Kansas Performance Level Descriptors

High School
9/22/2025

Contents

HS-PS1.1.	**Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy 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.*
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 designed world(s). • Use a model to predict the relationships between systems or between components of a system.	
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. 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.	

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Identify patterns using the periodic table as a model.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Use the periodic table as a model to predict elements likely to bond based on the patterns of electrons in the outermost energy level of atoms.

HS-PS1.2.	**Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** 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.*

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 and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, and 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.

PS1.A: Structure and Properties of Matter

- 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. 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.

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Identify evidence for the outcome of a simple chemical reaction based on the outermost electron states of atoms. • Construct an explanation for the outcome of a simple chemical reaction based on trends in the periodic table. • Construct an explanation for the outcome of a simple chemical reaction based on knowledge of the patterns of chemical properties.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Make a prediction for the products of a reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

HS-PS1.3.	**Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** 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.*
Planning and Carrying Out Investigations • Planning and carrying out investigations in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • 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.	
PS1.A: Structure and Properties of Matter • The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.	

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Identify variables in an investigation about the large-scale structure of substances and the strength of electrical forces between particles.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Use evidence from an investigation to predict the large-scale structures when given the electrical forces between and among atoms.

HS-PS1.4.	**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.*

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 designed worlds.
- Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

PS1.A: Structure and Properties of Matter

- 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.

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.

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use a model to show how chemical reactions depend upon the changes in total bond energy.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Develop a model to show how changes in the kinetic energy of atoms and molecules during a reaction can be used to predict if the reaction will release or absorb energy.

HS-PS1.5.	**Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.** 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.*
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. • Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.	
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.	

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Apply scientific principles to identify variables that affect the rate at which a reaction occurs.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Apply scientific principles to explain how molecular collisions affect the reaction rate when the temperature or concentration changes.

HS-PS1.6.	**Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*** Clarification Statement: Emphasis is on the application of Le Chatelier'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.*

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.
- Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

PS1.B: Chemical Reactions

- 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.

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 (tradeoffs) may be needed. (secondary)

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Identify how changes in temperature, pressure, or concentration can affect the outcome of a chemical reaction. • Use a design solution to show that some reactions are reversible and can reach equilibrium.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Evaluate different design solutions to predict how changes of some conditions (e.g., adding/removing heat, changing concentration) can shift equilibrium.

HS-PS1.7.	**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.*
Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 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 representations of phenomena to support claims.	
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.	

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use mathematical representations to identify that the number of atoms stays the same before and after a chemical reaction.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Use mathematical representations of mole ratios and atomic masses to explain mass conservation across chemical reactions.

HS-PS1.8.	**Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.** 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.*
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 designed worlds. • Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	
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.	

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use a model to describe changes in the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Compare models to show differences in energy release and nucleus composition across fission, fusion, and radioactive decay.

<table>
<tr><td>HS-PS2.1.</td><td>Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force.

Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.</td></tr>
<tr><td colspan="2">Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 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.
Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.</td></tr>
<tr><td colspan="2">PS2.A: Forces and Motion
Newton’s second law accurately predicts changes in the motion of macroscopic objects.</td></tr>
</table>

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Analyze observational data to identify that Newton's second law of motion includes force on a macroscopic object, its mass, and its acceleration.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Analyze data to predict, using Newton's second law of motion, how changes on the net force on a macroscopic object can determine the object's mass, or the object's acceleration if the mass is known.

<table>
<tr><td>HS-PS2.2.</td><td>Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.

Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.</td></tr>
<tr><td colspan="2">Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 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 representations of phenomena to describe explanations.</td></tr>
<tr><td colspan="2">PS2.A: Forces and Motion

• Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.
• If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.</td></tr>
</table>

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Identify the variables involved in momentum calculations (i.e., mass and velocity).	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Use mathematical representations of a system of objects to predict the momentum conservation in a different system involving different mass or different velocity.

HS-PS2.3.	**Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.** Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute. *Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.*

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.

- Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.

PS2.A: Forces and Motion

- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.

ETS1.A: Defining and Delimiting an Engineering Problem

- 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. (secondary)

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 (tradeoffs) may be needed. (secondary)

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Identify a design feature that can reduce force during a collision. • Apply science and engineering ideas to describe how increasing time during impact can reduce the force.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Compare how differences in designs account for effectiveness in energy transfer and force distribution during collisions.

<table>
<tr><td>HS-PS2.4.</td><td>Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects.

Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.

Assessment Boundary: Assessment is limited to systems with two objects.</td></tr>
<tr><td colspan="2">Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 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 representations of phenomena to describe explanations.</td></tr>
<tr><td colspan="2">PS2.B: Types of Interactions

• Newton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
• Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.</td></tr>
</table>

<table>
<tr>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
</tr>
<tr>
<td>Students at level 2 show a basic ability to demonstrate their knowledge and skills such as:
Use mathematical models to describe gravitational forces between objects.
Use mathematical models to describe what causes electric fields.</td>
<td>Students at level 3 show a proficient ability to demonstrate their knowledge and skills such as:
Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects.
Use mathematical representations of Newton’s Law of Gravitation to describe and predict the gravitational forces between objects.
Use mathematical representations of Coulomb’s Law to describe and predict the electrostatic forces between objects.</td>
<td>Students at level 4 show an advanced ability to demonstrate their knowledge and skills such as:
Use mathematical representations to explain characteristics of gravitational and electric forces (e.g., gravity is always an attractive force, electric fields can be both attractive and repulsive, and changes in the gravitational forces or electric forces between two objects can be predicted by knowing the distance between objects).</td>
</tr>
</table>

HS-PS2.5.	**Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.** *Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.*

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical and empirical models.

