1-1, HS-LS3-1)		+		+				+
DNA (DCI: LS1.A, LS3.A; PE: HS-LS1-1, MS-LS3-	+			+				+

1, HS-LS3-1)								
DNA Structure, Function and Replication (DCI: LS1.A, LS3.A; PE: HS-LS1-1, MS-LS3-1, HS-LS3-1)	+			+				+
From Gene to Protein - Transcription and Translation (DCI: LS1.A, LS3.A, LS3.B; PE: HS-LS1-1, HS-LS3-1)	+						+	+
Genetic Engineering Challenge - How can scientists develop a type of Rice that could prevent vitamin A deficiency? (DCI: LS1.A, LS3.A; PE: HS-LS3-1)				+*		+		+

*Includes Engineering Practice = Designing solutions

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[2] Mechanism = Cause and Effect: Mechanism and explanation; Models = Systems and System Models; Structure/Function = Structure and Function

Units 5 and 6 Activities: Natural Selection and Evolution

Learning Activities for Disciplinary Core Ideas (DCI) **LS4.A - Evidence of Common Ancestry and Diversity**

LS4.B - Natural Selection and **LS4.C - Adaptation**

(from http://serendip.brynmawr.edu/exchange/bioactivities/NGSS)

These activities prepare students to meet **Performance Expectations** (PE)

- MS-LS4-4, "Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment."
- MS-LS4-6, "Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time."
- 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 (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 increases in the number of individuals of some species..."
- HS-LS4-1, "Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence."

Activity	Scientific Practices[1]					Crosscutting Concepts[2]			
	Model	Math	Data	Explain	Argue	Mechanism	Models	Structure/ Function	Stability/ Change
How could complex eyes	+			+	+			+	+

have evolved? (DCI: LS4.A, LS4.C; PE: HS-LS4-1)									
Evolution by Natural Selection (DCI: LS4.B, LS4.C; PE: MS-LS4-4, MS-LS4-6, HS-LS4-2, HS-LS4-3, HS-LS4-4)	+	+	+	+	+	+	+		+
Natural Selection - Major Concepts and Learning Activities (DCI: LS4.B, LS4.C; PE MS-LS4-4, MS-LS4-6, HS-LS4-2, HS-LS4-3, HS-LS4-4)	+	+	+	+	+	+	+		+ See
Using Molecular and Evolutionary Biology to Understand HIV/AIDS and Treatment (DCI: LS3.A LS4.B; PE: HS-LS4-4)				+		+		+	+
Evolution and Adaptations (DCI: LS4.B, LS4.C; PE: HS-			+	+	+	+			+

LS4-4)									
The Ecology of Lyme Disease (DCI: LS4.C; PE: HS-LS4-5)			+	+	+				+

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[2] Mechanism = Cause and effect: Mechanism and explanation; Models = Systems and system models; Structure/Function = Structure and function Stability/Change = Stability and change

TOWNSHIP OF UNION PUBLIC SCHOOLS

Action Chemistry

Curriculum Guide 2016

Curriculum Committee

John Rickel

Academic Area

Action Chemistry

Course Description

This course is specifically designed for students that are considering higher educational alternatives upon graduating from high school. Chemistry is a discipline that teaches students to think mathematically and how to apply abstract scientific concepts to real world challenges.

References

The following curriculum guide was adapted from the Next Generation Science Standards and the State of New Jersey Department of Education High School Chemistry Model Curriculum.

"Model Curriculum: HS Chemistry." *Model Curriculum: HS Chemistry.* State of New Jersey. 2014. Web. 26 Apr. 2016.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press. Web. 26 Apr. 2016.

Curriculum Unit Overview

Unit 1 - Structure and Properties of Matter

Unit 2 – Energy of Chemical Systems

Unit 3 - Bonding and Chemical Reactions

Unit 4 – Matter and Energy in Living Systems

Unit 5 – Nuclear Chemistry

Curriculum Pacing Guide – Action Chemistry

Unit Name	**Estimated Number of Weeks**
Unit 1- Structure and Properties of Matter	10
Unit 2- Energy of Chemical Systems	5
Unit 3- Bonding and Chemical Reactions	8
Unit 4- Matter and Energy in Living Systems	6
Unit 5- Nuclear Chemistry	4

Course Proficiencies

For all units, students will understand and follow all laboratory and safety rules, understand scientific explanations, general scientific evidence through active investigations, reflection on scientific knowledge, and participate productively in science.

Unit 1: Structure and Properties of Matter

In this unit of study, students use investigations, simulations, and models to makes sense of the substructure of atoms and to provide more mechanistic explanations of the properties of substances. Chemical reactions, including rates of reactions and energy changes, can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Students are able to use the periodic table as a tool to explain and predict the properties of elements. Students are expected to communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials. The crosscutting concepts of *structure and function*, *patterns*, *energy and matter*, and *stability and change* are called out as the framework for understanding the disciplinary core ideas. Students use *developing and using models*, *planning and conducting investigations*, *using mathematical thinking*, and *constructing explanations and designing solutions*. Students are also expected to use the science and engineering practices to demonstrate proficiency with the core ideas.

HS-PS1-1, HS-PS1-2, HS-PS1-3, HS-PS2-6, HS-ETS1-3, and HS-ETS1-4.

Unit 2: Energy of Chemical Systems

In Energy of Chemical Systems, students will understand energy as a quantitative property of a system—a property that depends on the motion and interactions of matter and radiation within that system. They will also understand that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Students develop an understanding that energy, at both the macroscopic and the atomic scales, can be accounted for as motions of particles or as energy associated with the configurations (relative positions) of particles. Students understand the role that water plays in affecting weather. Students can examine the ways that human activities cause feedback that create changes to other systems. Students are expected to demonstrate proficiency in *developing and using models*, *planning and carrying out investigations*, *analyzing and interpreting data, engaging in argument from evidence*, and using these practices to demonstrate understanding of core ideas.

HS-PS3-4.

Unit 3: Bonding and Chemical Reactions

In this unit of study, students *develop and using models*, *plan and conduct investigations*, *use mathematical thinking*, and *construct explanations and design solutions* as they develop an understanding of the substructure of atoms and to provide more mechanistic explanations of the properties of substances. Chemical reactions, including rates of reactions and energy changes, can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Students also apply an understanding of the process of *optimization and engineering design* to chemical reaction systems. The crosscutting concepts of *patterns, energy and matter*, and *stability and change* are the organizing concepts for these disciplinary core ideas. Students are expected to demonstrate proficiency in *developing and using models*, *planning and conducting investigations*, *using mathematical thinking*, and *constructing explanations and designing solutions.*

HS-PS1-7, HS-PS1-4, HS-PS1-5, HS-PS1-6, and HS-ETS1-2.

