CONNECTICUT TECHNICAL EDUCATION AND CAREER SYSTEM

Grade 9

General Science Curriculum

SC115 and SC116 (Honors)

Connecticut Technical High School System
39 Woodland Street
Hartford, Connecticut 06105

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CTECS - Vision of a Graduate

The Vision of a Graduate (VoG) at the Connecticut Technical Education and Career System (CTECS) embodies our commitment to preparing students for success in Connecticut's workforce.

Developed in collaboration with students, parents, staff, and employers, the VoG ensures that CTECS students are not only job-ready but also equipped to lead, innovate, and adapt in a dynamic world.

As educators, we are dedicated to developing these qualities by providing a comprehensive education that empowers our students to achieve their fullest potential and make meaningful contributions to society.

A Problem Solver

Problem solvers tackle challenges by identifying root causes of issues, brainstorming solutions, implementing effective strategies, and demonstrating adaptability.

- ➔ Engage students with open-ended, creative thinking tasks that require both conventional and innovative solutions.
- ➔ Facilitate group discussions and collaborative projects.
- ➔ Use real-world scenarios and hands-on activities.
- ➔ Highlight the importance of effort, persistence, and continuous learning.
- ➔ Provide regular feedback and encourage reflection.

Work Ready

To be work-ready includes a combination of technical expertise, soft skills, and personal qualities that ensure a graduate can effectively contribute to the workplace from day one.

- ➔ Set high standards for punctuality, responsibility, professionalism, and task completion.
- ➔ Use project-based learning and collaborative assignments.
- ➔ Emphasize clear written and verbal communication.
- ➔ Offer practical exercises like mock interviews and resume workshops.
- ➔ Integrate technology and teach digital literacy.

Respectful

Graduates who embody respectfulness emphasize the importance of treating others with dignity, valuing diversity, and fostering an inclusive and positive environment, both personally and professionally.

- ➔ Demonstrate personal, interpersonal, and professional skills.
- ➔ Show respect for diversity.
- ➔ Model respect through active listening and empathy.
- ➔ Set clear expectations for respectful interactions.
- ➔ Promote collaboration and group discussions.
- ➔ Celebrate respectful behavior.
- ➔ Address disrespect promptly and constructively.

Skilled Socially

Graduates who are skilled socially are equipped to navigate social environments, build relationships, and contribute positively to their communities and workplaces.

- ➔ Show awareness of global responsibility to others and the environment.
- ➔ Participate in community involvement.
- ➔ Design cooperative group projects and team activities
- ➔ Set expectations for respect and give regular feedback.
- ➔ Facilitate discussions on inclusivity, kindness, and respect.
- ➔ Model positive interactions and recognize strong social skills.

A Critical Thinker

Critical thinkers approach problems systematically by analyzing, evaluating, and synthesizing information to make well-informed decisions and contribute to innovative solutions.

- ➔ Encourage critical thinking individually and collaboratively.
- ➔ Design lessons that challenge assumptions and explore diverse viewpoints.
- ➔ Use open-ended questions, rigorous activities, and cross-curricular projects.
- ➔ Integrate project-based learning and real-world problem-solving.
- ➔ Offer reflective opportunities like journaling and discussions.
- ➔ Cultivate an environment that values curiosity and inquiry.

An Effective Communicator

Effective communicators convey ideas, information, and emotions accurately and persuasively, fostering understanding and collaboration.

- ➔ Communicate effectively using oral, written, visual, artistic, and technical modes.
- ➔ Include group discussions, presentations, and peer reviews.
- ➔ Promote active listening and thoughtful responses.
- ➔ Offer clear guidelines and constructive feedback.
- ➔ Stress clear, respectful, and purposeful communication.

CTECS Instructional Model

CTECS uses the Marzano Compendium to guide research-based instructional strategies that differentiate learning and promote access, engagement, and success for all students. Teachers apply these strategies to support diverse learners (including multilingual learners, students with disabilities, and students with varied academic or technical backgrounds) through scaffolds, modeling, guided practice, and multiple ways to participate and show understanding. This approach ensures every student can work toward proficiency in the Priority Standards and the competencies outlined in the CTECS Vision of a Graduate.

Curriculum Introduction

This curriculum document outlines the essential learning for this academic program and provides a clear structure for planning, instruction, and assessment. It includes the components required by NEASC Standard 2.2a, along with elements that reflect the unique nature of CTECS academic programs. The curriculum is organized to show what students learn in each course, how learning progresses across grade levels, and how instruction supports both technical skill development and the CTECS Vision of a Graduate.

Teachers should use this document to:

- Understand the overall structure and expectations of the course sequence
- Reference the Course Map to see the scope and sequence of Priority Standards
- Use the Priority Standards and Units of Study to guide daily, weekly, and cycle-based planning
- Integrate Big Ideas, Essential Questions, Skills/Learning Outcomes, vocabulary, and resources during lesson design
- Plan and implement formative assessments to monitor progress and guide instruction
- Prepare students for the District Summative Assessments, ensuring alignment with the Course Map
- Maintain consistency of instruction across campuses while adapting to student needs

Curriculum Components

Course Map

A Course Map serves as the scope and sequence for this course by outlining the progression of instructional units and the standards that guide teaching and assessment. While each campus will have individual student needs, cycle schedules, and industry-based opportunities, all instructors are expected to teach the standards outlined in the Course Map. Using the Course Map below, teachers will intentionally plan learning experiences that prepare students to meet the identified standards within the designated assessment windows.

Priority Standards (Units of Study)

Priority Standards identify the most essential learning in the trade program. They reflect the core technical competencies, safety practices, and industry-aligned skills that require the greatest instructional focus and appear on program assessments. In CTE programs, each Priority Standard also functions as a Unit of Study, because it includes the required components such as big ideas, essential questions, content topics, and skills/learning outcomes aligned to assessments.

Learning Outcomes

Learning outcomes are what students will know (Concepts) and be able to do (Skills).
Concepts identify the major content topics within the Priority Standard (Unit of Study). They appear in the left column of the Learning Outcomes table and follow a similar coding structure as the Priority Standard. Skills are learning objectives that describe the measurable actions students must be able to perform to demonstrate proficiency. They appear in the right column of the Learning Outcomes table and show the progression of learning evidence in the Priority Standard.

Resources

Resources include the tools, equipment, texts, materials, and digital tools that support learning within each unit and reflect industry standards.

Assessment Practices

Teachers use ongoing formative assessments—such as questioning, checks for understanding, performance demonstrations, reflections, and teacher observation—to monitor progress, guide instruction, and support all learners in mastering the Priority Standards.

Vocabulary

Essential vocabulary includes the technical and academic terms students must understand and use accurately to engage in scientific learning and demonstrate proficiency on assessments. Vocabulary is foundational to safety, precision, and communication, and should be a primary initial focus within each unit and taught explicitly through modeling, demonstration, and repeated application.

