Minnesota Comprehensive Assessment-Series IV (MCA-IV)

Draft Test Specifications for Science

August 2020

Based on the Minnesota K-12 Academic Standards in Science –2019, Commissioner Approved Draft

The information contained in this document should **not** be used as a curriculum guide.

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MCA Purpose Statement

To ensure that all students have access to high-quality content and instruction, the Minnesota K–12 Academic Standards outline statewide expectations for student learning in Minnesota K–12 public and charter schools. Student mastery of the standards is best measured through a combination of classroom, school, district, and state assessment tools. The Science Minnesota Comprehensive Assessments-Series IV (Science MCA-IV) are assessment tools designed at the state level to measure effective implementation of the 2019 Minnesota K–12 Science Standards.

Federal law (Every Student Succeeds Act) and State law (MN Statutes, section 120B.30) require students to be assessed in science three times: once in grades 3–5, 6–9, and 10–12. The Minnesota Department of Education (MDE) has selected grades 5 and 8 for assessments in the first two grade bands. The grade 5 Science MCA assesses the grades 3–5 standards, and the grade 8 Science MCA assesses the grades 6–8 standards. Students in grades 9–12 are expected to take the High School Science MCA during the year in which they are enrolled in a life science or biology course and/or when they have received instruction on all 9–12 life science benchmarks. The life science credit is required for high school graduation for all students. This is why the high school MCAs assesses the life science benchmarks only.

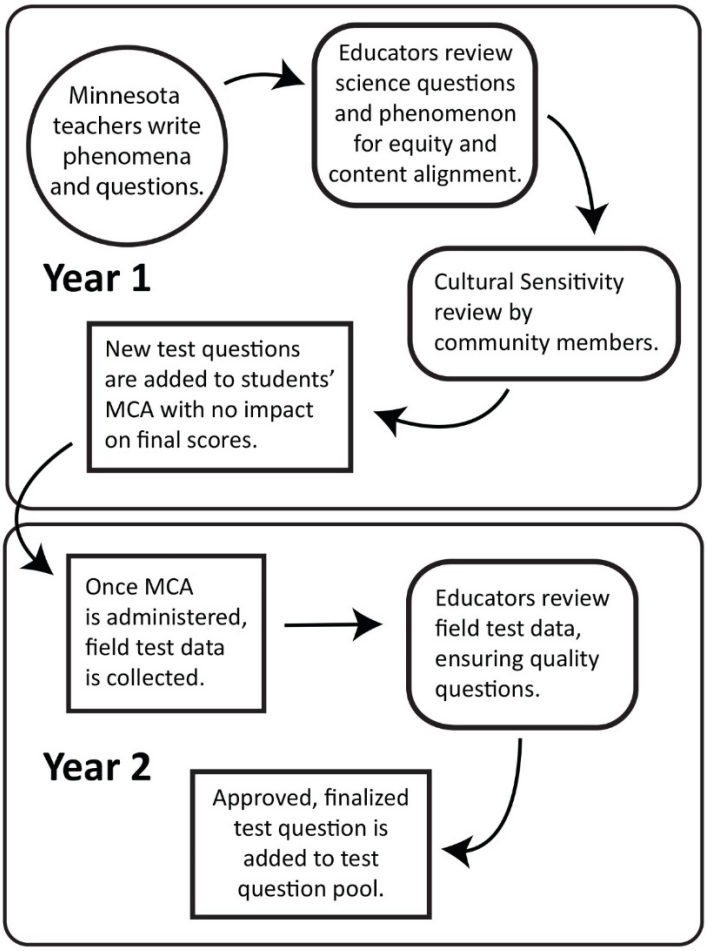
The MCAs are criterion-referenced assessments, which means they measure performance against a fixed set of criteria; for the MCAs, these criteria are the Minnesota Academic Standards. Criterion-referenced assessments are used to determine mastery of concepts and skills and to measure progress toward goals and objectives. While criterion-referenced tests may provide information about how well students have mastered certain concepts, they do not provide a complete picture of what students have learned throughout an entire school year. The MCAs provide one data point that should be considered in the context of additional evidence of student learning visible through classroom activities, local formative assessments, and district and classroom interim assessments. Visit Testing 1, 2, 3 (testing123.education.mn.gov > assess > formative) for more resources about standards-aligned classroom assessments.