Unit 4: Matter and Energy in Living Systems

In this unit of study, students construct explanations for the role of energy in the cycling of matter in organisms. They apply mathematical concepts to develop evidence to support explanations of the interactions of photosynthesis and cellular respiration and develop models to communicate these explanations. The crosscutting concept of *matter and energy* provides students with insights into the structures and processes of organisms. Students are expected to *develop and use models*, *plan and conduct investigations*, *use mathematical thinking*, and *construct explanations and design solutions* as they demonstrate proficiency with the disciplinary core ideas.

HS-LS1-7 and HS-LS1-6.

Unit 5: Nuclear Chemistry

In this unit of study, energy and matter are studied further by investigating the processes of nuclear fusion and fission that govern the formation, evolution, and workings of the solar system in the universe. Some concepts studied are fundamental to science and demonstrate *scale, proportion, and quantity*, such as understanding how the matter of the world formed during the Big Bang and within the cores of stars over the cycle of their lives. In addition, an important aspect of Earth and space sciences involves understanding the concept *of stability and change* while making inferences about events in Earth's history based on a data record that is increasingly incomplete the farther one goes back in time. A mathematical analysis of radiometric dating is used to comprehend how absolute ages are obtained for the geologic record. The crosscutting concepts of *energy and matter*; *scale, proportion, and quantity*; and *stability and change* are called out as organizing concepts for this unit. Students are expected to demonstrate proficiency in *developing and using models*; *constructing explanations and designing solutions; using mathematical and computational thinking; and obtaining, evaluating, and communicating information*; and they are expected to use these practices to demonstrate understanding of the core ideas.

HS-PS1-8, HS-ESS1-3, HS-ESS1-1, HS-ESS1-2, and HS-ESS1-6

Unit 1 – Summary: Structure and Properties of Matter
How can the substructures of atoms explain the observable properties of substances? In this unit of study, students use investigations, simulations, and models to makes sense of the substructure of atoms and to provide more mechanistic explanations of the properties of substances. Chemical reactions, including rates of reactions and energy changes, can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Students are able to use the periodic table as a tool to explain and predict the properties of elements. Students are expected to communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials. The crosscutting concepts of *structure and function*, *patterns*, *energy and matter*, and *stability and change* are called out as the framework for understanding the disciplinary core ideas. Students use *developing and using models*, *planning and conducting investigations*, *using mathematical thinking*, and *constructing explanations and designing solutions*. Students are also expected to use the science and engineering practices to demonstrate proficiency with the core ideas.
Student Learning Objectives
Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. *[Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.]* **(HS-PS1-1)**
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. *[Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [*Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.*]* **(HS-PS1-2)**
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. *[Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite).* Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [*Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.*] **(HS-PS1-3)**

Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* *[Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.]* [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.] **(HS-PS2-6)**
Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.(HS-ETS1-3)
Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. (HS-ETS1-4)

Part A: *How can a periodic table tell me about the subatomic structure of a substance?*

Concepts	Formative Assessment
• Different patterns may be observed at each of the scales at which a system is studied, and these patterns can provide evidence for causality in explanations of phenomena. • Each atom has a charged substructure. • An atom's nucleus is made of protons and neutrons and is surrounded by electrons. • The periodic table orders elements horizontally by number of protons in the nucleus of each element's atoms and places elements with similar chemical properties in columns. • The repeating patterns of this table reflect patterns of outer electron states. • Patterns of electrons in the outermost energy level of atoms can provide evidence for the relative properties of	*Students who understand the concepts are able to:* • Use the periodic table as a model to provide evidence for relative properties of elements at different scales based on the patterns of electrons in the outermost energy level of atoms in main group elements. • Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms in main group elements.

elements at different scales. • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	

Part B: *How can I use the periodic table to predict if I need to duck before mixing two elements?*

Concepts	Formative Assessment
• The periodic table orders elements horizontally by number of protons in the nucleus of each element's atoms and places elements with similar chemical properties in columns. • The repeating patterns of the periodic table reflect patterns of outer electron states. • The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. • Different patterns may be observed at each of the scales at which a system is studied, and these patterns can provide evidence for causality in explanations of phenomena.	*Students who understand the concepts are able to:* • Use valid and reliable evidence (obtained from students' own investigations, models, theories, simulations, and peer review) showing the outermost electron states of atoms, trends in the periodic table, and patterns of chemical properties to construct and revise an explanation for the outcome of a simple chemical reaction. • Use the assumption that theories and laws that describe the outcome of simple chemical reactions operate today as they did in the past and will continue to do so in the future. • Observe patterns in the outermost electron states of atoms, trends in the periodic table, and chemical properties. • Use the conservation of atoms and the chemical properties of the elements involved to describe and predict the outcome of a chemical reaction.

Part C: *How can I use the properties of something (in bulk quantities) to predict what is happening with the subatomic particles?*

Concepts	Formative Assessment
• The structure and interactions of matter at the bulk scale are determined by electrical forces within and between	*Students who understand the concepts are able to:* • Plan and conduct an investigation individually and

atoms. • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.	collaboratively to produce data that can serve as the basis for evidence for comparing the structure of substances at the bulk scale to infer the strength of electrical forces between particles. In the investigation design, decide on types, how much, and accuracy of data needed to produce reliable measurements; consider limitations on the precision of the data (e.g., number of trials, cost, risk, time); and refine the design accordingly. • Use patterns in the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

Part D: I want to do the right thing, what is the greener choice for *grocery bags (paper or plastic/reusable vs. disposable); cold drink containers (plastic, glass, or aluminum); or hot drink containers (paper, Styrofoam, or ceramic)? [Clarification: Students should have the opportunity to select the product and use the Life Cycle Analysis (LCA) to make an evidence-based claim.]*

Concepts	Formative Assessment
• The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, aesthetics, and to consider social, cultural, and environmental impacts. • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or	*Students who understand the concepts are able to:* • Communicate scientific and technical information about why the molecular - level structure is important in the functioning of designed materials. • Evaluate a solution to a complex real-world problem based on scientific knowledge, student generated sources of evidence, prioritized criteria, and tradeoffs considerations to determine why the molecular level structure is important in the functioning of designed materials. • Use mathematical models and/or computer simulations to show why the molecular level structure is important in the functioning of designed materials. • Communicate scientific and technical information about the attractive and repulsive forces that determine the functioning of the material.

economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. • Models (e.g., physical, mathematical, computer models) can be used to simulate why the molecular-level structure is important in the functioning of designed materials.	• Use mathematical models and/or computer simulations to show the attractive and repulsive forces that determine the functioning of the material. • Examine in detail the properties of designed materials, the structure of the components of designed materials, and the connections of the components to reveal the function. • Use models (e.g., physical, mathematical, computer models) to simulate systems of designed materials and interactions--including energy, matter, and information flows--within and between designed materials at different scales.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Translate information from the periodic table about the patterns of electrons in the outermost energy level of atoms into words that describe the relative properties of elements.
- Write 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 of elements using well-chosen, relevant, and sufficient facts; extended definitions; and concrete details from students' own investigations, models, theories, simulations, and peer review.
- Develop and strengthen explanations for the outcome of a simple chemical reaction by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties of elements.
- Draw evidence from informational texts about the outermost electron states of atoms, trends in the periodic table, and patterns of chemical properties of elements to construct a rigorous explanation of the outcome of a simple chemical reaction.
- Cite specific textual evidence comparing the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

- Conduct short as well as more sustained research projects to compare the structure of substances at the bulk scale and use this research to infer the strength of electrical forces between particles.
- Gather applicable information from multiple reliable sources to support the claim that electrical forces between particles can be used to explain the structure of substances at the bulk scale.
- Develop evidence comparing the structure of substances at the bulk scale and the strength of electrical forces between particles.

Mathematics

- Determine a level of accuracy appropriate to limitations on measurement when reporting quantities representing periodic trends for main group elements based on patterns of electrons in the outermost energy level of atoms.
- Considering the outermost energy level of atoms, define appropriate quantities for descriptive modeling of periodic trends for main group elements based on patterns of electrons in outermost energy levels.
- Use units as a way to understand the outcome of a simple chemical reaction involving main group elements based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. Choose and interpret units consistently in chemical reactions.
- Determine and interpret the scale and origin in graphs and data displays representing patterns of chemical properties, outer electron states of atoms, trends in the periodic table, and patterns of chemical properties.
- Determine a level of accuracy appropriate to limitations on measurement when reporting quantities of simple chemical reactions.
- Use units as a simple way to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. Choose and interpret units comparing the structure of substances at the bulk scale to infer the strength of electrical forces between particles. Choose and interpret the scale and origin in graphs and data displays comparing the structure of substances and the bulk scale and electrical forces between particles.
- Determine a level of accuracy appropriate to limitations on measurements of the strength of electrical forces between particles.

Suggested Learning Activities
Build an Atom - This simulation allows students to create different illustrations of atoms and provides evidence that protons determine the identity of the element. **Periodic Table Trends** - This is a virtual investigation of the periodic trends. **Path to Periodic Table** - This investigation provides students with the opportunity to make sense of how and why the periodic table is organized the way that it is. Students will re-create the thought process that Dmitri Mendeleev and Julius Lothar Meyer went through to devise their early periodic tables. **Castle of Mendeleev** - Students engage in a fantasy world that requires them to make claims, based on evidence, regarding the identity of unknown materials. **Shall We Dance? – Classifying Types of Chemical Reactions** - Students identify and differentiate between four types of chemical reactions: synthesis, decomposition, single replacement and double replacement. Students also develop models for chemical reactions and identify the limitations of the models using evidence. **Reactivity of Alkaline Earth Metals lab** - In order to understand the predictive power of the periodic table, students should write electron configurations for main group elements, paying attention to patterns of electrons in the outermost energy level. Students annotate the periodic table to determine its arrangement horizontally by number of protons in the atom's nucleus and its vertical arrangement by the placement of elements with similar chemical properties in columns. Students also be able to translate information about patterns in the periodic table into words that describe the importance of the outermost electrons in atoms. **Ionic and Covalent lab** - Students use the ideas of attraction and repulsion (i.e., charges—cations/anions) at the atomic scale to explain the structure of matter, such as in ion formation, and to explain the properties of matter such as density, luster, melting point, boiling point, etc. Students also use the ideas of attraction and repulsion (charges—cations/anions) at the atomic scale to explain transformations of matter—for example, reaction with oxygen, reactivity of metals, types of bonds formed, and number of bonds formed. Students will explain bonding through the patterns in outermost electrons, periodic trends, and chemical properties. **Law of Conservation of Mass Demonstration** - To explain the outcomes of chemical reactions using the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties, students use investigations, simulations, and models of chemical reactions to prove that atoms are conserved. For example, students observe simple reactions in a closed system and measure the mass before and after the reaction as well as count atoms in reactants and

products in chemical formulas.

Chemical Reactions lab - Students will construct chemical formulas involving main group elements in order to model that atoms are conserved in chemical reactions (the Law of Conservation of Mass). Students need to describe and predict simple chemical reactions, including combustion, involving main group elements. Students use units when modeling the outcome of chemical reactions. When reporting quantities, students choose a level of accuracy appropriate to limitations on measurement. Students will write a rigorous explanation of the outcome of simple chemical reactions, using data from their own investigations, models, theories, and simulations.

Intermolecular Forces activity - Students plan and conduct investigations using attraction and repulsion (charges—cations/anions) at the atomic scale to explain the structure of matter at the bulk scale. For example, students investigate how the strength of forces between particles is dependent on particle type (ions, atoms, molecules, networked materials [allotropes]).

Liquids and Solids demo/activity - Students plan and conduct investigations using attraction and repulsion (charges—cations/anions) at the atomic scale to explain the properties of matter at the bulk scale—for example, investigating melting point, boiling point, vapor pressure, and surface tension, plus collecting data to create cooling and heating curves.

LCA activity - Students research information about Life Cycle Analysis (LCA), which examines every part of the production, use, and final disposal of a product. LCA requires that students examine the inputs (raw materials and energy) required to manufacture products, as well as the outputs (atmospheric emissions, waterborne wastes, solid wastes, coproducts, and other resources). This allows them to make connections between molecular-level structure and product functionality. Students evaluate the LCA process and communicate a solution to a real-world problem, such as the environmental impact of different types of grocery bags (paper or plastic/reusable vs. disposable), cold drink containers (plastic, glass, or aluminum), or hot drink containers (paper, Styrofoam, or ceramic). They base their solution to their chosen real-world problem on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Methods of Assessment
Do Nows, Exit Tickets, Question and Answer Techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental, Cumulative Assessments, Lab Performance and Analysis, Classwork and Homework Reinforcement Techniques, Discussion

Appendix A: NGSS and Foundations for the Unit
Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. *[Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.]* **(HS-PS1-1)**
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. *[Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.]* [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.] **(HS-PS1-2)**
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. *[Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite).* Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [*Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.*] **(HS-PS1-3)**
Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* *[Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.]* [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.] **(HS-PS2-6)**