General Science - Grade 9

Description of the Course

(1 credit) General Science is designed to help students develop an interest in global issues and learn how to collect, analyze, and use data to explore and explain related scientific concepts. Based on the Next Generation Science Standards (NGSS), the course is made up of four related disciplines: Earth and Space Science; Physical Sciences; Life Sciences; and Engineering, Technology, and Applications of Science. This framework articulates the standards as well as the science and engineering performances, disciplinary core ideas, and crosscutting concepts. The curriculum describes the specific performances that will be assessed on the Next Generation Science Assessment.

General Science with Honors is an accelerated course. Students are expected to complete several inquiry-based projects over the course of the year, in addition to meeting additional, more challenging objectives. **Additional performance expectations for honors students are listed as Unit 4 in the curriculum map. These performance expectations may also be integrated into the regular curriculum as appropriate.**

CTECS Science Assessment & Instruction Guidelines

The grade-level **SEP (Science and Engineering Practices) Summative Assessments** for grades 9 through 11 and the **Basic Skills Assessment** for grade 12 are designed to measure mastery of the *science and engineering practices* identified by the NGSS (Next Generation and Science Standards). The practices describe behaviors that scientists engage in as they investigate and build models and theories about the natural world and the key set of engineering practices that engineers use as they design and build models and systems.

The SEPs are:

- **Asking Questions and Defining Problems**: A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested.
- **Developing and Using Models**: A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.
- **Planning and Carrying Out Investigations**: Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.
- **Analyzing and Interpreting Data**: Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.
- **Using Mathematics and Computational Thinking**: In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are

used for a range of tasks such as constructing simulations; statistically analyzing data; and recognizing, expressing, and applying quantitative relationships.

- **Constructing Explanations and Designing Solutions**: The products of science are explanations and the products of engineering are solutions.
- **Engaging in Argument from Evidence**: Argumentation is the process by which explanations and solutions are reached.
- **Obtaining, and Evaluating, and Communicating Information**: Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity.

Each grade-level SEP Summative Assessment is designed to assess mastery of specific **practices**. The expectation is that students should demonstrate mastery as outlined below in preparation for the NGSS Assessment in 11th grade. Cross-cutting concepts are incorporated across all courses.

Grade Level	**Science Engineering and Practices (SEP) to be Mastered**
9 General Science	Asking Questions and Defining Problems
	Planning and Carrying Out Investigations
	Analyzing and Interpreting Data
10 Biology	Developing and Using Models
	Engaging in Argument from Evidence
	Obtaining, Evaluating, and Communicating Information
11 Chemistry Advanced Topics Physics	Using Mathematics and Computational Thinking
	Constructing Explanations and Designing Solutions

Cross-Cutting Concepts (incorporated into all courses)
Cause and Effect
Structure and Function
Systems and System Models
Scale, Proportion, and Quantity
Stability and Change
Energy and Matter
Patterns

Instruction, Grading and Assessment Considerations

The manner and pedagogy used to teach the Disciplinary Core Ideas (DCIs) is at the discretion of the instructors. They are, however, expected to support their students in demonstrating mastery of the SEPs on the common summative assessments by the end of the course, in unit order.

Instruction:
- Keeping in mind that all DCIs should be covered by the end of the school year for each course, instructors are encouraged to engage students in learning tasks that consider relevance, interest, school trades, and available materials and supplies.
- The instructional focus should be on the SEPs and the Cross-Cutting Concepts (CCCs) as identified by the NGSS.
- Instruction can be linear or spiraling and be designed around anchoring phenomena and/or storylines.
- Interim Based Assessment:
    - 9th Grade: Students will be exposed to NGSS style questions through the NGSS Practice Assessments. Skills of focus include: Test Taking Skills, Navigating Multi Select Questions, Desmos Calculator, Highlighting, Online Graphing
    - Minimum of 4 IAB practice sessions during Freshman year.

Grading:
- As mandated by the District, Mandated Grading Categories are:
    - Assessment 40%
    - Labs/Projects 30%
    - Classwork/Activities 30%

Assessment: (Summative and Formative)
- Three dimensional district wide unit assessments will measure mastery of Science and Engineering Practices in Alignment with Cross Cutting Concepts (CCCs) and Disciplinary Core Ideas (DCIs).
- Claim Evidence Reasoning: CERs will measure a student's ability to use data, critical thinking, and scientific reasoning to form and support an argument.

Supporting ELs: For information on how to support English Learners in this unit, refer to the Connecticut English Language Proficiency (CELP) Standards with Correspondences to the K-12 Practices and Connecticut Core Standards. https://portal.ct.gov/-/media/SDE/English-Learners/celp_standards_content_standards_practices.pdf
Use the EL Strategies Desk Cards (Tip Sheets for ALL Classroom Teachers) https://www.crec.org/docs/4339/RESC_Alli-ance_Desk_Cards_Revised_2.pdf for specific questioning techniques and teaching strategies to sup-port students' learning.

Course Map - 9th Grade General Science

Unit	Cycles	Big Ideas	Standards	Interim Assessments
Unit 1: Earth's History and Interior	**1-3** **H: 4-5**	**Big Idea(s):** The Earth is a System of Systems. Physical and chemical principles are unchanging and drive both gradual and rapid changes in the Earth system.	**HS-ESS1-6** (Earth's Formation and Early History) **HS-ESS1-5** (Movement of Earth's Crust) **HS-ESS2-1** (Earth's Processes)	**HS-ESS1-6A** **HS-ESS1-6B**
Unit 2: Earth's Surface and Processes	**4-7** **H: 6-8**	**Big Idea(s):** The Flow of Energy Drives the Cycling of Matter. Physical and chemical principles are unchanging and drive both gradual and rapid changes in the Earth system.	**HS-ESS2-2** (Analyze GeoScience data) **HS-ESS2-3** (Develop a model to describe Earth's interior) ○ *HS-ESS2-4* (Variations in flow of energy result in changes in climate) **HS-ESS2-5** (Investigate properties of water and its effect on Earth's materials and surface processes) ○ *HS-ESS2-6* (Cycling of carbon among the biogeosphere) ○ *HS-ESS2-7* (Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.)	**HS-ESS2-3** **HS-ESS2-4** **HS-ESS2-6** **HS-ESS2-7**

Unit 3: Sustainability	**8-10** **H: 9-10**	**Big Idea(s):** Life influences and is influenced by the environment.	HS-ESS3-1 (Explain how natural resource availability changes) ○ *HS-ESS3-2* (Evaluate competing design solutions based on cost-benefit ratios) ○ *HS-ESS3-3* (Illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity) HS-ESS3-4 (Technology design for reducing human impact to natural resources) HS-ESS3-5 (Forecast rate of global climate change) ○ *HS-ESS3-6* (Relationships among Earth systems and how those relationships are being modified due to human activity)	**HS-ESS3-3** **HS-ESS3-4A** **HS-ESS3-4B** **HS-ESS3-5**
Unit 4: Big Bang (honors only)	**H: 1-3**	**Big Idea(s):** The universe is expanding and we can understand its origins through evidence. Stars change over time and create the elements that make up the universe.	HS-ESS 1-2 (Explanation of Big Bang Theory based on multiple lines of evidence) HS-ESS 1-3 (Communicate scientific ideas about the way stars, over their life cycle, produce elements) HS-ESS 1-1 (Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy in the form of radiation)	**HS-ESS1-2** **HS-ESS1-3** **HS-ESS1-1**