Test Development Overview

The Science MCA-IV scenes, simulations, and test questions are written by trained Minnesota science educators in conjunction with MDE and our service provider. All scenes, simulations, and test questions developed for the MCAs are reviewed and revised by Minnesota educator committees and science experts for accuracy and appropriateness. The test development cycle involves many opportunities to review material developed for the Science MCA to ensure they:

- Align with the intended multidimensional science standards and are appropriate for Minnesota students
- Provide a valid measurement of the full range of student performance and student achievement, including the performance of high- and low-performing students
- Have been reviewed to avoid factors that would advantage or disadvantage any students

Item Development Cycle



Each committee (Educator Review, Community Review, Data Review) plays a vital role in developing quality tests for Minnesota students. MDE needs experienced educators and community members to serve on Educator and Community MCA Review Committees. (Sign up to participate in MCA Review Committees (MDE website > Districts, Schools and Educators > Statewide Testing.))

Test Specifications Purpose

The Science MCA-IV Test Specifications document provides information on how the 2019 Minnesota K–12 Academic Standards in Science are assessed on a test. The specifications were developed in collaboration with Minnesota science educators during the Science MCA Test Specification Committee and during public review. They delineate specific rules and characteristics that guide the development of the Science MCA-IV content and format, and provide guidelines for writers and MDE's service provider to support multidimensional question development. The specifications also provide the blueprint for test construction, specifying the number of questions for each score-reporting category. The purpose of the blueprint is to outline the test design to provide consistency across test forms for the life of the Science MCA-IV. While teachers may use this document to clarify the expectations for the assessment of the science standards, the test specifications are intended for large-scale assessments only, and not to form the basis of curriculum and instruction.

Assessing Multidimensional Science Standards

The 2019 Minnesota K-12 Science Standards are based on current science education principles found in *A Framework for K-12 Science Education*. The Framework emphasizes the inclusion of three dimensions (Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas) within science standards, curriculum, and instruction. The standards are broken down further into individual benchmarks that incorporate aspects of the Framework's three dimensions. The benchmarks indicate how students could demonstrate mastery of the knowledge and skills underlying that benchmark. It is intended that the specific combination of Practice, Crosscutting Concept, and Core Idea indicated in the benchmark should NOT dictate instruction. Instruction will normally include a mixture of several Practices and Crosscutting Concepts.

However, for purposes of the Science MCA-IV, test questions will be aligned to the specific practice, core idea, and cross cutting concept as written in the benchmark. Each question on the MCA will be multidimensional, which means that at a minimum, each question will align to the practice and core idea of the benchmark. Where possible, questions will also align to the cross cutting concept of the benchmark.

Structure of the Test

The Science MCA is an online phenomenon-based assessment. The context for each phenomenon is focused around observable events occurring in the universe that can be explained or predicted with scientific reasoning (Achieve, Next Generation Science Storylines and STEM Teaching Tools). Text, graphics, animations, or simulations are used to provide context for the student to engage in the phenomena. Various question types, including multiple choice, technology enhanced, and constructed response, are used to assess Minnesota's multidimensional benchmarks. The Science MCA is a fixed form test, which means all students taking the same test version are administered the same questions. The operational test includes embedded field test questions that do not contribute to a student's score.

The total number of points for the Grade 5, Grade 8, and High School Science MCA will be (45), (45), and (56) points.

Test Construction: All Grades Science MCA

Grade Level	Total Number of Test Questions	Total Number of Points	Total Number of 1-Point Questions	Total Number of 3-Point Questions
Grade 5	39–43	45	36–42	1–3
Grade 8	39–43	45	36–42	1–3
High School	48–54	56	44–53	1–4

Grade 5 Science MCA: Numbers in Each Reporting Category

Reporting Category	Number of Test Questions	Number of Points	Number of 3-Point Questions
Practices in Earth Science (3–5E)	13–15	15	0–1
Practices in Life Science (3–5L)	13–15	15	0–1
Practices in Physical Science (3–5P)	13–15	15	0–1

Grade 8 Science MCA: Numbers in Each Reporting Category

Reporting Category	Number of Test Questions	Number of Points	Number of 3-Point Questions
Practices in Earth Science (6E)	13–15	15	0–1
Practices in Life Science (7L)	13–15	15	0–1
Practices in Physical Science (8P)	13–15	15	0–1

High School Science MCA: Numbers in Each Reporting Category

Reporting Category	Number of Test Questions	Number of Points	Number of 3-Point Questions
Practices in LS1	12–14	14	0–1
Practices in LS2	12–14	14	0–1
Practices in LS3	12–14	14	0–1
Practices in LS4	12–14	14	0–1

LS1-From molecules to organisms: Structure and processes. LS2-Ecosystems: Interactions, energy, and dynamics. LS3-Heredity: Inheritance and variation of traits. LS4-Biological Evolution: Unity and diversity

Cognitive Complexity

On the Science MCA, questions associated with the scenario will require students to use levels of cognitive complexity based on Webb's Depth of Knowledge scale. Questions assessing the multiple dimensions of the Practices, Core Ideas, and Crosscutting Concepts will assess a range of knowledge, skills, and abilities and will reflect the cognitive complexity called for by the three dimensions of the Minnesota K-12 Science Standards.