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.(HS-ETS1-3)
Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. (HS-ETS1-4)

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models • Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1) **Planning and Carrying Out Investigations** • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS1-3) **Constructing Explanations and Designing Solutions**	**PS1.A: Structure and Properties of Matter** • Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1) • The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1),(HS-PS1-2) • The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (*secondary to HS-PS2-6*)	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-1),(HS-PS1-2),(HS-PS1-3) **Structure and Function** • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-PS2-6) **Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—

• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-PS1-2) • Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3) **Obtaining, Evaluating, and Communicating Information** • Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS2-6) **Using Mathematics and Computational Thinking** • Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions	**PS1.B: Chemical Reactions** • The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2) **PS2.B: Types of Interactions** • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. *(secondary to HS-PS1-1),(secondary to HS-PS1-3)* **ESS2.D: Weather and Climate** • Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6) **ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of	including energy, matter, and information flows— within and between systems at different scales. (HS-ETS1-4) - ***Connections to Engineering, Technology, and Applications of Science* Influence of Science, Engineering, and Technology on Society and the Natural World** New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3)

between systems. (HS-ETS1-4)	purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)	

Embedded English Language Arts/Literacy and Mathematics Standards	
English Language Arts/Literacy	
RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-3)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-2)
WHST.9-12.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-PS1-2),(HS-ETS1-3)
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-3)
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS1-3),(HS-ETS1-3)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS1-3),(HS-ETS1-3)
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in

	presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS1-4)
Mathematics	
MP.2	Reason abstractly and quantitatively. (HS-ETS1-3),(HS-ETS1-4)
MP.4	Model with mathematics. (HS-ETS1-3),(HS-ETS1-4)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2),(HS-PS1-3)

Unit 2 Summary – Energy and Chemical Systems
How is energy transferred within a system?
In Energy and Chemical Systems, students will understand energy as a quantitative property of a system—a property that depends on the motion and interactions of matter and radiation within that system. They will also understand that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Students develop an understanding that energy, at both the macroscopic and the atomic scales, can be accounted for as motions of particles or as energy associated with the configurations (relative positions) of particles. Students understand the role that water plays in affecting weather. Students can examine the ways that human activities cause feedback that create changes to other systems. Students are expected to demonstrate proficiency in *developing and using models*, *planning and carrying out investigations*, *analyzing and interpreting data, engaging in argument from evidence*, and using these practices to demonstrate understanding of core ideas.
Student Learning Objectives
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). *[Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.]* **(HS-PS3-4)**

Part A: *Does thermal energy always transfer or transform in predictable ways?*	
Concepts	**Formative Assessment**
• When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. • Uncontrolled systems always move toward more stable	*Students who understand the concepts are able to:* • Plan and conduct an investigation individually or collaboratively to produce data on transfer of thermal energy in a closed system that can serve as a basis for evidence of uniform energy distribution among components of a system when two components of different temperatures are combined. • Use models to describe a system and define its

states—that is, toward a more uniform energy distribution. • Although energy cannot be destroyed, it can be converted into less useful forms—for example, to thermal energy in the surrounding environment.	boundaries, initial conditions, inputs, and outputs. • Consider the limitations of the precision of the data collected and refine the design accordingly

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy-

- Ask and refine questions to support uniform energy distribution among the components in a system when two components of different temperature are combined, using specific textual evidence.
- Conduct short as well as more sustained research projects to determine energy distribution in a system when two components of different temperature are combined.
- Collect relevant data across a broad spectrum of sources about the distribution of energy in a system and assess the strengths and limitations of each source.

Mathematics-

- Use symbols to represent energy distribution in a system when two components of different temperature are combined, and manipulate the representing symbols. Make sense of quantities and relationships in the energy distribution in a system when two components of different temperature are combined.
- Use a mathematical model to describe energy distribution in a system when two components of different temperature are combined. Identify important quantities in energy distribution in a system when two components of different temperature are combined and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

Suggesting Learning Activities
Calorimetry - In this unit of study, students begin by building their understanding of the law of conservation of energy by planning and conducting investigations of thermal energy transfer. Students investigate and describe a system focusing specifically on thermal energy transfer in a closed system. These investigations will provide opportunities for students to use models that can be made of a variety of materials, such as student-generated drawings and/or digital simulations, such as those available from PhET. These models can be used to describe a system, and define its boundaries, initial conditions, inputs, and outputs. Students collect relevant data from several sources, including their own investigations, and synthesize their findings into a coherent understanding. **Heat Transfer activity** - Using the knowledge that energy cannot be created or destroyed, students create computational or mathematical models to calculate the change in the energy in one component of a system when the change in energy of the other component(s) and energy flows in and out of the systems are known. In order to do this, students manipulate variables in specific heat calculations. For example, students will use data collected from simple Styrofoam calorimeters to investigate the mixing of water at different initial temperatures or the adding of objects at different temperatures to water to serve as a basis for evidence of uniform energy distribution among components of a system. Students will conduct an investigation using different materials such as various metals, glass, and rock samples. Using the specific heat values for these substances, students create mathematical models to represent the energy distribution in a system, identify important quantities in energy distribution, map relationships, and analyze those relationships mathematically to draw conclusions. These investigations allow students to collect data to show that energy is transported from one place to another or transferred between systems, and that uncontrolled systems always move toward more stable states with more uniform energy distribution. Students also observe during investigations that energy can be converted into less useful forms, such as thermal energy released to the surrounding environment. During the design and implementation of investigations, students must consider the precision and accuracy appropriate to limitations on measurement of the data collected and refine their design accordingly.