Unit 1: Earth's History and Interior

Earth's History

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Priority Standard (Performance Expectation): HS-ESS1-6 Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.
Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.
Big Idea(s): Active geological processes like plate tectonics have altered Earth's early rock record; objects like lunar rocks and asteroids are vital for understanding Earth's formation. Earth is a 'recycling' planet that erases its own history; to understand our origins, we must look to the 'witnesses' in the solar system.
Essential Question(s): ● If Earth is constantly destroying its oldest rocks, how can we be sure of its age? ● How does Earth's formation and early history impact biological and geological components over time?
Examples of Engaging Phenomenon: ● 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. ● Ann Hodges has the distinction of being the only human to have been hit by a meteorite. While Mrs. She was able to walk away from the incident. Scientists can learn about the composition of the early solar system and the formation of the Earth by studying these primordial objects orbiting in space.   ○ HS-ESS1-6: Evidence of the Earth's History

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
<u>The History of Planet Earth</u> ● 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. <u>Nuclear Processes</u> ● 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.	**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. ● 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.

<u>Cross-Cutting Concepts:</u> Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable.

<u>Academic Vocabulary:</u>

- Science vocabulary students ARE expected to know:
    - Plate tectonics, radiometric dating, isotope, continental crust, oceanic crust, lithosphere, asthenosphere, cycle, bedrock, ocean trench, sedimentation, convection current, inner core, mantle, nuclear, ocean ridge, sea-floor spreading
- Additional tier 2 words that students should be familiar with:
    - Apply, Scientific reasoning, Evidence, Differentiation

Science vocabulary students are NOT expected to know: Nebular hypothesis, planetesimals, solar nebula, bolide impacts

<u>Resources</u>: NGSS Phenomenon Master List

Movement of Earth's Crust

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Priority Standard (Performance Expectation): HS-ESS1-5
Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.

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

Big Idea(s): The movement of tectonic plates, and resulting patterns in the age of crustal rocks, provides evidence about the history of the earth.

Essential Question(s):
- How can the age of a rock on the ocean floor prove that entire continents are moving?
- What are the implications of plate tectonics and the ages of crustal rocks for Earth's geological history and ongoing processes?

Examples of Engaging Phenomenon:
Rocks near Bildudalur Iceland were formed about 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.
- The geologic column is used to study evolution; rocks are stacked in layers containing fossils with the oldest fossils at the deepest layers.
  - HS-ESS1-5: Evidence of Plate Tectonics

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
<u>The History of Planet Earth</u> ● 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. <u>Plate Tectonics and Large Scale System Interactions</u> ● 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. <u>Nuclear Processes</u> ● Spontaneous radioactive decay follows a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.	**Engaging in Argument from Evidence** ● Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. ● 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

<u>Cross-Cutting Concepts</u>: Patterns
- Empirical evidence is needed to identify patterns.

<u>Academic Vocabulary:</u>
- Science vocabulary students ARE expected to know:
  - Convergence, divergence, sedimentary, metamorphic, igneous, volcanic, crust, mantle, core, mid-ocean ridge, trench
- Additional tier 2 words that students should be familiar with:
  - Evaluate, evidence, patterns, explain

Science vocabulary students are NOT expected to know: Isotope, anticline, syncline

<u>Resources</u>: NGSS Phenomenon Master List

Earth's Processes

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Priority Standard (Performance Expectation): ESS2-1
Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.

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

Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.

Big Idea(s): Earth is a dynamic system where the continuous exchange of energy between the molten interior and the atmospheric surface drives the constant recycling and reshaping of the lithosphere.

Essential Question(s):

- How do Earth's internal and surface processes work together to shape continental and ocean-floor features over time?
- How do the competing forces of the hot interior and the cooling surface fight to reshape the face of our planet?
- Why is Earth's internal and surface processes important for interpreting geological history and predicting future landscape changes?

Examples of Engaging Phenomenon:

- 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 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.
- HS-ESS2-1: The Creation of Landforms

<table>
<tr><th>Students will know: (Disciplinary Core Ideas)</th><th>As evidenced by: (Science & Engineering Practices)</th></tr>
<tr><td>
<u>Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.</u>

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.

The top part of the mantle, along with the crust, forms structures known as tectonic plates
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 the gravitational movement of denser materials toward the interior.

The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun’s energy output or Earth’s orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities.

These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

<u>Plate tectonics</u>
</td><td>
Developing and Using Models

Develop a model based on evidence to illustrate the relationships between systems or between components of a system.
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.
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, given models or diagrams of land features, internal and surface processes
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

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● Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. ● Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. ● 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.	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.

Cross-Cutting Concepts: 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.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
  - 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
- Additional tier 2 words that students should be familiar with:
  - Develop, Model, rate of change, quantify

Science vocabulary students are NOT expected to know: Geomorphology, anticline, syncline, monocline

Resources: NGSS Phenomenon Master List

Unit 2:Earth's Surface and Processes

Analyze GeoScience data

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Priority Standard (Performance Expectation): HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that causes changes to other Earth systems.
Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.
Big Idea(s): Earth's surface includes dynamic feedback loops between the interconnected atmosphere, hydrosphere, geosphere, and biosphere; Earth is a system of 'triggers' where a single change can set off a chain reaction across the entire planet.
Essential Question(s): ● How do changes to Earth's surface create feedback loops that impact other Earth systems? ● What happens to the rest of the Earth system when one 'loop' is broken?
Examples of Engaging Phenomenon: ● Farming causes the loss of forest 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 the 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 CO_2 in the atmosphere warms the oceans. Warmer oceans take up less CO_2 than cooler oceans, further increasing atmospheric temperature. ● The Grand Canyon is a mile-deep and was carved by the Colorado River over millions of years. This phenomenon shows how consistent weathering and erosion over a long period of time can radically shape the earth. ● HS-ESS2-2: Feedback in Earth's Systems

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
<u>Earth Materials and Systems</u> • Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. <u>Weather and Climate</u> • The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's reradiation into space. • Climate change can occur when certain parts of Earth's systems are altered. • Geological evidence indicates that past climate changes were either sudden changes caused by alterations in the atmosphere; longer term changes (e.g., ice ages) due to variations in solar output, Earth's orbit, or the orientation of its axis; or even more gradual atmospheric changes due to plants and other organisms that captured carbon dioxide and released oxygen. • The time scales of these changes varied from a few to millions of years. Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.	**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 solution. • 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 feedback 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 feedback that affect Earth's systems. This may include sorting out distractors. • Predict how changing the Earth's surfaces affects the feedback loop, using relationships identified in the data. • 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.