- 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.

PS2.B: Types of Interactions

- Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4)
- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

PS3.A: Definitions of Energy

- "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (secondary)

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use evidence of an investigation to show that electric currents and magnetic fields are related.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Plan and conduct an investigation to show how the electric field would be affected by varying the conditions in the magnetic field or vice versa (e.g., number of coils, rate of field change).

<table>
<tr><td>HS-PS2.6.</td><td>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.</td></tr>
<tr><td colspan="2">Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

• 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).</td></tr>
<tr><td colspan="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.</td></tr>
</table>

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Communicate that the arrangement of atoms and molecules affects material properties.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Communicate the structure-function tradeoffs in a design and how the properties that emerge from molecular-level features depend on electrical charges among atoms.

HS-PS3-1.	**Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.** Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model. *Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.*
Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 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. • Create a computational model or simulation of a phenomenon, designed device, process, or system.	

PS3.A: Definitions of Energy

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.

PS3.B: Conservation of Energy and Energy Transfer

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use a computational model to identify that energy can be converted across the boundary of a closed system.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Create a computational model to calculate the change in the energy of one component in a system when the change in the energy of the other component(s) and energy flows in and out of the system are known.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Create a computational model to predict the energy limit a system is able to produce and why in practice that limit can never be reached.

HS-PS3-2.	**Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).** Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.

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 designed worlds.

- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.

PS3.A: Definitions of Energy

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use a model to identify energy conversions (e.g., between thermal and kinetic, kinetic and potential) and conservation in macroscopic systems.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Develop quantitative models to predict the relationship among the position, motion, and energy of a given object.

HS-PS3-3.	**Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*** Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency. *Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.*

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.

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

PS3.A: Definitions of Energy

- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.

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.

ETS1.A: Defining and Delimiting an Engineering Problem

<table>
<tr><td colspan="3">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. (secondary)</td></tr>
<tr><td>Level 2

Students at level 2 show a basic ability to demonstrate their knowledge and skills such as:
Identify common energy forms in everyday devices.</td><td>Level 3

Students at level 3 show a proficient ability to demonstrate their knowledge and skills such as:
Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.</td><td>Level 4

Students at level 4 show an advanced ability to demonstrate their knowledge and skills such as:
Evaluate tradeoffs between design constraints and energy output.</td></tr>
</table>

HS-PS3-4.	**Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).** 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.*
Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • 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.	

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.
- 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).

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.

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use data from an investigation to determine how the flow of energy moves through closed versus open systems. • Use data from an investigation to show how a new component of a system, when introduced, will cause the system to change its temperature to a more stable state.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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).	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Refine investigations that demonstrate how variables affect the rate of thermal energy transfer (e.g., the starting thermal energy, the ambient environment) and lead to equilibrium in a closed system. • Investigate limitations of system boundaries' impact on the validity of conclusions about energy transfer and thermal equilibrium.

HS-PS3-5.	**Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.** Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other. *Assessment Boundary: Assessment is limited to systems containing two objects.*
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 designed worlds. • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.	
PS3.C: Relationship Between Energy and Forces • When two objects interacting through a field change relative position, the energy stored in the field is changed.	

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use a model to describe that electric and magnetic fields can cause forces between objects when their fields interact.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Use a model to predict changes in energy and force direction when interacting objects change relative position.

HS-PS4-1.	**Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.** Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth. *Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.*
Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 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 representations of phenomena or design solutions to describe and/or support claims and/or explanations.	
PS4.A: Wave Properties • The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.	

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use mathematical representations to describe that waves travel at different speeds in different materials.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Use mathematical models to predict the impact of how different types of waves move through the same media.

HS-PS4-2.	**Evaluate questions about the advantages of using digital transmission and storage of information.** Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.

Asking Questions and Defining Problems

Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.

- Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.

PS4.A: Wave Properties

- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Ask questions to identify that digital signals use waves for communication and storage.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Evaluate questions about the advantages of using digital transmission and storage of information.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Evaluate questions about how the medium a signal must pass through can determine the advantages and disadvantages of analog versus digital transmission (e.g., a wall, open space, through a wire, etc.).

<table>
<tr><td>HS-PS4-3.</td><td>Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.

Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.

Assessment Boundary: Assessment does not include using quantum theory.</td></tr>
<tr><td colspan="2">Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed worlds. Arguments may also come from current scientific or historical episodes in science.

• Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.</td></tr>
<tr><td colspan="2">PS4.A: Wave Properties

• [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.)

PS4.B: Electromagnetic Radiation

• Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.</td></tr>
</table>

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Make a claim that some phenomena (like interference) relate to wave behavior, and others (like photoelectric effect) relate to particles.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Support or refute claims about which model of electromagnetic radiation, a wave model or particle model, better explains a specific phenomenon (e.g., rainbows, light moving through empty space).

HS-PS4-4.	**Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.** Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias. *Assessment Boundary: Assessment is limited to qualitative descriptions*.
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible.	
PS4.B: Electromagnetic Radiation • When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.	