The Science MCA Test Specifications will remain in draft form and will be modified annually to reflect lessons learned during the assessment development cycle. A Modification Log will be used to document changes to the Test Specifications.

References

National Research Council (NRC). (2012). *A framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: National Academies Press.

National Research Council. (2014). *Developing Assessments for the Next Generation Science Standards*. Washington, CD: The National Academies Press

Next Generation Science Standards (NGSS) Lead States. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press

Benchmark Language
Specific knowledge or skill that a student must master to complete part of an academic standard by the end of the grade level

Benchmark code
6E-Grade and content area
3-Strand
1-Substrand
1-Standard
3-Benchmark

NGSS Dimensions associated with the benchmark

Benchmark 6E.3.1.1.3

Develop a model, based on observational and experimental evidence, to describe the cycling of water through Earth's systems driven by energy from the Sun and the force of gravity. (P: 2, CC: 5, CI: ESS2) Emphasis of the practice is on developing a way to represent the mechanisms of water changing state, the global movements of water and energy, and on how the observational and experimental evidence supports the model. Examples of models may be conceptual or physical.

Practices Dimension

Item Specifications:

P: 2 Developing and using models

Developing and using models may include, but is not limited to:

- Recognizing advantages and limitations of models.
- Evaluating or comparing existing models.
- Comparing and contrasting two or more models.
- Developing or using simple models with uncertain or less predictable factors.
- Developing or using models to show relationships among variables, including those variables that are not observable but predict observable phenomena.
- Using models to make predictions and explanations or generate data.
- Revising models based on new information, including change of a variable or system component.
- Using diagrams, graphs, data sets, numerical representations, analogies, or computer simulations.

Crosscutting Concepts Dimension

CC: 5 Energy and matter: Flows, cycles, and conservation

Energy that drives these processes may include, but is not limited to:

- Energy transfer as conduction, convection, or radiation.
- Heat energy stored in oceans.

Core Idea Dimension

CI: ESS2 Earth's systems

Cycling of water may include, but is not limited to:

- Water exists as solid, liquid, or vapor, with phase change driven by transfer of energy.
- Evaporation, transpiration, respiration, condensation, precipitation, infiltration, groundwater, aquifers, runoff, glaciers, surface water, or reservoirs such as oceans, lakes, and rivers.
- Distribution of materials and purification of water.
- A quantitative understanding of the latent heats of vaporization and fusion will not be assessed.

Clarification Statements- provide the rules and characteristic that guide the development of item content

Items will **not** assess quantitative understanding of the latent heats of vaporization and fusion.

Benchmark 3E.2.1.1.1

Record observations of the Sun, Moon, and stars and use them to describe patterns that can be predicted.** (P: 4, CC: 1, CI: ESS1) Examples of patterns may include that the sun and moon appear to rise in one part of the sky, move across the sky, and set; and stars other than our sun are visible at night but not during the day.

Item Specifications:

P: 4 Analyzing and interpreting data

Recording observations may include, but is not limited to:

- Collecting categorical or numerical data for presentation in tables or various graphs to reveal patterns.
- Comparing and contrasting data collected by others to reveal similarities and differences.
- Analyzing and interpreting data, using reasoning, mathematics and/or computation.
- Using representations such as maps, charts, graphs, and/or tables.

CC: 1 Patterns

No clarification needed.

CI: ESS1 Earth's place in the universe

Observations of the Sun, Moon, and stars may include, but are not limited to:

- Sun and Moon being visible in the sky during the day.
- Moon and stars being visible in the sky during the night.
- The Sun at different positions in the sky depending on the season and time of day.
- The Moon at different positions in the sky at different times of the day or night.
- The appearance of the Moon at different times of the month.

Benchmark 3E.2.2.1.1

Organize and electronically present collected data to identify and describe patterns in the amount of daylight in the different times of the year.** (P: 5, CC: 1, CI: ESS1) Emphasis is on relative comparisons of the amount of daylight in the winter to the amount in the spring or fall.

Item Specifications:

P: 5 Using mathematics and computational thinking

Organizing and electronically presenting collected data may include, but is not limited to:

- Deciding if qualitative or quantitative data are best to identify and describe patterns.
- Organizing simple data sets to reveal patterns.

Electronic presentation of data is limited to classroom level only.

CC: 1 Patterns

No clarification needed.

CI: ESS1 Earth's place in the universe

Evidence of daylight patterns may include, but is not limited to:

- Relative length of the day (sunrise to sunset) throughout the year.

Benchmark 3E.4.2.2.1

Gather information and communicate how Minnesota American Indian tribes and communities and other cultures use patterns in stars to make predictions and plans. (P 8, CC: 1, CI: ESS1) Examples of cultures may include those within the local context of the learning community and within the context of Minnesota. Examples may include using star maps to predict seasons, star patterns to inform navigation, and using star stories to identify numeric patterns that guide behavior.