<u>Cross-Cutting Concepts</u>: Stability and Change

- Feedback (negative or positive) can stabilize or destabilize a system

<u>Academic Vocabulary:</u>

- Science vocabulary students ARE expected to know:
  - Ocean circulation, biosphere, feedback effect, atmospheric circulation, convection cycle, greenhouse gas, geoscience, sea level, mean surface temperature, methane
- Additional tier 2 words that students should be familiar with:
  - Analyze, Claim, Interconnected, Data interpretation, Causal relationship, Data analysis techniques, Long-term sustainability

Science vocabulary students are NOT expected to know: Electromagnetic radiation, probabilistic, irreversible, geoengineering, ozone, pollutant, acidification

<u>Resources</u>: NGSS Phenomenon Master List

Develop a model to describe Earth's interior

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Priority Standard (Performance Expectation): HS-ESS2-3 Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.
Clarification Statement: Emphasis is on both a one dimensional model of Earth, with radial layers determined by density, and a three dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.
Big Idea(s): Heat from Earth's core creates convection currents in the mantle, driving the movement of tectonic plates and the recycling of matter.
Essential Question(s): ● How does heat deep underground dictate the movement of the ground we walk on?
Examples of Engaging Phenomenon: ● 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 mWm-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. ● The Marianas Trench is the deepest point in the ocean. This trench is formed at a subduction zone as the Pacific and Marina oceanic plates collide. This also creates the volcanic Mariana island. ● HS-ESS2-3: Cycling of Matter in the Earth's Interior

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)

<u>Earth's Materials and Systems</u> ● 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. <u>Plate Tectonics and Large-Scale System Interactions</u> ● 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. <u>Wave Properties</u> ● Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet.	**Developing and Using Models** ● Develop a model based on evidence to illustrate the relationships between systems or between components of a system. ● 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 is capable of representing 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. ● Identify, given models or diagrams of the earth's interior, 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.
<u>Cross-Cutting Concepts</u>: Energy and Matter - Energy drives the cycling of matter within and between systems.	

Academic Vocabulary:
- Science vocabulary students ARE expected to know:
    - 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
- Additional tier 2 words that students should be familiar with:
    - Develop, Model, Evidence, Density
 	
Science vocabulary students are NOT expected to know: Geoneutrino, primordial heat

Resources: NGSS Phenomenon Master List

Variations in flow of energy result in changes in climate

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Supporting Standard (Performance Expectation): HS-ESS2-4 Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate
Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition. Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.
Big Idea(s): Variations in flow of energy in the atmosphere, hydrosphere, geosphere, and biosphere can result in changes in global climate.
Essential Question(s): ● How do variations in the flow of energy into and out of Earth's systems drive changes in climate over different timescales? ● How do evidence and models support understanding the relationship between energy flow, climate change, and human activity's impacts on Earth's systems?
Examples of Engaging Phenomenon: ● Temperatures were warmer in 1990 than in the previous 5 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) ● The Dark Snow Project ● HS-ESS2-4: Energy Variation and Climate Change

<table>
<tr><th>Students will know: (Disciplinary Core Ideas)</th><th>As evidenced by: (Science & Engineering Practices)</th></tr>
<tr><td>
<u>Earth and the Solar System</u>

Cyclical changes in the shape of Earth’s orbit around the sun, together with changes in the orientation of the planet’s axis of rotation, both occurring over tens to hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth.
These phenomena cause cycles of ice ages and other gradual climate changes.

<u>Earth Materials and Systems</u>

Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth’s surface and its magnetic field
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.

<u>Tectonics Plates; Convection Currents</u>

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

<u>Weather and Climate</u>

The foundation for Earth’s global climate system is the

</td><td>
Developing and Using Models

Provide mechanistic accounts of phenomena, using a model.
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.
Identify factors, given models or diagrams of energy flow in Earth’s systems, 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.

</td></tr>
</table>

electromagnetic radiation from the sun as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems and this energy's reradiation into space. • Climate change can occur when certain parts of Earth's systems are altered. • Geological evidence indicates that past climate changes were either sudden changes caused by alterations in the atmosphere; longer term changes (e.g., ice ages) due to variations in solar output, Earth's orbit, or the orientation of its axis; or even more gradual atmospheric changes due to plants and other organisms that captured carbon dioxide and released oxygen. • The time scales of these changes varied from a few to millions of years. Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate	

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

Academic Vocabulary:
- Science Vocabulary Students ARE expected to Know:
    - Interdependence, solar radiation, solar flare, biosphere, atmospheric circulation, ocean circulation, climatic pattern, sea level, glacier, atmospheric composition, hydrosphere, greenhouse gas, fossil fuel, combustion,
- Additional tier 2 words that students should be familiar with:
    - Use, Model, Variation, cause, effect, balance, claim, evidence, cause, correlation

Science vocabulary students are NOT expected to know: Acidification, cryosphere

Resources: NGSS Phenomenon Master List

Investigate properties of water and its effect on Earth's materials and surface processes

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Supporting Standard (Performance Expectation): HS-ESS2-5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.	
Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).	
Big Idea(s): Water has unique chemical and physical properties making it a powerful agent of change of Earth's surfaces.	
Essential Question(s): ● How do the properties of water influence its interactions with Earth materials and surface processes and what evidence can be gathered to understand water's effects? ● Why is understanding the role of water in shaping Earth's surface important for understanding geological processes like erosion and weathering?	
Examples of Engaging Phenomenon: ● 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. ● Augmented Reality Sandbox; How Was The Grand Canyon Formed? ● HS-ESS2-5: Interactions of the Hydrologic and Rock Cycles	
Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
The Roles of Water in Earth's Surface Processes ● Abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics.	**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

Properties of water 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.	reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. ● 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. ● 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.

Cross-Cutting Concepts: 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.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
  - 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, adhesion, polarity.
- Additional tier 2 words that students should be familiar with:
  - Plan, Conduct, Investigation, data, evidence

Science vocabulary students are NOT expected to know:

Resources: NGSS Phenomenon Master List

Cycling of carbon among the biogeosphere

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Supporting Standard (Performance Expectation): HS-ESS2-6
Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.

Big Idea(s): The movement of carbon through the hydrosphere, atmosphere, geosphere, and biosphere is affected by biogeochemical processes and human activity.

Essential Question(s):

- How can a quantitative model be developed to describe the movement of carbon and its influence among Earth's systems?
- What key processes and components are involved in the carbon cycle across the hydrosphere, atmosphere, geosphere, and biosphere?

