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High School ISAT Science Specifications

IDAHO STATE DEPARTMENT OF EDUCATION
ASSESSMENT AND ACCOUNTABILITY | ISAT

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INTRODUCTION

Item specifications establish the parameters for the items featured on the Idaho Standards Achievement Test (ISAT) in the field of science, ensuring they are in line with the 2022 Idaho Content Standards in Science. These specifications outline the characteristics of each possible test question, such as the permissible terminology, potential topics, and the requirements placed on students to evaluate their understanding and abilities with respect to each standard.

This document can serve as a resource for stakeholders, allowing them to examine each Idaho Content Standard for middle school science in conjunction with its assessment criteria, facilitating assessment planning and instructional guidance.

Dimensions in the Idaho Content Standards in Science

The 2022 Idaho Content Standards embrace a holistic approach to science education, departing from rote memorization and isolated skill development. Instead, they adopt a comprehensive perspective that acknowledges the interrelated nature of scientific knowledge. Science encompasses overarching themes that span and include all aspects of science content and practices. The Idaho Content Standards in Science are designed to embody this interconnectedness through a three-dimensional learning model. This approach encourages Idaho students to cultivate critical thinking, problem-solving abilities, and be better equipped to engage with the world as informed citizens. These three dimensions are as follows.

1. **Disciplinary Core Ideas (DCI):** Disciplinary Core Ideas (DCIs) are designed to equip students with a comprehensive understanding of fundamental concepts in Earth Science, Life Science, and Physical Science. In our fast-paced world, where information is readily accessible through technology, the goal of teaching DCIs is not merely to have students memorize facts. Instead, it's to help them establish a robust foundational comprehension of these core concepts, which can serve as a platform for further learning as they accumulate more knowledge.
2. **Science and Engineering Practices (SEP):** SEPs describe the major practices that scientists and engineers employ to explore the world, develop models for understanding natural phenomena, and engineer systems to solve problems.
3. **Crosscutting Concepts (CCC):** CCCs encompass skills and ideas that apply universally across all scientific domains. These common concepts serve as cognitive tools that assist students in connecting and making sense of information from diverse areas of science and engineering. Crosscutting

concepts reflect the cyclical nature of science education—as students progress from elementary school through high school, they will engage with and employ similar patterns of thinking to understand and solve increasingly complex phenomena and problems.

Test Development

Item Development Cycle

Items on the Science ISAT undergo a rigorous development process, outlined below.

1. **Item Development:** Test developers create items that are aligned to the Idaho Content Standards in Science and according to the item specifications set forth by the SDE.
2. **SDE Review:** These items are reviewed and edited by professional test developers and by professionals at the SDE.
3. **Stakeholder Review:** After review by the SDE, items are examined and approved by science educators and stakeholders from across Idaho through the following processes:
    i. **Content Review**: Science educators in all grade levels and content areas review items to ensure science content is accurate and aligned with the standards.
    ii. **Rubric Validation**: Idaho educators analyze student responses generated from field tests to finalize scoring metrics and rubrics used to assess student achievement.
    iii. **Data Review:** Idaho educators review item performance statistics and determine if items are eligible to assess student achievement.
    iv. **Bias and Sensitivity Review**: Stakeholders, including teachers, parents, administrators, and community members, review items to ensure fairness and lack of bias for all Idaho students.

Test Structure

Items on the Science ISAT begin with a stimulus, which is a phenomenon (a discrete observation about the natural world) or engineering/design problem. The stimulus can include text, graphics, tabular or graphical data, and/or animations. Items engage the student in a meaningful, grade-appropriate activity that allows them to demonstrate their three-dimensional knowledge, skills, and scientific thinking.

All Items on the Science ISAT are aligned to one Idaho Content Standard and follow one of two formats to assess students' knowledge and skills:

1. **Clusters:** Clusters engage students with a phenomenon or engineering design problem by asking students to perform a series of related interactions. Each associated interaction is crafted using the Task Demand statements found in the specifications. A cluster will assess a student in all three dimensions of the aligned standard.
2. **Standalones:** Standalone items engage students with a phenomenon or engineering design problem by asking students to perform a single task or interaction with the stimulus. A standalone item will assess students in two or three dimensions of the aligned standard.

Interaction Types

The Science ISAT includes several different interaction types that allow students to engage in grade-appropriate science activities. These interactions allow students to demonstrate their two- and three-dimensional scientific knowledge, skills, and abilities. Each of the interaction types listed are included in the science Practice and Training Test, which is accessible to the public via the Idaho Portal. Interaction types are as follows.

- Multiple Choice (MC)
- Multi-Select (MS)
- Edit Task Choice (ETC)
- Grid Item (GI)
- Hot Text (HT)
- Simulation (SIM)
- Table Input (TI)
- Table Match (TM)
- External Copy Interactions (EC)
- Equation Interaction (EQ)

Scoring Assertions

Scoring assertions set forth the inferences that can be made about a student's knowledge, skills, and abilities based on their interaction with the test item. Scoring assertions convey two pieces of information:

1. The task completed by the student.
2. Evidence of the student's knowledge, skills, and abilities (KSA) can be inferred from the completion of that task.

Each cluster and stand-alone have their own unique scoring assertions. The number of scoring assertions for each cluster and stand-alone varies.

Sections of ISAT Science Item Specifications

For each standard, the following information is available.

Idaho Content Standard Code and Language
The standard code (e.g., MS-PS-1.1) and standard language (Develop models to describe the atomic composition of simple molecules.) are taken directly from the published 2022 Idaho Content Standards in Science.

Dimensions

The science content/disciplinary core idea for each standard is taken directly from the published 2022 Idaho Content Standards in Science. The science and engineering practice and crosscutting concepts of each standard are taken from the Idaho Content Standards in Science along with additional context from other three-dimensional science standards.

Further Explanation and Content Limit

The Further Explanation and Content Limit information comes from the published Idaho Content Standards in Science with additional context and language added by the professional test developers, writers of other three-dimensional science standards, and Idaho science educators. All additional context and language added from those various sources has been vetted and approved by Idaho science educators.

Science Vocabulary

For each standard, vocabulary is listed in two sections: vocabulary that may be used in assessment items and vocabulary that should not be used in assessment items. Vocabulary lists are aligned to grade-appropriate words that students should be familiar with and ensure that words used on assessment items are within content limits.

It is important to note that neither vocabulary list is exhaustive. The lists are **not** intended to be used by educators for memorization purposes in the classroom. Science assessment items will never require students to simply recall the definition of words found in the vocabulary section of this document.

Context/Phenomena

Each assessment item begins with a phenomenon, a discrete observation about the natural world, or an engineering/design problem.

The phenomena or design problems listed in this section give the professional test developers ideas as to the grade-appropriate observations about the natural world or engineering/design problems that are fitting for an assessment item aligned to the standard. Please note that the phenomena and engineering/design problems listed in this section are examples and will not appear in any actual test items on the Science ISAT.

Task Demands

Each interaction in an assessment item is crafted using task demand statements found in the specifications. The task demands inform the professional test developers how to construct interactions that are two- or three-dimensionally aligned. The task demands give the professional test developers ideas as to which interaction types could be used to engage the student in grade-appropriate, meaningful scientific activities. When constructing associated interactions in a cluster, the task demands can be used in any combination or any number of times.

HIGH SCHOOL SCIENCE ISAT SPECIFICATIONS

High School Earth and Space Science

HS-ESS-1.1 Students who demonstrate understanding can:
Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.

Dimensions:

- **SEP:** *Developing and Using Models:* Develop a model based on evidence to illustrate the relationships between systems or between components of a system.
- **DCI:** *Earth's Place in the Universe*:
    - The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.
    - Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. *(secondary)*
- **CCC:** *Scale, Proportion, and Quantity*: The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Further Explanation and Content Limit:

- Further Explanation: 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.
- Content Limits: Assessment does not include details of the atomic and sub-atomic processes involved with the sun's nuclear fusion.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - sunspot cycle
    - solar maximum
    - solar minimum
    - sunspots
    - solar flares
    - UV radiation
    - IR radiation
    - convection
    - nuclear fusion
    - core

- atmosphere
    - solar storm
    - luminosity

- Vocabulary that should not be used in assessment items:
    - photosphere
    - chromosphere
    - corona
    - coronal mass ejections

Phenomena

- The habitable zone in our solar system currently contains both Earth and Mars. In the future it will contain a different set of planets.
- The sun's current surface temperature is about 5,800 K. In 5 billion years, the sun's surface temperature will cool to 3,500 K.
- The sun is 40% brighter, 6% larger than 5% hotter than it was 5 billion years ago.
- The Earth’s atmosphere will contain more water vapor and the oceans will contain less water in a few billion years.

Task Demands

- Organize and/or arrange (e.g., using illustrations and/or labels), summarize or make inferences about data to highlight trends, patterns, or correlations.
- Identify patterns or evidence in the data that supports inferences about the lifespan of the sun or the transfer of energy from the sun to the earth.
- Select or identify from a collection of potential model components, including distractors, the components needed for a model that illustrates the lifespan of the sun or the transfer of energy from the sun to the earth.
- Construct or complete a model capable of illustrating the lifespan of the sun or the transfer of energy from the sun to the earth.
- Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that are relevant to the lifespan of the sun or the transfer of energy from the sun to the earth.
- Identify missing components, relationships, or other limitations of the model.
- Make predictions about the effects of changes in the sun or in the transfer of energy from the sun to the earth. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.

HS-ESS-1.2 Students who demonstrate understanding can:

Construct an explanation of the current model of the origin of the universe based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.

Dimensions:

- **SEP:** *Constructing Explanations and Designing Solutions:* 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.
- **DCI:** *Earth's Place in the Universe*:
    - 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 non-stellar 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.
- **CCC:** *Energy and Matter*: Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on the astronomical evidence of the redshift 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).

Content Limits:

- N/A

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - recessional velocity
    - galaxy

    - star
    - galaxy cluster
    - spectrum
    - spectra
    - wavelength
    - frequency
    - Doppler Effect
    - redshift
    - blueshift
    - light years
    - big bang theory
    - helium
    - emission
    - absorption
- Vocabulary that should not be used in assessment items:
    - cosmological redshift
    - Hubble's Law
    - photometric redshift
    - spectroscopy

Phenomena

- The farthest known galaxy has a greater recessional velocity than the farthest known quasar.
- The spectrum of NGC450 shows a greater abundance of elements heavier than helium than does the spectrum of NGC60
- Two galaxy clusters observed in opposite parts of the sky both contain galaxies with about the same chemical composition: 75% hydrogen and 25% helium.
- A galaxy in the constellation Cetus is moving away from us at a different speed than another galaxy in the adjacent constellation Pisces.

Task Demands

- Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail organizing, interpreting, and analyzing data, making calculations, and sorting relevant from irrelevant information or features.
- Identify evidence that supports and/or does not support the Big Bang Theory.
- Describe, select, or identify components of the Big Bang Theory supported by given evidence.
- Use an explanation of the Big Bang Theory to predict how the universe will continue to change over time.
- Construct an explanation based on evidence that explains how particular aspects of the Big Bang Theory are supported by empirical observations of the universe.

- Identify and justify additional pieces of evidence that would help distinguish among competing hypotheses.

HS-ESS-1.3 Students who demonstrate understanding can:
Communicate scientific ideas about the way stars, over their life cycle, transform elements.

Dimensions:

- **SEP:** *Obtaining, Evaluating, and Communicating Information:* 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).
- **DCI:** *Earth's Place in the Universe*:
  - 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.
- **CCC:** *Energy and Matter*: In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits:

- Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.
- Include basic/simplified nucleosynthesis reactions:
  - Hydrogen fuses into helium
  - Helium fuses into carbon
  - Carbon fuses into oxygen
  - Oxygen fuses into silicon
  - Silicon fuses into iron
- Exclude complex nucleosynthesis reactions and details:
  - CNO cycle
  - Neutron-capture (r-process and s-process)
  - Proton-capture: Rp-process
  - Photodisintegration: P-process
  - Other details about radiation or particles – focus on conservation of nucleons

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - Vocabulary that Could be Used in Clusters/Standalones
  - main sequence
  - nucleosynthesis
  - nuclear reactions
  - fission
  - fusion
  - nucleons
  - proton
  - neutron
  - gamma rays
  - neutrinos
  - red giant
  - blue giant
  - white dwarf
  - planetary nebula
  - supernova
  - supernova remnant
  - globular cluster
  - open
  - exothermic reactions
  - endothermic reactions
  - emissions spectrum
  - absorption spectrum
  - emission lines
  - absorption lines
  - H-R Diagram
- Vocabulary that should not be used in assessment items:
  - Neutron-capture
  - proton-capture
  - photodisintegration
  - CNO cycle, radiogenesis
  -

Phenomena

- Two larger stars, Spica and Pollux, are eight times larger than the sun. However, Spica is 420 times brighter and 6 times more massive than Pollux.
- Procyon is a 1.5 solar mass star and is 8 times brighter than the sun. Aldebaran is a star of similar mass, but Aldebaran is 425 times brighter than the sun.

- The stars in a globular cluster (old low mass stars) are red and show few absorption lines in their spectra while the stars in an open cluster (young high mass stars) are blue and show many absorption lines in their spectra.
- In the core of some stars, carbon can fuse into neon, sodium or magnesium.

Task Demands

- Illustrate, model, or make calculations involving the nucleosynthesis process in stars of different mass, different luminosity, different age or different evolutionary stage using graphs, diagrams, text and mathematical models.
- Compare and contrast the nucleosynthesis processes of stars of different mass, different luminosity, different age, or different evolutionary stage using graphs, diagrams, text and mathematical models.
- Make predictions about nucleosynthesis processes given changes or differences in other stellar characteristics.
- Identify and communicate evidence supporting an explanation regarding the relationship between stellar properties and age, how those stellar properties change over time.
- Synthesize an explanation regarding the relationship between stellar properties and age, how those stellar properties change over time.

HS-ESS-1.4 Students who demonstrate understanding can:
Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.

Dimensions:

- **SEP:** *Using Mathematical and Computational Thinking:* Use mathematical or computational representations of phenomena to describe explanations.
- **DCI:** *Earth's Place in the Universe*: 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.
- **CCC:** *Scale, Proportion, and Quantity*: Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Further Explanation and Content Limit:

- Further Explanation:
    - Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets, moons, rings, asteroids, and comets.

- The term “satellite” can be used to describe both man-made and natural objects that orbit another object.

- Content Limits:
  - Mathematical representations for the gravitational attraction of bodies and Kepler’s Laws of orbital motions should not deal with systems of more than two bodies, nor involve calculus.
  - Comparing different orbiting bodies is acceptable as long as each system only contains two bodies (example: satellite 1 orbiting Earth compared to satellite 2 orbiting Earth).
  - Students will be given the Law of Gravitation to make calculations but should know/apply Kepler’s laws conceptually. These laws are:
    - Orbits are elliptical.
    - Line connecting orbiting body and parent body sweeps out equal areas in equal time.
    - $(\text{Orbital period})^2$ is proportional to $(\text{semi-major axis distance})^3$.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - gravitation
  - orbit
  - revolution
  - rotation
  - period
  - semi-major axis
  - eccentricity
  - semi-minor axis
  - focus
  - foci
  - ellipse
  - gravitational constant
  - astronomical unit
  - satellite
- Vocabulary that should not be used in assessment items:
  - aphelion
  - perihelion
  - angular momentum

Phenomena

- The International Space Station orbits Earth at an altitude of 250 miles with a speed of 5 miles per second while a global positioning system satellite orbits ten times as far and half as fast.
- China's Tiangong space station's orbital speed can no longer be controlled. It is expected to burn up in the atmosphere as it falls to the Earth.
- The shape of Comet Shoemaker-Levy 9's orbit changed just before it collided with Jupiter in 1994.
- In 100 years, the moon will be about half a meter further from Earth and Earth's rotation will be 2 milliseconds slower.

Task Demands

- Make simple calculations using given data to calculate or estimate the motion of orbiting objects (satellites).
- Illustrate, graph, or identify relevant features or data that can be used to calculate, estimate, or make inferences about the motion of satellites.
- Calculate or estimate properties of motions for a satellite and the object it orbits based on data from one or more sources.
- Select or construct relationships between a satellite and the object it orbits based on data from one or more sources.
- Compile, from given information, the particular data needed for a particular inference about the motion of a satellite. This can include sorting out the relevant data from the given information.
- Construct or identify an inference that can be made based on data from one or more sources.

HS-ESS-1.5 Students who demonstrate understanding can:
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.

Dimensions:

- **SEP:** *Engaging in Argument from Evidence:* Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments.
- **DCI:** *Earth's Systems*:
    - 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.
    - 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. *(secondary)*

    - 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)*
- **CCC:** *Patterns*: Empirical evidence is needed to identify patterns.

Further Explanation and Content Limit:

Further Explanation:

- 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).

Content Limit:

- Students do not need to calculate radioactive decay rates.
- Students do not need to know names of supercontinents, names of fault lines, names of tectonic plates

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - convergence
    - divergence
    - sedimentary
    - metamorphic
    - igneous
    - volcanic
    - crust
    - mantle
    - core
    - mid ocean ridge
    - trench
- Vocabulary that should not be used in assessment items:
    - isotope
    - anticline
    - syncline

Phenomena

- Rocks near Bildudalur, Iceland were formed about 16 million years ago, rocks near Geysir, Iceland were formed about 3.3 million years ago.
- The patterns of magnetic reversals on the youngest continental rock columns are the same as the pattern of magnetic reversals found at the center of the Mid-Atlantic ridge.

- Iceland gains about 1.8 centimeters of land surface per year.
- From 1996 to 2016, Mount St. Elias has gotten 0.08 meters taller.

Task Demands

- Based on the provided data or information, identify the explanation that could explain the age difference in continental and oceanic crust.
- Identify and/or explain the claims, evidence, and reasoning supporting the explanation that tectonic plates have moved over time.
- Identify and/or describe additional relevant evidence not provided that would support or clarify the explanation of the movement of tectonic plates and/or the ages of rocks.
- Evaluate the strengths and weaknesses of a claim to explain the theory of plate tectonics and the ages of rocks.
- Analyze and/or interpret evidence and its ability to support the explanation that plate tectonics or radioactive decay can determine the age of a rock.
- Provide and/or evaluate reasoning to support the explanation that volcanoes, mountains, and earthquakes are formed/caused as a result of plate tectonics.

HS-ESS-1.6 Students who demonstrate understanding can:
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.

Dimensions:

- **SEP:** *Constructing Explanations and Designing Solutions:* Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- **DCI:** *Earth's Place in the Universe:*
    - 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.
    - 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)*
- **CCC:** *Stability and Change:* Much of science deals with constructing explanations of how things change and how they remain stable.

Further Explanation and Content Limit:

- Further Explanation:
    - 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.
- Content Limits: N/A

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - plate tectonics
    - radiometric dating
    - isotope
    - continental crust
    - oceanic crust
    - lithosphere
    - asthenosphere
    - cycle
    - bedrock
    - ocean trench
    - sedimentation
    - convection current
    - ancient core
    - inner core
    - mantle
    - nuclear
    - ocean ridge
    - sea-floor spreading
- Vocabulary that should not be used in assessment items:
    - nebular hypothesis
    - planetesimals
    - solar nebula
    - bolide impacts

Phenomena

- A thin section of a rock from western Australia is examined under a microscope and elongate crystals are observed.
- A rock from Earth and a rock from Mars are the same age.
- When astronauts returned to Earth with rocks from the moon, they were all very old. A rock found in the Great Lakes Region of North America is very old, but rock found in Iceland are all relatively young. Meteor Crater is a large depression, with a depth of 170m, in an otherwise flat area of Arizona.

Task Demands

- Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
- Express or complete a causal chain explaining Earth's formation and/or early history. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram or completing cause and effect chains.
- Identify evidence supporting the inference of causation that is expressed in a causal chain.
- Describe, identify, and/or select information needed to support an explanation about the formation of Earth and its early history.
- Construct an explanation based on evidence and scientific reasoning that explains the formation of Earth and its early history.

HS-ESS-2.1 Students who demonstrate understanding can:
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.

Dimensions:

- **SEP:** *Developing and Using Models:* Develop a model based on evidence to illustrate the relationships between systems or between components of a system.
- **DCI:** *Earth's Systems:*
  - Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
  - 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 of continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust.
- **CCC:** *Stability and Change:* Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Further Explanation and Content Limit:

- Further Explanation: 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).
- Content Limits:
  - Students do not need to know the details of the formation of specific geographic features of Earth's surface.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - tectonic uplift
    - seismic waves
    - feedback effect
    - irreversible
    - Earth’s magnetic field
    - electromagnetic radiation
    - inner core
    - outer core
    - mantle
    - continental crust
    - oceanic crust
    - sea-floor spreading
    - isotope
    - thermal convection
    - radioactive decay
    - rock composition
    - continental boundary
    - ocean trench
    - recrystallization
    - nuclear
    - geochemical reaction
    - mass wasting
- Vocabulary that should not be used in assessment items:
    - geomorphology
    - anticline
    - syncline
    - monocline

Phenomena

- A limestone cliff that contains Cambrian-aged fossils extends several hundred feet above the surface of the ocean. A large section of the cliff has collapsed.
- An oceanic trench 10,000 is meters below sea level. Inland, 200km away, a chain of active volcanoes is present.
- 1.8-billion-year-old rocks in the Black Hills of South Dakota are capped by 10,000-year-old gravel terraces.
- A photograph from March shows a large Precambrian-aged pink granite boulder at the top of a 100 m tall hill. A photograph in April shows the same boulder sitting in a pile of soil and sediment in the valley below the hill.