Methods of Assessment
Do Nows, Exit Tickets, Question and Answer Techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental, Cumulative Assessments, Lab Performance and Analysis, Classwork and Homework Reinforcement Techniques, Discussion

Appendix A: NGSS and Foundations for the Unit
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). *[Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.]* **(HS-PS3-4)**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS3-4)	**PS3.B: Conservation of Energy and Energy Transfer** • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-4) • Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (HS-PS3-4) **PS3.D: Energy in Chemical Processes** • Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding	**Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-PS3-4)

	environment. (HS-PS3-4)	

Embedded English Language Arts/Literacy and Mathematics	
English Language Arts/Literacy	
RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS3-4)
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-PS3-4)
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-4)
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS3-4)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS3-4)
Mathematics	
MP.2	Reason abstractly and quantitatively. (HS-PS3-4)
MP.4	Model with mathematics. (HS-PS3-4)

Unit 3 – Summary: Bonding and Chemical Reactions
How can one explain the structure, properties, and interactions of matter?   In this unit of study, students *develop models*, *plans and conduct investigations*, *use mathematical thinking*, and *construct explanations and design solutions* as they develop an understanding of the substructure of atoms and to provide more mechanistic explanations of the properties of substances. Chemical reactions, including rates of reactions and energy changes, can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Students also apply an understanding of the process of *optimization and engineering design* to chemical reaction systems. The crosscutting concepts of *patterns, energy and matter*, and *stability and change* are the organizing concepts for these disciplinary core ideas. Students are expected to demonstrate proficiency in *developing and using models*, *planning and conducting investigations*, *using mathematical thinking*, and *constructing explanations and designing solutions.*
Student Learning Objectives
Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. *[Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]* **(HS-PS1-7)**
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. *[Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]* **(HS-PS1-4)**
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. *[Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.]* **(HS-PS1-5)**
Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.* *[Clarification Statement: Emphasis is on the application of Le Chatlier's Principle and on refining*

designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.] **(HS-PS1-6)**
Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. (HS-ETS1-2)

Part A: *Where do the atoms go during a chemical reaction?*

Concepts	Formative Assessment
• The fact that atoms are conserved, together with the knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. • The total amount of energy and matter in closed systems is conserved. • The total amount of energy and matter in a chemical reaction system is conserved. • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. • Changes of energy and matter in a chemical reaction system can be described in terms of energy and matter flows into, out of, and within that system.	*Students who understand the concepts are able to:* • Use mathematical representations of chemical reaction systems to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. • Use mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale, using the mole as the conversion from the atomic to the macroscopic scale. • Use the fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, to describe and predict chemical reactions. • Describe changes of energy and matter in a chemical reaction system in terms of energy and matter flows into, out of, and within that system.

Part B: *What is different inside a heat pack and a cold pack?*

Concepts	Formative Assessment
• A stable molecule has less energy than the same set of atoms separated; at least this much energy must be provided in order to take the molecule apart. • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. • Changes of energy and matter in a chemical reaction system can be described in terms of collisions of molecules and the rearrangements of atoms into new molecules, with subsequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. • Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.	*Students who understand the concepts are able to:* • Explain the idea that a stable molecule has less energy than the same set of atoms separated. • Describe changes of energy and matter in a chemical reaction system in terms of energy and matter flows into, out of, and within that system. • Describe chemical processes, their rates, and whether or not they store or release energy in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. • Develop a model based on evidence to illustrate the relationship between the release or absorption of energy from a chemical reaction system and the changes in total bond energy.

Part C: *Is it possible to change the rate of a reaction or cause two elements to react that do not normally want to?*

Concepts	Formative Assessment
• Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.	*Students who understand the concepts are able to:* • Use the number and energy of collisions between molecules (particles) to explain the effects of changing the temperature or concentration of the reacting articles on the rate at which a reaction occurs. • Use patterns in the effects of changing the temperature or

• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. • Patterns in the effects of changing the temperature or concentration of the reacting particles can be used to provide evidence for causality in the rate at which a reaction occurs.	concentration of the reactant particles to provide evidence for causality in the rate at which a reaction occurs. • Apply scientific principles and multiple and independent student-generated sources of evidence to provide an explanation of the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

Part D: *What can we do to make the products of a reaction stable?*

Concepts	Formative Assessment
• Much of science deals with constructing explanations of how things change and how they remain stable. • In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others may be needed. • Explanations can be constructed explaining how chemical reaction systems can change and remain stable.	*Students who understand the concepts are able to:* • Construct explanations for how chemical reaction systems change and how they remain stable. • Design a solution to specify a change in conditions that would produce increased amounts of products at equilibrium in a chemical system based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. • Refine the design of a solution to specify a change in conditions that would produce increased amounts of products at equilibrium in a chemical system based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Connecting with English Language Arts/Literacy

English Language Arts/Literacy

- Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations showing that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy to enhance understanding of findings, reasoning, and evidence and to add interest.

- Cite specific textual evidence to support the concept that changing the temperature or concentration of the reacting particles affects the rate at which a reaction occurs.
- Develop an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples.
- Construct short as well as more sustained research projects to answer how to increase amounts of products at equilibrium in a chemical system. Synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

Mathematics

- Represent an explanation that atoms, and therefore mass, are conserved during a chemical reaction symbolically and manipulate the representing symbols. Make sense of quantities and relationships about the conservation of atoms and mass during chemical reactions symbolically and manipulate the representing symbols.
- Use units as a way to understand the conservation of atoms and mass during chemical reactions; choose and interpret units consistently in formulas representing proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale; choose and interpret the scale and origin in graphs and data displays representing the conservation of atoms and mass in chemical reactions.
- Define appropriate quantities for the purpose of descriptive modeling of the proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale.
- Use a mathematical model to explain how the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy, and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Represent an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs symbolically and manipulate the representing symbols. Make sense of quantities and relationships about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs symbolically and manipulate the representing symbols.
- Use units as a way to understand an explanation about the effects of changing the temperature or concentration of the

reacting particles on the rate at which a reaction occurs. Choose and interpret units consistently in formulas representing the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. Choose and interpret the scale and the origin in graphs and data displays representing the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
- Use a mathematical model to explain how to increase amounts of products at equilibrium in a chemical system. Identify important quantities in the cycling of matter and flow of energy among organisms in an ecosystem, and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

Suggested Learning Activities

Endothermic/Exothermic Reaction - This unit ties together the how to describe and predict chemical reactions, and energy flow and conservation within a system. Students develop an understanding that the total amount of energy and matter in a closed system (including chemical reaction systems) is conserved and that changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. Using this knowledge, and knowledge of the chemical properties of elements, students describe and predict simple chemical reactions in terms of mass and energy.

Percent Composition or Water in a Hydrate - The mole concept and stoichiometry are used to show proportional relationships between masses of reactants and products. Students will balance equations to show mass relationships between reactants and products. Students also gain an understanding of the use of dimensional analysis to perform mass to mole conversions that demonstrate how mass is conserved during chemical reactions. Students use mathematics to demonstrate their thinking about proportional relationships among masses of reactants and products and to make connections between the atomic and macroscopic world. Students use units appropriately and consistently, considering limitations on measurement, for the purpose of descriptive modeling of the proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale.

Counting by Weighing (Counting Large Numbers)

Limiting Reactant Lab/Percent Yield - This unit also expands student understanding of the conservation of energy within a system by emphasizing the key idea that a stable molecule has less energy than the same set of atoms when separated. To support this concept, students might look at the change in energy when bonds are made and broken in a reaction system. Students also analyze molecular-level drawings and tables showing energies in compounds with multiple bonds to show that energy is conserved in a chemical reaction.