Examples of Engaging Phenomenon:

- 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.
- Terraforming Mars
- HS-ESS2-6: Carbon Cycling in Earth's Systems

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
Weather and Climate • Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. • Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.	**Developing and Using Models** ● Develop a model based on evidence to illustrate the relationships between systems or between components of a system. ● 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. ● 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, 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 missing components, mathematical variables, mathematical and/or quantitative relationships, or other limitations of the mathematical and/or quantitative model.

Cross-Cutting Concepts: Energy and Matter

- The total amount of energy and matter in closed systems is conserved.

Academic Vocabulary:

- Science Vocabulary Students ARE Expected to Know:
    - 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
- Additional tier 2 words that students should be familiar with:
    - Develop, Quantitative model, Cycling, Components, Processes, model, relationship, evidence

Science Vocabulary Students are NOT Expected to Know: assimilation, residence time, facies, orogenic, strata, outgassing, LeChatelier's Principle

Resources: NGSS Phenomenon Master List

Coevolution of Earth's systems and life on Earth

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Supporting Standard (Performance Expectation): HS-ESS2-7
Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.

Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.

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

Big Idea(s): Earth's abiotic and biotic factors are interconnected in ways that changes in one can influence evolution of the other.

Essential Question(s):
- How can evidence be used to construct an argument about the coevolution of Earth's systems and life on Earth
- What is the role of Earth's systems and life in influencing each other through coevolution?
- What are the implications of the simultaneous coevolution of Earth's systems and life for the planet's long-term sustainability?

Examples of Engaging Phenomenon:
- 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 Eospermatopteris.
- 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).
- Terraforming Mars

<table>
<tr><td colspan="2">HS-ESS2-7: Coevolution of Life and Earth's Systems</td></tr>
<tr><td>Students will know: (Disciplinary Core Ideas)</td><td>As evidenced by: (Science & Engineering Practices)</td></tr>
<tr><td>Weather and Climate

Scientific explanations about the composition of Earth’s atmosphere shortly after its formation
Current atmospheric composition
Evidence for the emergence of photosynthetic organisms
Evidence for the effect of the presence of free oxygen on evolution and processes in other Earth systems

Biogeology

Causal links and feedback mechanisms between changes in the biosphere and changes in Earth’s other systems.
Evolution of photosynthetic organisms led to a drastic change in Earth’s atmosphere and oceans in which the free oxygen produced caused worldwide deposition of iron oxide formations, increased weathering due to an oxidizing atmosphere and the evolution of animal life that depends on oxygen for respiration
</td>
<td>Engaging in Argument from Evidence

Construct an oral and written argument or counter-arguments based on data and evidence.
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.
</td></tr>
</table>

<u>Cross-Cutting Concepts</u>: Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable.

<u>Academic Vocabulary:</u>

- Science Vocabulary Students ARE Expected to Know:
    - 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
- Additional tier 2 words that students should be familiar with:
    - Construct, Argument, Evidence, Interactions, Interconnectedness, claim, evidence, data, change, stability

Science vocabulary students are NOT expected to know: Ecosystem services, Anthropocene, eutrophication, ecohydrology, geomorphology, heterogeneity

<u>Resources</u>: NGSS Phenomenon Master List

Unit 3: Sustainability

Explain how natural resource availability changes

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Priority Standard (Performance Expectation): HS-ESS3-1 Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.
Big Idea(s): Geological hazards, climate, and the availability of Earth's resources impact human activity.
Essential Question(s): ● How does where we live determine how we survive, and how does our survival change where we live?
Examples of Engaging Phenomenon: ● In 2001, 85% of Australians lived within 50 km of the ocean. ● There are large solar power plants in the southern California desert. California solar power had a capacity of 18,296 MW in 2016. In the same year, New York State had a capacity of 927 MW. ● As many as 1.5 million inhabitants of Dhaka, Bangladesh, have moved there from villages near the Bay of Bengal. ● After the eruption of Mt. Vesuvius in 79 AD, the city of Pompeii was completely buried in volcanic ash. The city was never reoccupied and was lost for more than 1,500 years. ● The 2010 Haiti Earthquake destroyed about 80,000 buildings and killed 316,000 people. ● HS-ESS3-1: Global Impacts on Human Activity

<table>
<tr><th>Students will know: (Disciplinary Core Ideas)</th><th>As evidenced by: (Science & Engineering Practices)</th></tr>
<tr><td><u>Natural Resources</u>
● Renewable vs. Nonrenewable resources
● Resources are not distributed equally (ex. Gold in california or oil in Middle East)
<u>Natural Hazards</u>
● Natural Hazards (volcanoes, tsunamis, severe weather, floods)
● Humans can avoid them by moving, tracking events, and satellite monitoring.
● Some are not predictable;
    ● Destroy buildings and cities
    ● Erode land
    ● These events affect population size
    ● Can be local or global
    ● Drive human migration
    ● Risks increase with bigger population size
<u>Human activity</u>
● Human activity contributes to natural hazards</td><td>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.
● 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 resource availability/natural hazards/climate change drive changes in human society/population/migration. 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.
● Predict, using an explanation, the change in human /activity given a change in resource availability/natural hazards/climate.
● Describe, identify, and/or select information and/or evidence needed to support an explanation.
● Construct an explanation based on evidence that explains that the availability of natural resources/occurrence of natural hazards/changes in climate have influenced human activity.</td></tr>
<tr><td colspan="2"><u>Cross-Cutting Concepts:</u> Cause and Effect
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
</table>

Academic Vocabulary:

- Science Vocabulary Students ARE Expected to Know:
    - Renewable, non-renewable, mitigation, economic cost.
- Additional tier 2 words that students should be familiar with:
    - Construct, Explanation, Evidence, Technological advancements, Infrastructure Advancement, Decision-making, Resource depletion, Risk assessment, Adaptation strategies

Science vocabulary students are NOT expected to know: Biome

Resources: NGSS Phenomenon Master List

Evaluate competing design solutions based on cost-benefit ratios

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Supporting Standard (Performance Expectation): HS-ESS3-2
Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.

Big Idea(s): The analysis of design solution data about the use of Earth's resources can maximize cost-benefit ratios and minimize negative human impacts.

Essential Question(s):
- How can competing design solutions for energy and mineral resource management be evaluated using cost-benefit analysis?
- What are the economic, environmental, and social impacts of different design solutions for managing energy and mineral resources?