<table>
<tr>
<td>Level 2

Students at level 2 show a basic ability to demonstrate their knowledge and skills such as:

• Identify evidence that electromagnetic radiation exists on a spectrum, which defines the wavelength and energy of each wave.</td>
<td>Level 3

Students at level 3 show a proficient ability to demonstrate their knowledge and skills such as:

• Evaluate the validity and reliability of claims in published materials about the effects that different frequencies of electromagnetic radiation have when absorbed by matter.</td>
<td>Level 4

Students at level 4 show an advanced ability to demonstrate their knowledge and skills such as:

• Evaluate the validity and reliability of claims about how different frequencies of the electromagnetic spectrum can increase the thermal energy in matter or ionize atoms and cause damage to cells.</td>
</tr>
</table>

HS-PS4.5.	**Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*** Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology. *Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.*

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

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

PS3.D: Energy in Chemical Processes

- Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (secondary)

PS4.A: Wave Properties

- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.

PS4.B: Electromagnetic Radiation

- Photoelectric materials emit electrons when they absorb light of a high-enough frequency.

PS4.C: Information Technologies and Instrumentation

- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Obtain and use information to identify a technological device that uses the principles of wave behavior or wave matter to transmit and capture information and energy.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Communicate the role of wave interactions through different devices as they work together to perform a function.

HS-ESS1-1.	**Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy 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 sub-atomic processes involved with the sun's nuclear fusion.*

Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

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.

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)

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use a model to describe that the sun follows a predictable life cycle. • Use a model to describe that the sun generates energy through nuclear fusion.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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 in the form of radiation.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Develop a model to predict how changes in nuclear fusion at different stages of the sun's life cycle affect its radiation output and impact on Earth.

HS-ESS1-2.	**Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.** 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).
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.	

ESS1.A: The Universe and Its Stars

- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
- The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and nonstellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.
- 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.

PS4.B: Electromagnetic Radiation

- 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)

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use evidence to support a claim that galaxies are moving away from Earth. • Use evidence to support a claim that hydrogen and helium are the most abundant elements in the universe.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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. • Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra. • Construct an explanation of the Big Bang theory based on motion of distant galaxies. • Construct an explanation of the Big Bang theory based on composition of matter in the universe.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Construct an explanation describing how redshift data supports the acceleration expansion of the universe (e.g., comparing local and distant galaxies). • Evaluate data from cosmic microwave background studies to refine explanations of the universe's origins.

HS-ESS1-3.	**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.*

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.

- 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).

ESS1.A: The Universe and Its Stars

- 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.

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Communicate scientific ideas about the basic stages of a star's life cycle. • Communicate scientific ideas about how new elements form over time (i.e., nuclear fusion).	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Communicate scientific ideas about the way stars, over their life cycle, produce elements.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Communicate scientific ideas to compare different stellar masses and how their different life cycles contribute to element formation.

HS-ESS1-4.	**Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.** Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons. *Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's laws of orbital motions should not deal with more than two bodies, nor involve calculus.*

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.

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.

<table>
<tr><th>Level 2</th><th>Level 3</th><th>Level 4</th></tr>
<tr><td>Students at level 2 show a basic ability to demonstrate their knowledge and skills such as:
Recognize that gravity influences planetary orbits and that changes in gravitational forces can alter motion from mathematical representations.
Identify that simple patterns in orbital motion (e.g., planets farther from the sun take longer to orbit) can be represented by mathematical models.
Recognize the proportional relationship of the force of gravity as it relates to the distance between two objects or the mass of two objects.</td><td>Students at level 3 show a proficient ability to demonstrate their knowledge and skills such as:
Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.</td><td>Students at level 4 show an advanced ability to demonstrate their knowledge and skills such as:
Use mathematical representations to explain how external factors (e.g., gravitational interactions between planets) affect orbital motion.
Recognize the limitations of mathematical models that predict very large objects that orbit each other.</td></tr>
</table>

HS-ESS1-5.	**Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.** Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages of oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust decreasing with distance away from a central ancient core of the continental plate (a result of past plate interactions).

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

- Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments.

ESS1.C: The History of Planet Earth

- Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old.

ESS2.B: Plate Tectonics and Large-Scale System Interactions

- Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. (ESS2.B Grade 8 GBE) (secondary)

PS1.C: Nuclear Processes

- 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)

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Make a claim based on evidence that continental rocks are older than oceanic rocks.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Evaluate scientific arguments about the age of crustal rocks by analyzing reasoning, assessing supporting evidence, and identifying gaps or contradictions that require further investigation. • Construct an argument about applying the exponential-decay law to model to determine the age of rocks.

HS-ESS1-6.	**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.

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.

- Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

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.

PS1.C: Nuclear Processes

- 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)

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Make a claim about ancient Earth materials providing information about Earth's history.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Construct an argument evaluating the strengths and limitations of different dating methods in determining Earth's age.

<table>
<tr><td>HS-ESS2-1.</td><td>Develop a model to illustrate how Earth’s internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.

Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).

Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth’s surface.</td></tr>
<tr><td colspan="2">Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).

• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td></tr>
<tr><td colspan="2">ESS2.A: Earth Materials and Systems

• Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

ESS2.B: Plate Tectonics and Large-Scale System Interactions

• Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth’s surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth’s crust. (ESS2.B Grade 8 GBE)</td></tr>
</table>

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use a model that represents Earth processes (e.g., plate movement or erosion) to describe how each process affects Earth's surface features. • Use a model to describe that Earth's surface features change over time.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Refine a model to show how feedback effects in Earth's internal and surface processes can increase or decrease the changes to continental or ocean floor features. • Develop a model to predict future changes in Earth's surface based on geological processes.