Task Demands

- Select or identify from a collection of potential model components, including distractors, the components that are relevant for explaining the phenomenon. Components might include different rock types, rates of uplift and erosion, surface environments on Earth where these processes occur and where different rock types exist, and layers within Earth where these processes occur. Sources of energy (radiation, convection) that drive the cycling (but *not* the creation of) matter should also be included as components.
- Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon of Earth's internal and surface processes.
- Make predictions about the effects of changes in the magnitude and/or rate of Earth's internal and surface properties. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
- Given models or diagrams of land features, internal and surface processes, identify factors that affect constructive and destructive forces, feedback effects and how they vary in different scenarios OR identify the constructive and destructive mechanisms that operate at different spatial and temporal time scales and how this causes changes in the appearance of continental and ocean-floor features.
- Identify missing components, relationships, or other limitations of the model of how Earth's internal and surface processes form continental and ocean-floor features.
- Describe, identify, or select the relationships among components of a model that describe the formation of continental and ocean-floor features with respect to spatial and temporal variability in internal and external surface processes or explains how changes in these processes affect the formation of continental and ocean-floor features.
- Express or complete a causal chain explaining how changes in the flow of energy (interval vs. surface processes) affect the formation of continental and ocean-floor features. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram or completing cause and effect chains.

HS-ESS-2.2 Students who demonstrate understanding can:

Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to Earth's systems.

Dimensions:

- **SEP:** *Analyzing and Interpreting 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.
- **DCI:** *Earth's Systems:*
  - Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

    - The foundation for the 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 re-radiation into space.
- **CCC:** *Stability and Change:* Feedback (negative or positive) can stabilize or destabilize a system.

Further Explanation and Content Limit:

Further Explanation: Examples of models can be conceptual or physical.

- 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.

Content Limits

- Students do not need to know which gases are greenhouse gases or the composition of the atmosphere.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - ocean circulation
    - biosphere
    - feedback effect
    - atmospheric circulation
    - convection cycle
    - greenhouse gas
    - geoscience
    - sea level
    - mean surface temperature
    - methane
- Vocabulary that should not be used in assessment items:
    - electromagnetic radiation
    - probabilistic
    - irreversible
    - geoengineering
    - ozone

- pollutant
- acidification

Phenomena

- Farming causes deforestation in the Amazon. This leads to an increase in erosion and water runoff, which leads to more forest loss.
- Loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.
- As Permafrost in the Arctic melts, methane is released into the atmosphere. Methane, a greenhouse gas, traps heat causing the Earth to heat up, leading to more Permafrost melting.
- Increased CO2 in the atmosphere warms the oceans. Warmer oceans take up less CO2 than cooler oceans, further increasing atmospheric temperature.

Task Demands

- Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations in how changes to Earth's surface can create feedbacks that affect Earth's systems.
- Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations in how changes to Earth's surface can create feedbacks that affect Earth's systems. This may include sorting out distractors.
- Use relationships identified in the data to predict how changing the Earth's surfaces affects the feedback loop.
- Identify patterns or evidence in the data that supports inferences about how the altering of Earth's surface will affect the Earth in the long term.

HS-ESS-2.3 Students who demonstrate understanding can:
Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.

Dimensions:

- **SEP:** *Developing and Using Models:* Develop a model based on evidence to illustrate the relationships between systems or between components of a system.
- **DCI:** *Earth's 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.

    - 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.
- **CCC:** *Energy and Matter:* Energy drives the cycling of matter within and between systems.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits: N/A

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - convection
    - radioactive
    - inner core
    - outer core
    - isotope
    - mantle
    - seismic wave
    - geochemical reaction
    - geoscience
    - molten rock
    - Earth's elements
    - Earth's internal energy sources
    - geochemical cycle
    - tectonic uplift
- Vocabulary that should not be used in assessment items:
    - geoneutrino
    - primordial heat

Phenomena

- The temperature of the water in a hot spring in Iceland is around 100°F. The average air temperature in Iceland is about 52°F.

- The average heat flow from the Earth's interior is 80 mW/m^{-2}. The heat flow of a volcano on Hawaii is ~400 mWm^{-2}.
- The total heat transfer from the Earth to space is 44 terawatts. Radioactive decay of unstable isotopes contributes 20 terawatts from Earth's interior. (KamLAND Collaboration, 2011).
- In the central valley of California, the temperature at 5 meters below the ground is 2°C warmer than the temperature at the surface. In northern Oregon near Mt. Hood, the temperature 5 meters underground is 10°C warmer than the temperature at the surface.

Task Demands

- Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include the structure of the Earth, the cycling of matter and/or energy, or instruments used to measure seismic waves.
- Assemble or complete, from a collection of potential model components, an illustration or flow chart that can represent the structure and the flow of matter/energy from the Earth's interior. This does not include labeling an existing diagram.
- Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.
- Make predictions about the effects of changes in the cycling of matter and energy. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
- Given models or diagrams of the earth's interior, identify the chemical and physical properties of the Earth's structure that cause the cycling of matter.
- Identify missing components, relationships, or other limitations of the model.
- Describe, select, or identify the relationships among components of a model that describe the cycling of matter within Earth's interior.

HS-ESS-2.4 Students who demonstrate understanding can:
Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

Dimensions:

- **SEP:** *Developing and Using Models:* Use a model to provide mechanistic accounts of phenomena.
- **DCI:** *Earth's Systems:*
    - 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 Earth. These phenomena cause a cycle of ice ages and other gradual climate changes. *(secondary)*
    - The geologic record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output of Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of timescales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.
    - The foundation for Earth's global climate system 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 re-radiation into space.
- **CCC:** *Cause and Effect:* Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Further Explanation and Content Limit:

Further Explanation:

- Examples of the causes of climate change differ by time scale, 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.

Content Limits

- 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.
- Students do not need to know chemical mechanisms of fossil fuel combustion or ozone depletion.

Science Vocabulary

Vocabulary that may be used in assessment items:

- interdependence
- solar radiation,
- solar flare
- biosphere
- atmospheric circulation
- ocean circulation
- climatic pattern
- sea level
- glacier

- atmospheric composition
- hydrosphere
- greenhouse gas
- fossil fuel
- combustion

Vocabulary that should not be used in assessment items:

- acidification
- cryosphere

Phenomena

- Temperatures were warmer in 1990 than in the 5 previous years. In 1992 and 1993, the global temperatures were 1°F cooler than in 1991. (volcanic eruption of Mount Pinatubo)
- 11,000 years ago, large portions of the northern United States contained glaciers. Today, very little of this area contains glaciers. (changes to Earth's orbit)
- Earth experiences 4 distinct seasons. Venus does not experience distinct seasons. (tilt of planet's axis)
- 25,000 years ago, the level of carbon dioxide in the atmosphere was around 180 parts per million (ppm). Today, carbon dioxide levels exceed 400 ppm. (atmospheric composition)

Task Demands

- Select or identify from a collection of potential model components, including distractors, the components that are relevant for explaining the phenomenon. Components might include factors that affect the input, storage, redistribution, and output of energy in Earth's systems.
- Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon of the flow of energy in Earth's systems.
- Make predictions about the effects of changes in energy flow on Earth's climate.
- Given models or diagrams of energy flow in Earth's systems, identify factors that affect energy input, output, storage, and redistribution and how they change in different scenarios OR identify the changes in energy flow that cause changes in Earth's climate.
- Identify missing components, relationships, or other limitations of the model of energy flow in Earth's systems.
- Describe, identify, or select the relationships among components of a model that describe changes in the flow of energy in Earth's systems or explains how changes in energy flow affect climate.

- Express or complete a causal chain explaining how changes in the flow of energy in Earth's systems affect climate. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram or completing cause and effect chains.

HS-ESS-2.5 Students who demonstrate understanding can:
Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

Dimensions:

- **SEP:** *Planning and Carrying out Investigations:* Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., the number of trials, cost, risk, time), and refine the design accordingly.
- **DCI:** *Earth's Systems*
    - 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.
- **CCC:** *Structure and Function:* The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide evidence for the 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, and 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).

Content Limits: 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.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - viscosity
    - melting point
    - freezing point
    - absorption
    - dissolve
    - hydrologic cycle
    - rock cycle
    - stream transportation
    - stream deposition
    - stream table
    - erosion
    - soil moisture content
    - frost wedging
    - chemical weathering
    - solubility
    - mechanical erosion
    - heat capacity
    - density
    - molecular structure
    - sediment
    - cohesion
    - polarity
- Vocabulary that should not be used in assessment items:
    - N/A

Phenomena

- In a cave in Guam, sections of stalactites that formed during seasons of high rainfall contain a lower ratio of the isotopes oxygen-18 to oxygen-16 than sections of the stalactites that formed during seasons of low rainfall.
- Wookey Hole Caves have about 4,000 meters of cave system in a rock formation.
- The Colorado River runs through the rock formation known as the Grand Canyon.

Task Demands

- Identify from a list, including distractors, the materials/tools needed for an investigation of the properties of water and its effects on Earth's materials and surface processes.
- Identify the outcome data that should be collected in an investigation of the properties of water and its effects on Earth's materials and surface processes.
- Evaluate the sufficiency and limitations of data collected to explain the effects of water on Earth's materials and surface processes.
- Make and/or record observations about the chemical and/or physical properties of liquid water and its effects on Earth's materials.
- Interpret and/or communicate the data from an investigation of the effect of water on Earth's materials and surface processes.
- Explain or describe the causal processes that lead to the observed effects of water.
- Select, describe, or illustrate a prediction made by applying the findings from an investigation of the effects of water on Earth's materials and surface processes.

HS-ESS-2.6 Students who demonstrate understanding can:
Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

Dimensions:

- **SEP:** *Developing and Using Models:* Develop a model based on evidence to illustrate the relationships between systems or between components of a system.
- **DCI:** *Earth's Systems*
    - 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.
- **CCC:** *Energy and Matter:* The total amount of energy and matter in closed systems is conserved.

Further Explanation and Content Limit:

Further Explanation:

- 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

Content Limits:

- Students do not need to know how to calculate the residence time by dividing the reservoir size by the flow rate, either in or out; how to calculate the biomass in a given ecosystem.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - concentration
  - rate of transfer/flow
  - pathway
  - hydrosphere
  - geosphere
  - biosphere
  - reservoir
  - sink
  - basin
  - pool
  - accumulate
  - biomass
  - equilibrium
  - chemosynthesis
  - byproduct
  - element
  - hydrocarbon
  - organic
  - inorganic
  - biotic
  - abiotic
  - diffusion
  - decompose
  - decay
  - microbe
  - fungi
  - bacteria
  - sediments
  - sequestered
- Vocabulary that should not be used in assessment items:
  - assimilation
  - residence time
  - facies
  - orogenic
  - strata
  - outgassing
  - Le Chatelier's Principle

Phenomena

- Data indicates that higher levels of atmospheric carbon dioxide increase both carbon's input and release from the soil.
- Even though trees take up carbon dioxide from the atmosphere, scientists find little carbon accumulation in the soil of a North Carolina forest.
- Human activity releases more than 30 billion tons of carbon dioxide into the atmosphere per year. However, scientists estimate that Earth's soil releases roughly nine times more carbon dioxide into the atmosphere than all human activities combined.

Task Demands

- Select or identify from a collection of potential model components, mathematical variables, and/or mathematical operators, including distractors, the components, variables, and/or operators needed to mathematically and/or quantitatively model the phenomenon. Components and mathematical variables might include/represent organisms, spheres, molecules and/or elements, chemical, physical, and/or biological processes, and reservoirs. Operators might include symbols for addition, subtraction, multiplication, division, etc.
- Assemble or complete, from a collection of potential model components, mathematical variables, and/or mathematical operators, an illustration or flow chart that is capable of mathematically and/or quantitatively representing how matter and energy are continuously transferred within and between organisms and their physical environment. This does not include labeling an existing diagram.
- Describe, select, or identify the mathematical and/or quantitative relationships among components of a model and/or mathematical variables that describe how matter and energy are continuously transferred within and between organisms and their physical environment.
- Manipulate the components of a mathematical and/or quantitative model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.
- Make predictions about the effects of changes in the rate at which materials or elements move from one reservoir or sphere to another. Predictions can be made by manipulating model components, mathematical variables, and/or mathematical formulas, completing illustrations, selecting from lists with distractors, or performing calculations given sufficient information to do so.
- Given mathematical and/or quantitative models or diagrams of how matter and energy are continuously transferred within and between organisms and their physical environment, identify the pathways of matter and/or energy transfer within an environment and how they change in each scenario OR identify the properties of the

environment that cause changes in the transfer of matter and/or energy within that environment.
- Identify missing components, mathematical variables, mathematical and/or quantitative relationships, or other limitations of the mathematic and/or quantitative model.

HS-ESS-2.7 Students who demonstrate understanding can:
Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.

Dimensions:

- **SEP:** *Engaging in Argument from Evidence:* Construct an oral and written argument or counter-arguments based on data and evidence.
- **DCI:** *Earth's Systems*
    - Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
    - The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.
- **CCC:** *Stability and Change:* Much of science deals with constructing explanations of how things change and how they remain stable.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and the Earth's 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; and 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.

Content Limits:

- Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - plate tectonics
    - rock formation
    - geologic evidence
    - ocean basin

- radioactive
- rock strata
- time scale
- continental boundary
- ocean trench
- sedimentation
- continental shelf
- crustal deformation
- crustal plate movement
- fracture zone
- convection
- atmospheric composition
- groundwater
- igneous rock
- metamorphic rock
- sedimentary rock
- water cycle
- landslide
- deposition
- greenhouse gas
- mass wasting
- molten rock
- surface runoff

- Vocabulary that should not be used in assessment items:
  - ecosystem services
  - Anthropocene
  - eutrophication
  - ecohydrology
  - geomorphology
  - heterogeneity

Phenomena

- *Eospermatopteris* fossils (first trees) begin to appear in rocks dated 390 million years. Fossils of *Tiktaalik* (four-legged fish), one of the earliest land animals, are found in the rock layers above *Esopermatopteris*.
- The appearance of cyanobacteria is recorded in fossils that formed roughly 3.5 billion years ago. Superior Type banded iron formed roughly 1.8 to 2.7 billion years ago. It is characterized by alternating red and gray layers of iron rich minerals and silica rich minerals.
- The Rhynie Chert beds in Aberdeenshire Scotland contain detailed fossils of early plants. Bryophyte fossils from about 500 million years ago show small simple structured plants.

Cooksonia pertoni fossils from about 430 million years ago show plants that were larger, spore bearing, and contained tissues that move water through the plant (vascular).
- In 2016 two-thirds of the Northern portion of the Great Barrier Reef experienced severe bleaching. The Great Barrier Reef prior to this event, was made up of corals with a variety of bright colors that attracted a variety of marine life. In 2016, the coral turned completely white, and few fish inhabit the area where bleaching has occurred.

Task Demands

- Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
- Express or complete a causal chain explaining how Earth's systems coevolved simultaneously with life on Earth. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.
- Identify and/or describe additional relevant evidence not provided that would support or clarify the explanation of the simultaneous coevolution of Earth's systems and life on Earth. This may entail sorting relevant from irrelevant information or features.
- Construct or identify from a collection, including distractors, an explanation based on evidence that explains how Earth's systems coevolved simultaneously with life on Earth.
- Describe, identify, and/or select information and/or evidence needed to support an explanation. This may entail sorting relevant from irrelevant information or features.
- Identify patterns or evidence in the data that support conclusions about the relationship between the evolution of life on Earth and Earth's systems.

HS-ESS-3.1 Students who demonstrate understanding can:
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.

Dimensions:

- **SEP:** *Constructing Explanation and Designing Solutions:* Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- **DCI:** *Earth and Human Activity*
    - Resource availability has guided the development of human society.
    - 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.
- **CCC:** *Cause and Effect:* Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits:

- Students do not need to know the distribution of specific resources.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - renewable
  - non-renewable
  - mitigation
  - economic cost
- Vocabulary that should not be used in assessment items:
  - biome

HS-ESS-3.2 Students who demonstrate understanding can:

Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

Dimensions:

- **SEP:** *Engaging in Argument from Evidence:* 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).
- **DCI:** *Earth and Human Activity*
  - 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.
  - 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).
- **CCC: N/A**

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits:N/A

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - renewable
    - non-renewable
    - mitigation
    - economic cost
    - irreversible
    - reversible
    - exponential
    - logarithmic
    - basin
    - sustainability
    - recycle
    - reuse
    - species
    - societal
    - wetland
    - groundwater
    - metal
    - consumption
    - per-capita
    - stabilize
    - fossil fuel
    - mining
    - conservation
    - extract
    - agriculture
    - timber
    - fertile land
    - solar radiation
    - biotic
    - abiotic

- depletion
- extinction
- economics
- manufacturing
- technology

- Vocabulary that should not be used in assessment items:
  - trigonometric
  - derivative
  - feedback
  - regulation
  - dynamic
  - aquifer
  - hydrothermal
  - geopolitical
  - oil shale
  - tar sand
  - urban planning
  - waste management
  - fragmentation

Phenomena

- There is a tower in the middle of North Dakota with flames shooting out the top of it.
- In Pennsylvania, a match is struck next to a running water faucet and a large flame appears.
- On the Yangtze River in China, blades of an underwater turbine turn and generate electricity.
- In the desert of Oman, a farmer uses seawater to irrigate crops.

Task Demands

- Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail organizing, interpreting and analyzing data, making calculations, and sorting relevant from irrelevant information or features.
- Identify evidence that supports and/or does not support the success of competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios, societal needs for that resource, and associated environmental risks and benefits.
- Describe, select, or identify components of competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios supported by given evidence.

- Evaluate the strengths of competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios, societal needs for those resources, and associated environmental risks and benefits.
- Use an explanation of the design solutions for developing, managing, and utilizing energy and mineral resources to evaluate which design solution has the most preferred cost-benefit ratio.

HS-ESS-3.3 Students who demonstrate understanding can:
Illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

Dimensions:

- **SEP:** *Using Mathematics and Computational Thinking:* Create a computational model or simulation of a phenomenon, designed device, process, or system.
- **DCI:** *Earth and Human Activity*
- The sustainability of human societies and the biodiversity that supports them require responsible management of natural resources.
- **CCC:** *Stability and Change:* Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Further Explanation and Content Limit:

Further Explanation:

- Examples of factors that affect the management of natural resources include the costs of resource extraction and waste management, per-capita consumption, and development of new technologies.
- Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.

Content Limits: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - biosphere
  - geosphere
  - hydrosphere
  - renewable
  - non-renewable
  - mitigation
  - economic cost
  - irreversible
  - reversible
  - exponential

- logarithmic
    - basin
    - ecological
    - biome
    - recycle
    - reuse
    - mineral
    - societal
    - wetland
    - consumption
    - per-capita
    - mining
    - conservation
    - extract
    - agriculture
    - timber
    - fertile land
    - solar radiation
    - biotic
    - abiotic
    - depletion
    - extinction
    - manufacturing
    - technology
- Vocabulary that should not be used in assessment items:
    - trigonometric
    - derivative
    - feedback
    - regulation
    - dynamic
    - aquifer
    - hydrothermal
    - geopolitical
    - oil shale
    - tar sand
    - urban planning
    - waste management
    - fragmentation

Phenomena

- The number of birds and other wildlife in an area decreases by 30% after a shopping mall is built in northern California.
- Two 1,330 square-foot homes are side by side in northern California. One has six solar panels on the roof, and the other does not. During one month in June, the one with solar panels produces less carbon dioxide than the other house by 174 kilograms.
- Beetles are present throughout a forest. Chemicals are sprayed at intervals needed to control the beetles on one acre. Fifty years later, this acre is the only part of the forest that has oak trees.
- Three species of fish, the Colorado squawfish, the roundtail chub, and the bonytail chub became extinct in the years immediately following construction of the Glen Canyon Dam in Colorado.

Task Demands

- Use data to calculate or estimate the effect of an action or solution on natural resources, the sustainability of human populations, and/or biodiversity.
- Illustrate, graph, or identify features or data that can be used to determine the effects of an action or solution on natural resources, the sustainability of human populations, and/or biodiversity.
- Estimate or infer the effects of an action or solution that affects natural resources, the sustainability of human populations, and/or biodiversity.
- Compile the data needed for an inference about the impacts of an action or solution on natural resources, the sustainability of human populations, and/or biodiversity. This can include sorting out the relevant data from the given information (or choosing relevant inputs for a simulation).
- Using the information, select or identify the criteria against which the solution should be judged.
- Using a simulator, test a proposed action or solution and evaluate the outcomes; may include proposing modifications to the action or solution.
- Evaluate and/or critique models, simulations, or predictions in terms of identifiable limitations and whether they yield realistic results.

HS-ESS-3.4 Students who demonstrate understanding can:
Evaluate or refine a technological solution that mitigates or enhances impacts of human activities on natural systems.

Dimensions:

- **SEP:** *Constructing Explanations and Designing Solutions:* 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.
- **DCI:** *Earth and Human Activity*

    - Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.
    - 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).*
- **CCC:** *Stability and Change:* Feedback (negative or positive) can stabilize or destabilize a system.