Examples of Engaging Phenomenon:
- 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.
- Algae Fuel and Food; Earthship Living
- HS-ESS3-2: Cost-Benefit Ratio Design Solutions

<table>
<tr><th>Students will know: (Disciplinary Core Ideas)</th><th>As evidenced by: (Science & Engineering Practices)</th></tr>
<tr><td>Natural Resources
Resource availability shaped development of human society
Develop near rivers
Technology etc
<u>Humans track and adapt for hazards</u>
Tracking helps prepare how to respond
Adaptations for natural hazards
Improving construction improves mortality rates
Identifying high risk areas has the same impact
Ex. Predicting volcanic eruptions (tracking magma) but can’t track earth quakes
But can map fault lines to help future possibilities
<u>Developing Possible Solutions</u>
Factors of solutions (cost, safety, reliability, aesthetics, social - cultural and environmental impacts)
Physical and computer models aid the engineering design process.
Computer models are used for simulations</td><td>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).
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 that resources, and associated environmental risks and benefits.
Evaluate which design solution has the most preferred cost-benefit ratio, using an explanation of the design solutions for developing, managing, and utilizing energy and mineral resources.</td></tr>
<tr><td colspan="2"><u>Cross-Cutting Concepts</u>: Influence of Science, Engineering, and Technology on Society and the Natural World
Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.
Analysis of costs and benefits is a critical aspect of decisions about technology.</td></tr>
</table>

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
  - 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, sustainability
- Additional tier 2 words that students should be familiar with:
  - Evaluate, evidence, argument, competing design solutions, developing, managing/management, utilizing, ratios/analysis, production, economic costs, environmental impacts, social impacts

Science vocabulary students are NOT expected to know: Trigonometric, derivative, feedback, regulation, dynamic, aquifer, hydrothermal, geopolitical, oil shale, tar sand, urban planning, waste management, fragmentation

Resources: NGSS Phenomenon Master List

Illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity

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Supporting Standard (Performance Expectation): HS-ESS3-3 Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.
Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning. Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.
Big Idea(s): Mathematical models can identify the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.
Essential Question(s): ● How can we effectively communicate and interpret the results of the computational simulation to highlight the relationships among natural resource management, human populations, and biodiversity? ● How can a computational simulation be used to illustrate the relationships among natural resource management, human population sustainability, and biodiversity?
Examples of Engaging Phenomenon: ● 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 by174 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. ● Terraforming Mars ● HS-ESS3-3: Biodiversity, Natural Resources, and Human Sustainability ●

<table>
<tr><th>Students will know: (Disciplinary Core Ideas)</th><th>As evidenced by: (Science & Engineering Practices)</th></tr>
<tr><td><u>Human Impacts on Earth’s Systems</u>
● Management of natural resources
  ● Technology to produce less pollution and waste that lead to ecosystem degradation
  ● International agreements - lead to regulating human activities
  ● Mitigates global impacts</td><td>Using Mathematics and Computational Thinking
● Create a computational model or simulation of a phenomenon, designed device, process, or system.
● Calculate or estimate, using data, 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).
● Select or identify, using given information, the criteria against which the solution should be judged.
● Test, using a simulator, 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 or not they yield realistic results.</td></tr>
<tr><td colspan="2"><u>Cross-Cutting Concepts</u>: 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.</td></tr>
</table>

Academic Vocabulary:

- Science Vocabulary Students ARE Expected to Know:
    - 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, sustainability, conservation
- Additional tier 2 words that students should be familiar with:
    - Create, simulation, relationships, management, components, variables, computational model

Science vocabulary students are NOT expected to know: Trigonometric, derivative, feedback, regulation, dynamic, aquifer, hydrothermal, geopolitical, oil shale, tar sand, urban planning, waste management, fragmentation

Resources: NGSS Phenomenon Master List

Technology design for reducing human impact to natural resources

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Priority Standard (Performance Expectation): HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).
Big Idea(s): Innovation requires a balance; every technological 'fix' for the environment comes with its own set of trade-offs and costs.
Essential Question(s): ● How do we decide if a new technology is helping the planet or just creating a different problem? ● What criteria and evidence are used to assess the effectiveness of technological solutions in mitigating environmental impacts? ● How can we refine technological solutions based on evaluation and feedback to better reduce human impact on natural systems?
Examples of Engaging Phenomenon: ● 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. ● The Gravity Light; Earthships; Algae Fuel and Food; Precious Plastic; The Salmon Canon; The Mystery Of The Missing Bees ● HS-ESS3-4: Reducing Human Impact Design Solutions

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)

<u>Human Impacts on Earth's Systems</u>
● Management of natural resources
    ● Sustainability of human societies
● Science helps management
    ● Develop technology
    ● Helps less pollution
    ● Produce less waste
● When environmental problems are understood:
    ● International agreements can be reached
    ● Human activities can be regulated to mitigate global impacts.
<u>Developing Possible Solutions</u>
● Solution constraints (cost, safety, reliability, aesthetics, social and cultural impacts)
● Models
    ● Physical and computer models can be used in the engineering design process.
	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.
	● 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.
	● Explain the technological solution, using an explanation of the impacts of human activities on natural systems.
	● Identify or select the information needed to support an explanation of the impacts 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, using given information about the effects of human activities on natural systems.
	● 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.
	● Propose a potential solution, using given data, to resolve or improve the impact of human activities on natural systems.
	● Test, using a simulator, 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

Cross-Cutting Concepts: Stability and Change

- Feedback (negative or positive) can stabilize or destabilize a system.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
  - 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, conservation
- Additional tier 2 words that students should be familiar with:
  - Evaluate, refine, technological solution, impacts, criteria, evidence, effectiveness, design, refine, feedback

Science vocabulary students are NOT expected to know: Trigonometric, derivative, feedback, regulation, dynamic, aquifer, hydrothermal, geopolitical, oil shale, tar sand, urban planning, waste management, fragmentation

Resources: NGSS Phenomenon Master List

Forecast rate of global climate change

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Priority Standard (Performance Expectation): HS-ESS3-5
Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.

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

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

Big Idea(s): Patterns in geoscience data and global climate models can be used to predict changes in Earth's climate and systems, providing insight into how to manage resources responsibly.

Essential Question(s):

- How can geoscience data and global climate models be used to forecast the current rate of global or regional climate change?
- How do we use data from the past to 'see' into the future of our climate?
- How do global climate models help predict the future impacts of climate change on Earth systems such as temperature, precipitation, and ecosystems?

Examples of Engaging Phenomenon:

- 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°
- Glacier National Park Is Melting Away
- HS-ESS3-5: Climate Change and Future Impacts

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
Global Climate Change ● Global climate models are often used to understand the process of climate change because these changes are complex and can occur slowly over Earth's history. ● 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 ● Science and engineering will be essential both to understanding the possible impacts of global climate change and to informing decisions about how to slow its rate and consequences—for humanity as well as for the rest of the planet.	**Analyzing and Interpreting Data** ● Analyze data using computational models in order to make valid and reliable scientific claims. ● Organize and/or arrange (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. ● Forecast, using relationships in the data to, the current rate of global or regional climate change and how it will affect Earth's systems. ● Identify patterns in the data that supports inferences about how the changing climates will affect Earth's systems in the long term.