<table>
<tr><td>HS-ESS2-2.</td><td>Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.</td></tr>
<tr><td colspan="2">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.

• Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.</td></tr>
<tr><td colspan="2">ESS2.A: Earth Materials and Systems

• Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

ESS2.D: Weather and Climate</td></tr>
</table>

<table>
<tr><td colspan="3">The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's reradiation into space.</td></tr>
<tr>
<td>Level 2

Students at level 2 show a basic ability to demonstrate their knowledge and skills such as:
Analyze geoscience data to describe an environmental change (e.g., melting glaciers)
Analyze data to describe that a change in Earth's surface affects another system.</td>
<td>Level 3

Students at level 3 show a proficient ability to demonstrate their knowledge and skills such as:
Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.</td>
<td>Level 4

Students at level 4 show an advanced ability to demonstrate their knowledge and skills such as:
Analyze geoscience data to predict the potential long-term effects of feedback loops within Earth's systems.
Analyze geoscience data to construct and defend claims about how human activities amplify or mitigate natural feedback mechanisms.</td>
</tr>
</table>

<table>
<tr><td>HS-ESS2-3.</td><td>Develop a model based on evidence of Earth’s interior to describe the cycling of matter by thermal convection.

Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth’s three-dimensional structure obtained from seismic waves, records of the rate of change of Earth’s magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth’s layers from high-pressure laboratory experiments.</td></tr>
<tr><td colspan="2">Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).

• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td></tr>
<tr><td colspan="2">ESS2.A: Earth Materials and Systems

• Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth’s surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth’s interior and gravitational movement of denser materials toward the interior.

ESS2.B: Plate Tectonics and Large-Scale System Interactions</td></tr>
</table>

- The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection.

PS4.A: Wave Properties

- Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (secondary to HS-ESS2-3)

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use a model to describe how movement in the mantle contributes to changes in Earth's surface features.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Develop a model that demonstrates how the radioactive decay of unstable isotopes generates heat within Earth's crust and mantle, driving mantle convection. • Develop and revise a model to explain the relationship between thermal energy, density changes, and mantle movement. • Develop a model using seismic wave data to demonstrate how geologists use wave reflection at layer interfaces to infer Earth's internal structures.

HS-ESS2-4.	**Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.** Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition. *Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.*

Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).

- Use a model to provide mechanistic accounts of phenomena.

ESS1.B: Earth and the Solar System

- Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary)

ESS2.A: Earth Materials and System

- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

ESS2.D: Weather and Climate

- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's reradiation into space.

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use a model to identify the energy inputs and outputs of Earth's energy system. • Use a model to show changes in energy flow of Earth's systems. • Use a model to identify that changes in climate occur over differing time scales.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Evaluate multiple models to determine their effectiveness in explaining variations in Earth's climate over time. • Compare different models to assess their accuracy in representing the role of the sun and Earth systems in past and future climate scenarios. • Use a model to predict long-term climate trends based on different scenarios of energy flow.

HS-ESS2-5.	**Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).

Planning and Carrying Out Investigations

Planning and carrying out investigations in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

- 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.

ESS2.C: The Roles of Water in Earth's Surface Processes

- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use data from an investigation to describe the properties of water, such as density of water in different states, ability to dissolve and transport materials, and heat capacity.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Plan and conduct an investigation to produce data to provide evidence that both the chemical and physical properties of water effect Earth's materials and processes.

<table>
<tr><td>HS-ESS2-6.</td><td>Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.</td></tr>
<tr><td colspan="2">Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).
Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td></tr>
<tr><td colspan="2">ESS2.D: Weather and Climate
Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.</td></tr>
</table>

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use a model to identify major carbon reservoirs within the hydrosphere, atmosphere, geosphere, and biosphere. • Use a model to show how processes (e.g., photosynthesis, respiration) transfer carbon between two interacting Earth systems.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Develop a quantitative model to predict the effects of specific human actions on carbon reservoirs and the cycling of carbon.

HS-ESS2-7.	**Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.** Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms. *Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.*
Engaging in Argument from Evidence Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Construct an oral and written argument or counter-arguments based on data and evidence.	
ESS2.D: Weather and Climate • Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. ESS2.E Biogeology	

• The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual coevolution of Earth's surface and the life that exists on it.		
Level 2 Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Make a claim that the environment affects biological evolution. • Identify evidence to describe a historical event that shows interactions between life and Earth's systems.	**Level 3** Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.	**Level 4** Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Construct an argument based on evidence to predict future changes in Earth's systems based on past trends of coevolution between life and Earth's systems, given a potential geologic change.

<table>
<tr><td>HS-ESS3-1.</td><td>Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.</td></tr>
<tr><td colspan="2">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 knowledge, principles, and theories.

• 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.</td></tr>
<tr><td colspan="2">ESS3.A: Natural Resources

• Resource availability has guided the development of human society.

ESS3.B: Natural Hazards</td></tr>
</table>

• Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations.