Further Explanation and Content Limit:

Further Explanation:

- 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)

Content Limits :N/A

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - renewable
    - non-renewable
    - mitigation
    - economic cost
    - irreversible
    - reversible
    - exponential
    - logarithmic
    - basin
    - recycle
    - reuse
    - societal
    - wetland
    - metal
    - consumption
    - per-capita
    - biodiversity
    - stabilize
    - mining

  - conservation
  - extract
  - agriculture
  - timber
  - fertile land
  - solar radiation
  - biotic
  - abiotic
  - depletion
  - extinction
  - economics
  - manufacturing
  - technology
- Vocabulary that should not be used in assessment items:
  - trigonometric
  - derivative
  - feedback
  - regulation
  - dynamic
  - aquifer
  - hydrothermal
  - geopolitical
  - oil shale
  - tar sand
  - urban planning
  - waste management
  - fragmentation

Phenomena

- Recycling and composting almost 87 million tons of municipal solid waste saved more than 1.1 quadrillion Btu of energy; roughly equivalent to the same amount of energy consumed by 10 million U.S. households in a year.
- Mixed Paper recycling saves the equivalent of 165 gallons of gasoline.

Task Demands

- Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail organizing, interpreting and analyzing data, making calculations, and sorting relevant from irrelevant information or features.
- Identify evidence that supports and/or does not support the success of the technological solution that reduced impacts of human activities on natural systems.

- Describe, select, or identify components of the impacts of human activities on natural systems supported by given evidence.
- Use an explanation of the impacts of human activities on natural systems to explain the technological solution.
- Identify or select the information needed to support an explanation of the impacts of human activities on natural systems.
- Using given information about the effects of human activities on natural systems, select or identify criteria against which the solution should be judged.
- Using given information about the effects of human activities on natural systems, select or identify constraints that the solution must meet.
- Evaluate the criteria and constraints, along with trade-offs, for a proposed or given solution to resolve or improve the impact of human activities on natural systems.
- Using given data, propose a potential solution to resolve or improve the impact of human activities on natural systems.
- Using a simulator, test a proposed solution to resolve or improve the impact of human activities on natural systems, biodiversity and evaluate the outcomes.
- Evaluate and/or revise a solution to resolve or improve the impact of human activities on natural systems and evaluate the outcomes.

HS-ESS-3.5 Students who demonstrate understanding can:
Analyze geoscience data and the results from global climate models to make an evidence-based explanation of how climate variability can affect Earth's systems on a global and regional scale.

Dimensions:

- **SEP:** *Analyzing and Interpreting Data:* Analyze data using computational models in order to make valid and reliable scientific claims.
- **DCI:** *Earth and Human Activity*
    - 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.
- **CCC:** *Stability and Change:* Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Further Explanation and Content Limit:

Further Explanation:

- 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 sea level, glacial ice volumes, or atmosphere and ocean composition).

Content Limits: Assessment is limited to one example of a climate change and its associated impacts.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - orientation
  - probabilistic
  - redistribute
  - volcanic ash
  - concentration
  - electromagnetic radiation
  - radiation
  - sea level
  - geochemical reaction
  - geoscience
  - greenhouse gas
  - atmospheric change
  - biosphere
  - global temperature
  - ice core
  - methane
  - glacier
- Vocabulary that should not be used in assessment items:
  - anthropogenic
  - absorption spectrum
  - determinant
  - NOx (oxides of nitrogen)
  - carbon footprint

Phenomena

- The model predictions for the Great Lakes region of the United States consist of increased precipitation of 5-30% during the spring and decreased precipitation of 5-10% in the summer.
- Concentrations of CO_2 under the higher emissions scenario for 2100 could reach as high as 850 parts per million (ppm).
- Global warming of 2°C is predicted by the year 2050
- The model mean global temperature change for a high emissions scenario is 4-6°C

Task Demands

- Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations in global or regional climate models and their associated future impacts on Earth's systems.

- Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations in global or regional climate models to forecast regional climate change and the associated future impacts on Earth's systems. This may include sorting out distractors.
- Use relationships identified in the data to forecast the current rate of global or regional climate change and how it will affect Earth's systems.
- Identify patterns or evidence in the data that supports inferences about how the changing of global or regional climates will affect Earth's systems in the long term.

HS-ESS-3.6 Students who demonstrate understanding can:
Communicate how relationships among Earth systems are being influenced by human activity.

Dimensions:

- **SEP:** *Using Mathematics and Computational Thinking:* Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.
- **DCI:** *Earth and Human Activity*
    - 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)*.
    - 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.
- **CCC:** *Systems and System Models:* When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Further Explanation and Content Limit:

Further Explanation:

- 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.
- Content Limits: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - orientation
    - probabilistic
    - redistribute
    - volcanic ash
    - concentration
    - electromagnetic radiation
    - radiation
    - sea level
    - geochemical reaction
    - geoscience
    - greenhouse gas
    - atmospheric change
    - biosphere
    - global temperature
    - ice core
    - methane
    - glacier
- Vocabulary that should not be used in assessment items:
    - anthropogenic
    - absorption spectrum
    - determinant
    - NOx (oxides of nitrogen)
    - Carbon Footprint

Phenomena

- Beetles are present throughout a forest. Chemicals are sprayed at intervals needed to control the beetles on one acre. Fifty years later, this acre is the only part of the forest that has oak trees.
- In July 2016, the size of the hypoxic area due to algae blooms in the Chesapeake Bay in late June was the second smallest since 1985.

Task Demands

- Use data to calculate or estimate the effect of human activity on Earth systems.
- Illustrate, graph, or identify features or data that can be used to determine the relationships among Earth systems and how human activity is affecting those relationships.
- Estimate or infer the effects of human activity on Earth systems.

- Compile the data needed for an inference about the impacts of human activity on Earth systems. This can include sorting out the relevant data from the given information (or choosing relevant inputs for a simulation).
- Using a simulator, test a prediction and evaluate the outcomes. This may include proposing modifications to the action to mitigate or the solution to the effect(s) of human activity on Earth systems.
- Evaluate and/or critique models, simulations, or predictions in terms of identifiable limitations and whether they yield realistic results.

High School Life Science

HS-LS-1.1 Students who demonstrate understanding can:

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.

Dimensions:

- **SEP:** *Constructing Explanation and Designing Solutions:* Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- **DCI:** *From Molecules to Organisms: Structure and Processes*
    - 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 DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.
- **CCC:** *Structure and Function:* Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and the connections of these components in order to solve problems.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on the structure of the double helix, the pairing and sequencing of the nitrogenous bases, transcription, translation, and protein synthesis.

Content Limits: Students do not need to know:

- 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.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - nucleus
  - chromosome
  - DNA
  - nucleated cell
  - transcription
  - double helix
  - adenine
  - guanine
  - cytosine
  - thymine
  - deoxyribose
  - phosphate
  - hydrogen bond
  - nucleotide base
  - mRNA
  - amino acid
  - translation
- Vocabulary that should not be used in assessment items:
  - primary
  - secondary
  - tertiary protein structure
  - tRNA
  - ribosome

Phenomena

- Sweat glands cool the body by releasing sweat onto the skin's surface. A protein transports salt to help carry the water to the skin's surface. In some individuals, the salt is not reabsorbed and is left on the skin.
- When a blood vessel is cut, several proteins act to form a blood clot. This blood clot helps to stop the loss of blood from the body. In some individuals, when a blood vessel is cut, a blood clot does not form.
- During cell division, a copy of DNA in the cell is made. Sometimes mistakes are made in the DNA copy that are corrected by specific proteins. In some cells, when those mistakes in the DNA are not corrected, uncontrolled cellular division results.
- After a person eats, sugars from food are absorbed from the bloodstream into the body's cells. Insulin—a polypeptide hormone—allows those cells to absorb glucose from the bloodstream. In some individuals, sugars are not absorbed into the body's cells and are left in the bloodstream.

Task Demands

- Identify from a list, including distractors, the materials/tools needed for an investigation to find the smallest unit of life (cell).
- Identify the outcome data that should be collected in an investigation of the smallest unit of living things.
- Evaluate the sufficiency and limitations of data collected to explain that the smallest unit of living things is the cell.
- Make and/or record observations about whether the sample contains cells or not.
- Interpret and/or communicate data from the investigation to determine if a specimen is alive or not.
- Construct a statement to describe the overall trend suggested by the observed data.

HS-LS-1.2 Students who demonstrate understanding can:
Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

Dimensions:

- **SEP:** *Developing and Using Models:* Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.
- **DCI:** *From Molecules to Organisms: Structure and Processes*
    - 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.
- **CCC:** *Systems and System Models:* Models (e.g., physical, mathematical, and computer models) can be used to simulate systems and interactions — including energy, matter, and information flows — within and between systems at different scales.

Further Explanation and Content Limit:

Further Explanation:

- 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.
- Content Limits:
    - Assessment does not include interactions and functions at the molecular or chemical reaction level (e.g., hydrolysis, oxidation, reduction, etc.).

- Assessment does not include mutations in genes that could contribute to modified bodily functions.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - circulatory
    - respiratory
    - digestive
    - excretory
    - nervous
    - immune
    - integumentary
    - skeletal
    - muscle
    - reproductive
    - external stimuli
    - cell
    - tissue
    - organ
- Vocabulary that should not be used in assessment items:
    - synaptic transmission
    - neuron
    - neurotransmitter
    - biofeedback
    - hormonal signaling

Phenomena

- After a healthy person eats a large meal, both their blood pressure and heart rate increase.
- When a normal, adult male exercises, both his breathing rate and heart rate increase.
- The area around a person’s skin where a small scab has formed feels warm to the touch.
- Skin surface capillaries dilate when a person feels hot.

Task Demands

- Assemble or complete an illustration or flow chart that can represent how structures in two (or more) body systems interact to carry out normal, necessary bodily functions. This <u>does not</u> include labeling an existing diagram.
- Using the developed model, identify and describe the relationships between the structures and their coordinated functions in two (or more) body systems.

- Using the developed model, show that interacting systems have a hierarchical organization and provide specific functions within the body at those specific levels or organization.
- Make predictions about, or generate explanations for, how additions/substitutions/removal of certain components in the model can interrupt or change the relationships between those components and, thus, the bodily functions carried out by those structures in two (or more) body systems.
- Given models or diagrams of hierarchical organization of interacting systems, identify the components and the mechanism in each level of the hierarchy OR identify the properties of the components that allow those functions to occur.
- Identify missing components, relationships, or other limitations of the model.

HS-LS-1.3 Students who demonstrate understanding can:
Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

Dimensions:

- **SEP:** *Planning and Carrying out Investigations:* Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence. 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.
- **DCI:** *From Molecules to Organisms: Structure and Processes*
    - 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.
- **CCC:** *Stability and Change:* Feedback (negative or positive) can stabilize or destabilize a system.

Further Explanation and Content Limit:

Further Explanation:

- Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.

Content Limits:

- Assessment does not include the cellular processes involved in the feedback mechanism.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - equilibrium
  - steady state
  - stable state
  - balanced state
  - stimulus
  - receptor
  - biotic factor
  - abiotic factor
  - external environment
  - internal environment
  - muscle
  - nerve
  - hormone
  - enzyme
  - chemical regulator
  - gland
  - system
  - metabolism
  - disturbance
  - fluctuation
  - maintenance
  - concentration
  - hibernation
  - convection
  - conduction
  - radiation
  - evaporation
- Vocabulary that should not be used in assessment items:
  - effector
  - osmoregulation
  - conformer
  - set point
  - sensor
  - circadian rhythm
  - acclimatization
  - thermoregulation
  - endothermic
  - ectothermic

    - integumentary system
    - countercurrent exchange
    - bioenergetics
    - basal metabolic rate
    - standard metabolic rate
    - torpor
    - poikilotherm
    - homeotherm
    - countercurrent heat exchange

Phenomena

- Fruit ripeness (positive feedback loop):
    - In nature, a tree or bush will suddenly ripen all of its fruits or vegetables without any visible signal.
- Human blood sugar concentration (negative feedback loop):
    - The liver both stores and produces sugar in response to blood glucose concentration.
    - The pancreas releases either glucagon or insulin in response to blood glucose concentration.
- Sunning lizards (negative feedback loop):
    - Lizards sun on a warm rock to regulate body temperature.
- Thermoregulation in dolphins due to counter-current arrangement of veins around arteries (negative feedback loop):
    - The counter-current system minimizes the loss of heat incurred when blood travels to the different parts of dolphins' bodies.

Task Demands

- Identify the outcome data that should be collected in an investigation to provide evidence that feedback mechanisms maintain homeostasis. This could include measurements and/or identifications of changes in the external environment, the response of the living system, stabilization/destabilization of the system's internal conditions, and/or the number of systems for which data are collected.
- Make and/or record observations about the external factors affecting systems interacting to maintain homeostasis, responses of living systems to external conditions, and/or stabilization/destabilization of the systems' internal conditions.
- Identify or describe the relationships, interactions, and/or processes that contribute to and/or participate in the feedback mechanisms maintaining homeostasis that led to the observed data.
- Using the collected data, express or complete a causal chain explaining how the components of (a) mechanism(s) interact in response to a disturbance in equilibrium to maintain homeostasis. This may include indicating directions of causality in an

incomplete model such as a flow chart or diagram or completing cause and effect chains.
- Evaluate the sufficiency and limitations of data collected to explain the cause-and-effect mechanism(s) for maintaining homeostasis.

HS-LS-1.4 Students who demonstrate understanding can: **Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.**

Dimensions:

- **SEP:** *Developing and Using Models:* Use a model based on evidence to illustrate the relationships between systems or between components of a system.
- **DCI:** *From Molecules to Organisms: Structure and Processes*
    - 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.
- **CCC:** *Systems and System Models:* Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Further Explanation and Content Limit:

Further Explanation: N/A
Content Limit:

- Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.
- Students do not need to know the specific names of the stages of mitosis – Interphase, G1 phase, S phase, G2 phase, prophase, metaphase, anaphase, telophase, cytokinesis.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - nucleus
    - chromosome
    - sister chromatids
    - sperm cell
    - egg cell
    - fertilize
    - genome
    - gene

    - differential gene expression
    - cellular differentiation
    - cellular division
    - cytoplasm
    - daughter cell
    - parent cell
    - somatic cell
    - cell cycle
    - homologous
    - haploid
    - diploid
    - DNA
- Vocabulary that should not be used in assessment items:
    - spindle
    - metaphase plate
    - cleavage furrow
    - chromatin modification
    - transcription regulation initiation
    - enhancers
    - transcription factors
    - post-transcriptional regulation
    - noncoding RNAs
    - cytoplasmic determinants
    - inductive signals
    - chiasmata
    - kinetochore
    - microtubule

Phenomena

- Genomic sequencing of a parent cell and one of its daughter cells reveals that both have the same genetic makeup.
- At the end of an hour, approximately 30,000 skin cells were shed by a person, but a loss of mass was not noticeable.
- Ears and noses can be grown from stem cells in laboratory.
- Plant cells in a root tip longitudinal cross section are different sizes and shapes.

Task Demands

- Assemble or complete an illustration or flow chart that is capable of representing how a parent (somatic) cell is formed through fertilization, undergoes cellular division, forming daughter cells, and how those daughter cells contain all genetic material from the

parent cells but differentiate via gene expression necessary. This does **not** include labeling an existing diagram.
- Using the model, identify and describe the relationship between the amount and composition of the genetic material that daughter cells receive from parent cells.
- Using the model, show that in multicellular organisms, different cell types arise from differential gene expression, not because of dissimilar genetic material within the cell's nucleus.
- Use a model of cellular division and differentiation to explain/illustrates the relationships between components that allow multicellular organisms to grow and carry out specific and necessary functions.
- Given models or diagrams of cellular division and differentiation, show that cells form tissues and organs that have specific structures and interact to carry out specific and necessary functions.
- Identify missing components, relationships, or other limitations of the model.

HS-LS-1.5 Students who demonstrate understanding can:
Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

Dimensions:

- **SEP:** *Developing and Using Models:* Use a model based on evidence to illustrate the relationship between systems or between components of a system.
- **DCI:** *From Molecules to Organisms: Structure and Processes*
    - The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
- **CCC:** *Energy and Matter:* Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits: Assessment does not include specific biochemical steps or cell signaling pathways.

Science Vocabulary

- Vocabulary that may be used in assessment items:

    - organic
    - hydrocarbon
    - net transfer
    - chloroplast
    - chlorophyll
    - cytoplasm
    - mitochondria
    - vacuole
    - nucleus
    - protein
    - ATP
    - amino acid
    - autotroph(s)
    - heterotroph(s)
    - algae
- Vocabulary that should not be used in assessment items:
    - thylakoid
    - NADP(H/+)
    - Calvin cycle
    - carbon fixation
    - redox reactions
    - electron transport chain
    - oxidative phosphorylation
    - photoautotroph(s)
    - mesophyll
    - stomata
    - stroma
    - thylakoids
    - thylakoid membrane
    - light reactions
    - carotenoids
    - cytochrome complex
    - C3 pants, C4 plants

Phenomena

- A maple tree in Washington state survives in the winter after losing all of its leaves.
- The waters of the Laguna Grande lagoon in Puerto Rico give off a bluish-green glow at night when disturbed.
- On the sill of a stained-glass window, a soy plant behind the red glass panel grew taller than a soy plant behind the green glass panel.

- In a parking lot in the city of Bordeaux, France a tank filled with algae produces a green light.

Task Demands

- Assemble or complete, from a collection of potential model components and distractors, an illustration or flow chart that can represent the transformation of light energy into stored chemical energy.
- Use a model to identify and describe the relationships in terms of matter and/or energy between the reactants and the products of photosynthesis.
- Use a model to show the transfer of matter and flow of energy between an organism and its environment during photosynthesis.
- Make predictions about how additions/substitutions/removals of model components affect the transformation of light energy into stored chemical energy.
- Sort relevant from irrelevant information to support a model that demonstrates how sugar and oxygen are produced by carbon dioxide and water through the process of photosynthesis.
- Given models or diagrams of photosynthesis, identify the components and the mechanism in each scenario OR identify the properties of the components that allow photosynthesis to occur.
- Identify missing components, relationships, or other limitations of a model intended to show how photosynthesis transforms light energy into stored chemical energy.
- Describe changes of energy and matter that occur in a system due to photosynthesis.

HS-LS-1.6 Students who demonstrate understanding can:
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.

Dimensions:

- **SEP:** *Constructing Explanations and Designing Solutions:* Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- **DCI:** *From Molecules to Organisms: Structure and Processes*
    - Sugar molecules contain carbon, hydrogen, and oxygen. Their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used, for example, to form new cells.
    - As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

- **CCC:** *Energy and Matter:* Changes of energy and matter in a system can be described as energy and matter flowing into, out of, and within that system.

Further Explanation and Content Limit:

Further Explanation: Emphasis is on using evidence from models and simulations to support explanations.
Content Limits:

- Assessment does not include the details of the specific chemical reactions or identification of macromolecules.
- Students do not need to know specific biochemical pathways and processes. Specific enzymes, oxidation-reduction.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - hydrocarbon
    - carbohydrate
    - amino acid
    - nucleic acid
    - DNA
    - ATP
    - lipid
    - fatty acid
    - ingestion
    - rearrangement
    - stable
    - open system
- Vocabulary that should not be used in assessment items:
    - endothermic reaction
    - exothermic reaction
    - aerobic respiration
    - oxidation
    - reduction
    - oxidation-reduction reaction
    - glycolysis
    - citric acid cycle
    - electron transport chain

Phenomena

- Hagfish produce, and are covered in, a thick layer of protective slime.

- The black widow spider's silk is several times as strong as any other known spider silk, making it about as durable as Kevlar.
- The female silk moth, releases a pheromone that is sensed by the male's feather-like antennae, inducing his excited fluttering behavior.
- The bombardier beetle releases a boiling, noxious, pungent spray that can repel potential predators.

Task Demands

- Describe, identify, or select evidence supporting or contradicting a claim that sugar molecules containing organic elements (e.g., carbon, hydrogen, and oxygen) that are ingested by an organism are broken down and rearranged via chemical reactions to form proteins, lipids, and nucleic acids.
- Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses.
- Express or complete a description of the flow of energy and/or matter within and between living systems. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram or completing cause and effect chains.
- Articulate, describe, or select the relationships, interactions, reactions and/or processes to be explained. This may entail sorting relevant information from irrelevant information or features of the reactants and products.
- Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in the amount and types of organic molecules ingested and the amount and type of products formed within a living system.

HS-LS-1.7 Students who demonstrate understanding can:
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.

Dimensions:

- **SEP:** *Developing and Using Models:* Use a model based on evidence to illustrate the relationships between systems or between components of a system.
- **DCI:** *From Molecules to Organisms: Structure and Processes*
  - 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.

- **CCC:** *Energy and Matter:* Energy cannot be created or destroyed—it only moves between one place and another, between objects and/or fields, or between systems.

Further Explanation and Content Limit:

Further Explanation: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.

Content Limits:

- Students aren't expected to identify the steps or specific processes involved in cellular respiration.
- Assessment does not include mechanisms of cellular respiration (enzymatic activity, oxidation, molecular gradients, etc.).
- Students do not need to know enzymes, ATP synthase, metabolism, biochemical pathways, redox reactions, molecular transport.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - ATP
    - chemical bonds
    - energy transfer
    - glycolysis
    - enzymes
    - mitochondria
    - cytosol
    - cytoplasm
    - nitrogen
    - adenine
    - phosphate
    - amino acid
- Vocabulary that should not be used in assessment items:
    - biochemical
    - fatty acids
    - oxidizing agent
    - electron acceptor
    - biosynthesis
    - locomotion
    - phosphorylation
    - electron transport chain

- chemiosmosis
- pyruvate
- pentose

Phenomena

- A young plant is grown in a bowl of sugar water. As it grows, the amount of sugar in the water decreases.
- A bacterial colony in a petri dish is continually provided with sugar water. Over the course of a few days, the bacteria grow larger. When sugar water is no longer provided, the colonies shrink, and some disappear.
- A person feels tired and weak before eating lunch. After eating some fruit, the person feels more energetic and awake.
- An athlete completing difficult training feels that her muscles recover and repair faster when she eats more food in a day, compared to when she ate less food in a day.