Cross-Cutting Concepts: Stability and Change

- Rates of change can be quantified and modeled over short or long periods of time. Some system changes are irreversible.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
    - Orientation, probabilistic, redistribute, glacier, volcanic ash, concentration, electromagnetic radiation, radiation, sea level, geochemical reaction, geoscience, greenhouse gas, atmospheric change, biosphere, global temperature, ice core, methane,
- Additional tier 2 words that students should be familiar with:
    - Analyze, data, interpret, evidence-based, rate

Science vocabulary students are NOT expected to know: Anthropogenic, absorption spectrum, determinant, Nitrous Oxides, Carbon Footprint

Resources: NGSS Phenomenon Master List

Relationships among Earth systems and how those relationships are being modified due to human activity

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Supporting Standard (Performance Expectation): HS-ESS3-6 Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.
Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations. Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.
Big Idea(s): The impact of human activity on Earth's systems is evidenced in climate and environmental data.
Essential Question(s): ● In what ways does human activity modify the interactions among Earth systems? ● How can a computational representation effectively demonstrate the impact of human activity on Earth systems and their relationships?
Examples of Engaging Phenomenon: ● 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. ● Glacier National Park Is Melting Away; Ocean Acidification ● HS-ESS3-6: Human Impacts on Earth Systems

<table>
<tr><th>Students will know: (Disciplinary Core Ideas)</th><th>As evidenced by: (Science & Engineering Practices)</th></tr>
<tr><td>
<u>Weather and Climate</u>

Components of each of the Earth systems modeled in the given computational representation, including system boundaries, initial conditions, inputs and outputs, and relationships that determine the interaction (e.g., the relationship between atmospheric CO2 and production of photosynthetic biomass and ocean acidification)

<u>Global Climate Change</u>

Relationships among at least two of Earth's systems, including how the relevant components in each individual Earth system can drive changes in another, interacting Earth system.
How human activity could affect the relationships between the Earth's systems.

</td><td>
Using Mathematics and Computational Thinking

Describe and/or support claims and/or explanations, using a computational representation of phenomena or design solutions to.
Identify and describe the relevant components of each of the Earth systems modeled in the given computational representation, including system boundaries, initial conditions, inputs and outputs, and relationships that determine the interaction (e.g., the relationship between atmospheric CO2 and production of photosynthetic biomass and ocean acidification).
Illustrate and describe relationships, using the given computational representation of Earth systems, among at least two of Earth's systems, including how the relevant components in each individual Earth system can drive changes in another, interacting Earth system. Students use evidence from the computational representation to describe how human activity could affect the relationships between the Earth's systems.
Identify and describe the relevant components of each of the Earth systems modeled in the given computational representation, including system boundaries, initial conditions, inputs and outputs, and relationships that determine the interaction (e.g., the relationship between atmospheric CO2 and production of photosynthetic biomass and ocean acidification)

</td></tr>
<tr><td colspan="2">
<u>Cross-Cutting Concepts</u>: 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.

</td></tr>
</table>

Academic Vocabulary:

- Science Vocabulary Students ARE Expected to Know:
    - 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
- Additional tier 2 words that students should be familiar with:
    - Use, computational representation, relationships, interconnections, modifications, describe, claim, evidence, inputs/outputs

Science vocabulary students are NOT expected to know: Anthropogenic, absorption spectrum, determinant, NOX, Carbon Footprint

Resources: NGSS Phenomenon Master List

Unit 4: Big Bang Theory (Honors Only)

The Big Bang Theory

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

Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).

Big Idea(s): Spectral data from stars, distance galaxies, and the composition of matter supports the Big Bang theory of the universe's origin.

Essential Question(s):

- How do astronomical observations provide evidence for the origin and evolution of the universe?
- If the universe is expanding, what does that tell us about where it started and where it's going?

- Even though light travels between the Sun and the Earth, space appears black because there is nothing (e.g. gas, dust, etc.) for the light to reflect off of.
- 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.

<table>
<tr><th>Students will know: (Disciplinary Core Ideas)</th><th>As evidenced by: (Science & Engineering Practices)</th></tr>
<tr><td>
<u>The Big Bang theory</u>

Supported by observations of distant galaxies receding from our own, of the measured composition of stars and nonstellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.

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.

The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.

Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.
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

</td><td>

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.
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.
Predict how the universe will continue to change over time using an explanation of the Big Bang Theory.
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.

</td></tr>
</table>

the particle model explains other features.	

Cross-Cutting Concepts: 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

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
    - Recessional velocity, galaxy, star, galaxy cluster, spectrum, spectra, wavelength, frequency, Doppler Effect, redshift, blueshift, light years, big bang theory, helium, emission, absorption
- Additional tier 2 words that students should be familiar with:
    - Construct, explain, theory/law, evidence

Science vocabulary students are NOT expected to know: cosmological redshift, Hubble Law, photometric redshift, spectroscopy

Resources: NGSS Phenomenon Master List

Stellar Nucleosynthesis

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Priority Standard (Performance Expectation): HS-ESS1-3 Communicate scientific ideas about the way stars, over their life cycle, produce elements
Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime. Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.
Big Idea(s): The life cycle of a star determines which elements are formed within the star's nucleus, and how those elements are distributed throughout the universe.
Essential Question(s): ● How do stars produce elements over their life cycle? ● How is it possible that every atom in our bodies was once forged inside a dying star? ● How does the size, mass, and composition of a star impact its ability to produce elements?
Examples of Engaging Phenomenon: ● An explanation for the Big Bang based on evidence from light spectra, the motion of distant galaxies, and the composition of matter in the universe. ● 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. ● HS-ESS1-3: Stellar Nucleosynthesis

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
Nucleosynthesis ● 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	● Communicate scientific ideas (about phenomena and/or the process of development and the design/performance of a proposed process or system) in multiple formats (orally, graphically, textually, and mathematically). ● 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, in particular how those stellar properties change over time. ● Synthesize an explanation regarding the relationship between stellar properties and age, and how those stellar properties change over time.

Cross-Cutting Concepts: Energy and Matter
- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Academic Vocabulary:
- Science vocabulary students ARE expected to know:
    - main sequence, nucleosynthesis, nuclear reactions, fission, fusion, nucleons, proton, neutron, gamma rays, neutrinos, red giant, blue giant, white dwarf, planetary nebular, supernova, supernova remnant, globular cluster, open , exothermic reactions, endothermic reactions, emissions spectrum, absorption spectrum, emission lines, absorption lines, H-R Diagram
- Additional tier 2 words that students should be familiar with:
    - Construct, evidence, communicate, evaluate

Science vocabulary students are NOT expected to know: Neutron-capture, proton-capture, photo-disintegration, CNO cycle, radiogenesis