Item Specifications:

P: 8 Obtaining, evaluating, and communicating information

Gathering information and communicating may include, but is not limited to:

- Comparing and contrasting information across the resources and texts provided to determine which are most relevant to explaining the phenomenon.
- Evaluating and integrating information across the resources (e.g., text, graphs, animations, and diagrams) to address a scientific question or solve a problem.
- Combining information from various resources to explain phenomena or solutions to a design problem.
- Communicating scientific information through various formats such as tables, diagrams, or graphs.

CC: 1 Patterns

Patterns may include, but are not limited to:

- Constellations and stars appearing to move together in the sky because of Earth's rotation.

CI: ESS1 Earth's place in the universe

Movement of stars may include, but is not limited to:

- Patterns of appearance of stars and/or constellations.

Benchmark 3L.1.2.1.2

Plan and conduct an investigation to determine how amounts of sunlight and water impact the growth of a plant. (P: 3, CC: 2, CI: LS2) Emphasis of the practice is on conducting fair tests and using data to support explanations. Examples of investigations may include simple experiments with fast-growing plants.

Item Specifications:

P: 3 Planning and carrying out investigations

Planning and conducting an investigation may include, but is not limited to:

- Evaluating appropriate methods and/or tools for collecting data.
- Making observations and/or measurements when collecting data that can serve as evidence for an explanation of a phenomenon or design solution.
- Predicting what would happen if a variable changes.
- Planning and conducting an investigation that produces data to serve as evidence in which variables are controlled and the number of trials are considered.
- Identifying variables as changed, stay the same, or measured.
- Carrying out descriptive, comparative, or experimental investigations.

CC: 2 Cause and effect

The impact of sunlight and water on the growth of a plant may include, but is not limited to:

- Testing causal relationships and using these relationships to explain change.
- Recognizing that events that occur together regularly may or may not signify a cause and effect relationship.

CI: LS2 Ecosystems: Interaction, energy

Plant growth may include, but is not limited to:

- The need to take in matter and energy to grow.
- Sunlight as the source of energy.
- The requirement of matter such as water.

Items will **not** assess photosynthesis.

Benchmark 3L.3.1.1.2

Develop multiple models to describe how organisms have unique and diverse life cycles but all have birth, growth, reproduction, and death in common. (P: 2, CC: 4, CI: LS1) Emphasis is on the pattern of changes organisms go through during their life. Examples of models may include diagrams, drawings, physical models, or computer programs.

Item Specifications:

P: 2 Developing and using models

Developing multiple models may include, but is not limited to:

- Identifying limitations of models.
- Using models to describe or predict phenomena, scientific principles, or design solutions.
- Revising a model based on evidence that shows the relationships among variables.
- Using a model to test cause and effect relationships.
- Comparing and contrasting simple models.
- Creating prototypes or conceptual models that use data, graphs, and/or diagrams.

CC: 4 Systems and system models

Systems may include, but are not limited to:

- Organism inputs and outputs.

CI: LS1 From molecules to organisms: Structures and processes

Life cycles of organisms may include, but are not limited to:

- Metamorphosis and incomplete metamorphosis in context but not the specific terminology of metamorphosis.
- Causal direction of the cycle (e.g., without birth, there is no growth; without reproduction, there are no births).

Items that assess plant life cycles will be limited to those of flowering plants.

Items will **not** assess the details of human reproduction.

Benchmark 3L.3.2.1.1

Construct an explanation using evidence from various sources for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing. (P: 6, CC: 2, CI: LS4) Examples of cause and effect relationships may include how individual plants of the same species with different-length thorns may be more or less likely to be eaten by predators; or animals that have better camouflage coloration than others of their species may be more likely to survive and therefore more likely to leave offspring.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Constructing an explanation may include, but is not limited to:

- Using evidence to analyze explanations that describe and predict phenomena.
- Evaluating data and evidence to construct an evidence-based model or explanation.
- Identifying variables and incorporating the resulting observations into an explanation of a phenomenon.
- Evaluating various explanations for an investigation or phenomenon for consistency with the evidence.
- Identifying the evidence that supports an explanation.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Relationships between a specific variation in a characteristic and its effect on the ability of the individual organism to survive and reproduce.

CI: LS4 Biological evolution: Unity and diversity

Variations in characteristics among individuals may include, but are not limited to:

- Observable physical features and behaviors.
- Organisms found in Minnesota.
- Potential benefits of a given variation of the characteristic.

Benchmark 3L.4.1.1.1

Construct an argument about strategies animals use to survive. (P: 7, CC: 2, CI: LS2) Emphasis is on group behavior and how being part of a group helps animals obtain food, defend themselves, and cope with changes. Examples of animals should include wolves or other animals that live in Minnesota.