Task Demands

- Assemble or complete an illustration or flow chart that can represent the transformation of food plus oxygen into energy and/or new compounds. This does not include labeling an existing diagram.
- Using the developed model, identify and describe the relationships between the reactants of the transformation and the products of the transformation.
- Using the developed model, show that matter and energy are only rearranged during cellular respiration, but never created or destroyed.
- Make predictions about how additions/substitutions/removals of certain components can maintain/destroy the balance of the food plus oxygen → energy/new compounds reaction.
- Given models or diagrams of cellular respiration, identify the components and the mechanism in each scenario OR identify the properties of the components that allow cellular respiration to occur.
- Identify missing components, relationships, or other limitations of the model.
- Describe, select, or identify the relationships among components of a model that describe or explain cellular respiration.

HS-LS-2.1 Students who demonstrate understanding can:
Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

Dimensions:

- **SEP:** *Using Mathematical and Computational Thinking:* Use mathematical and/or computational representations of phenomena or design solutions to support explanations.
- **DCI:** *Ecosystems: Interactions, Energy, and Dynamics:* 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 challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of greater 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.
- **CCC:** *Scale, Proportion, and Quantity:* The significance of a phenomenon is dependent on the scale, proportion, and quantity involved.

Further Explanation and Content Limit:

Further Explanation:

- 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.
- Examples of mathematical representations include finding the average, determining trends, and using graphic comparisons of multiple sets of data.

Content Limits:

- Assessment does not include deriving mathematical equations to make comparisons.
- Students do not need to know calculus/advanced mathematics (e.g., exponential growth and decay).

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - predation
    - interdependent
    - disturbance
    - equilibrium of ecosystems
    - fluctuation
    - stable
    - biotic
    - abiotic
    - sustain
    - anthropogenic
    - overexploitation
    - urbanization

- population
- emigrants
- immigrants
- exponential
- generation
- rebounding
- limiting resources
- logistic
- competition
- negative feedback
- population control

- Vocabulary that should not be used in assessment items:
    - dispersion
    - demography
    - survivorship curve (J or S)
    - reproductive table
    - semelparity
    - iteroparity
    - metapopulation
    - demographic transition
    - resource partitioning
    - Shannon-Wiener diversity
    - biomanipulation
    - density dependent selection (K-selection)
    - density independent selection (r-selection)
    - intrinsic factors

Phenomena

- On Ngorongoro Crater in Tanzania in 1963, a scientist sees that there are much fewer lions than there were on previous visits.
- On St. Matthew Island, reindeer were introduced in 1944, but today no reindeer can be found on the island.
- In Washington State, more harbor seals are present today than in the past.
- In Alaska, you can see many more brown bears in Lake Clark National Park than in Denali National Park.

Task Demands

- Make calculations using given data to calculate or estimate factors affecting the carrying capacity of an ecosystem.
- Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate factors affecting the carrying capacity of ecosystems of different scales.

- Calculate or estimate properties of or relationships between factors affecting the carrying capacity of an ecosystem based on data from one or more sources.
- Compile, from given information, the data needed for a particular inference about factors affecting the carrying capacity of an ecosystem. This can include sorting out the relevant data from the given information and representing the data through graphs, charts, and/or histograms.
- Use quantitative or abstract reasoning to make a claim about the factors that affect the carrying capacity of an ecosystem.

HS-LS-2.2 Students who demonstrate understanding can:

Use mathematical representations to support explanations that biotic and abiotic factors affect biodiversity at different scales within an ecosystem.

Dimensions:

- **SEP:** *Using Mathematics and Computational Thinking:* Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena.
- **DCI:** *Ecosystems: Interactions, Energy, and Dynamics:*
    - Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits results from factors such 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 greater 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.
    - 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 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.
- **CCC:** *Scale, Proportion, and Quantity:* Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

Further Explanation and Content Limit:

Further Explanation:

- Examples of mathematical representations include finding the average, determining trends, and using graphic comparisons of multiple sets of data.

Content Limits:

- Assessment is limited to provided data.

- Students do not need to know calculus/advanced mathematics (e.g., exponential growth and decay).

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - carrying capacity
    - anthropogenic changes
    - overexploitation
    - extinction
    - demographic
    - population pyramid
    - deforestation
    - habitat fragmentation
    - sustainable
    - abiotic factor
    - biotic factor
    - species richness
    - symbiosis
    - niche
    - fragile ecosystem
    - biodiversity index
    - zero population growth
    - density
    - dispersion
    - immigration
    - emigration
    - limiting factor
- Vocabulary that should not be used in assessment items:
    - water regime
    - direct driver
    - eutrophication
    - species evenness
    - range of tolerance
    - realized niche
    - niche generalist
    - niche specialist
    - edge habitat
    - endemic species
    - logistic growth model
    - exponential population growth
    - mark-recapture method

- territoriality
- demography
- cohort
- survivorship curve
- reproductive table
- life history
- iteroparity
- K-selection
- r-selection
- dieback

Phenomena

- After brown tree snakes were accidentally introduced to Guam in the 1950s, 11 native bird species went extinct.
- When European settlers decreased the wolf population for safety, deer populations thrived and overconsumed native plant species.
- California’s Central Valley can support fewer waterfowl in the winter during drought.
- The cones of Lodgepole pines do not release their seeds until a fire melts the resin that keeps them sealed.

Task Demands

- Make simple calculations using given data to calculate or estimate factors affecting biodiversity and populations in ecosystems.
- Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate factors affecting biodiversity and populations in ecosystems of different scales.
- Calculate or estimate properties of or relationships between factors affecting biodiversity and populations in ecosystems based on data from one or more sources.
- Compile, from given information, the data needed for a particular inference about factors affecting biodiversity and populations in ecosystems. This can include sorting out the relevant data from the information.
- Construct an explanation regarding the relationship between biodiversity and populations in ecosystems of different scales using the given, calculated, or compiled information.
- Revise or evaluate a given explanation of the relationship between biodiversity and populations in ecosystems of different scales based on the given, calculated, or compiled information.

HS-LS-2.3 Students who demonstrate understanding can:
Construct an explanation using mathematical representations to support claims for the flow of energy through the trophic levels and the cycling of matter in an ecosystem.

Dimensions:

- **SEP:** *Constructing Explanations and Designing Solutions:* Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, 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.
- **DCI:** *Ecosystems: Interactions, Energy, and Dynamics:* Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for the processes.
- **CCC:** *Energy and Matter:* Energy drives the cycling of matter within and between systems.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.
- Emphasis is on conceptual understanding that the supply of energy and matter restricts a system's operation; for example, without inputs of energy (sunlight) and matter (carbon dioxide and water), a plant cannot grow.

Content Limits:

- Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.
- Students do not need to know lactic acid vs. alcoholic fermentation, chemical equations for photosynthesis, cellular respiration, or fermentation.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - organic compound synthesis
  - net transfer
  - biomass
  - carbon cycle
  - solar energy
- Vocabulary that should not be used in assessment items:
  - lactic acid fermentation
  - alcoholic fermentation
  - glycolysis
  - Krebs cycle
  - electron transport chain

Phenomena

- After running for a long period of time, human muscles develop soreness and a burning sensation, and breathing rate increases.
- Bread baked with yeast looks and tastes differently than bread that is baked without yeast.
- A plant that is watered too much will have soft, brown patches on their leaves and will fail to grow.
- Cyanobacteria differ from other bacteria in that cyanobacteria appear blue green in color and also lack flagella.

Task Demands

- Describe, identify, or select evidence supporting or contradicting a claim about the role of photosynthesis and aerobic and anaerobic respiration in the cycling of matter and energy in an ecosystem.
- Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses.
- Express or complete a description of the flow of energy and/or matter between organisms. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause-and-effect chains.
- Articulate, describe, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features of the reactants and products.
- Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in environmental conditions on the flow of matter and energy between organisms.

HS-LS-2.4 Students who demonstrate understanding can:

Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

Dimensions:

- **SEP:** *Developing and Using Models:* Develop a model to describe phenomena.
- **DCI:** *Ecosystems: Interactions, Energy, and Dynamics:* Plants or algae from 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.

- **CCC:** *Energy and Matter:* 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.

Content Limits:

- Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.
- Students do not need to know the specific biochemical mechanisms or thermodynamics of cellular respiration to produce ATP or of photosynthesis to convert sunlight energy into glucose.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - interdependent
    - nutrient
    - hydrocarbon
    - transfer system
    - equilibrium of ecosystems
    - decomposer
    - producer
    - ATP
    - solar energy
    - predator-prey relationship
    - trophic level
- Vocabulary that should not be used in assessment items:
    - detritivore
    - denitrification
    - thermodynamics
    - nitrogen fixation
    - biogeochemical cycle
    - anaerobic process

Phenomena

- In the 6,000-hectare rainforest of San Lorenzo, Panama, there are 312 arthropods for every mammal, including humans.
- In Silver Springs, Florida, the biomass of plants is 809 g/m2, while the biomass of large fish is 5 g/m2.
- A herd of grazing caribou in the Seward Peninsula of Alaska are seen eating the leaves of birch trees in July. In December, they are seen eating tree lichen.
- A pine tree growing in a forest remains in one location throughout its lifetime. A fox in the same forest moves around every day of its life.

Task Demands

- Calculate or estimate changes or differences in matter and energy between trophic levels of an ecosystem.
- Illustrate, graph, or identify a mathematical model describing changes in stored energy through trophic levels of an ecosystem.
- Compile and interpret data from given information to establish the relationship between organisms at different trophic levels.
- Use quantitative or abstract reasoning to make a claim about the cycling of matter and flow of energy through the trophic levels of an ecosystem. This may include sorting relevant from irrelevant information.
- Identify and describe the components of a mathematical representation of an ecosystem that could include relative quantities related to organisms, matter, energy, and the food web of that ecosystem.

HS-LS-2.5 Students who demonstrate understanding can:
Evaluate the claims, evidence, and reasoning that changing the conditions of a static ecosystem may result in a new ecosystem.

Dimensions:

- **SEP:** *Engaging in Argument from Evidence:* Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- **DCI:** *Ecosystems: Interactions, Energy, and Dynamics:* 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.
- **CCC:** *Stability and Change:* Small changes in one part of a system might cause large changes in another part.

Further Explanation and Content Limit:

Further Explanation:

- 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.
- To show full comprehension of the PE, the student must demonstrate an understanding that, in a stable ecosystem, the average activity by the nutrients, decomposers, producers, primary consumers, secondary consumers, and tertiary consumers remains relatively consistent. When each of these levels has high levels of diversity, the ecosystem is stable because the group as a whole is better able to respond to pressures. However, even a healthy, diverse ecosystem is subject to extreme changes when faced with enough pressure.

Content Limits:

- Assessment does not include Hardy-Weinberg equilibrium calculations.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - biosphere
    - biodiversity
    - carbon cycle
    - water cycle
    - nitrogen cycle
    - fluctuation
    - consistent
    - stable
    - equilibrium
    - species
    - emergence
    - extinction
    - niche
    - native
    - non-native
    - invasive
    - overgrazing
    - human impact
    - succession
    - primary succession
    - secondary succession
- Vocabulary that should not be used in assessment items:
    - genetic drift

    - founder effect
    - Hardy-Weinberg
    - intermediate disturbance hypothesis
    - species-area curve text

Phenomena

- The populations of rabbits and deer in the Florida Everglades significantly decreased with the introduction of the Burmese python.
- The biodiversity of an area of the Amazon rainforest is affected differently in sustainable and non-sustainable lumber farms.
- After a fire, the biodiversity of a forest immediately decreases but eventually increases.
- An increase in mouse populations is observed the year after a flood but return to pre-flood numbers the following year.

Task Demands

- Based on the provided data or information, identify the explanation that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- Identify and/or explain the claims, evidence, and reasoning supporting the explanation that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- Identify and/or describe additional relevant evidence not provided that would support or clarify the explanation of the complex interactions in ecosystems, factors that affect biodiversity, relationships between species and the environment, and changes in numbers of species and organisms in a stable or changing ecosystem.
- Evaluate the strengths and weaknesses of a claim to explain the relationship of biodiversity and the environment in an ecosystem based on the evidence or data provided.
- Analyze and/or interpret evidence and its ability to support the explanation of the resiliency of an ecosystem in response to different levels of change.
- Provide and/or evaluate reasoning to support the explanation that an ecosystem remains relatively consistent when faced with modest disturbances, but it may experience extreme changes or fluctuations in biodiversity when faced with extreme disturbances.

HS-LS-2.6 Students who demonstrate understanding can:
Design, evaluate, and/or refine practices used to manage a natural resource based on direct and indirect influences of human activities on biodiversity and ecosystem health.

Dimensions:

- **SEP:** *Constructing Explanations and Designing Solutions:* 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.
- **DCI:** *Ecosystems: Interactions, Energy, and Dynamics:* 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.
- **CCC:** *Stability and Change:* Small changes in one part of a system might cause large changes in another part.

Further Explanation and Content Limit:

Further Explanation:

- Examples of human activities can include urbanization, building dams, and dissemination of invasive species, utilization of non-renewable resources as opposed to a renewable resource.

- Examples of design solution constraints could include scientific, economic, and social considerations.

Content Limits:

- Assessment does not include physical equations describing mechanics of solutions or mechanics of engineered structures.
- Students do not need to know quantitative statistical analysis, specific conditions required for failure, specifics of constructing the solution.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - carrying capacity
    - ecosystems
    - climate
    - competition
    - population
    - biodiversity
    - atoms
    - molecules
    - compounds
    - carbon
    - oxygen
    - hydrogen
    - nitrogen
    - conservation of energy
    - conservation of matter

    - photosynthesis
    - biosphere
    - atmosphere
    - hydrosphere
    - geosphere
    - seasonal changes
    - urbanization
    - conservation biology
    - endangered species
    - exotic/nonnative species
    - invasive species
    - threatened species
    - species
    - introduced species
    - overharvesting
    - extinction
    - carbon dioxide
    - greenhouse effect
    - climate
    - carbon footprint
- Vocabulary that should not be used in assessment items:
    - biomass
    - trophic level
    - laws of thermodynamics
    - Hardy-Weinberg equilibrium
    - Lotka-Volterra equations
    - allelopathy
    - density-dependent population regulation
    - extinction vortex
    - minimum viable population (MVP)
    - effective population size
    - movement corridor
    - biodiversity hot spot
    - zoned reserve
    - critical load
    - biological magnification
    - assisted migration
    - sustainable development

Phenomena

- The spread of cities through urbanization has destroyed wildlife habitats across the planet.
- Air pollution from driving cars has made the air unsafe to breathe in many areas.
- Fishing has drastically changed marine ecosystems, removing certain predators or certain prey.

Task Demands

- Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
- Express or complete a causal chain explaining how human activity impacts the environment. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram or completing cause-and-effect chains.
- Use an explanation to predict the environmental outcome, given a change in the design of human technology.
- Identify or describe relevant aspects of the problem that given design solutions for reducing the impacts of human activities on the environment and biodiversity, if implemented, will resolve, or improve.
- Using given information about the effects of human activities on the environment and biodiversity, select or identify criteria against which the solution should be judged.
- Using given information about the effects of human activities on the environment and biodiversity, select or identify constraints that the solution must meet.
- Evaluate the criteria and constraints, along with trade-offs, for a proposed or given solution to resolve or improve the impact of human activities on the environment and biodiversity.
- Using given data, propose a potential solution to resolve or improve the impact of human activities on the environment and biodiversity.
- Using a simulator, test a proposed solution to resolve or improve the impact of human activities on the environment and biodiversity and evaluate the outcomes.
- Evaluate and/or revise a solution to resolve or improve the impact of human activities on the environment and biodiversity and evaluate the outcomes.

HS-LS-2.7 Students who demonstrate understanding can:
Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.

Dimensions:

- **SEP:** *Engaging in Argument from Evidence:* Evaluate the evidence behind currently accepted explanations to determine the merits of arguments.

- **DCI:** *Ecosystems: Interactions, Energy, and Dynamics:* Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.
- **CCC:** *Cause and Effect:* Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits:

- Students do not need to know:
    - How to develop or analyze computer simulations and mathematical models that emulate the flocking behavior of animals.
    - Individual genes or complex gene interactions determining individual animal behavior.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - behavioral ecology
    - cooperative behavior
    - altruism
    - environmental stimuli
    - circadian clock
    - communication
    - foraging
    - optimal foraging model
    - energy costs and benefits
    - competition
    - predator
    - mutual protection
    - packs
- Vocabulary that should not be used in assessment items:
    - fixed action pattern
    - pheromones
    - innate behavior

- learning
- imprinting
- spatial learning
- social learning
- associative learning
- problem solving
- cognition
- game theory
- agonistic behavior
- mating behavior
- mating systems
- parental care
- mate choice
- male competition for mates
- reciprocal altruism
- shoaling

Phenomena

- Several hundred naked mole rats are observed living together in a colony. However, only one large naked mole rat is observed reproducing, while the others in the colony bring her food.
- A worker bee is observed flying away from its colony. Upon returning many other worker bees crowd around him while he moves in a distinct pattern.
- A lioness charges toward a large herd of galloping zebra, but then stops and runs away in the opposite direction.
- A certain species of short-horned grasshoppers changes color, band together, and fly over several square kilometers over a period of a few weeks.

Task Demands

- Based on the provided data, identify, describe, or construct a claim regarding how specific group behavior(s) can increase an individual's or species' chances of surviving and reproducing.
- Sort inferences about the effect of specific group behaviors on an individual's and species' chances to survive and reproduce into those that are supported by the data, contradicted by the data, outliers in the data, or neither, or some similar classification.
- Identify patterns of information/evidence in the data that support correlative/causative inferences about the effect of specific group behaviors on an individual's and species' chances to survive and reproduce.
- Construct an argument using scientific reasoning, drawing on credible evidence to explain the effect of specific group behaviors on an individual's and species' chances to survive and reproduce.

- Identify additional evidence that would help clarify, support, or contradict a claim or causal argument regarding the effect of specific group behaviors on an individual's and species' chances to survive and reproduce.
- Identify, summarize, or organize given data or other information to support or refute a claim regarding the effect of specific group behaviors on an individual's and species' chances to survive and reproduce.
- Evaluate and/or revise a solution to resolve or improve the impact of human activities on the environment and biodiversity and evaluate the outcomes.

HS-LS-3.1 Students who demonstrate understanding can:
Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

Dimensions:

- **SEP:** *Asking Questions and Defining Problems:* Ask questions that arise from examining models or a theory to clarify relationships.
- **DCI:** *Heredity: Inheritance and Variation of Traits:*
    - All cells contain genetic information in the form of DNA molecules. Genes are regions in DNA that contain the instructions that code for the formation of proteins. *(secondary)*.
    - 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.
- **CCC:** *Cause and Effect:* Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects.

Further Explanation and Content Limit:

Further Explanation:

- At this level, the study of inheritance is restricted to Mendelian genetics, including dominance, codominance, incomplete dominance, and sex-linked traits.
- Focus is on expression of traits on the organism level and should not be restricted to protein production.

Content Limits:

- Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.

- Assessment does not include mutations or species-level genetic variation including Hardy-Weinberg equilibrium.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - genome
  - zygote
  - fertilization
  - dominant
  - recessive
  - codominance
  - incomplete dominance
  - sex-linked
  - allele
  - sequencing
  - pedigree
  - parent generation
  - F1
  - F2
  - haploid
  - diploid
  - replication
- Vocabulary that should not be used in assessment items:
  - interphase
  - prophase
  - metaphase
  - anaphase
  - telophase
  - cytokinesis
  - epistasis

Phenomena

- DNA sequencing shows that all people have the gene for lactase production, but only about 30% of adults can digest milk.
- Polydactyl tabby cat Jake holds the world record for most toes, with seven toes on each paw.
- *E. coli* bacteria are healthful in mammalian intestines but makes mammals sick when ingested.
- *E. coli* bacteria are used to produce human insulin.

Task Demands

- Identify or construct an empirically testable question based on the phenomenon that could lead to design of an experiment or model to define the relationships between the role of DNA and/or chromosomes in the inheritance of traits.
- Assemble or complete, from a collection of potential model components, an illustration, or pedigree that can represent the role of genetic material in coding the instructions for inheritance.
- Construct a question that arises from examining a model or theory to clarify the connections between DNA/chromosomes and inheritance of traits.
- Make predictions about the pattern of inheritance based on a model derived from the empirically testable question. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
- Assemble or complete a flow chart describing the cause-and-effect relationships between genetic material and the characteristic traits passed from parents to offspring.

HS-LS-3.2 Students who demonstrate understanding can:
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.

Dimensions:

- **SEP:** *Engaging in Argument from Evidence:* Make and defend a claim based on evidence about the natural world that reflects scientific knowledge and student-generated knowledge.
- **DCI:** *Heredity: Inheritance and 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, they 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.
- **CCC:** *Cause and Effect:* Empirical evidence is required to differentiate between cause and correlation, and to make claims about specific causes and effects.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on using data to support arguments for the way variation occurs.

- Inheritable traits should be traits that can be passed down through more than one generation.
- Inheritable traits for this standard do not include dominant/recessive traits.
- Examples of evidence for new genetic combinations and viable errors can include:
    - karyotype comparison between parents and children.
    - DNA sequence comparison.