Heating/Cooling Curve/Phase Diagrams (Heat of Fusion of Ice) - In addition to conservation of energy, students should explore energy flow into, out of, and within systems (including chemical reaction systems). Given data and asked to graph the relative energies of reactants and products, students determine whether energy is released or absorbed. They also conduct simple chemical reactions that allow them to apply the law of conservation of energy by collecting data from their own investigations. Students be able to determine whether reactions are endothermic and exothermic, constructing explanations in terms of energy changes. These experiences allow them to develop a model that relates energy flow to changes in total bond energy. Examples of models might include molecular-level drawings, energy diagrams, and graphs.

Le Chatelier's activity - Students expand their study of bond energies by relating this concept to kinetic energy. This can be understood in terms of the collisions of molecules and the rearrangement of atoms into new molecules as a function of their kinetic energy content. Students also study the effect on reaction rates of changing the temperature and/or concentration of a reactant (Le Chatelier's principle). Examples of these investigations may include the iodine clock reaction, the ferrous cyanide complex, as well as computer simulations such as those located at www.harpercollege.edu/tm-ps/chm/100/dgodambe/thedisk/equil/equil.htm. Using results from these investigations, students develop an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs and on equilibrium. In order to meet the engineering requirement for Unit 3, students design a solution to specify a change in conditions that would produce increased amounts of products at equilibrium. As they consider their design, students keep in mind that much of science deals with constructing explanations for how things change and how they remain stable. Through investigations and practice in changing reaction conditions (as mentioned above), as well as through teacher demonstrations such as MOM to the Rescue/Acid–Base Reaction (Flinn Scientific), students come to understand that in many situations, a dynamic and condition dependent balance between a reaction and the reverse reaction determines the number of all types of molecules present. Examples of designs that students may refine include different ways to increase product formation. Designs include methods such as adding reactants or removing products as a means to change equilibrium. Students base these design solutions on scientific knowledge, student-generated sources of evidence from prior investigations, prioritized criteria, and tradeoff considerations. They do this in order to produce the greatest amount of product from a reaction system.

Methods of Assessment
Do Nows, Exit Tickets, Question and Answer Techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental, Cumulative Assessments, Lab Performance and Analysis, Classwork and Homework Reinforcement Techniques, Discussion

Appendix A: NGSS and Foundations for the Unit
Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. *[Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]* **(HS-PS1-7)**
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. *[Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]* **(HS-PS1-4)**
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. *[Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.]* **(HS-PS1-5)**
Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.* *[Clarification Statement: Emphasis is on the application of Le Chatlier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [Assessment Boundary: Assessment is limited to specifying the change in*

only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.] **(HS-PS1-6)**
Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. (HS-ETS1-2)

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models • Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-4),(HS-PS1-8) • Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1) **Planning and Carrying Out Investigations** • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS1-3) **Using Mathematics and Computational**	**PS1.A: Structure and Properties of Matter** • Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1) • The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1),(HS-PS1-2) • The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3),*(secondary to HS-PS2-6)* • A stable molecule has less energy than the same set of atoms	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-1),(HS-PS1-2),(HS-PS1-3),(HS-PS1-5) **Energy and Matter** • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8) • The total amount of energy and matter in closed systems is conserved. (HS-PS1-7) • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS1-4)

Thinking • Use mathematical representations of phenomena to support claims. (HS-PS1-7) **Constructing Explanations and Designing Solutions** • Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (HS-PS1-5) • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-PS1-2) • Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS1-6) **Asking Questions and Defining Problems** • Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)	separated; one must provide at least this energy in order to take the molecule apart. (HS-PS1-4) **PS1.B: Chemical Reactions** • Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. (HS-PS1-4),(HS-PS1-5) • In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. (HS-PS1-6) • The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2),(HS-PS1-7) **PS1.C: Nuclear Processes** • Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy.	**Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable. (HS-PS1-6) - ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS1-7)

Using Mathematics and Computational Thinking • Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-4) **Constructing Explanations and Designing Solutions** • Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2) • Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)	The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8) **PS2.B: Types of Interactions** • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.*(secondary to HS-PS1-1),(secondary to HS-PS1-3)* **ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS1-6) **ETS1.A: Defining and Delimiting Engineering Problems** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1) • Humanity faces major global challenges today, such as the need	

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<td>for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1)

ETS1.B: Developing Possible Solutions

• When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

• Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)

ETS1.C: Optimizing the Design Solution

• Criteria may need to be broken down into simpler ones that can be approached systematically, and</td>
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	decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)	

Embedded English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (HS-PS1-1)
RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-5)
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1),(HS-ETS1-3)
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-1),(HS-ETS1-3)
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1),(HS-ETS1-3)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-5)
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-6)

SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS1-4)
Mathematics -	
MP.2	Reason abstractly and quantitatively. (HS-PS1-5),(HS-PS1-7),(HS-ETS1-1),(HS-ETS1-3),(HS-ETS1-4)
MP.4	Model with mathematics. (HS-PS1-4), (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),(HS-PS1-7)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-4),(HS-PS1-5),(HS-PS1-7)

Unit 4 - Summary Matter and Energy in Living Systems
How do organisms obtain and use the energy they need to live and grow?   In this unit of study, students construct explanations for the role of energy in the cycling of matter in organisms. They apply mathematical concepts to develop evidence to support explanations of the interactions of photosynthesis and cellular respiration and develop models to communicate these explanations. The crosscutting concept of *matter and energy* provides students with insights into the structures and processes of organisms. Students are expected to *develop and use models*, *plan and conduct investigations*, *use mathematical thinking*, and *construct explanations and design solutions* as they demonstrate proficiency with the disciplinary core ideas.
Student Learning Objectives
Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. *[Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.]* **(HS-LS1-5)**
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. *[Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.]* **(HS-LS1-7)**
Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. *[Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.] [Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.]* **(HS-LS1-6)**

Part A: *How does photosynthesis transform light energy into stored chemical energy?*	
Concepts	**Formative Assessment**
• The process of photosynthesis converts light energy to	*Students who understand the concepts are able to:*

stored energy by converting carbon dioxide plus water into sugars plus released oxygen. • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within a system.	• Provide a mechanistic explanation for how photosynthesis transforms light energy into stored chemical energy. • Use their understanding of energy flow and conservation of energy to illustrate the inputs and outputs of matter and the transformation of energy in photosynthesis.