Item Specifications:

P: 7 Engaging in argument from evidence

Constructing an argument may include, but is not limited to:

- Identifying evidence used in an argument.
- Comparing arguments based on an evaluation of the evidence presented in an explanation.
- Distinguishing between evidence and opinion.
- Supporting an argument with evidence, data, and/or a model provided.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Recognition that events occurring together with regularity may or may not signify a cause and effect relationship.
- Using data to evaluate claims about cause and effect.

CI: LS2 Ecosystems: Interactions, energy, and dynamics

Strategies animals use to survive may include, but are not limited to:

- Formation of groups that help each member survive by obtaining food and defending themselves.
- Use of Minnesota animals where possible.
- Hibernation, migration, self-defense mechanism, food storage, shelter building, close relationships with other species (e.g., bees and flowers).

Benchmark 3L.4.2.1.1

Obtain information from various types of media to support an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.** (P: 8, CC: 4, CI: LS1) Examples of structures may include thorns, stems, roots, colored petals, heart, stomach, lungs, brain, and skin. Examples of media may include electronic sources.

Item Specifications:

P: 8 Obtaining, evaluating, and communicating information

Obtaining information from various types of media may include, but is not limited to:

- Comparing and contrasting information across the resources and texts provided to determine which are most relevant to explaining the phenomenon.
- Evaluating and integrating information across the resources (e.g., text, graphs, animations, and diagrams) to address a scientific question.
- Combining information from various resources to explain phenomena.
- Communicating scientific information through various formats such as tables, diagrams, or graphs.

CC: 4 Systems and system models

Plant and animal systems may include, but are not limited to:

- A group of related parts that make up a whole and can carry out functions its individual parts cannot.
- A system that can be described in terms of its components and their interactions.

CI: LS1 From molecules to organisms: Structures and processes

Plant and animal structures that support survival, growth, behavior, and reproduction may include, but are not limited to:

- Different structures working together as part of a system to support survival, growth, behavior, and/or reproduction (e.g., the heart working with the lungs to carry oxygenated blood throughout the system; thorns protecting the plant, allowing reproduction).

Items in the assessment are limited to macroscopic structures within plant and animal systems.

Benchmark 3P.1.1.1.1

Ask questions based on observations about why objects in darkness can be seen only when illuminated. (P: 1, CC: 2, CI: PS4) Emphasis should be on addressing the misconception that people can see in the dark if they wait long enough and on the way eyes receive light. Examples of observations may include those made in a completely dark room, a pinhole box, and a video of a cave explorer with a flashlight.

Item Specifications:

P: 1 Asking questions

Asking questions based on observations may include, but is not limited to:

- Identifying questions about what would happen if a variable were changed.
- Identifying testable and non-testable questions.
- Evaluating what questions can be investigated and predicting possible outcomes.
- Identifying evidence necessary to answer a question.
- Describing human needs and/or local or global issues that are reflected in the problem.

CC: 2 Cause and effect

Cause and effect may include, but is not limited to:

- Visible light being required for objects to be seen by humans.

CI: PS4 Waves and their applications in technologies for information transfer

Observations of objects may include, but are not limited to:

- Various lighting conditions (e.g., amount, source type, color, and filters).
- Objects observed in a space with no light, the appearance of objects in a space with light, and objects that give off light (e.g., light bulbs and glow sticks).
- Human eyesight requires the presence of light energy to function.
- Light energy is received by the eye, which then relays signals to the brain and is perceived as vision.

Items can assess the concept of illumination but will **not** use the term illuminate.

Benchmark 3P.1.2.1.1

Plan and conduct a controlled investigation to determine the effect of placing objects made with different materials in the path of a beam of light. (P: 3, CC: 2, CI: PS4) Emphasis is on conducting fair tests by controlling variables. Examples of materials may include those that are transparent (such as clear plastic), translucent (such as wax paper), opaque (such as cardboard), and reflective (such as a mirror).

Item Specifications:

P: 3 Planning and carrying out investigations

Planning and conducting a controlled investigation may include, but is not limited to:

- Evaluating appropriate methods and/or tools for collecting data.
- Making observations and/or measurements when collecting data that can serve as evidence for an explanation of a phenomenon.
- Predicting what would happen if a variable changes.
- Planning and conducting an investigation that produces data to serve as evidence in which variables are controlled and the number of trials are considered.
- Identifying variables as changed, stay the same, or measured.
- Carrying out descriptive, comparative, or experimental investigations.

CC: 2 Cause and effect

No clarification needed.