Content Limits:

- Assessment does not include assessing meiosis or the biochemical mechanism of specific steps in the process.
- Students do not need to know bioinformatics, specific genetic disorders.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - amino acid
    - DNA
    - enzyme
    - protein synthesis
    - chromosome
    - egg
    - egg cell
    - sperm
    - sperm cell
    - dominant trait
    - recessive trait
    - recombination
    - sex cell
    - sex chromosome
    - sex-linked trait
    - meiosis
    - mutation
    - advantageous
    - expression
    - base pairs
    - genome
    - UV radiation
    - triplet codon
    - insertion
    - deletion
    - frameshift
    - substitution

    - somatic
    - epigenetic
- Vocabulary that should not be used in assessment items:
    - polyploidy
    - single nucleotide polymorphisms (SNPs)
    - conjugation
    - DNA polymerase
    - mutagenic
    - chromosomal translocation
    - missense
    - nonsense
    - nongenic region
    - tautomerism
    - depurination
    - deamination
    - slipped-strand mispairing
    - Sheik disorder
    - prion
    - epidemiology

Phenomena

- Due to pesticide residue, frogs have extra, non-functioning, limbs.
- Most chickens have feathers that lay flat against their bodies. In one family of chickens, 50% of offspring have feathers that curl away from their bodies.
- A single gene mutation accounts for the blue color of irises in over 99.5% of people with blue eyes.
- One sunflower growing in a field has a wide, flat stem and an unusual number of leaves. The next year, several sunflowers in the field share these traits.

Task Demands

- Based on the provided data, make or construct a claim regarding inheritable genetic variations that may result from: 1) new genetic combinations through meiosis, 2) viable errors occurring during replication, and/or 3) mutations caused by environmental factors. This *does not* include selecting a claim from a list.
- Sort inferences about inheritable genetic variation into those that are supported by the data, contradicted by the data, outliers in the data, or none of these—or some similar classification.
- Identify patterns of information/evidence in the data that support correlative/causative inferences about inheritable genetic variation.
- Construct an argument using scientific reasoning that draws on credible evidence to explain how 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.
- Identify additional evidence that would help clarify, support, or contradict a claim or causal argument.
- Identify, describe, and/or construct alternate explanations or claims, and cite the data needed to distinguish among them.
- Predict outcomes of genetic variations, given the cause-and-effect relationships of inheritance.

HS-LS-3.3 Students who demonstrate understanding can:
Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

Dimensions:

- **SEP:** *Analyzing and Interpreting 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.
- **DCI:** *Heredity: Inheritance and Variation of Traits:*
    - Environmental factors also affect expression of traits, and, hence, they 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.
- **CCC:** *Scale, Proportion, and Quantity:* Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Further Explanation and Content Limit:

Further Explanation:

- 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.
- Sensitivity and precaution should be used around the use of both lethal recessive and dominant human traits (i.e., Huntington’s, achondroplasia, Tay-Sachs, cystic fibrosis).

Content Limits:

- Assessment is limited to basic statistical and graphical analysis.
- Assessment does not include Hardy-Weinberg calculations ($p^2 + 2pq + q^2 = 1$ or $p + q = 1$).
- Students do not need to know pleiotropy, meiosis, specific names of genetic disorders.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - gene

- allele
- dominant
- recessive
- homozygous
- heterozygous
- phenotype
- genotype
- P generation
- F1 generation
- F2 generation
- complete dominance
- incomplete dominance
- codominance
- pedigree
- carrier
- fertilization
- sex linked traits
- gamete
- Mendelian genetics
- zygote
- haploid
- diploid
- epistasis

- Vocabulary that should not be used in assessment items:
    - test-cross
    - monohybrid
    - dihybrid
    - law of independent assortment
    - law of segregation
    - pleiotropy
    - norm of reaction
    - multifactorial
    - Barr Body
    - genetic recombination
    - latent allele

Phenomena

- O Positive is the most common blood type. Not all ethnic groups have the same mix of these blood types. Hispanic people, for example, have a relatively high number of O's, while Asian people have a relatively high number of B's.

- Hydrangea flowers of the same genetic variety range in color from blue violet to pink, with the shade and intensity of color depending on the acidity and aluminum content of the soil.
- Most humans were born with five fingers on each hand, yet the polydactyl trait (having more than five fingers on each hand) is the dominant trait.
- When a red rose is crossed with a white rose, all pink roses are produced.

Task Demands

- Describe data or patterns/relationships in given data that support (or refute) an explanation for the change in trait frequency or magnitude in a population, due to both genetic and environmental factors.
- Make predictions about the trait frequency or distribution in a population due to the presence/absence or addition/removal of both genetic and environmental factors.
- Organize and/or arrange (e.g., using illustrations and/or labels) data, or summarize data to provide evidence for an explanation of the relationship between a trait's occurrence in a population and genetic and environmental factors.
- Analyze, evaluate, estimate, calculate, and/or construct an equation for the statistical mean and/or the standard deviation, to describe the change in the distribution of a trait in a population over time, due to genetic and environmental factors.
- Identify statistical anomalies or outliers for a trait or a population that are outside the expected range (norm reaction), which may or may not be quickly removed due to genetic and environmental factors.

HS-LS-4.1 Students who demonstrate understanding can:
Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

Dimensions:

- **SEP:** *Obtaining, Evaluating, and Communicating Information:* Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).
- **DCI:** *Biological Adaptation: Unity 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.
- **CCC:** *Patterns:* Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits:

- Students do not need to know specific genetic mutations, specific genetic disorders, specific proteins, Occam's razor (maximum parsimony), formation of orthologous and paralogous genes, molecular clock, Neutral theory.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - amino acids
  - cladogram
  - comparative anatomy
  - DNA sequencing
  - electrophoresis
  - embryology
  - evolution
  - fossil record
  - gene flow
  - genetic drift
  - mutation
  - natural selection
  - nucleotides
  - sedimentary layers
  - species
  - descent with modification
  - homologous structures
  - evolutionary tree
  - analogous structures
- Vocabulary that should not be used in assessment items:
  - phylogenetic
  - phylogeny
  - phylogenetic tree
  - taxonomy
  - cladistics
  - vestigial structures
  - convergent evolution

- analogous
- endemic
- PhyloCode
- sister taxa
- basal taxon
- polytomy
- homoplasy
- molecular systematics
- monophyletic
- parphyletic
- polyphyletic
- maximum parsimony
- orthologous genes
- paralogous genes
- horizontal gene transfer

Phenomena

- Red pandas look a bit like bears and a bit like raccoons. Task Statement: Provide evidence about whether red pandas are better classified as raccoons or bears. Stimulus material might include pictures, DNA information, embryological information, and homologous structures.
- Hermit crabs live in shells, like oysters, but look like crabs. Provide evidence classifying hermit crabs either as mollusks (like oysters) or arachnids (like crabs).
- Crawfish look just like lobster, but smaller. Which came first, the lobster or the crawfish?
- Fossil records of an extinct hooved animal show a thickened knob of bone in its middle ear. This structure is also found in modern whales and helps them hear underwater.

Task Demands

- Analyze and interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols, mathematical representations that support common ancestry among organisms and/or biological evolution.
- Evaluate the validity/relevance/reliability of scientific evidence about biological evolution.
- Identify relationships or patterns in scientific evidence at macroscopic and/or microscopic scales.
- Describe the specific evidence needed to support an explanation about how organisms share a common ancestor.
- Synthesize an explanation that incorporates the scientific evidence from multiple sources.

HS-LS-4.2 Students who demonstrate understanding can:

Construct an explanation based on evidence that the process of evolution, through the mechanism of natural selection, 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.

Dimensions:

- **SEP:** *Constructing Explanations and Designing Solutions:* Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, 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.
- **DCI:** *Biological Adaptation: Unity and Diversity:*
    - Natural selection occurs only if there is both 1) variation in the genetic information between organisms in a population and 2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals.
    - Evolution is a consequence of the interaction of four factors: 1) the potential for a species to increase in number, 2) the genetic variation of individuals in a species due to mutation and sexual reproduction, 3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and 4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.
- **CCC:** *Cause and Effect:* Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on using evidence to explain the influence each of the four factors has on the 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.

Content Limits:

- Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.
- Students do not need to know: Hardy-Weinberg equation.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - beneficial change
    - detrimental change
    - distribution
    - emergence
    - gene frequency
    - biotic
    - abiotic
    - advantageous
    - diverge
    - proliferation
    - bottleneck effect
    - island effect
    - geographic isolation
    - founder effect
    - recombination
- Vocabulary that should not be used in assessment items:
    - Hardy-Weinberg equilibrium
    - biotechnology
    - relative fitness
    - directional selection
    - disruptive selection
    - stabilizing selection
    - heterozygote advantage
    - frequency-dependent selection
    - prezygotic barriers
    - postzygotic barriers

Phenomena

- Cane toads introduced to Australia in the 1930s have evolved to be bigger, more active, and have longer legs.
- In the late 1990s, a resurgence of bedbug outbreaks began. Bedbugs are now much harder to kill with thick, waxy exoskeletons, faster metabolism, and mutations to block certain insecticides.
- Skinks living in cooler regions give live birth, while those living in warm coastal areas lay eggs.
- A butterfly parasite found on the Samoan Islands destroyed the male embryos of blue moon butterflies, decreasing the male population to only 1%. After a year, males had rebounded to 40% of the population.

Task Demands

- Describe the cause-and-effect relationship between: (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 and change in species over time. This may include indicating directions of causality in a model or completing cause-and-effect chains.
- Describe, identify, or select evidence supporting or contradicting a claim about the role of (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment in causing the phenomenon. The evidence may be evidence generated by the students in the simulation or selected from provided data.
- Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in environmental conditions on the population.
- Use evidence to construct an explanation of the changes in species over time because of (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
- Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses for the changes in species over time.

HS-LS-4.3 Students who demonstrate understanding can:

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.

Dimensions:

- **SEP:** *Analyzing and Interpreting 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.
- **DCI:** *Biological Adaptation: Unity and Diversity:*
    - Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation —that leads to differences in performance among individuals.
    - The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.

- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. The differential survival and reproduction of organisms in a population that have an advantageous heritable trait lead 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.
- **CCC:** *Patterns:* Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.

Content Limits:

- Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.
- Students do not need to know sexual selection, kin selection, artificial selection, frequency-dependent selection.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - fitness
    - gene
    - allele
    - directional selection
    - diversifying (disruptive) selection
    - stabilizing selection
    - standard deviation
    - vestigial structure
- Vocabulary that should not be used in assessment items:
    - hemizygous
    - aneuploidy
    - intragenomic conflict
    - sexual dimorphism
    - balanced polymorphism
    - apostatic selection

Phenomena

- Green Treefrogs (*Hyla versicolor*) are abundant in the wetlands of Florida where no Gray Treefrogs (*Hyla cinerea*) are observed. In the wooded areas of New York, only Gray Treefrogs are observed.
- In the Amazon rainforest, a kapok tree (*Ceiba pentandra*) measures 200 feet in height, approximately 30 feet above the rest of the canopy.
- A school of mummichog fish (*Fundulus heteroclitus*) is found in the 6°C waters of Chesapeake Bay. These fish are normally found in warmer climates, like the 21°C waters of Kings Bay, Georgia.
- A population of the fish *Poecilia mexicana* lives in the murky hydrogen-sulfide (H2S)-rich waters in southern Mexico that would kill the same species of fish living in clear freshwaters only 10 km away.

Task Demands

- Describe or identify patterns or relationships in given data that support (or refute) an explanation for the change in trait frequency or magnitude in a population due to natural selection/selection pressure(s).
- Make predictions about the trait frequency or distribution in a population due to the presence/absence or addition/removal of selection pressure(s) in the environment (including Hardy-Weinberg-based predictions about changes in allele/trait frequency/magnitude NOT based on calculations).
- Organize and/or arrange (e.g., using illustrations and/or labels) data, or summarize data to provide evidence for an explanation of the effect of selection on a population.
- Analyze, evaluate, estimate, calculate, and/or construct an equation to describe the change in the distribution of a trait in a population over time due to selection pressure(s).
- Identify statistical anomalies or outliers for a trait or a population that are outside the expected range (for example, Joe DiMaggio's hitting streak, tossing 10 consecutive heads on a fair coin, etc.) which may or may not be quickly removed due to selection pressure.
- Use statistical analysis to calculate changes in traits in a population over time to provide evidence for an explanation of the relationship between a trait's occurrence and its prevalence in the population at different points in time.
- Identify explanations for a change in a trait's frequency and/or distribution in a population over time that can be supported by patterns or relationships in data.

MS-LS-4.4 Students who demonstrate understanding can:
Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

Dimensions:

- **SEP:** *Constructing Explanations and Designing Solutions:* Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- **DCI:** *Biological Adaptation: Unity and Diversity:* 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. The differential survival and reproduction of organisms in a population that has 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.
- **CCC:** *Cause and Effect:* Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits:

- Assessment does not include the Hardy-Weinberg equation.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - beneficial change
    - detrimental change
    - distribution
    - emergence
    - gene frequency
    - gene
    - biotic
    - abiotic
    - advantageous
    - diverge
    - proliferation
    - sexual reproduction
    - bottleneck effect

- island effect
    - geographic isolation
    - gene flow
    - genetic drift
    - founder effect
- Vocabulary that should not be used in assessment items:
    - Hardy Weinberg Equilibrium
    - biotechnology
    - relative fitness
    - directional selection
    - disruptive selection
    - stabilizing selection
    - heterozygote advantage
    - frequency-dependent selection
    - prezygotic barriers
    - postzygotic barriers

Phenomena

- Following a four-year drought in California, field mustard plants are found to flower earlier in the season.
- A new antibiotic is discovered. Within ten years, many bacterial diseases that were previously treated by the antibiotic no longer respond to treatment (e.g., MRSA).
- A small population of Italian wall lizards that feed mainly on insects is introduced to a neighboring island. After several decades, the lizards are found to have thrived and heavily populated the island, and their diet is now mostly vegetation.

Task Demands

- Organize or summarize the given data or evidence of population characteristics, environmental characteristics, and/or the relationships between them.
- Generate or construct graphs or tables of data to highlight patterns within the given data.
- Describe the cause-and-effect relationship between natural selection and adaptation using evidence. This may include assembling descriptions from illustrations or lists of options and distractors or indicating directions of causality in a model or completing cause and effect chains.
- Describe, identify, or select evidence supporting or contradicting a claim about the role of adaptation in causing the phenomenon. The evidence may be generated by the students in a simulation.
- Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in environmental conditions on the population.

- Use evidence to construct an explanation of the adaptation of a species through natural selection. Evidence can be described, identified, or selected/assembled from lists with distractors. Explanations can be written, assembled by manipulating the components of a flow chart or model, or assembled from lists of options that include distractors. Options and distractors should not be single words or short phrases; rather, they should be complete thoughts that, when correctly emplaced within a sentence or paragraph, work to provide evidence of a coherent train of thought.
- Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses.

HS-LS-4.5 Students who demonstrate understanding can:
Evaluate models that demonstrate how changes in an environment may result in the evolution of a population of a given species; the emergence of new species over generations; or the extinction of other species due to the process of genetic drift, gene flow, mutation, and natural selection.

Dimensions:

- **SEP:** *Engaging in Argument from Evidence:* Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.
- **DCI:** *Biological Adaptation: Unity and Diversity:*
  - 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 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.
- **CCC:** *Cause and Effect:* Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Further Explanation and Content Limit:

Further Explanation: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Content Limits: Students do not need to know the Hardy-Weinburg equation

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - beneficial change
  - detrimental change
  - distribution
  - emergence
  - gene frequency

- biotic
- abiotic
- advantageous
- diverge
- mutation
- proliferation
- bottleneck effect
- island effect
- geographic isolation
- founder effect
- recombination
- microevolution
- gene flow
- speciation
- hybrid

- Vocabulary that should not be used in assessment items:
  - biotechnology
  - relative fitness
  - directional selection
  - disruptive selection
  - stabilizing selection
  - heterozygote advantage
  - frequency dependent selection
  - prezygotic barriers
  - postzygotic barriers
  - average heterozygosity
  - cline
  - sexual selection
  - sexual dimorphism
  - intrasexual selection
  - intersexual selection
  - neutral variation
  - balancing selection

Phenomena

- PCB pollution in the Hudson River wiped out many fish species, but the Atlantic tomcod thrives there (results 1 and 3).
- The population of Greater Prairie Chickens in Illinois decreased from millions of birds in the 1800s to fewer than 50 birds in 1993 (result 3).
- In 1681 the dodo bird went extinct due to hunting and introduction of invasive species (result 3).

- In 1988, the Orange-Spotted Filefish went extinct in response to warmer ocean temperatures (result 3).

Task Demands

- Based on the provided data, identify, describe, or construct a claim regarding the effect of changes to the environment on the (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.
- Sort inferences about the effect of changes to the environment on (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 into those that are supported by the data, contradicted by the data, outliers in the data, or neither, or some similar classification.
- Identify patterns of information/evidence in the data that support correlative/causative inferences about the effect of changes to the environment on the (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.
- Construct an argument and/or explanation using scientific reasoning drawing on credible evidence to explain the effect of changes to the environment on the (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.
- Identify additional evidence that would help clarify, support, or contradict a claim or causal argument regarding the effect of changes to the environment on the (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.
- Identify, summarize, or organize given data or other information to support or refute a claim regarding the effect of changes to the environment on (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.

High School Physical Science- Chemistry

HS-PSC-1.1 Students who demonstrate understanding can:

Develop models to describe the atomic composition of simple molecules and extended structures.

Dimensions:

- **SEP:** *Developing and Using Models:* Develop and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

- **DCI:** *Structure and Properties of Matter:* Develop and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
- **CCC:** *Scale, Proportion, and Quantity:*
    - Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
    - Patterns observable at one scale may not be observable or exist at other scales.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on reviewing how to develop models of molecules that vary in complexity. This should build on the MS-PS-1.1 standard.
- Emphasis is on the development of chemical formulas of molecules and compounds.
- Examples of simple molecules could include ammonia or methanol.
- Examples of extended structures could include sodium chloride or diamonds.
- Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.

Content Limits:

- Students will be provided with the names of elements, a list of common ions, a list of numerical prefixes and their meanings, and the charges of all cation and anions within the item as necessary.
- Confine element symbols to the representative and familiar transition metal elements.
- Assessment does not include:
    - Bond angles, specific shapes/configurations of molecules or function of molecules related to shape
    - Chemical reactions or bond strength
    - Quantum numbers

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - atomic mass
    - bond
    - electron sharing
    - ion
    - carbon
    - electron transfer
- Vocabulary that should not be used in assessment items:
    - angstroms
    - any shape above tetrahedral

- electron orbital shapes
- VSPER theory
- polysaccharides
- phospholipids
- DNA
- oxidation-reduction reaction
- chirality
- stereoisomers
- Lewis structures
- isomers
- dissociation

Phenomena

- Submarines can stay underwater for months using sea water as a source of oxygen for air. Special machines run electricity through large amounts of sea water, generating oxygen from the water.
- Water and hydrogen peroxide are both made up of hydrogen and oxygen. When water is poured on a chunk of $CaCO_3$, there is no reaction. When hydrogen peroxide is poured on a chunk of $CaCO_3$, it fizzes.
- Graphite is an extremely soft substance and diamonds are the hardest substance known. Both are made completely of carbon atoms in different arrangements.
- Oxygen (O2) is a gas we breathe to stay alive. Ozone (O3), also made only of oxygen atoms, is unhealthy to breathe.

Task Demands

- Select or identify from a collection of potential components, the components needed to model the phenomenon. Components might include single elements or molecules.
- Describe or identify the relationships among components of a model of a simple molecule or extended structure.
- Assemble or complete a model of a simple molecule or extended structure from a collection of potential model components. This does not include labeling an existing diagram.
- Identify missing components, relationships or limitations of the model of a simple molecule or extended structure.
- Manipulate the model to demonstrate the properties of a simple molecule or extended structure.
- Make predictions about the effects of changes in a simple molecule or extended structure. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.

HS-PSC-1.2 Students who demonstrate understanding can:

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.

Dimensions:

- **SEP:** *Developing and Using Models:* Use a model to predict the relationships between systems or between components of a system.
- **DCI:** *Structure and Properties of Matter:*
    - Each atom has a 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.
- **CCC:** *Patterns:* Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits:

- Elements will be limited to main group elements.
- Students do not need to know the properties of individual elements, names of groups, anomalous electron configurations (Chromium and Copper)

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - proton
    - electron
    - neutron
    - valence shell
    - filled shell
    - ion
    - cation
    - anion
    - solid
    - liquid
    - gas
    - metal
    - nonmetal
    - metalloid

- group
- period
- family
- atom
- molecule
- matter
- elements
- states of matter
- pure substance
- physical property
- chemical property
- atomic number
- atomic symbol
- atomic weight
- chemical formula
- ionic bond
- covalent bond
- s, p, d, f orbitals
- electron configuration
- core electrons
- nucleus
- single, double, triple bond(s)
- molar mass
- atomic radius
- melting point
- boiling point
- electronegativity

- Vocabulary that should not be used in assessment items:
    - oxidation state
    - diatomic
    - polyatomic ions
    - empirical formulas
    - molecular formulas
    - quantum
    - photon
    - Heisenberg Uncertainty Principle
    - Hund’s Rule
    - Pauli Exclusion Principle

Phenomena

- Potassium chloride (KCl) tastes like table salt (sodium chloride (NaCl)).

- Diamond, graphene, and fullerene are different molecules/materials that are only made of carbon.
- Balloons are filled with helium gas instead of hydrogen gas.
- Scientists work with silicate substrates in chambers filled with Argon instead of air.

Task Demands

- Select or identify from a collection of periodic table components (periods, groups, etc.), including distractors, the components needed to model the phenomenon.
- Make predictions about the properties of elements based on the number of valence electrons. Predictions can be made by completing illustrations or selecting from lists with distractors.
- Identify missing components, relationships, or other limitations of the model. (Hydrogen like Alkali metals, one valence electron, and Halogens, missing only one valence electron).
- Describe, select, or identify the relationships among components of the periodic table that describe the properties of valence electrons, or explain the properties of elements.