Part B: *How does cellular respiration result in a net transfer of energy?*

Concepts	Formative Assessment
• As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. • As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. • Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. • Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. • Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.	*Students who understand the concepts are able to:* • Construct an evidence-based 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. • Use their understanding of energy flow and conservation of energy to illustrate the inputs and outputs of the process of cellular respiration.

Part C: *How do elements of a sugar molecule combine with other elements and what molecules are formed?*

Concepts	Formative Assessment
• Sugar molecules contain carbon, hydrogen, and oxygen: Their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be	*Students who understand the concepts are able to:* • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources

assembled into larger molecules (such as proteins or DNA), used for example to form new cells. • As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.	(including students' own investigations, models, theories, simulations, peer review) 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. • Construct and revise an explanation, based on valid and reliable evidence from a variety of sources (including models, theories, simulations, peer review) and on the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, 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. • Use evidence from models and simulations to support explanations 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.

Connecting with English Language Arts/Literacy

English Language Arts/Literacy

- Make strategic use of digital media in presentations to enhance understanding of how photosynthesis transforms light energy into stored chemical energy.
- Use digital media in presentations to enhance understanding of the inputs and outputs of the process of cellular respiration.
- Cite specific textual evidence to support how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large, carbon-based molecules.
- Use evidence from multiple sources to clearly communicate an explanation 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.
- Revise an explanation 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 by planning, revising, editing, rewriting, or trying a new

approach, focusing on addressing what is most significant.

- Draw evidence from informational texts to describe how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large, carbon-based molecules.

Suggested Learning Activities

Model Building - Models use evidence to illustrate how photosynthesis transforms light energy into stored chemical energy; how 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; and to illustrate the inputs and outputs of matter and the transformations of energy in both processes. Models include chemical equations, flow diagrams, manipulatives, and conceptual models. Models also illustrate that energy cannot be created or destroyed, and that it moves only between one place and another, between objects, or between systems. Students use models such as diagrams, chemical equations, and conceptual models to illustrate how matter and energy flow through different organizational levels of living systems, from microscale to macroscale. In particular, both photosynthesis and cellular respiration reactions emphasize that the reactants (inputs) and products (outputs) show the transfer of matter and energy from one system of interacting molecules to another. In developing models to represent how photosynthesis transforms light energy into stored chemical energy and the inputs and outputs of cellular respiration, students might use digital media in presentations to enhance understanding

Polymerization lab / Food Chemistry lab - At the same time, students take an in-depth look at the polymerization of sugar; they research and investigate how simple sugars (made from carbon, hydrogen, and oxygen) are combined and recombined in different structures with specific functions. Students construct and revise explanations for how simple sugars help form hydrocarbon backbones (amino acids) or carbon-based backbones (protein, DNA, new organism). Explanations supported and revised using evidence from multiple sources of text, models, theories, simulations, students' own investigations, and peer review. Students' explanations describe the formation of amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA) that can be used, for example, to form new cells. It is important to remember that students are only required to conceptually understand the process, not the specific chemical reactions or the identification of macromolecules such as amino acids and DNA.

Proof of CO_2 in Exhalation activity - Students test the products of cellular respiration found in their breath to verify that CO2 is a product of respiration.

Petri Dish Toxicity testing- Students categorize each growth medium according to its acidity, basicity, polarity, etc and test to see which medium is most conducive to growth of radish seeds. Students use models such as diagrams, chemical equations,

and conceptual models to illustrate how matter and energy flow through different organizational levels of living systems, from microscale to macroscale.

Methods of Assessment
Do Nows, Exit Tickets, Question and Answer Techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental, Cumulative Assessments, Lab Performance and Analysis, Classwork and Homework Reinforcement Techniques, Discussion

Appendix A: NGSS and Foundations for the Unit
Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. *[Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.]* **(HS-LS1-5)**
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. *[Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.]* **(HS-LS1-7)**
Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. *[Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.] [Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.]* **(HS-LS1-6)**

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**

Developing and Using Models	LS1.A: Structure and Function	Energy and Matter
• Use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-5),(HS-LS1-7) **Constructing Explanations and Designing Solutions** • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-6)	• Systems of specialized cells within organisms help them perform the essential functions of life. (secondary to HS-LS1-4, HS-LS1-5, HS-LS1-6) • All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (secondary to HS-LS1-4, HS-LS1-5, HS-LS1-6) • Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (secondary to HS-LS1-4, HS-LS1-5, HS-LS1-6) • Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (secondary to HS-LS1-4, HS-LS1-5, HS-LS1-6)	• Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-LS1-5), (HS-LS1-6) • Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS1-7)

	LS1.B: Growth and Development of Organisms • In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. (HS-LS1-4) **LS1.C: Organization for Matter and Energy Flow in Organisms** • The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS-LS1-5) • The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as	

	proteins or DNA), used for example to form new cells. (HS-LS1-6) • As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. (HS-LS1-6),(HS-LS1-7) • As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. (HS-LS1-7)	

Embedded English Language Arts/Literacy and Mathematics Standards

English Language Arts/Literacy

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS1-6)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS1-6)
WHST.9-12.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS1-

	6)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1-6)
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-LS1-4),(HS-LS1-5),(HS-LS1-7)
Mathematics	
MP.4	Model with mathematics. (HS-LS1-4)
HSF-IF.C.7	Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. (HS-LS1-4)
HSF-BF.A.1	Write a function that describes a relationship between two quantities. (HS-LS1-4)

Unit 5- Summary Nuclear Chemistry

What happens in stars?

In this unit of study, energy and matter are studied further by investigating the processes of nuclear fusion and fission that govern the formation, evolution, and workings of the solar system in the universe. Some concepts studied are fundamental to science and demonstrate *scale, proportion, and quantity*, such as understanding how the matter of the world formed during the Big Bang and within the cores of stars over the cycle of their lives.

In addition, an important aspect of Earth and space sciences involves understanding the concept *of stability and change* while making inferences about events in Earth's history based on a data record that is increasingly incomplete the farther one goes back in time. A mathematical analysis of radiometric dating is used to comprehend how absolute ages are obtained for the geologic record.

The crosscutting concepts of *energy and matter*; *scale, proportion, and quantity*; and *stability and change* are called out as organizing concepts for this unit. Students are expected to demonstrate proficiency in *developing and using models*; *constructing explanations and designing solutions; using mathematical and computational thinking; and obtaining, evaluating, and communicating information*; and they are expected to use these practices to demonstrate understanding of the core ideas.

Student Learning Objectives

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. *[Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.]* **(HS-PS1-8)**

Communicate scientific ideas about the way stars, over their life cycle, produce elements. *[Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.]* **(HS-ESS1-3)**

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. *[Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for* *the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [Assessment Boundary: Assessment does not include details of the atomic and subatomic processes involved with the sun's nuclear fusion.]* **(HS-ESS1-1)**

Part A: *Why is fusion considered the Holy Grail for the production of electricity?*

Why aren't all forms of radiation harmful to living things?