CI: PS4 Waves and their applications in technologies for information transfer

Investigating objects in the path of a light beam may include, but is not limited to:

- Some materials allowing light to pass through them, others allowing only some light to pass through, and others blocking all light to create a dark shadow on any surface beyond the object, where the light cannot reach.
- Mirrors being used to redirect a light beam.

Items will **not** assess the concept of speed of light.

Benchmark 3P.3.1.1.1

Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen. (P: 2, CC: 2, CI: PS4) Examples of models may include diagrams, drawings, physical models, or computer programs.

Item Specifications:

P: 2 Developing and using models

Developing a model may include, but is not limited to:

- Identifying limitations of models.
- Using models to describe or predict phenomena or scientific principles.
- Revising a model based on evidence that shows the relationships among variables.
- Using a model to test cause and effect relationships.
- Comparing and contrasting simple models.
- Using conceptual models that use data, graphs, and/or diagrams.

CC: 2 Cause and effect

Cause and effect may include, but is not limited to:

- Effects of removing, blocking, or changing the light source (e.g., a dimmer light and filter).
- Effects of closing the eye.
- A change in the path of the light (e.g., using mirrors to direct the path of light to allow the visualization of a previously unseen object).
- A change in object placement.

CI: PS4 Waves and their applications in technologies for information transfer

Light reflecting and entering the eye may include, but is not limited to:

- Objects seen only if light follows a path between a light source, the object, and the eye.
- Relationship between light reflection and visibility of objects.
- Identification of the relevant components, including light (including the light source), objects, the path that light follows, and the eye.

Items will **not** assess knowledge of specific colors reflected and seen, the cellular mechanisms of vision, or how the retina works.

Benchmark 4E.1.1.1.2

Ask questions about how water moves through the Earth system and identify the type of question. (P: 1, CC: 5, CI: ESS2) Emphasis is on the processes of evaporation, condensation, and precipitation. Examples of types of questions may include those that can be tested by an experiment, and questions that may be answered from a text.

Item Specifications:

P: 1 Asking questions (for science) and defining problems (for engineering)

Asking questions may include, but is not limited to:

- Identifying questions about what would happen if a variable were changed.
- Identifying testable and non-testable questions.
- Evaluating what questions can be investigated and predicting possible outcomes.
- Identifying evidence necessary to answer a question.
- Describing human needs and/or local or global issues that are reflected in the problem.
- Identifying questions based on data sets.

CC: 5 Energy and matter: Flows, cycles, and conservation

Water moving through the Earth's systems may include, but is not limited to:

- Matter, such as water, cycling through the Earth's systems.

CI: ESS2 Earth's systems

Movement of water through the Earth's systems may include, but is not limited to:

- Runoff, collection, groundwater, evaporation, precipitation, and condensation.
- Locations of water on Earth (e.g., ice caps, vapor, fog, clouds, oceans, and groundwater).

Benchmark 4E.1.2.1.1

Make observations and measurements to provide evidence of the effects of weathering or the rate of erosion by the forces of water, ice, wind, or vegetation.* (P: 3, CC: 2, CI: ESS2) Emphasis is on predicting the rate of change when variables are changed. Examples of variables to test may include angle of slope in the downhill movement of water, amount of vegetation, speed of wind, relative rate of deposition, cycles of freezing and thawing of water, cycles of heating and cooling, and volume of water flow.

Item Specifications:

P: 3 Planning and carrying out investigations

Making observations and measurements may include, but is not limited to:

- Evaluating appropriate methods and/or tools for collecting data.
- Making observations and/or measurements when collecting data that can serve as evidence for an explanation of a phenomenon.
- Predicting what would happen if a variable changes.
- Planning and conducting an investigation that produces data to serve as evidence in which variables are controlled and the number of trials are considered.
- Identifying variables as changed, stay the same, or measured.
- Carrying out descriptive, comparative, or experimental investigations.

CC: 2 Cause and effect: Mechanism and explanation

No clarification needed.

CI: ESS2 Earth's systems

No clarification needed.

Benchmark 4E.1.2.1.2

Plan and carry out fair tests in which variables are controlled and failure points are considered to improve a model or prototype to prevent erosion.* (P: 3, CC: 2, CI: ESS2, ETS1, ETS2) Examples of prototypes to prevent erosion include retaining walls, wind breaks, use of shrubs or other vegetation, and drainage systems.

Item Specifications:

P: 3 Planning and carrying out investigations

Planning and carrying out fair tests may include, but is not limited to:

- Evaluating appropriate methods and/or tools for collecting data.
- Making observations and/or measurements when collecting data that can serve as evidence for an explanation of a phenomenon or design solution.
- Predicting what would happen if a variable changes.
- Planning and conducting an investigation that produces data to serve as evidence in which variables are controlled and the number of trials are considered.
- Testing two different models of the same proposed design solution to determine which better meets criteria.
- Identifying variables as changed, stay the same, or measured.
- Carrying out descriptive, comparative, or experimental investigations.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Effects of human or natural disturbances on natural systems.
- Downhill movement of water on Earth's surface.
- The freezing and thawing cycle.