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Make a claim that the availability of natural resources, occurrence of natural hazards, or changes in climate influenced human activity.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. • Construct an explanation based on evidence for how the availability of natural resources influenced human activity. • Construct an explanation based on evidence for how occurrence of natural hazards has influenced human activity. • Construct an explanation based on evidence for how changes in climate have influenced human activity.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Construct an argument using evidence to predict how resource availability, occurrence of natural hazards, and changes in climate will shape future societal development. • Construct an explanation based on evidence, such as synthesizing historical data and scientific models, to predict how future climate-driven natural disasters might influence global population distributions.

HS-ESS3-2.	**Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*** Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

- Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

ESS3.A: Natural Resources

- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

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. (secondary)

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use evidence to make a list of factors (economic, social, environmental) that influence decisions about resource use. • Make a claim using evidence that resource extraction can have both positive and negative impacts.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Justify the effectiveness of a resource-management solution using both quantitative and qualitative data, considering the constraints of the design. • Predict how a new technology or social regulation could affect future resource management.

HS-ESS3-3.	**Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.** Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning. *Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.*

Using Mathematics 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.

- Create a computational model or simulation of a phenomenon, designed device, process, or system.

ESS3.C: Human Impacts on Earth Systems

- The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use computational simulation data to identify relationships among management of natural resources, the sustainability of human populations, and biodiversity. • Use computational simulation data to describe observable changes in biodiversity based on resource use. • Use computational simulation data to describe different management strategies.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. • Create a computational simulation to illustrate the relationships among management of natural resources and the sustainability of human populations. • Create a computational simulation to illustrate the relationships between management of natural resources and biodiversity.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Use computational models to predict long-term impacts of resource-management decisions. • Evaluate simulation models to suggest modifications to improve accuracy and applicability to real-world scenarios. • Compare multiple computational models to assess different approaches to sustainability. • Construct an argument using evidence from multiple simulations to support sustainable management recommendations.

HS-ESS3-4.	**Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*** Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).

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 knowledge, principles and theories.

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

ESS3.C: Human Impacts on Earth Systems

- Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

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. (secondary)

<table>
<tr>
<td>Level 2

Students at level 2 show a basic ability to demonstrate their knowledge and skills such as:
Make a claim using evidence that technological solutions can mitigate human impacts on the environment.
Make a claim using evidence that human activities impact natural systems.</td>
<td>Level 3

Students at level 3 show a proficient ability to demonstrate their knowledge and skills such as:
Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.</td>
<td>Level 4

Students at level 4 show an advanced ability to demonstrate their knowledge and skills such as:
Justify proposed refinements of a technological solution with data and systems thinking.
Design a new solution to reduce human impact that optimizes cost, effectiveness, and sustainability.
Compare and contrast multiple technological solutions to determine the best approach for sustainability.
Evaluate the effectiveness of technologies that limit waste and pollution through evidence-based comparisons that include long-term environmental benefits and reduced ecological impact.</td>
</tr>
</table>

<table>
<tr><td>HS-ESS3-5.</td><td>Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.

Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).

Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.</td></tr>
<tr><td colspan="2">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.

• Analyze data using computational models in order to make valid and reliable scientific claims.</td></tr>
<tr><td colspan="2">ESS3.D: Global Climate Change

• Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.</td></tr>
</table>

<table>
<tr>
<td>Level 2

Students at level 2 show a basic ability to demonstrate their knowledge and skills such as:
Analyze geoscience data to describe human activities that contribute to climate change.
Analyze geoscience data to identify patterns related to climate change.</td>
<td>Level 3

Students at level 3 show a proficient ability to demonstrate their knowledge and skills such as:
Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.</td>
<td>Level 4

Students at level 4 show an advanced ability to demonstrate their knowledge and skills such as:
Analyze geoscience data to evaluate the reliability and limitations of climate models and their predictions.
Analyze geoscience data to compare and contrast different global climate models to assess their predictive power.
Analyze geoscience data related to a current management strategy to describe the impact on climate change, sea level rise, ecosystem, or human societies.</td>
</tr>
</table>

HS-ESS3-6.	**Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.** Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations. *Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.*

Using Mathematics 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 a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.

ESS2.D: Weather and Climate

- Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (secondary)

ESS3.D: Global Climate Change • Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.		
Level 2 Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use computational data to identify interactions between Earth's systems. • Use qualitative and quantitative data to identify human activities that affect Earth's systems (e.g., deforestation, fossil fuel use).	**Level 3** Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.	**Level 4** Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Evaluate the reliability of computational models in predicting environmental changes. • Synthesize multiple data sources of computational models to predict future environmental changes. • Use computational model data to propose solutions to mitigate negative human impacts.

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.** *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.*
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, 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.	
LS1.A: Structure and Function • 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. (Note: This Disciplinary Core Idea is also addressed by HS-LS3-1.)	

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Make a claim regarding the relationship between the structure of DNA and the functionality of proteins (e.g., if the structure of DNA changes, the protein may not be able to perform its function). • Identify evidence from multiple sources that supports a given claim for how the structure of DNA affects the ability of specialized cells to perform processes necessary for life.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Revise an explanation for how the structure of DNA determines the structure of proteins, when presented with new evidence.

<table>
<tr><td>HS-LS1-2.</td><td>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.</td></tr>
<tr><td colspan="2">Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

• Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.</td></tr>
<tr><td colspan="2">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.</td></tr>
</table>

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use a given model to identify how multiple systems interact to perform a specific function within a multicellular organism.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Develop and use a model to predict how changes to a component of a system will affect interacting systems and the function of the organism.