HS-PSC-1.3 Students who demonstrate understanding can:

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.

Dimensions:

- **SEP:** *Planning and Carrying Out Investigations:* Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
- **DCI:** *Structure and Properties of Matter:* The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
- **CCC:** *Patterns:* Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on understanding the strength 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.

Content Limits:

- Assessment does not include Raoult’s law, nor calculations of vapor pressure.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - nucleus
    - proton
    - electron
    - neutron
    - electron cloud
    - intramolecular force
    - covalent bond
    - ionic bond
    - intermolecular force
    - electrostatic force
    - electronegativity
    - electron distribution
    - polarity
    - temporary polarity
    - permanent polarity
    - polarize
    - surface area
    - atomic radius
    - atomic weight
    - atomic mass
    - solute
    - solvent
    - dissolve
- Vocabulary that should not be used in assessment items:
    - dipole
    - induced dipole
    - dipole moment
    - delta
    - Coulomb’s law
    - dipole-dipole
    - London forces
    - Van der Waals forces
    - ion-dipole
    - hydrogen bonding
    - pi-electron cloud
    - pi stacking
    - colligative properties

- electron shielding

Phenomena

- Two neighbors apply different salt treatments to their driveways the night before a freeze is predicted. The next morning, no ice formed on one of their driveways. However, the other driveway was covered with a thin layer of ice.
- A chef makes salad dressing by completely mixing oil, water, and vinegar in a large container. Afterwards, he pours the mixed dressing from the large container into individual containers and places one container on each of the restaurant's tables before leaving for the night. In the morning, the chef finds a layer of oil floating on top of a liquid layer in each of the containers on the tables.
- After working with painting oils, an artist finds that she must wash her hands with soap and water to remove the oil from her hands, as rinsing with water alone does not remove the oil.
- A glass is filled with water. When coins are added to the full glass of water, the surface of the water rises above the rim of the glass without spilling.

Task Demands

- Identify from a list, including distractors, the materials/tools needed for an investigation of the physical properties/interactions of atomic and/or molecular substances at the bulk scale to gather evidence about the strengths of the electrostatic attractions between the particles of those substances.
- Identify the outcome data that should be collected in an investigation of the physical properties/interactions of atomic and/or molecular substances at the bulk scale to gather evidence about the strengths of the electrostatic attractions between the particles of those substances.
- Evaluate the sufficiency and limitations of collected data about the physical properties/interactions of substances at the bulk scale to explain the phenomenon.
- Make and/or record observations about the physical properties/interactions of substances at the bulk scale that provide evidence to support inferences about the relative strengths of the electrostatic attractions between the particles of those substances.
- Interpret, summarize, and/or communicate the data from an investigation concerning the physical properties/interactions of substances at the bulk scale.
- Explain or describe the causal processes that lead to the observed data.
- Select, describe, or illustrate a prediction concerning the physical properties of or interactions between additional substance(s), and/or the strength of electrostatic attractions between the particles of additional substance(s), made by applying the findings from an investigation.

HS-PSC-1.4 Students who demonstrate understanding can:

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.

Dimensions:

- **SEP:** *Developing and Using Models:* Develop a model based on evidence to illustrate the relationships between systems or between components of a system.
- **DCI:** *Structure and Properties of Matter:* 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.
- **CCC:** *Energy and Matter:* In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits:

- Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - absorption
    - transformation
    - nuclear reaction
    - nucleus
    - decay rate
    - fission
    - fusion
    - neutron
    - nuclear mass
    - unstable
    - half-life
    - radioactive
    - radiation
    - alpha particle
    - alpha decay
    - beta particle
    - beta emission
    - gamma radiation

    - atomic number
    - atomic mass
    - proton
    - radioactive decay
- Vocabulary that should not be used in assessment items:
    - nucleon(s)
    - radioisotopes
    - positron
    - positron emission
    - electron capture
    - radioactive series
    - nuclear disintegration series
    - magic numbers
    - nuclear transmutations
    - particle accelerators
    - transuranium elements
    - radiometric dating
    - becquerel (Bq) unit
    - curie (Ci) unit
    - Geiger counter
    - radiotracer
    - critical mass
    - supercritical mass
    - nuclear reactor
    - ionizing radiation
    - nonionizing radiation
    - target nucleus
    - bombarding particle
    - nuclear process
    - nuclear stability
    - particle emission
    - rate of nuclear decay
    - spontaneous nuclear reaction

Phenomena

- Rocks from the Tuna Creek area of the Grand Canyon were tested and found to contain less lead (Pb) and more uranium (U) than rocks from the Elves Chasm area of the Grand Canyon.
- A brand-new nuclear fuel rod containing 3% U-235 was used in a nuclear reactor in New Jersey for 18 months. When it was taken out the reactor, it was found to contain 0.8% U-235, 5.2% fission products, and 1.2% plutonium.

- Scientists in Dubna, Russia, after using a heavy ion accelerator to smash berkelium and detected atoms of elements 115 and 113 along with alpha particles.

- Task Demands
- Select or identify from a collection of components, including distractors, the components needed to model the changes in nuclear composition and energy released during fission, fusion, and/or radioactive decay.
- Identify missing components, relationships, or other limitations of the model.
- Describe, select, or identify the relationships among components of the nucleus and/or nuclear processes that explain the release or absorption of energy and/or the conservation of protons and neutrons.
- Assemble or complete, from a collection of potential model components, an illustration or flow chart that can represent a release or absorption of energy from a nuclear process. This does not include labeling an existing diagram.
- Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.

HS-PSC-1.5 Students who demonstrate understanding can:
Communicate scientific and technical information about why the molecular level structure is important in the functioning of designed materials.

Dimensions:

- **SEP:** *Obtaining, Evaluating, and Communicating Information:* Communicate scientific and/or 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 (i.e., orally, graphically, textually, and mathematically).
- **DCI:** *Matter and Its Interactions:*
    - The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
    - Attraction and repulsion between electric charges at the atomic scale explain the structure, properties (physical and chemical), and transformations of matter, as well as the contact forces between material objects.
- **CCC:** *Structure and Function:* The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits:

- Assessment is limited to the provided molecular structures of specific designed materials.
- For questions involving polar vs. nonpolar bonds, item distractors containing ionic bonds may not be used.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - polar
    - nonpolar
    - ionic bond
    - covalent bond
    - net charge
    - salts
    - polymer
    - monomer
    - conductor
    - insulator
    - heat conductivity
    - soluble
    - insoluble
- Vocabulary that should not be used in assessment items:
    - electronegativity
    - hydrogen bond
    - electrostatic attraction
    - dipoles
    - phospholipids
    - polysaccharides
    - proteins
    - lipids
    - enzymes
    - substrate
    - miscible
    - immiscible

Phenomena

- Zinc oxide was dissolved in water and the resulting solution was very difficult to stir. Upon the addition of a clear, amber colored liquid, the solution became much thinner and easier to stir.
- Water spilled on two shirts. One shirt absorbed the water very quickly, leaving a large wet spot. On the other shirt, the water formed tiny spheres and bounced off, leaving the shirt dry.
- A sample of cotton fabric was dyed with two different kinds of dye and then was washed several times to determine how well the dye stayed in the fabric. One dye faded over time, the other did not.
- Food cooked in a bronze-colored pot cooked quickly and evenly. Food cooked in a silver-colored pot took longer and was not evenly cooked.

Task Demands

- Analyze and interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols, mathematical representations that support the importance of the molecular level structure to the functioning of designed materials.
- Evaluate the validity/relevance/reliability of scientific evidence about the relationship between the molecular level structure and function of the designed material.
- Identify relationships or patterns in scientific evidence at macroscopic and/or microscopic scales.
- Describe the specific evidence needed to support an explanation about the importance of the molecular level structure to the functioning of designed materials.
- Synthesize an explanation that incorporates scientific evidence from multiple sources.

HS-PSC-2.1 Students who demonstrate understanding can:

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.

Dimensions:

- **SEP:** *Constructing Explanations and Designing Solutions:* Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- **DCI:** *Chemical Reactions:*
    - The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar physical and chemical properties in

    - columns. The repeating patterns of this table reflect patterns of outer electron states.
    - The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.
- **CCC:** *Patterns:* Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Further Explanation and Content Limit:

Further Explanation:

- Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.
- Content Limits:
    - Identify types of chemical reactions including synthesis/formation/combination reactions, decomposition reactions, single replacement/displacement reactions, double replacement/displacement reactions, oxidation-reduction (redox) reactions (single replacement only), acid base reactions, and combustion reactions (for hydrocarbons).
    - Predict the products of double replacement, single replacement, and combustion reactions only. For the second skill statement, do not use acid names or hydrocarbons when translating between words and formulas.
    - Items will include a list of common ions, as needed.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - molecule
    - carbon dioxide
    - reversible
    - atomic weight
    - chemical bond
    - electron sharing
    - ion
    - outer electron state
    - energy level
    - electron transfer
    - chemical properties
    - carbon
    - concentration
    - equilibrium
    - endo/exothermic reactions
    - stable

- proton
- neutron
- electron
- combustion
- yield(s)
- reactant
- product
- mass
- solid
- liquid
- gas
- flammability
- element
- compound
- chemical reaction
- octet

- Vocabulary that should not be used in assessment items:
  - orbital diagram
  - multiplicity
  - rearrangement
  - by-product
  - oxidation-reduction reaction
  - decomposition
  - single replacement reaction
  - double replacement reaction
  - synthesis reaction
  - precipitate

Phenomena

- A coal oven without proper ventilation produces billows of dark smoke.
- Two metals are placed in water. One bubbles and fizzes, while the other gives off a yellow flame and white smoke.
- Carlsbad Caverns is a large cave in New Mexico. Inside, large pointy structures appear to be growing from the ceiling.
- A shiny metallic solid is combined with a green gas, resulting in a white crystalline solid.

Task Demands

- Use relationships identified in the data to predict properties of other chemical compounds/ elements/ mixtures.
- Identify patterns or evidence in the data that supports inferences about the properties of other chemical compounds/ elements/ mixtures.

- Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations.
- Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
- Use an explanation to predict the properties of other chemical compounds/elements/mixtures given a change in reagents or conditions.
- Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations relating to the periodic table. This may include sorting out distractors.
- Select, articulate, construct and/or revise an explanation about a chemical reaction. This may include identifying/selecting the products of the reaction as part of an explanation.

HS-PSC-2.2 Students who demonstrate understanding can:

Develop a model to illustrate that the energy transferred during an exothermic or endothermic chemical reaction is based on the bond energy difference between bonds broken (absorption of energy) and bonds formed (release of energy).

Dimensions:

- **SEP:** *Developing and Using Models:* Develop a model based on evidence to illustrate the relationships between systems or between components of a system.
- **DCI:** *Chemical Reactions:*
    - 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.
    - 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.
- **CCC:** *Energy and Matter:* Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on the idea that a chemical reaction is a system that affects energy change. Examples of models could include molecular-level drawing and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.

Content Limits:

- Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - transfer
  - heat energy
  - atomic arrangement
  - stored energy
  - conversion
  - bond energy
  - release of energy
  - endothermic
  - exothermic
- Vocabulary that should not be used in assessment items:
  - recombination of chemical elements
  - stable
  - chemical system
  - chemical reaction rate

Phenomena

- Scientists gather samples of rock from the ocean floor. One sample looks and feels like ice but burns and produces a flame when ignited.
- Wet cement is left sitting outside. After one day, the cement becomes hard and stiff.
- A temperature of a sample of tin is lowered from room temperature to 0 °C. The tin changes color from silver to gray, becomes brittle, and starts developing cracks on its surface.
- Baking soda is added to a container of citric acid at room temperature. The resulting solution becomes cold and returns to room temperature after 2 minutes.

Task Demands

- Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include models of bonds breaking and forming, heat absorbed or released, or aspects of a chemical reaction.
- Assemble or complete, from a collection of potential model components, an illustration or flow chart that can represent a release or absorption of energy from a chemical reaction. This does not include labeling an existing diagram.
- Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.
- Make predictions about the effects of changes in bond energies. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.

- Describe, select, or identify the relationships among components of a model that describes a release or absorption in energy, or explains why a release or absorption in energy is dependent on total bond energy.

HS-PSC-2.3 Students who demonstrate understanding can:
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.

Dimensions:

- **SEP:** *Constructing Explanations and Designing Solutions:* Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- **DCI:** *Chemical Reactions:* Chemical processes, their rates, and whether 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.
- **CCC:** *Patterns:* Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanation of phenomena.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.

Content Limits:

- Can also include concentration and titration relationships or a titration curve.
- Factors that influence the rate of reaction may include temperature, surface area, size of particles, concentration, and catalysts.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - carbon dioxide
  - molecule
  - boiling point
  - melting point
  - oxygen
  - atomic mass
  - atomic energy
  - atomic motion
  - covalent bond

- ionic bond
    - ion
    - closed system
    - carbon
    - endothermic
    - exothermic
    - average reaction rate
    - pH
    - solution
    - solute
    - solvent
    - dilute
    - concentrated
    - surface area
- Vocabulary that should not be used in assessment items:
    - Le Chatelier's principle
    - instantaneous reaction rate
    - isolation method
    - acid/ base catalysis
    - covalent catalysis
    - conjugate base
    - conjugate acid
    - enzyme substrate complex
    - catalyst
    - activation energy
    - transition state
    - acid-base reaction
    - oxidation-reduction reaction
    - oxidation

Phenomena

- An activated glow stick glows brighter in a cup of warm water than an activated glow stick in a cup of cold water.
- A warm cup of baking soda solution poured into a calcium chloride forms bubbles more quickly than a cold cup of baking soda solution poured into a calcium chloride solution.
- A piece of zinc placed in a flask of high concentration hydrochloric acid forms bubbles more quickly than a piece of zinc placed in a flask of low concentration hydrochloric acid.
- A beaker of 50mL 0.15 M sodium thiosulfate became opaque when 5.0 mL 2M hydrochloric acid was added, in under 20 seconds. When the same amount of

hydrochloric acid was added to a solution of 10.0 mL sodium thiosulfate and 40.0 mL water, the solution became opaque after four minutes had passed.

Task Demands

- Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
- Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations in reacting particles or reaction rates. This may include sorting out distractors.
- Identify patterns or evidence in the data that supports inferences about the properties of reacting particles or reaction rates.
- Organize, arrange, or summarize data to highlight trends, patterns, or correlations in the relationships among reacting particles, the rate of reaction, and changes to the system.
- Use relationships identified in the data to predict properties of other chemical reactions.
- Complete a causal chain to make an inference about the effects of changes to a system on reaction rate or properties of the reacting particles.
- Describe, identify, and/or select additional information and/or evidence needed to support an explanation about the effects of changes to a system on reaction rate.
- Construct an explanation based on evidence that explains the effects a change to a system has on reacting particles and reaction rate.

HS-PSC-2.4 Students who demonstrate understanding can:
Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Dimensions:

- **SEP:** *Using Mathematics and Computational Thinking:* Use mathematical representations of phenomena to support claims.
- **DCI:** *Motion and Stability: Forces and Interactions:* The fact that atoms are conserved, together with knowledge of chemical properties of the elements involved, can be used to describe, and predict chemical reactions.
- **CCC:** *Energy and Matter:* The total amount of energy and matter in closed systems is conserved.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits:

- Conversion problems will be one to two steps (e.g., grams to moles to atoms/molecules).
- Compounds and formulas should be provided in the stem of the question.
- Students should be given molecular masses in problems involving gram to other unit conversions.
- Molar mass calculations should not be combined with conversion problems.
- All volumes must be at standard temperature and pressure (STP).
- A balanced equation and molar masses should be included in the item.
- Calculations may include grams/moles/volume of reactant to grams/moles/volume of product.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - moles
  - chemical formulas
  - chemical equations
  - compounds
  - coefficient
  - subscripts
  - acid
  - base
  - pH
  - solution
  - reactant
  - product
  - atomic mass
  - dimensional analysis
  - conversion factor
- Vocabulary that should not be used in assessment items:
  - molar mass
  - STP
  - stoichiometry

Phenomena

- When salt water is added to a silver nitrate solution, a solid forms.
- A tree grows in a pot. The tree gains mass but the soil's mass remains the same.
- Methane gas flows into a Bunsen burner. When a spark is applied, methane gas reacts with oxygen in the air to produce a blue flame. The flame gets larger as the oxygen valve is turned to allow more oxygen to mix with methane.

- When colorless solutions of sodium sulfate (Na_2SO_4) and strontium nitrate ($Sr(NO_3)_2$) are mixed, a white solid forms. Equal masses of the white solid are recovered when 30.0 mL of 0.10 M Na_2SO_4 solution is added to 70.0 mL of 0.20 M $Sr(NO_3)_2$ solution and when 30.0 mL of 0.20 M Na_2SO_4 solution is added to 70.0 ml of 0.20 M $Sr(NO_3)_2$ solution.

Task Demands

- Make simple calculations using given data to calculate or estimate the total mass in the system OR the mass of individual objects within the system.
- Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate the total mass or energy in the system OR the mass or energy of individual objects within the system.
- Calculate or estimate properties or relationships between masses and/or energy based on data from one or more sources.
- Identify data or compile from given information, the information needed to support inferences about how mass and/or energy is conserved within a system. This can include sorting out the relevant data from the given information.

HS-PSC-3.1 Students who demonstrate understanding can:
Ask questions to clarify the idea that electromagnetic radiation can be described either by a wave model or a particle model.

Dimensions:

- **SEP:** *Engaging in Argument from Evidence:* Evaluate the claims, evidence and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- **DCI:** *Energy:*
  - Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of waves), but they emerge unaffected by each other. (*Boundary: the discussion at this grade level is qualitative only; it can be since two different sounds can pass a location in different directions without getting mixed up*).
  - 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.
- **CCC:** *Systems and System Models:* Models (e.g., physical, mathematical and computer models) can be used to simulate systems and interactions – including energy, matter and information flows – within and between systems at different scales.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on how experimental evidence supports the claim and how a theory is generally modified considering new evidence. Assessment should only test the qualitative aspect of the wave model vs. particle model.
- Examples of a phenomenon could include:
    - Resonance
    - Interference
    - Diffraction
    - Photoelectric Effect

Content Limits:

- Assessment does not include using Quantum Theory or in-depth calculations.
- Students do not need to know specific types of electromagnetic radiation and their wavelengths/frequencies.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - interference
    - diffraction
    - refraction
    - photoelectric effect
    - emission
    - absorption
    - brightness
    - resonance
    - transmission
    - visible light
    - transverse wave
- Vocabulary that should not be used in assessment items:
    - Doppler effect for light (redshift)
    - microwave radiation
    - ultraviolet radiation
    - ionize
    - infrared radiation
    - wave-particle duality
    - quantum
    - quanta
    - X-ray
    - gamma rays
    - radio waves
    - oscillations
    - electrostatic induction

- Planck’s equation
- Planck’s constant
- magnetic dipole
- electric dipole

Phenomena

- When light hits a metal, a stream of electrons is ejected from the metal. When the color of the light pointed at the metal changes, the kinetic energy of the stream of electrons changes.
- Light is made to pass through two small slits on a piece of dark construction paper. The light that goes through the slits is then projected on a second piece of dark construction paper. A pattern of bright and dark bands is seen on the second piece of dark construction paper.
- The emission spectra of Hydrogen are completely black but for 4 discrete lines violet, blue, green and red color.
- A red laser is pointed at a glass prism. The light bends as it goes through the prism. A violet laser is then pointed at the glass prism and the light bends more than the light from the red laser.

Task Demands

- Based on the provided data or information, identify the explanation that describes light behaves like a particle and or behaves like a wave.
- Identify and/or explain the claims, evidence, and reasoning supporting the explanation that light can behave like a particle or a wave, and why certain evidence is best explained by only one of these models.
- Identify and/or describe additional relevant evidence not provided that would support or clarify the explanation of how light can behave like a particle or a wave.
- Evaluate the strengths and weaknesses of a claim to explain which pieces of evidence support the fact that light behaves as a particle or a wave.
- Analyze and/or interpret evidence and its ability to support the explanation that light can behave as both a wave and a particle.
- Provide and/or evaluate reasoning to support the explanation that light can behave as both a wave and a particle and that some evidence is only supported by one of the models.

HS-PSC-3.2 Students who demonstrate understanding can:
Create a computational model to calculate the change in 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.

Dimensions:

- **SEP:** *Using Mathematics and Computational Thinking:* Create a computational model or simulation of a phenomenon, designed device, process or system.
- **DCI:** *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 because 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.
  - 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.
- **CCC:** *Systems and System Models:* Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on explaining the meaning of mathematical expressions used in the model.

Content Limits:

- Assessment is limited to:
  - Basic algebraic expressions or computations
  - Systems of two or three components
  - Thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, and electric fields.
- Students do not need to know detailed understanding of circuits or thermodynamics

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - mechanical energy
  - potential energy
  - conversion

- kinetic energy
    - conduction
    - electrical circuit
    - electrical current
    - heat radiation
    - insulate
    - resistor
    - volt
    - amp
    - Ohm’s Law
- Vocabulary that should not be used in assessment items:
    - entropy
    - second law of thermodynamics
    - thermodynamics
    - Stirling cycle
    - Carnot cycle
    - capacitor
    - inductance
    - inductor
    - Faraday’s law

Phenomena

- A block is attached to a spring and laid down on a table. The spring is stretched by pulling the block a certain distance. The spring is then released. As the block oscillates back and forth, the amplitude of each successive oscillation gets smaller until the block stops moving.
- A light bulb is hooked up to an energy source. When a resistor is added in series to the circuit, the brightness of the light bulb dims.
- Two metal pots are placed on a stove top. Pot 1 has a metal handle while Pot 2 has a rubber handle. The stove is turned on and the pots heat up. After 10 minutes, the handle on Pot 1 is much hotter than the handle on Pot 2.
- A toy truck is placed at the top of a frictionless ramp. When it travels down the ramp it collides with a stationary toy truck sitting on a horizontal surface (with friction) at the bottom of the ramp. The truck at the bottom of the ramp then begins to move.