Resources: NGSS Phenomenon Master List

Nuclear Fusion and the Sun's Energy

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Priority Standard (Performance Expectation): HS-ESS1-1 Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy in the form of radiation.
Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries. Assessment Boundary: Assessment does not include details of the atomic and sub-atomic processes involved with the sun's nuclear fusion.
Big Idea(s): By fusing hydrogen into helium in its core, it releases the massive amounts of energy that sustain life on Earth.
Essential Question(s): ● How can models based on evidence illustrate the life span of the sun? ● How does the energy released from the sun's core eventually reach Earth in the form of radiation? ● How can we effectively communicate and explain the relationship between the sun's life span, nuclear fusion, and the radiation reaching Earth?
Examples of Engaging Phenomenon: ● The massive amount of energy released in a solar flare originally comes from nuclear fusion in the Sun's core but the mechanism of energy transfer is not fully understood. Solar flares tend to emanate from dark areas on the Sun known as sun spots. Sun spot numbers cycle on an 11-year period known as the solar cycle. Students could discover this cycle on their own, make predictions based on the cycle, or attempt to connect these phenomena to the nuclear fusion driving the entire process. ● 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. ● HS-ESS1-1: Nuclear Fusion and the Sun's Energy

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
<u>The Sun</u> ● The sun is changing and will burn out over a lifespan of approximately 10 billion years. ● The sun is just one of more than 200 billion stars in the Milky Way galaxy, and the Milky Way is just one of hundreds of billions of galaxies in the universe. <u>Nuclear Fusion</u> ● Nuclear fusion is the process in the center of the sun that releases the energy that ultimately reaches Earth as radiation. ● The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth	● Develop a model based on evidence to illustrate the relationships between systems or between components of a system. ● 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.
<u>Cross-Cutting Concepts</u>: Scale, Proportion, and Quantity - The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.	

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
  - sunspot cycle, solar maximum, solar minimum, sunspots, solar flares, UV radiation, IR radiation, convection, nuclear fusion, core, atmosphere, solar storm, luminosity
- Additional tier 2 words that students should be familiar with:
  - Construct, evidence, motion, universe, develop, life span, energy hydrogen, helium

Science vocabulary students are NOT expected to know: photosphere, chromosphere, corona, coronal mass ejections

Resources: NGSS Phenomenon Master List

Appendix A: Vocabulary

- Abiotic: Non-living physical and chemical elements in an ecosystem, such as sunlight, water, and minerals.
- Absorption: The process by which matter takes in energy, such as a substance taking in liquid or a molecule absorbing light.
- Absorption Lines: Dark lines in a spectrum caused by the absorption of specific wavelengths of light by gases.
- Asthenosphere: The upper layer of the Earth's mantle, below the lithosphere, which is plastic enough to allow for tectonic plate movement.
- Atmospheric Circulation: The large-scale movement of air that distributes thermal energy across the surface of the Earth.
- Basin: A large-scale depression on the Earth's surface where sediments often accumulate, such as an ocean basin or a river drainage area.
- Big Bang Theory: The leading scientific explanation for the origin of the universe, suggesting it began as a hot, dense point and has been expanding for billions of years.
- Biodiversity: The variety and variability of life forms within a given ecosystem or the entire planet.
- Biomass: The total mass of living organisms in a given area or volume.
- Biosphere: The global sum of all ecosystems; the zone of life on Earth.
- Biotic: Relating to or resulting from living organisms.
- Chemical Weathering: The erosion or disintegration of rocks caused by chemical reactions (chiefly with water and substances dissolved in it).
- Continental Crust: The thick part of the earth's crust that forms the large landmasses, generally older and less dense than oceanic crust.
- Convection: The transfer of heat through the movement of a fluid (liquid or gas) caused by density differences.
- Convergence: A tectonic boundary where two plates are moving toward each other.
- Divergence: A tectonic boundary where two plates are moving away from each other.
- Doppler Effect: The change in frequency or wavelength of a wave in relation to an observer moving relative to the wave source.
- Electromagnetic Radiation: Energy that travels through space at the speed of light in the form of waves, including visible light, UV, and X-rays.
- Feedback Effect: A process in which the output of a system eventually influences its own input, either amplifying (positive) or dampening (negative) the original change.
- Fossil Fuel: A natural fuel such as coal or gas, formed in the geological past from the remains of living organisms.

- Geosphere: The solid part of the earth consisting of the crust and outer mantle.
- Greenhouse Gas: Gases in Earth's atmosphere that trap heat, such as carbon dioxide, methane, and water vapor.
- Hydrosphere: All the waters on the earth's surface, such as lakes and seas, and sometimes including water over the earth's surface, such as clouds.
- Igneous Rock: Rock formed through the cooling and solidification of magma or lava.
- Inner Core: The solid, innermost central portion of Earth, composed primarily of iron and nickel.
- Isotope: Forms of the same element that contain equal numbers of protons but different numbers of neutrons.
- Lithosphere: The rigid outer part of the earth, consisting of the crust and upper mantle.
- Luminosity: The total amount of energy emitted by a star per unit of time.
- Mantle: The layer of the Earth between the crust and the core, consisting of hot, solid rock that can flow over long periods.
- Metamorphic Rock: Rock that has been transformed by heat, pressure, or other natural agencies.
- Mid-ocean Ridge: An underwater mountain range, formed by plate tectonics, where new seafloor is created.
- Mitigation: Actions taken to reduce the severity or impact of something, such as natural hazards or climate change.
- Nuclear Fusion: A nuclear reaction in which atomic nuclei of low atomic number fuse to form a heavier nucleus with the release of energy.
- Nucleosynthesis: The cosmic formation of atoms more complex than the hydrogen nucleus.
- Oceanic Crust: The relatively thin part of the earth's crust that underlies the ocean basins.
- Plate Tectonics: The theory that Earth's outer shell is divided into several plates that glide over the mantle.
- Radioactive Decay: The process by which an unstable atomic nucleus loses energy by radiation.
- Radiometric Dating: A method of dating geological or biological specimens by determining the relative proportions of particular radioactive isotopes present.
- Redshift: A phenomenon where light from an object moving away from the observer is increased in wavelength, shifting toward the red end of the spectrum.
- Renewable Resource: A natural resource that can be replaced at the same rate at which the resource is consumed.
- Sea-floor Spreading: The process that occurs at mid-ocean ridges, where new oceanic crust is formed through volcanic activity and then gradually moves away from the ridge.
- Sedimentary Rock: Rock that has formed from the accumulation and solidification of sediment.
- Seismic Wave: An elastic wave in the earth produced by an earthquake or other means.
- Solar Radiation: Radiant energy emitted by the sun from a nuclear fusion reaction.

- Spectra: A plural of spectrum; the distribution of colors or wavelengths produced when light is dispersed.
- Supernova: A star that suddenly increases greatly in brightness because of a catastrophic explosion that ejects most of its mass.
- Sustainability: The ability to be maintained at a certain rate or level, particularly regarding the avoidance of depletion of natural resources.
- Tectonic Uplift: The portion of the total geologic uplift of the Earth's surface that is not attributable to an isostatic response to unloading.
- Viscosity: The state of being thick, sticky, and semi-fluid in consistency, due to internal friction.
- Water Cycle: The continuous process by which water moves from Earth's surface to the atmosphere and back