HS-LS1-3.	**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.*

Planning and Carrying Out Investigations

Planning and carrying out in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

- 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.

LS1.A: Structure and Function

- 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.

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Identify independent and dependent variables relevant to investigating feedback mechanisms, and variables that need to be controlled. • Make a directional hypothesis that specifies how a living system will respond (dependent variable) to an external stimulus (independent variable).	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Plan and conduct an investigation to provide evidence how both positive and negative feedback mechanisms maintain homeostasis. • Refine an investigation plan to control variables that may impact the ability to explain the cause-and-effect relationship between external stimuli and feedback mechanisms.

HS-LS1-4.	**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.*
Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Use a model based on evidence to illustrate the relationships between systems or between components of a system.	
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.	

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use a model to describe the inputs and outputs of mitosis. • Use a model to compare and contrast differentiated and undifferentiated cells.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Refine a model to illustrate the passing of genetic material during mitosis through chromosomes, and the role of chromosomes in differentiation of cells. • Develop a model to illustrate the relationship among mitosis, differentiation, and the formation of tissues and organs.

HS-LS1-5.	**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.*
Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Use a model based on evidence to illustrate the relationships between systems or between components of a system.	
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.	

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Identify components of a model relevant to illustrating the transfer of energy during photosynthesis (e.g., CO_2, O_2, light, glucose).	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Develop a model to compare the energies of the chemical bonds in the inputs and outputs of photosynthesis. • Use a model to predict how changes to a component of photosynthesis may affect energy storage (e.g., light availability, carbon dioxide availability).

HS-LS1-6.	**Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.** 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.*
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 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.	
LS1.C: Organization for Matter and Energy Flow in Organisms • 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.	

- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Make a claim regarding the relationship between the atoms in sugar molecules and the atoms in amino acids and/or other large carbon-based molecules.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Construct an explanation for how matter and energy are conserved as they are recombined in different ways to form products.

<table>
<tr><td>HS-LS1-7.</td><td>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.</td></tr>
<tr><td colspan="2">Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

• Use a model based on evidence to illustrate the relationships between systems or between components of a system.</td></tr>
<tr><td colspan="2">LS1.C: Organization for Matter and Energy Flow in Organisms

• 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.</td></tr>
</table>

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Identify components of a model relevant to illustrate the reorganization of matter during cellular respiration. • Identify components of a model relevant to illustrate the transfer of energy as chemical bonds are broken and reformed during cellular respiration.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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. • 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. • Use a model to illustrate that cellular respiration is a chemical process resulting in a net transfer of energy.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Develop a model to illustrate that matter and energy are conserved during cellular respiration. • Develop a model to illustrate the use of energy from the chemical bonds in food to move muscles, maintain body heat, and/or perform other processes in an organism. • Develop a model to illustrate the difference in the amount of stored energy when energy is transferred from one system of interacting molecules to another.

HS-LS2-1.	**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.*

Using Mathematics 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 and/or computational representations of phenomena or design solutions to support explanations.

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 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.

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Identify components of a mathematical and/or computational representation that provide evidence of changes to a population or ecosystem over time. • Use a mathematical and/or computational representation to explain that changes to an ecosystem caused a population to increase or decrease.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Use mathematical and/or computational representations to support the interdependency of factors that affect carrying capacity (e.g., reduction in resources causes an increase in competition). • Use mathematical and/or computational representations to predict how a change in environmental factors will affect the carrying capacity of an ecosystem.

HS-LS2-2.	**Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.** 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.*

Using Mathematics 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 representations of phenomena or design solutions to support and revise explanations.

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 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.

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

<table>
<tr><td colspan="3">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.</td></tr>
<tr>
<td>Level 2

Students at level 2 show a basic ability to demonstrate their knowledge and skills such as:

• Identify components of a mathematical and/or computational representation that provide evidence of changes to biodiversity or populations over time.</td>
<td>Level 3

Students at level 3 show a proficient ability to demonstrate their knowledge and skills such as:

• Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.</td>
<td>Level 4

Students at level 4 show an advanced ability to demonstrate their knowledge and skills such as:

• Use mathematical representations to support and revise explanations based on evidence that ecosystem resilience is affected by the magnitude of the disturbance.</td>
</tr>
</table>

HS-LS2-3.	**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.*
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 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.	
LS2.B: Cycles of Matter and Energy Transfer in Ecosystems • Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.	

<table>
<tr>
<td>Level 2

Students at level 2 show a basic ability to demonstrate their knowledge and skills such as:
Identify evidence for the movement of matter or energy in aerobic and anaerobic conditions.
Identify differences in the movement of matter between aerobic and anaerobic respiration.</td>
<td>Level 3

Students at level 3 show a proficient ability to demonstrate their knowledge and skills such as:
Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.</td>
<td>Level 4

Students at level 4 show an advanced ability to demonstrate their knowledge and skills such as:
Construct and revise an explanation based on evidence for the relationship between photosynthesis and cellular respiration in providing energy for life processes.
Revise an explanation based on evidence for the ability of anaerobic respiration to provide energy for life processes in environments without photosynthesis or aerobic respiration.</td>
</tr>
</table>

HS-LS2-4.	**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.*

Using Mathematics 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 representations of phenomena or design solutions to support claims.