Task Demands

- Make simple calculations using given data to calculate or estimate the amount of energy in certain components of the system.
- Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate how energy changes in one component of the system affect the energy

changes in another component of the system OR how the flow of energy into and out of the system affects the energy change of each component within the system.
- Calculate or estimate properties for, or the relationships between, each component of the system based on data from one or more sources.
- Compile, from given information, the data needed for a particular inference about how energy changes in one component of the system affects the energy changes in another component of the system. This can include sorting out the relevant data from the given information.

HS-PSC-3.3 Students who demonstrate understanding can:
Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).

Dimensions:

- **SEP:** *Developing and Using Models:* Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.
- **DCI:** *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 movers across space.
- **CCC:** *Energy and Matter:* Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.

Further Explanation and Content Limit:

Further Explanation:

- 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
    - The energy that is stored between two electrically-charged plates.

- Examples of models could include diagrams, drawings, descriptions, and computer simulations.

Content Limits:

- Students do not need to know:
    - Thermodynamics in detail
    - Gravitational fields
    - Thermonuclear fusion

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - mechanical energy
    - potential energy
    - kinetic energy
    - electric field
    - magnetic field
    - molecular energy
    - heat conduction
    - circuit
    - current
    - heat radiation
    - work
- Vocabulary that should not be used in assessment items:
    - entropy
    - Second Law of Thermodynamics
    - thermodynamics
    - root mean velocity
    - Boltzmann's constant
    - gravitational fields
    - fusion
    - fission

Phenomena

- Two electrically charged plates, one with a positive charge and one with a negative charge, are placed a certain distance apart. Electron 1 is placed in the middle of the two plates. It accelerates to the positive plate and hits it with a certain velocity. Electron 2 is then placed closer to the negative plate. This electron gains more speed before reaching the positive plate.
- A gas is placed inside a container and sealed with a piston. The outside of the container is heated up. The piston begins to move upwards.
- A person rubs their hands together. Afterwards their hands feel warm.

- A block is attached to a spring and placed on a horizontal table. When the spring is un-stretched, the spring and block do not move. When the spring is stretched to a certain distance (x), the block oscillates back and forth.

Task Demands

- Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include equations used to calculate energy or objects used to set up the experimental model. The model can be a conceptual model (flow chart).
- Manipulate the components of a model to demonstrate how energy at the macroscopic scale can be accounted for as a combination of energy associated with the workings of particles at the microscopic scale, result in the observation of the phenomenon.
- Make predictions about the effects of changes in the motion or relative position of objects in the model. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
- Identify missing components, relationships, or other limitations of the model showing how energy at the macroscopic scale is affected by the motion and positioning of particles at the microscopic scale.
- Describe, select, or identify the relationships among components of a model that describes, or explains, how energy is related to the motion and relative position of objects.

HS-PSC-3.4 * Students who demonstrate understanding can:
Design, build and refine a device that works within given constraints to convert one form of energy into another form of energy. *Optional

Dimensions:

- **SEP:** *Constructing Explanations and Designing Solutions:* Develop a model to describe unobservable mechanisms.
- **DCI:** *Energy:*
  - At the macroscopic scale, energy manifests itself in multiple ways such as in motion, sound, light, and thermal energy.
  - Although energy cannot be destroyed, it can be converted to less useful forms – For example, to thermal energy in the surrounding environment.
  - 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)*
- **CCC:** *Energy and Matter:* Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on both qualitative and quantitative evaluations of devices.
- Examples of constraints could include use of renewable energy forms and efficiency.
- Examples of devices could include, but are not limited to:
  - Rube Goldberg devices
  - Wind Turbines
  - Solar cells
  - Solar ovens
  - Generators

Content Limits:

- Assessment for quantitative evaluations is limited to total output for a given input.
- Assessment is limited to devices constructed with materials provided to students.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - electric current
  - electrical energy
  - electromagnet
  - magnetic field
  - electric field
  - mechanical energy
  - renewable energy
  - generator
  - wind turbine
  - Rube Goldberg Device
  - solar cell
  - solar oven
- Vocabulary that should not be used in assessment items:
  - torque
  - entropy
  - molecular energy
  - second law of thermodynamics
  - thermodynamics
  - thermal equilibrium
  - Stirling engine

Phenomena

- Engineering standards are built around meaningful design problems rather than phenomena. For this performance expectation, the design problem and solutions replace phenomena:
    - Use an engine to generate the most light from an LED.
    - Refine a Stirling Engine to make it run for over 30mins.
    - Create a solar oven that will cook an egg in 10mins.
    - Refine a solar cell such that it maximizes energy output.

Task Demands

- Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
- Express or complete a causal chain explaining how the device converts one form of energy into another form of energy. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram or completing cause and effect chains.
- Using given information, select or identify constraints that the energy converting device or solution must meet.
- Identify evidence supporting the inference of causation that is expressed in a causal chain.
- Using given data, propose, illustrate, or assemble a potential energy converting device (prototype) or solution.
- Using a simulator, test a proposed energy converting prototype and evaluate the outcomes, potentially including proposing and testing modifications to the prototype.

HS-PSC-3.5 Students who demonstrate understanding can:
Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

Dimensions:

- **SEP:** *Planning and Carrying Out Investigations:* Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
- **DCI:** *Energy:*
    - 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).

    - Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.
- **CCC:** *Systems and System Models:* When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits:

- Assessment is limited to investigations based on materials and tools provided to students.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - specific heat
    - specific heat capacity
    - kinetic energy
    - microscopic scale
    - macroscopic scale
    - molecular energy
    - heat conduction
    - heat radiation
    - Kelvin
    - Joules
    - calorimetry
- Vocabulary that should not be used in assessment items:
    - entropy
    - root mean velocity
    - Boltzmann’s constant
    - gravitational fields
    - fusion
    - fission

Phenomena

- The temperature of a can of soda decreases when the can is placed in a container of ice.
- Hot coffee cools down after cold cream is added to the cup.

- A scoop of ice cream begins to melt when added to cold soda in a glass.
- A foam cup has 200 grams of room temperature water after 100 grams of hot water are mixed with 100 grams of cold water.

Task Demands

- Identify, make, plan, and/or record observations/outcome data concerning changes in substances' properties to provide evidence of transfer of thermal energy within a closed system.
- Organize, arrange, and/or generate/construct graphs, flowcharts, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations among observations and data concerning transfer of thermal energy within a closed system, and/or the boundaries of a closed system in which thermal energy is transferred.
- Describe, analyze, and/or summarize data (e.g., using illustrations and/or labels), to identify/highlight trends, perform calculations and other mathematical analyses, and identify patterns or correlations among observations and data concerning the transfer of thermal energy within a closed system.
- Use evidence to identify the boundaries of a closed system in which thermal energy is transferred.
- Identify patterns or evidence in the data that support inferences related to the transfer of thermal energy within a closed system.

High School Physical Science- Physics

HS-PSP-1.1 Students who demonstrate understanding can:
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.

Dimensions:

- **SEP:** *Analyzing and Interpreting Data:* Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) to make valid and reliable scientific claims or determine an optimal design solution.
- **DCI:** *Motion and Stability: Forces and Interactions:*
    - Newton's second law accurately predicts changes in the motion of macroscopic objects.

- **CCC:** *Cause and Effect:* Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Further Explanation and Content Limit:

Further Explanation:

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

Content Limits:

- Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.
- Stating the law or naming the law is not part of this PE.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - velocity
  - acceleration
  - net force
  - friction
  - air resistance
  - impulse
  - vectors
  - slope
  - y-intercept
- Vocabulary that should not be used in assessment items:
  - jerk
  - terminal velocity

Phenomena

The phenomena for these PEs *are* the given data. Phenomena should describe the data set(s) to be given in terms of patterns or relationships to be found in the data, and the columns and rows of a hypothetical table presenting the data, even if the presentation is not tabular. The description of the phenomenon should describe the presentation format of the data (e.g., maps, tables, graphs, etc.).

- Force is removed from two vehicles' accelerator pedals. The vehicles' positions over time are given.
- A water tank railcar is pulled by a train engine at constant speed and develops a leak allowing water to escape. The position and velocities of the water tank and train over time are given.

- A heavy model rocket rises a shorter distance than a lighter model rocket using the same type of engine. The position of each rocket over time is given.
- A falling skydiver's velocity increases for several minutes and then reaches a maximum speed. The velocity of the skydiver over time is given.

Task Demands

- Organize and/or arrange (e.g., using illustrations and/or labels), make calculations, or summarize data to highlight trends, patterns, or correlations.
- Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or relationships in the motion of a macroscopic object. This may include sorting out distractors.
- Construct, state, or select a claim or propose a design solution based on the relationships identified in the data.
- Use relationships identified in the data to predict the motion of and changes in the motion of macroscopic objects.
- Identify patterns or evidence in the data that supports inferences about the motion of and changes in the motion of macroscopic objects.
-

HS-PSP-1.2 Students who demonstrate understanding can:
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.

Dimensions:

- **SEP:** *Using Mathematics and Computational Thinking:* Use mathematical representations of phenomena to describe explanations.
- **DCI:** *Motion and Stability: Forces and Interactions:* 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.
- **CCC:** *Systems and System Models:* When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle
- Students should not be deriving formulas but can be using and manipulating them.

Content Limits:

- Assessment is limited to systems of no more than two macroscopic bodies moving in one dimension.

- Students do not need to know:
    - How to use a derivation to show that momentum is conserved only when there is no net force.
    - How to derive formulas regarding conservation of momentum.
    - How to resolve vectors and apply the understanding that momentum must be conserved in all directions.
    - Newton's Laws by name

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - friction
    - transfer
    - deceleration
    - frame of reference
    - net force
    - acceleration
    - velocity
    - internal
    - external
    - conversion
    - closed system
    - Newton's Second Law
    - collision
    - vector
- Vocabulary that should not be used in assessment items:
    - elastic collision
    - inelastic collision
    - inertial frame of reference

Phenomena

- A pool player hits a cue ball towards a stationary 8-ball. The cue ball collides with the 8-ball, causing the 8-ball to move. The 8-ball slows down until it comes to a rest 5 seconds after the collision.
- Two pool balls collide with each other, and two soccer balls collide with each other. After the collision, the soccer balls come to a stop quicker than the pool balls.
- A pool player hits a cue ball towards a stationary 8-ball. The cue ball collides with the 8-ball. The velocity of the 8-ball 1 second after the collision is greater than the velocity of the 8-ball 2 seconds after the collision.
- Two hockey pucks collide during an ice hockey practice. A player realizes that the two pucks take a long time to rest on the ice. After practice, he makes two street hockey

pucks collide on pavement. The pucks come to a stop more quickly than the ones on the ice did.

Task Demands

- Make simple calculations using given data to calculate or estimate the total momentum in the system OR the momentum of individual objects within the system.
- Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate the total momentum in the system OR the momentum of individual objects within the system.
- Calculate or estimate properties or relationships between momentum and other forces based on data from one or more sources.
- Identify data or compile from given information, the information needed to support inferences about net force and/or how momentum is conserved within a system. This can include sorting out the relevant data from the given information.

HS-PSP-1.3 Students who demonstrate understanding can:
Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

Dimensions:

- **SEP:** *Constructing Explanations and Designing Solutions:* Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.
- **DCI:** *Motion and Stability: Forces and Interactions:*
    - 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.
    - 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)*.
    - Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary).
- **CCC:** *Cause and Effect:* Systems can be designed to cause a desired effect.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits:

- Assessment is limited to qualitative evaluations and/or algebraic manipulations.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - exert
    - acceleration
    - deceleration
    - impact
    - inertia
    - Newton's First Law
    - Newton's Second Law
    - Newton's Third Law of Motion
    - impact
    - drag
    - velocity
    - qualitative
    - criteria
    - theoretical model
    - optimal
    - deformation
    - impulse
    - tradeoff
- Vocabulary that should not be used in assessment items:
    - rationale
    - aesthetics
    - consideration
    - representation
    - aspect
    - specification
    - critical
    - compressibility

Phenomena

Engineering standards are built around meaningful design problems rather than phenomena. For this performance expectation, the design problem and solutions replace phenomena.

- Bikers need to be both protected and have total visibility when riding. Design a helmet that protects the biker from collisions while maintaining awareness for his surroundings.
- Phone screens can be easily broken if dropped on the ground. Design a phone case that protects the phone from collisions while maintaining functionality.
- Design a material that can be implemented on a pool table, athletic field turf (fake grass), or miniature golf green to prevent wear and tear on the playing surface.

- Design an instrument case so that the instrument will still be in good condition even if the case is subject to being dropped or rolled around.

Task Demands

- Identify or assemble from a collection, including distractors, the relevant aspects of the problem, that with the given design solutions, if implemented, will resolve/improve the device by minimizing impact force.
- Using the given information, select or identify the criteria against which the device or solution should be judged.
- Using given data, propose/illustrate/assemble a potential device (prototype) or solution to minimize impact forces.
- Using given information, select or identify constraints that the device or solution must meet.
- Using a simulator, test a proposed prototype and evaluate the outcomes, potentially including proposing and testing modifications to the prototype.

HS-PSP-1.4 Students who demonstrate understanding can:

Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.

Dimensions:

- **SEP:** *Using Mathematics and Computational Thinking:* Use mathematical representations of phenomena to describe explanations.
- **DCI:** *Motion and Stability: Forces and Interactions:*
  - Newton's law of universal gravitation and Coulomb's law provide 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.
- **CCC:** *Patterns:* Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Further Explanation and Content Limit:

Further Explanation: N/A

Content Limits:

- Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.
- Assessment is limited to systems with two objects.

- Mathematical models can involve 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.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - attraction
    - charge
    - conductor
    - electric charge
    - induced electric current
    - electric field
    - electromotive force
    - electromagnetic field
    - electromagnet
    - frequency
    - induction
    - insulator
    - magnetic field
    - magnetic field lines
    - magnetic force
    - permanent magnet
    - polarity
    - repulsion
    - resistance
    - voltage
    - battery
    - direction
    - magnitude
    - ampere
    - charged particle
    - volts
    - right-hand rule
    - tesla
    - vectors
- Vocabulary that should not be used in assessment items:
    - electric potential
    - electromotive force
    - permeating
    - quantum property
    - Laplace force

- electrodynamics
- magnetic dipole
- electrostatic
- general relativity
- Ampere's Law
- Coulomb force
- Lorentz force

Phenomena

- A person weighs 150.00 pounds at sea level. At the top of Mount Everest, the same person weighs 149.25 pounds.
- When an uncharged sphere is brought near another stationary uncharged sphere, the stationary uncharged sphere does not move. When a charged sphere is brought near a stationary uncharged sphere, the stationary uncharged sphere always moves towards the charged sphere.
- The constant of proportionality in Coulomb's Law is 10^{20} times greater than the constant of proportionality in Newton's Law of Gravitation. However, the force of gravity on objects on Earth is usually much greater than the force exerted by magnets.

Task Demands

- Make simple calculations using given data to calculate or estimate the gravitational or electrostatic forces between objects.
- Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate the gravitational or electrostatic forces between objects.
- Calculate or estimate gravitational or electrostatic properties/relationships based on data from one or more sources.
- Compile, from given information, the particular data needed for a particular inference about the gravitational or electrostatic forces between objects. This can include sorting out the relevant data from the given information.

HS-PSP-1.5 Students who demonstrate understanding can:
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.

Dimensions:

- **SEP:** *Planning and Carrying Out Investigations:* Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
- **DCI:** *Motion and Stability: Forces and Interactions:*

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

- **CCC:** *Cause and Effect:* Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Further Explanation and Content Limit:

Further Explanation: N/A

Content Limits:

- Assessment is limited to designing and conducting investigations with provided materials and tools.
- Coulomb Law is provided in the stimulus if student is required to make calculations.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - conductor
  - electric charge
  - induced electric current
  - electromotive force
  - electromagnetic field
  - electromagnet
  - induction
  - insulator
  - magnetic field
  - magnetic field lines
  - permanent magnet
  - polarity
  - resistance
  - voltage
  - magnitude
  - ampere
  - charged particle
  - volts
  - right-hand rule
  - tesla
  - vectors
- Vocabulary that should not be used in assessment items:
  - electric potential

- electromotive force
- permeating
- quantum property
- Laplace force
- electrodynamics
- magnetic dipole
- electrostatic
- general relativity
- Ampere’s Law
- Coulomb force
- Lorentz force

Phenomena

- Paperclips on a table are picked up by a wire when both ends of the wire are attached to a battery.
- When electric current flows through a coil near a strong magnet, the coil rotates.
- The light bulb in a closed circuit turns on when a magnet moves near the wire in the circuit.
- A wind turbine built with a neodymium magnet produces more electricity than a wind turbine built with a ferrite magnet.

Task Demands

- Identify from a list, including distractors, the materials/tools/steps needed for an investigation to provide evidence that an electric current produces a magnetic field or that a changing magnetic field produces an electric current.
- Identify the outcome data that should be collected in an investigation to provide evidence that an electric current produces a magnetic field or that a changing magnetic field produces an electric current.
- Evaluate the sufficiency and limitations of data collected to explain the phenomenon.
- Make and/or record observations about the magnetic field created by an electric current or the electric current created by a changing magnetic field.
- Analyze, manipulate, interpret and/or communicate the data from an investigation to provide evidence that an electric current produces a magnetic field or that a changing magnetic field produces an electric current.
- Explain or describe the causal processes that lead to the observed data.
- Select, describe, or illustrate a prediction made by applying the findings from an investigation about electric currents and magnetic fields.

HS-PSP-1.6 Students who demonstrate understanding can:
Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Dimensions:

- **SEP:** *Obtaining, Evaluating, and Communicating Information:* Communicate scientific 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).
- **DCI:** *Motion and Stability: Forces and Interactions:*
  - The structure and properties of matter at the bulk scale are determined by electrical forces within and between atoms. *(secondary)*.
  - 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.
- **CCC:** *Structure and Function:* Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Further Explanation and Content Limit:

Further Explanation:

- 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 is limited to provided molecular structures of specific designed materials.

Content Limits:

- Students do not need to know specific molecular structures; specific names of synthetic materials such as vinyl, nylon, etc.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - macroscopic
  - microscopic
  - electrical conductivity
  - long chained molecules
  - contact force
  - electron sharing
  - electron transfer
  - polymers
  - network material

- surface tension
- synthetic polymer
- monomer
- reactivity
- intermolecular forces
- charge
- conductor
- electric charge
- insulator
- permanent magnet
- polarity
- resistance
- charged particle
- ionic bond
- covalent bond
- hydrogen bond
- ductile
- malleable
- friction

- Vocabulary that should not be used in assessment items:
  - electric potential
  - electromotive force
  - permeating
  - quantum property
  - Laplace force
  - electrodynamics
  - magnetic dipole
  - electrostatic
  - general relativity
  - Ampere's Law
  - Coulomb force
  - Lorentz force
  - Van der Waals forces
  - organic molecules

Phenomena

- Zinc oxide was dissolved in water and the resulting solution was very difficult to stir. Upon the addition of a clear, amber colored liquid, the solution became much thinner and easier to stir.

- Water was spilled on two shirts. One shirt absorbed the water very quickly, leaving a large wet spot. On the other shirt, the water formed tiny spheres and bounced off, leaving the shirt dry.
- A sample of cotton fabric was dyed with two different kinds of dye and then was washed several times to determine how well the dye stayed in the fabric. One dye faded over time, the other did not.
- Food cooked in a bronze-colored pot cooked quickly and evenly. Food cooked in a silver-colored pot took longer and was not evenly cooked.

Task Demands

- Analyze and interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols, mathematical representations that provide evidence that electrostatic forces on the atomic and molecular scale result in contact forces (e.g., friction, normal forces, stickiness) on the macroscopic scale.
- Identify relationships or patterns in scientific evidence to describe how electrostatic forces are related to properties of designed materials.
- Identify and communicate evidence for how the structure and properties of matter and the types of interactions of matter at the atomic scale determine its function.
- Synthesize an explanation for the function and properties of designed materials that incorporates scientific evidence from multiple sources.
- Evaluate the validity, credibility, accuracy, relevancy and/or possible bias of scientific/technical sources.

HS-PSP-2.1 Students who demonstrate understanding can:
Create a computational model to calculate the change in 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.

Dimensions:

- **SEP:** *Using Mathematics and Computational Thinking:* Create a computational model or simulation of a phenomenon, designed device, process or system.
- **DCI:** *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 since 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.
  - 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.

- **CCC:** *Systems and System Models:* Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on explaining the meaning of mathematical expressions used in the model.