CI: ESS2 Earth's systems, ETS1 Engineering design, ETS2 Links among engineering, technology, science, and society

Causes of erosion may include, but are not limited to:

- Wind, water, living organisms, gravity, and ice.

Benchmark 4E.2.2.1.1

Interpret charts, maps, and/or graphs of the amounts of salt water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.** (P: 5, CC: 4, CI: ESS2) Emphasis is on oceans, lakes, rivers, glaciers, groundwater, and polar ice caps.

Item Specifications:

P: 5 Using mathematics and computational thinking

Interpreting charts, maps, and/or graphs may include, but is not limited to:

- Deciding if qualitative or quantitative data are best to provide evidence.
- Organizing simple data sets to reveal patterns.
- Using graphical representations or simple algorithms.

CC: 4 Systems and system models

Systems may include, but are not limited to:

- Interaction of the Earth's systems in the cycling and distribution of water.

CI: ESS2 Earth's systems

The distribution of water on Earth may include, but is not limited to:

- Natural or manmade reservoirs.

Benchmark 4E.3.1.1.1

Develop a model based in part on student observations or data to describe ways the geosphere, biosphere, hydrosphere, and atmosphere interact. (P: 2, CC: 4, CI: ESS2) Emphasis is on how rock, living things, water, and/or air are individual systems that make up the larger Earth system and interact with each other.

Item Specifications:

P: 2 Developing and using models

Developing a model may include, but is not limited to:

- Identifying limitations of models.
- Using models to describe or predict phenomena or scientific principles.
- Revising a model based on evidence that shows the relationships among variables.
- Using a model to test cause and effect relationships.
- Comparing and contrasting simple models.
- Using conceptual models that use data, graphs, and/or diagrams.

CC: 4 Systems and system models

Systems and system models may include, but are not limited to:

- Geosphere, biosphere, hydrosphere, and atmosphere acting as individual systems and also interacting together as a larger system.
- A system as a group of related parts that make up a whole and can carry out functions its individual parts cannot.

CI: ESS2 Earth's systems

The interaction of the systems of the geosphere, biosphere, hydrosphere, and atmosphere may include, but is not is limited to:

- A description of ways the Earth's systems interact through the identification of relevant components.
- The identification and/or description of relationships (interactions) within and between the parts of the Earth's systems identified in the model.
- Earth's surface materials and processes.

Items will assess the interactions of only two systems at a time.

Items will assess the understanding of geosphere, hydrosphere, atmosphere, and biosphere but will **not** require students to define these terms.

Benchmark 4E.3.2.1.1

Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time. (P: 6, CC: 1, CI: ESS1) Examples of evidence from patterns may include rock layers with marine shell fossils above rock layers with plant fossils and no shells, indicating a change from land to water over time; and a canyon with different rock layers in the walls and a river in the bottom, indicating that over time a river cut through the rock.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Supporting an explanation may include, but is not limited to:

- Using evidence to analyze explanations that describe and predict phenomena.
- Evaluating data and evidence to construct an evidence-based model or explanation.
- Identifying variables and incorporating the resulting observations into an explanation of a phenomenon.
- Evaluating various explanations for an investigation or phenomena for consistency with the evidence.
- Identifying the evidence that supports an explanation.

CC: 1 Patterns

Patterns may include, but are not limited to:

- Similarities and differences in patterns that can be used to sort, classify, communicate, and analyze simple rates of change in landscapes over time.

CI: ESS1 Earth's place in the universe

Rock formations and fossils in rock layers may include, but are not limited to:

- Different rock layers found in an area (e.g., rock layers taken from the same location show marine fossils in some layers and land fossils in other layers).
- The order of rock layers.
- Presence of particular fossils (e.g., shells and land plants) in specific rock layers indicate environmental conditions under which this rock layer was formed.
- The occurrence of events (e.g., earthquakes) due to Earth forces.

Items will **not** assess specific knowledge of the mechanism of rock formation or memorization of specific rock formations and layers.

Benchmark 4E.3.2.2.1

Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.* (P: 6, CC: 2, CI: ESS3, ETS1) Emphasis is on cause and effect relationships to explain change. Examples of solutions may include designing an earthquake-resistant building and improving monitoring of volcanic activity.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Generating and comparing multiple solutions may include, but is not limited to:

- Comparing multiple solutions to a problem to evaluate criteria and constraints of a design solution.
- Applying scientific concepts to solve design problems.
- Using evidence to evaluate multiple solutions to a design problem.
- Describing the given constraints such as cost, materials, time, and relevant scientific information, including performance under a range of likely conditions.
- Evaluating each design solution based on whether and how well it meets each of the given criteria and constraints.
- Describing the design solutions in terms of how each alters the effect of Earth processes on humans.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect of natural processes on humans may include, but is not limited to:

- Events that occur together with regularity might or might not be a cause and effect relationship.
- Relationships between the Earth process and its observed effect.
- Negative effects of Earth processes on humans.