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

- 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.		
Level 2 Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Identify mathematical representations relevant to the transfer of matter and energy within an ecosystem. • Use mathematical representations to identify differences in matter or energy between trophic levels in an ecosystem.	**Level 3** Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.	**Level 4** Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Use mathematical representations to support an explanation for the relative number of consumers in each trophic level based on the flow of matter and energy. • Use mathematical representations to support how matter and energy that flow out of living organisms and into the environment are conserved.

<table>
<tr><td>HS-LS2-5.</td><td>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.</td></tr>
<tr><td colspan="2">Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show how relationships among variables between systems and their components in the natural and designed worlds.

• Develop a model based on evidence to illustrate the relationships between systems or components of a system.</td></tr>
<tr><td colspan="2">LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

• 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.

PS3.D: Energy in Chemical Processes

• The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary)</td></tr>
</table>

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use a given model to identify the carbon-containing inputs and outputs of photosynthesis and cellular respiration. • Identify the components relevant to model the role of photosynthesis and cellular respiration in the cycling of carbon.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Use a model to predict how changes to one component will affect the storage and exchange of carbon between Earth's systems.

<table>
<tr><td>HS-LS2-6.</td><td>Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

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.</td></tr>
<tr><td colspan="2">Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

• Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.</td></tr>
<tr><td colspan="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.</td></tr>
</table>

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Identify a claim based on evidence for how a biological or physical disturbance to an ecosystem has affected a population. • Identify evidence that supports an interaction in an ecosystem having a stabilizing effect on numbers or types of organisms.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Compare and evaluate competing arguments about whether a disturbance has led to a new ecosystem. • Critique an argument for how a disturbance has challenged the functioning of an ecosystem in terms of resources and habitat availability, and determine what additional information is required to resolve contradictions. • Evaluate claims, evidence, and reasoning for how complex interactions in an ecosystem affect ecosystem resiliency when facing modest disturbances.

HS-LS2-7.	**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.

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.

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

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.

LS4.D: Biodiversity and Humans

- Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (secondary)
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining

biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (secondary) (Note: This Disciplinary Core Idea is also addressed by HS-LS4-6.) 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. (secondary)		
Level 2 Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Make a claim regarding the relationship between human activity and the adverse effects on the environment or biodiversity. • Identify possible constraints to a solution for reducing the impacts of human activities. • Make a claim regarding a solution that reduces the impact of human activities on the environment.	**Level 3** Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.	**Level 4** Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Evaluate the tradeoff considerations for a solution for reducing the impacts of human activities. • Construct an explanation for the biodiversity benefits resulting from a solution for reducing the impacts of human activities.

<table>
<tr><td>HS-LS2-8.</td><td>Evaluate 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.</td></tr>
<tr><td colspan="2">Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

• Evaluate the evidence behind currently accepted explanations to determine the merits of arguments.</td></tr>
<tr><td colspan="2">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.</td></tr>
</table>

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Make a claim that distinguishes between group and individual behavior. • Identify relevant evidence to support the role of group behavior on individuals' and species' chances to survive or reproduce.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Evaluate evidence for the role of group behavior on individuals' and species' chances to survive and reproduce. • Evaluate evidence for the role of group behavior on individuals' chances to survive and reproduce. • Evaluate evidence for the role of group behavior on species' chances to survive and reproduce.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Construct an argument based on evidence that certain group behaviors have evolved over time because they increase individuals' chances to survive and reproduce. • Construct an argument based on evidence that increasing the chances of survival of genetic relatives contributes to the evolution of group behaviors.

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.** *Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*
Asking Questions and Defining Problems Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Ask questions that arise from examining models or a theory to clarify relationships.	
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) (Note: This Disciplinary Core Idea is also addressed by HS-LS1-1.) 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.	

<table>
<tr>
<td>Level 2

Students at level 2 show a basic ability to demonstrate their knowledge and skills such as:
Identify relevant and testable questions about the role of DNA and chromosomes.
Ask questions to clarify relationships between DNA, genes, chromosomes, and proteins.</td>
<td>Level 3

Students at level 3 show a proficient ability to demonstrate their knowledge and skills such as:
Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.</td>
<td>Level 4

Students at level 4 show an advanced ability to demonstrate their knowledge and skills such as:
Ask questions to clarify relationships about the DNA within each cell, and the genes used by different cells.
Ask questions from observations to clarify additional information about the function of DNA with no as-yet known function.</td>
</tr>
</table>

HS-LS3-2.	**Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.** 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.*
Engaging in Argument from Evidence Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence.	
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. • 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.	

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Evaluate evidence to determine if genetic variations are present. • Make a claim that the expression of a specific trait is dependent on the genetic code and the variations within that code that are passed from parent to offspring.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Make and defend a claim for how swapping sections of chromosomes during meiosis leads to an increase in genetic variation. • Make and defend a claim based on evidence for why errors during replication must be viable to be inherited. • Make and defend a claim based on evidence that both genetic and environmental factors affect the variation and distribution of traits. • Construct an argument based on evidence that the occurrence of a trait in a population may change if the genetic variation is heritable.

HS-LS3-3.	**Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.** Clarification Statement: Emphasis is 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.*
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.	
LS3.B: Variation of Traits • 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.	

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Identify patterns from data describing variation or distribution of traits in a population. • Organize data to better identify patterns in the variation or distribution of traits.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Use concepts of statistics and probability to predict changes in the distribution of expressed traits in a population when environmental changes occur. • Describe the limitations of concepts of statistics and probability in explaining the variation and distribution of expressed traits in a population.