Content Limits:

- Assessment is limited to:
    - Basic algebraic expressions or computations
    - Systems of two or three components
    - Thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, and electric fields
- Students do not need to know detailed understanding of circuits or thermodynamics.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - mechanical energy
    - potential energy
    - conversion
    - kinetic energy
    - conduction
    - electrical circuit
    - electrical current
    - heat radiation
    - insulate
    - resistor
    - volt
    - amp
    - Ohm's Law
- Vocabulary that should not be used in assessment items:
    - entropy
    - second law of thermodynamics

- thermodynamics
- Stirling cycle
- Carnot cycle
- capacitor
- inductance
- inductor
- Faraday's law

Phenomena

- A block is attached to a spring and laid down on a table. The spring is stretched by pulling the block a certain distance. The spring is then released. As the block oscillates back and forth, the amplitude of each successive oscillation gets smaller until the block stops moving.
- A light bulb is hooked up to an energy source. When a resistor is added in series to the circuit, the brightness of the light bulb dims.
- Two metal pots are placed on a stove top. Pot 1 has a metal handle while Pot 2 has a rubber handle. The stove is turned on and the pots heat up. After 10 minutes, the handle on Pot 1 is much hotter than the handle on Pot 2.
- A toy truck is placed at the top of a frictionless ramp. When it travels down the ramp it collides with a stationary toy truck sitting on a horizontal surface (with friction) at the bottom of the ramp. The truck at the bottom of the ramp then begins to move.

Task Demands

- Make simple calculations using given data to calculate or estimate the amount of energy in certain components of the system.
- Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate how energy changes in one component of the system affect the energy changes in another component of the system OR how the flow of energy into and out of the system affects the energy change of each component within the system.
- Calculate or estimate properties for, or the relationships between, each component of the system based on data from one or more sources.
- Compile, from given information, the data needed for a particular inference about how energy changes in one component of the system affects the energy changes in another component of the system. This can include sorting out the relevant data from the given information.

HS-PSP-2.2 Students who demonstrate understanding can:

Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).

Dimensions:

- **SEP:** *Developing and Using Models:* Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.
- **DCI:** *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 movers across space.
- **CCC:** *Energy and Matter:* Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.

Further Explanation and Content Limit:

Further Explanation:

- 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
    - The energy stored between two electrically-charged plates
- Examples of models could include diagrams, drawings, descriptions, and computer simulations

Content Limits:

- Students do not need to know:
    - Thermodynamics in detail
    - Gravitational fields
    - Thermonuclear fusion

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - mechanical energy
    - potential energy
    - kinetic energy

- electric field
- magnetic field
- molecular energy
- heat conduction
- circuit
- current
- heat radiation
- work

- Vocabulary that should not be used in assessment items:
  - entropy
  - Second Law of Thermodynamics
  - thermodynamics
  - root mean velocity
  - Boltzmann's constant
  - gravitational fields
  - fusion
  - fission

Phenomena

- Two electrically charged plates, one with a positive charge and one with a negative charge, are placed a certain distance apart. Electron 1 is placed in the middle of the two plates. It accelerates to the positive plate and hits it with a certain velocity. Electron 2 is then placed closer to the negative plate. This electron gains more speed before reaching the positive plate.
- A gas is placed inside a container and sealed with a piston. The outside of the container is heated up. The piston begins to move upwards.
- A person rubs their hands together. Afterwards their hands feel warm.
- A block is attached to a spring and placed on a horizontal table. When the spring is un-stretched, the spring and block do not move. When the spring is stretched to a certain distance (x), the block oscillates back and forth.

Task Demands

- Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include equations used to calculate energy or objects used to set up the experimental model. The model can be a conceptual model (flow chart).
- Manipulate the components of a model to demonstrate how energy at the macroscopic scale can be accounted for as a combination of energy associated with the workings of particles at the microscopic scale, result in the observation of the phenomenon.

- Make predictions about the effects of changes in the motion or relative position of objects in the model. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
- Identify missing components, relationships, or other limitations of the model showing how energy at the macroscopic scale is affected by the motion and positioning of particles at the microscopic scale.
- Describe, select, or identify the relationships among components of a model that describes, or explains, how energy is related to the motion and relative position of objects.

HS-PSP-2.3 Students who demonstrate understanding can:
Design, build and refine a device that works within given constraints to convert one form of energy into another form of energy.

Dimensions:

- **SEP:** *Constructing Explanations and Designing Solutions:* Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.
- **DCI:** *Energy:*
    - At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light and thermal energy.
    - Although energy cannot be destroyed, it can be converted to less useful forms – For example, to thermal energy in the surrounding environment.
    - 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)*
- **CCC:** *Energy and Matter:* Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on both qualitative and quantitative evaluations of devices.
- Examples of constraints could include use of renewable energy forms and efficiency.
- Examples of devices could include, but are not limited to:
    - Rube Goldberg devices
    - Wind Turbines
    - Solar cells
    - Solar ovens
    - Generators

Content Limits:

- Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - electric current
    - electrical energy
    - electromagnet
    - magnetic field
    - electric field
    - mechanical energy
    - renewable energy
    - generator
    - wind turbine
    - Rube Goldberg Device
    - solar cell
    - solar oven
- Vocabulary that should not be used in assessment items:
    - torque
    - entropy
    - molecular energy
    - second law of thermodynamics
    - thermodynamics
    - thermal equilibrium
    - Stirling engine

Phenomena

- Engineering standards are built around meaningful design problems rather than phenomena. For this performance expectation, the design problem and solutions replace phenomena:
    - Use an engine to generate light from an LED.
    - Refine a Stirling Engine to make it run for over 30mins.
    - Create a solar oven that will cook an egg in 10mins.
    - Refine a solar cell such that it maximizes energy output.

Task Demands

- Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
- Express or complete a causal chain explaining how the device converts one form of energy into another form of energy. This may include indicating directions of causality in

an incomplete model such as a flow chart or diagram or completing cause and effect chains.

- Using the given information, select or identify constraints that the energy converting device or solution must meet.
- Identify evidence supporting the inference of causation that is expressed in a causal chain.
- Using given data, propose, illustrate, or assemble a potential energy converting device (prototype) or solution.
- Using a simulator, test a proposed energy converting prototype and evaluate the outcomes, potentially including proposing and testing modifications to the prototype.

HS-PSP-2.4 Students who demonstrate understanding can:
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).

Dimensions:

- **SEP:** *Planning and Carrying Out Investigations:* Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
- **DCI:** *Energy:*
  - 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).
- **CCC:** *Systems and System Models:* When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits:

- Assessment is limited to investigations based on materials and tools provided to students.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - specific heat
    - specific heat capacity
    - kinetic energy
    - microscopic scale
    - macroscopic scale
    - molecular energy
    - heat conduction
    - heat radiation
    - Kelvin
    - Joules
    - calorimetry
- Vocabulary that should not be used in assessment items:
    - entropy
    - root mean velocity
    - Boltzmann's constant
    - gravitational fields
    - fusion
    - fission

Phenomena

- The temperature of a can of soda decreases when the can is placed in a container of ice.
- Hot coffee cools down after cold cream is added to the cup.
- A scoop of ice cream begins to melt when added to cold soda in a glass.
- A foam cup has 200 grams of room temperature water after 100 grams of hot water are mixed with 100 grams of cold water.

Task Demands

- Identify, make, plan, and/or record observations/outcome data concerning changes in substances' properties in order to provide evidence of transfer of thermal energy within a closed system.
- Organize, arrange, and/or generate/construct graphs, flowcharts, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations among observations and data concerning transfer of thermal energy within a closed system, and/or the boundaries of a closed system in which thermal energy is transferred.

- Describe, analyze, and/or summarize data (e.g., using illustrations and/or labels), to identify/highlight trends, perform calculations and other mathematical analyses, and identify patterns or correlations among observations and data concerning the transfer of thermal energy within a closed system.
- Use evidence to identify the boundaries of a closed system in which thermal energy is transferred.
- Identify patterns or evidence in the data that support inferences related to the transfer of thermal energy within a closed system.

HS-PSP-2.5 Students who demonstrate understanding can:
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.

Dimensions:

- **SEP:** *Developing and Using Models:* Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.
- **DCI:** *Energy:*
    - When two objects interacting through a field change relative position, the energy stored in the field is changed.
- **CCC:** *Cause and Effect:* Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits:

- Assessment is limited to systems containing two objects.
- Students do not need to know Gauss' Law, Ampere's Law, Faraday's Law, or anything that requires in-depth knowledge of the electromagnetism as a unified force.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - electric current
    - acceleration
    - net force
    - Newton's second law of motion
    - inertia

- velocity
- magnet
- electrical energy
- magnetic force
- attraction
- repulsion
- electromagnet
- Coulomb’s law
- electric/magnetic field
- potential energy
- kinetic energy

- Vocabulary that should not be used in assessment items:
    - semiconductor
    - superconductor
    - torque
    - Gauss’ Law
    - Ampere’s Law
    - Lorentz force
    - Faraday’s Law
    - Lenz’s Law

Phenomena

- Two magnets are held close together such that they attract each other. When the magnets are further away from each other it is easier to keep them apart.
- A light bulb connected to a circuit with a battery lights up. When a stronger battery is placed in the circuit, the light bulb becomes brighter.
- A magnet rotates when placed in a magnetic field perpendicular to the magnet. When the magnet is brought close to the source of the magnetic field, it rotates faster.
- A water molecule is placed in an electric field. After it is released, it begins to rotate. After it rotates 90 degrees, it stops rotating.

Task Demands

- Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon.
- Assemble or complete, from a collection of potential model components, an illustration or flow chart that can represent how the forces between the objects and the energy of each object change. This <u>does not</u> include labeling an existing diagram.
- Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.
- Make predictions about the effects of changes in orientation of objects, distance between objects or size of magnetic and electric charges on the forces between objects

and the energy of each object. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
- Describe, select, or identify the relationships among components of a model that describe or explains the behavior of electric and magnetic fields and/or how that affects the forces between objects and the energy of the objects.
- Identify missing components, relationships, or other limitations of the model.

HS-PSP-3.1 Students who demonstrate understanding can:
Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

Dimensions:

- **SEP:** *Using Mathematics and Computational Thinking:* Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.
- **DCI:** *Waves:*
    - The wavelength and frequency of a wave are related to each other by the speed of travel of the wave, which depends on the type of wave and the media through which it is passing.
- **CCC:** *Cause and Effect:* Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.

Further Explanation and Content Limit:

Further Explanation:

- 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 Earth.

Content Limits:

- Assessment is limited to algebraic relationships and describing those relationships qualitatively.
- Students are not expected to produce equations from memory, like Snell's Law, but the concepts and relationships should be assessed.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - simple wave
    - vacuum
    - electromagnetic radiation
    - radiation
    - wave source
    - index of refraction

  - Snell’s Law
  - angle of incidence
  - angle of reflection
  - normal at the point of incidence
  - critical angle
  - interface
- Vocabulary that should not be used in assessment items:
  - Clausius–Mossotti relation
  - dielectric constant
  - Fermat’s principle
  - phase velocity
  - permittivity
  - permeability

Phenomena

- A person uses their car horn to attract the attention of their friend who is swimming in a pool a short distance away. The friend hears only muffled noises.
- A person opens their curtains so that the sun shines in the window. A diamond in their necklace begins to sparkle brightly.
- An earthquake occurs in Japan. The vibrations are recorded in Brazil, but not in Miami.
- A person sees a fish through the glass wall of a rectangular fish tank. The person moves and looks through the end of the tank. The fish appears to be in a different place.

Task Demands

- Make calculations using given data to calculate or estimate relationships among the frequency, wavelength, speed of waves, and the media that they travel in.
- Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate relationships among the frequency, wavelength, speed of waves, and the media that they travel in.
- Calculate or estimate properties or relationships among the frequency, wavelength, and speed of waves in various media based on data from one or more sources.
- Compile, from given information, the data needed for a particular inference about a relationship among the frequency, wavelength, speed of waves, and the media they travel in. This can include sorting out the relevant data from the given information.
- Use quantitative or abstract reasoning to support a claim/explanation about a particular relationship between the velocity, wavelength, and frequency.

HS-PSP-3.2 Students who demonstrate understanding can:
Evaluate questions about the advantages of using a digital transmission and storage of information.

Dimensions:

- **SEP:** *Asking Questions and Defining Problems:* Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.
- **DCI:** *Waves:*
  - 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.
- **CCC:** *Stability and Change:* Systems can be designed for greater or lesser stability.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits:

- Assessment does not include the specific mechanism of any given device.

Science Vocabulary

- Vocabulary that may be used in assessment items:
  - wave pulse
  - Wi-Fi device
  - binary
  - capacity
  - civilization
  - interdependence
  - degradation
  - emit
  - pixel
  - suitability
  - performance
  - analog
  - digital
  - progress
  - vacuum
  - electromagnetic radiation
  - computer
  - machine
  - radio wave
  - USB
  - bit

- byte
- discrete vs. continuous
- decode
- encode

- Vocabulary that should not be used in assessment items:
  - analog jack
  - HDMI
  - router
  - impedance
  - granularity
  - bandwidth

Phenomena

- A person uses e-mail to back up all of their personal data.
- A person is reading some science papers that were written in 1905 and wonders how people got so much great research done before the internet was invented.
- One day in June 2009 a person noticed that their old analog television stopped broadcasting their favorite television channel.
- A person stays in constant contact with all of their friends and relatives using their cell phone.

Task Demands

- Identify or construct an empirically testable question(s) based on advantages and disadvantages associated with the phenomenon. In addition to other plausible distractors, distractors may include non-testable ("nonscientific") questions.
- Make and/or record observations about the factors that affect digitally stored or transmitted data.
- Assemble or complete an illustration, flow chart, or graph based on an empirically testable question that can identify clear advantages or disadvantages associated with digital transmission and storage of information in the phenomenon.
- Select or describe conclusions relevant to a question posed and supported by the data, especially inferences about causes and effects.
- Make predictions about the phenomenon derived from the questions. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors. Predict outcomes when properties are changed, given the inferred cause and effect relationships.
- Compile, from given information, the data needed for a particular inference about the advantages/disadvantages. This can include sorting out the relevant data from the given information.

HS-PSP-2.2 Students who demonstrate understanding can:
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.

Dimensions:

- **SEP:** *Engaging in Argument from Evidence:* Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- **DCI:** *Waves:*
    - Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of waves), but they emerge unaffected by each other. (*Boundary: the discussion at this grade level is qualitative only; it can be because two different sounds can pass a location in different directions without getting mixed up*).
    - 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.
- **CCC:** *Systems and System Models:* Models (e.g., physical, mathematical and computer models) can be used to simulate systems and interactions – including energy, matter, and information flows – within and between systems at different scales.

Further Explanation and Content Limit:

Further Explanation:

- Emphasis is on how experimental evidence supports the claim and how a theory is generally modified due to new evidence. Assessment should only test the qualitative aspect of the wave model vs. particle model.
- Examples of a phenomenon could include:
    - Resonance
    - Interference
    - Diffraction
    - Photoelectric Effect

Content Limits:

- Assessment does not include using Quantum Theory.
- Assessment does not include in-depth calculations
- Students do not need to know specific types of electromagnetic radiation and their wavelengths/frequencies

Science Vocabulary

- Vocabulary that may be used in assessment items:

    - interference
    - diffraction
    - refraction
    - photoelectric effect
    - emission
    - absorption
    - brightness
    - resonance
    - transmission
    - visible light
    - transverse wave
- Vocabulary that should not be used in assessment items:
    - Doppler effect for light (redshift)
    - microwave radiation
    - ultraviolet radiation
    - ionize
    - infrared radiation
    - wave-particle duality
    - quantum
    - quanta
    - X-ray
    - gamma rays
    - radio waves
    - oscillations
    - electrostatic induction
    - Planck's equation
    - Planck's constant
    - magnetic dipole
    - electric dipole

Phenomena

- When light hits a metal, a stream of electrons is ejected from the metal. When the color of the light pointed at the metal changes, the kinetic energy of the stream of electrons changes.
- Light is made to pass through two small slits on a piece of dark construction paper. The light that goes through the slits is then projected on a second piece of dark construction paper. A pattern of bright and dark bands is seen on the second piece of dark construction paper.
- The emission spectra of Hydrogen is completely black but for 4 discrete lines violet, blue, green and red color.

- A red laser is pointed at a glass prism. The light bends as it goes through the prism. A violet laser is then pointed at the glass prism and the light bends more than the light from the red laser.

Task Demands

- Based on the provided data or information, identify the explanation that describes light behaves like a particle and or behaves like a wave.
- Identify and/or explain the claims, evidence, and reasoning supporting the explanation that light can behave like a particle or a wave, and why certain evidence is best explained by only one of these models.
- Identify and/or describe additional relevant evidence not provided that would support or clarify the explanation of how light can behave like a particle or a wave.
- Evaluate the strengths and weaknesses of a claim to explain which pieces of evidence support the fact that light behaves as a particle or a wave.
- Analyze and/or interpret evidence and its ability to support the explanation that light can behave as both a wave and a particle.
- Provide and/or evaluate reasoning to support the explanation that light can behave as both a wave and a particle and that some evidence is only supported by one of the models.

HS-PSP-3.4 Students who demonstrate understanding can:
Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.

Dimensions:

- **SEP:** *Obtaining, Evaluating, and Communicating Information:* Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible.
- **DCI:** *Waves:*
  - 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.
- **CCC:** *Cause and Effect:* Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

Further Explanation and Content Limit:

Further Explanation:

- 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.

Content Limits: Assessment is limited to qualitative descriptions.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - interference
    - diffraction
    - refraction
    - photoelectric effect
    - emission
    - absorption
    - brightness
    - resonance
    - photon
    - visible light
    - transverse wave
    - phase
    - transparent
    - light scattering
    - light transmission
    - radio wave
    - visible light
    - electric potential
    - gamma ray
    - infrared radiation
    - ionize
    - microwave
    - ohm
    - photoelectric
    - ultraviolet
- Vocabulary that should not be used in assessment items:
    - Doppler effect for light (redshift)
    - microwave radiation
    - ultraviolet radiation
    - infrared radiation
    - wave-particle duality
    - quantum
    - quanta
    - X-ray

- gamma rays
- oscillations
- electrostatic induction
- Planck's equation
- Planck's constant
- magnetic dipole
- electric dipole

Phenomena

- A student places a glass bowl filled with soup in a microwave. After a minute in the microwave, the soup is hotter than the glass bowl.
- A lit candle is placed at one end of a tube filled with carbon dioxide. A student standing at the other end of the tube can see the candle's flame. When looking through a monitor that looks at the infrared radiation emitted by the flame, the student can no longer see the candle's flame.
- Astronauts aboard the International Space Station are exposed to a different amount of ultraviolet radiation from the sun than humans on Earth.
- In 2020, NASA is sending a rover to Mars with multiple materials on it in order to test whether or not they can be used as space suits for future Mars travelers. Ortho Fabric was chosen to be sent on the mission, while Spectra was not.

Task Demands

- Analyze and/or interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols, mathematical representations that provide evidence of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
- Identify relationships or patterns in scientific evidence to describe how different frequencies of electromagnetic radiation affect matter when absorbed.
- Illustrate, graph, or identify relevant features or data that can be used to communicate information about the effect that different frequencies of electromagnetic radiation have on matter when it is absorbed.
- Synthesize an explanation for the effects of electromagnetic radiation on matter when absorbed that incorporates scientific evidence from multiple sources.
- Evaluate the validity, credibility, accuracy, relevancy and/or possible bias of scientific/technical sources.
- Identify the cause-and-effect reasoning in a claim from the sources, including the extrapolations to larger scales from cause and effect relationships of mechanisms at small scales (e.g. extrapolating from the effect of a particular wavelength of radiation on a single cell to the effect of that wavelength on the entire organism).

HS-PSP-3.5 Students who demonstrate understanding can:
Communicate technical information about how some technological devices use the principles of wave behavior and wave interaction with matter to transmit and capture information and energy.

Dimensions:

- **SEP:** *Obtaining, Evaluating, and Communicating Information:* 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).
- **DCI:** *Waves:*
    - Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. *(secondary)*.
    - Information can be digitalized (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.
    - Photoelectric materials emit electrons when they absorb light of a high enough frequency.
    - 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.
- **CCC:** *Cause and Effect:* Systems can be designed to cause a desired effect.

Further Explanation and Content Limit:

Further Explanation:

- Examples could include solar cells capturing light and converting it to electricity, medical imaging, and communications technology.

Content Limits:

- Assessments are limited to qualitative information.
- Assessment does not include band theory.

Science Vocabulary

- Vocabulary that may be used in assessment items:
    - refraction
    - reflection
    - infrared
    - electromagnetic spectrum
    - constructive wave
    - destructive wave

- restoring
- periodic motion
- mechanical wave
- interference
- velocity
- diffraction
- standing wave
- nodes
- angle of incidence
- rarefaction
- superposition
- medium
- longitudinal wave
- transverse wave
- standing wave
- ultrasound
- dispersion
- intensity
- prism
- resonance
- radar
- sonar
- virtual image
- real image

- Vocabulary that should not be used in assessment items:
    - constructive interference
    - destructive interference
    - light ray
    - total internal reflection

Phenomena

Engineering Standards are built around meaningful design problems rather than phenomena. For this performance expectation, the design problem and solutions replace phenomena.

- When using light detection and ranging (LiDAR) over a forested area the light reflects off multiple surfaces and affects the accuracy of elevation models.
- Solar cells only capture about 20% of the energy from the sun.
- Marine radar is mounted to the front of ships used for collision avoidance. Occasionally the radar can distort the coastline and report a straight coastline when it is curved.
- Water reflects radar, blanking out entire regions of radar screens.

Task Demands

- Select or identify from a collection of potential model components, including distractors, Analyze and interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols, mathematical representations that provide evidence of how devices use wave behavior, the absorption of photons, and the production of electrons to solve problems.
- Identify relationships or patterns in scientific evidence to describe how waves are used to produce, transmit, and capture signals in electronic devices.
- Illustrate, graph, or identify relevant features or data that can be used to communicate wave information.
- Synthesize an explanation for the function and properties of designed materials that incorporates scientific evidence from multiple sources.
- Evaluate the validity, credibility, accuracy, relevancy and/or possible bias of scientific/technical sources.