Concepts	Formative Assessment
• Nuclear processes, including fusion, fission, and radioactive decay of unstable nuclei, involve release or absorption of energy. • The total number of neutrons plus protons does not change in any nuclear process. • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.	*Students who understand the concepts are able to:* • Develop models based on evidence 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. • Use simple qualitative models based on evidence to illustrate the scale of energy released in nuclear processes relative to other kinds of transformations. • Develop models based on evidence to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of alpha, beta, and gamma radioactive decays.

Part B: *How do stars produce elements?*

Concepts	Formative Assessment
• The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases	*Students who understand the concepts are able to:* • Communicate scientific ideas in multiple formats (including orally, graphically, textually, and mathematically) about the way stars, over their life cycles, produce elements. • Communicate scientific ideas about the way

electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.	nucleosynthesis, and therefore the different elements it creates, vary as a function of the mass of a star and the stage of its lifetime. • Communicate scientific ideas about how in nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Part C: *Is the life span of a star predictable?*

Concepts	Formative Assessment
• The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. • Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. • The significance of the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth is dependent on the scale, proportion, and quantity at which it occurs.	*Students who understand the concepts are able to:* • 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 in releasing energy that eventually reaches Earth in the form of radiation. • Develop a model based on evidence to illustrate the relationships between nuclear fusion in the sun's core and radiation that reaches Earth.

Part D: *How can chemistry help us to figure out ancient events?*

Concepts	Formative Assessment
• Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. • Much of science deals with constructing explanations of how things change and how they remain stable.	*Students who understand the concepts are able to:* • Apply scientific reasoning to link evidence from ancient Earth materials, meteorites, and other planetary surfaces to claims about Earth's formation and early history, and assess the extent to which the reasoning and data support the explanation or conclusion. • Use available evidence within the solar system to construct explanations for how Earth has changed and how it remains stable.

Suggested Learning Activities
Modeling a Radioactive Decay Series Activity – Documenting the decay series of Uranium-238 and chain reactions such as the fission of Uranium-235 in reactors, and fusion within the core of stars.
PhET Nuclear Fission inquiry lab and graphs - To illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of alpha, beta, and gamma radioactive decays. When modeling nuclear processes, students depict that atoms are not conserved, but the total number of protons plus neutrons is conserved. Models include changes in the composition of the nucleus of atoms and the scale of energy released in nuclear processes. Communication of scientific ideas about how stars produce elements should be done in multiple formats, including orally, graphically, textually, and mathematically. The conservation of the total number of protons plus neutrons is important in their explanations, and students will cite supporting evidence from text.
Spectroscope/Flame Test lab - Students develop an understanding of how analysis of light spectra gives us information about the composition of stars and interstellar gases. This lab will also illustrate the relationship between nuclear fusion in the sun's core and energy that reaches the Earth in the form of radiation. Students will quantify the amounts of energy in joules when comparing energy sources.
Radiometric Dating simulation - This unit concludes with the application of scientific reasoning and the use of evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of the Earth's formation and early history. For example, students will use examples of spontaneous radioactive decay as a tool to determine the ages of rocks or other materials (K-39 to Ar-40). Students construct graphs showing data on the absolute ages and composition of Earth's rocks, lunar rocks, and meteorites.

Connecting with English Language Arts/Literacy and Mathematics	
English Language Arts/Literacy	
RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS1-1)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS1-3),(HS-ESS1-2)
SL.11-12.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear

	pronunciation. (HS-ESS1-3)
Mathematics	
MP.2	Reason abstractly and quantitatively. (HS-ESS1-1), (HS-ESS1-2) ,(HS-ESS1-3) ,(HS-PS1-8)
MP.4	Model with mathematics. (HS-ESS1-1)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS1-1),(HS-ESS1-2)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS1-1), (HS-ESS1-2)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-1), (HS-ESS1-2)
HSA-SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-ESS1-1)
HSA-CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-ESS1-1), (HS-ESS1-2)
HSA-CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-ESS1-1),(HS-ESS1-2)

Methods of Assessment
Do Nows, Exit Tickets, Question and Answer Techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental, Cumulative Assessments, Lab Performance and Analysis, Classwork and Homework Reinforcement Techniques, Discussion

Appendix A: NGSS and Foundations for the Unit
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. *[Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.]* **(HS-PS1-8)**
Communicate scientific ideas about the way stars, over their life cycle, produce elements. *[Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.]* **(HS-ESS1-3)**
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. *[Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [Assessment Boundary: Assessment does not include details of the atomic and subatomic processes involved with the sun's nuclear fusion.]* **(HS-ESS1-1)**

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between	**PS1.C: Nuclear Processes** • Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total	**Energy and Matter** • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-ESS1-3), (HS-PS1-8), (HS-

systems and their components in the natural and designed worlds.

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8),(HS-ESS1-1)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS1-2)
- Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-ESS1-6)

number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8)

- Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.(secondary (HS-ESS1-6)

ESS1.A: The Universe and Its Stars

- The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (HS-ESS1-1)
- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-2),(HS-ESS1-3)
-

ESS1-1)

- Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems. (HS-ESS1-2)

Scale, Proportion, and Quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-ESS1-1)
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-ESS1-4)
- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS1-6)

Connections to Engineering, Technology, and Applications of Science

Using Mathematical and Computational Thinking Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical or computational representations of phenomena to describe explanations. (HS-ESS1-4) **Obtaining, Evaluating, and Communicating Information** • Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. (HS-ESS1-6) • Communicate scientific ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and		**Interdependence of Science, Engineering, and Technology** • Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-2),(HS-ESS1-4) - ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • 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. (HS-ESS1-2) • Science assumes the universe is a vast single system in which basic laws are consistent. (HS-ESS1-2) **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of

mathematically). (HS-ESS1-3)		facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-ESS1-2)

Embedded English Language Arts/Literacy and Mathematics

English Language Arts/Literacy -

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WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS1-3),(HS-ESS1-2)
SL.11-12.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (HS-ESS1-3)

Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-ESS1-1), (HS-ESS1-2) ,(HS-ESS1-3) ,(HS-PS1-8)
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HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS1-1), (HS-ESS1-2)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-1), (HS-ESS1-2)
HSA-SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-ESS1-1)
HSA-CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-ESS1-1), (HS-ESS1-2)
HSA-CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-ESS1-1),(HS-ESS1-2)