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

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.

- 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).

LS4.A: Evidence of Common Ancestry and Diversity

- Genetic information, like the fossil record, 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.

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use scientific literature to identify how a line of evidence supports common ancestry and/or biological evolution. • Compare sources of information to address a scientific question regarding common ancestry or biological evolution.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Use scientific information to justify how connecting multiple lines of evidence strengthens the argument for common ancestry and biological evolution. • Evaluate scientific information from multiple sources to assess the limitations of evidence for biological evolution, and how multiple lines of evidence address those limitations.

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.** 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.*
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, 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.	
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. LS4.C: Adaptation • Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.

Level 2	**Level 3**	**Level 4**
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Identify evidence relevant to determining factors for evolution. • Make a claim regarding the factors affecting a population and whether evolution will result.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Apply scientific reasoning to describe relationships between factors that influence evolution and explain how together they provide the conditions for the process of evolution (e.g., an increasing population may affect competition for resources, driving evolution).

	that are better able to survive and reproduce in the environment. • Construct an explanation based on evidence that the process of evolution results from the potential for a species to increase in number. • Construct an explanation based on evidence that the process of evolution results from the heritable genetic variation of individuals in a species due to mutation and sexual reproduction. • Construct an explanation based on evidence that the process of evolution requires competition for limited resources. • Construct an explanation based on evidence that the process of evolution requires the proliferation of those organisms that are better able to survive and reproduce in the environment.	• Apply scientific reasoning to explain the relationship between natural selection and evolution.

<table>
<tr><td>HS-LS4-3.</td><td>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.</td></tr>
<tr><td colspan="2">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.</td></tr>
<tr><td colspan="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.
The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.
LS4.C: Adaptation</td></tr>
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- 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.

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Level 2

Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as:

- Analyze data to identify variation within a population that is expressed through observable traits, and genetic variation that is not expressed.

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Level 3

Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as:

- 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.

</td><td>

Level 4

Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as:

- Apply concepts of statistics and probability to support a prediction of how a previously adapted population may change when environmental changes occur.
- Apply concepts of statistics and probability to explain why only traits that are heritable and affect reproductive success will be acted upon by natural selection.

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HS-LS4-4.	**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.

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, 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.

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.

<table>
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<td>Level 2

Students at level 2 show a basic ability to demonstrate their knowledge and skills such as:
Identify evidence of natural selection leading to adaptation in a population.
Make a claim that natural selection has led to an increase in the proportion of individuals that have a beneficial trait.</td>
<td>Level 3

Students at level 3 show a proficient ability to demonstrate their knowledge and skills such as:
Construct an explanation based on evidence for how natural selection leads to adaptation of populations.</td>
<td>Level 4

Students at level 4 show an advanced ability to demonstrate their knowledge and skills such as:
Construct an explanation for how natural selection leads to adaptation over generations, and not in individuals.
Apply scientific reasoning to predict how traits in a population will shift when specific biotic or abiotic factors in an ecosystem change.
Construct an explanation for how natural selection and adaptation lead to differences among living species.</td>
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HS-LS4-5.	**Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.** 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.

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current or historical episodes in science.

- Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.

LS4.C: Adaptation

- Changes in the physical environment, whether naturally occurring or human induced, have thus 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.

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Make a claim based on evidence that species are affected by changes to their environment.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • 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. • Evaluate the evidence supporting claims that changes in environmental conditions may result in increases in the number of individuals of some species. • Evaluate the evidence supporting claims that changes in environmental conditions may result in the emergence of new species over time. • Evaluate the evidence supporting claims that changes in environmental conditions may	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Construct an argument based on evidence for why a species may go extinct instead of adapting to a change in the environment (e.g., change is too fast or drastic). • Construct an argument based on evidence that human-induced and naturally occurring changes to the environment both affect species, but often in different ways. • Construct an argument that environmental changes can result in changes to species that are interconnected and may cause additional changes (e.g., an increase in one species can cause the extinction of another).

	result in the extinction of other species.	

HS-LS4-6.	**Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*** Clarification Statement: Emphasis is on testing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.

Using Mathematics 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.

- Create or revise a simulation of a phenomenon, designed device, process, or system.

LS4.C: Adaptation

- Changes in the physical environment, whether naturally occurring or human induced, have thus 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.

LS4.D: Biodiversity and Humans

- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (Note: This Disciplinary Core Idea is also addressed by HS-LS2-7.)

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. (secondary)
- 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. (secondary)

Level 2	Level 3	Level 4
Students at level 2 show a *basic* ability to demonstrate their knowledge and skills such as: • Use mathematical representations to describe adverse impacts of human activity on biodiversity. • Use mathematical representations to show that the extinction of species affects biodiversity. • Identify potential benefits or negative effects of a solution designed to mitigate the adverse impacts of human activity on biodiversity.	Students at level 3 show a *proficient* ability to demonstrate their knowledge and skills such as: • Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.	Students at level 4 show an *advanced* ability to demonstrate their knowledge and skills such as: • Describe limitations of a simulation by using mathematical representations to compare results with expected outcomes. • Use mathematical representations to explain how preserving biodiversity helps to maintain ecosystem functioning and productivity which is necessary to produce resources humans depend on.