CI: ESS3 Earth and human activity, ETS1 Engineering design

Natural Earth processes may include, but are not limited to:

- Earthquakes, floods, tsunamis, volcanic eruptions, extreme temperature change, and blizzards.

Benchmark 4E.4.2.1.1

Read and comprehend grade-appropriate complex texts and/or other reliable media to describe that energy and fuels are derived from natural resources and their uses affect the environment. (P: 8, CC: 2, CI: ESS3, ETS2) Examples of information about natural resources should include details about those found in Minnesota. Examples of renewable energy resources may include wind, water behind dams, and sunlight; nonrenewable energy resources include fossil fuels and fissile materials. Examples of environmental effects may include loss of habitat due to dams, loss of habitat due to surface mining, and air pollution and global warming from burning fossil fuels.

Item Specifications:

P: 8 Obtaining, evaluating, and communicating information

Reading and comprehending complex text may include, but is not limited to:

- Comparing and contrasting information across the sources and texts provided to determine which are most relevant to explaining the phenomenon.
- Evaluating and integrating information across the sources (e.g., text, graphs, animations, and diagrams) to address a scientific question or solve a problem.
- Combining information from various sources to explain phenomena or solutions to a design problem.
- Communicating scientific information through various formats such as tables, diagrams, and/or graphs.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- How obtaining and using natural resources affect the environment.
- Availability of natural resources and their effect on human activity.

CI: ESS3 Earth and human activity, ETS2 Links among engineering, technology, science, and society

Energy and fuels from natural resources may include, but are not limited to:

- Information about energy resources and fossil fuels (e.g., fossil fuels, solar, wind, water, nuclear, biofuels, and geothermal).
- How they are obtained from natural resources.
- How they address human energy needs.
- The positive and negative environmental effects of using each energy resource.
- The role of technology, including new and improved technology, in improving or mediating the environmental effects of using a given resource.

Benchmark 4E.4.2.2.1

Obtain and combine multiple sources of information about ways individual communities, including Minnesota American Indian tribes and communities and other cultures use evidence and scientific principles to make decisions about the uses of Earth's resources.* (P: 8, CC: 4, CI: ESS3, ETS1) Examples of cultures may include those within the local context of the learning community and within the context of Minnesota. Examples may include balancing the water, soil, wildlife, plant, and human needs to support sustainable use of resources.

Item Specifications:

P: 8 Obtaining, evaluating, and communicating information

Obtaining and combining multiple sources of information may include, but is not limited to:

- Comparing and contrasting information across the sources and texts provided to determine which are most relevant to explaining the phenomenon.
- Evaluating and integrating information across the sources (e.g., text, graphs, animations, and diagrams) to address a scientific question or solve a problem.
- Combining information from various sources to explain phenomena or solutions to a design problem.
- Communicating scientific information through various formats such as tables, diagrams, and/or graphs.

CC: 4 Systems and system models

Systems and system models may include, but are not limited to:

- Interactions of biosphere, atmosphere, hydrosphere, and geosphere.

CI: ESS3 Earth and human activity, ETS1 Engineering design

Use of Earth's resources may include, but is not limited to:

- How a given human activity (e.g., in agriculture, industry, and everyday life) affects the Earth's resources and environments.
- How a given community uses scientific ideas to protect a given natural resource and the environment in which the resource is found.
- Positive and negative effects on the environment as a result of human activities.

Benchmark 4L.4.1.1.1

Construct or support an argument that traits can be influenced by different environments. (P: 7, CC: 2, CI: LS3) Emphasis of the practice is on using evidence, data and/or a model to support an argument. Examples of the environment affecting a trait may include the stunted growth of a typically tall plant grown with insufficient water or an animal's weight being influenced by the availability of food.

Item Specifications:

P: 7 Engaging in argument from evidence

Constructing or supporting an argument may include, but is not limited to:

- Identifying evidence used in an argument.
- Comparing arguments based on an evaluation of the evidence presented in an explanation.
- Distinguishing between evidence and opinion.
- Supporting an argument with evidence, data, and/or a model provided.
- Using data to evaluate claims about cause and effect.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- The relationship between a specific causal environmental factor and its effect of a given variation in a trait (e.g., not enough water produces plants that are shorter and have fewer flowers than plants that had more water available).

CI: LS3 Heredity: Inheritance and variation of traits

Traits and the influence of different environments may include, but are not limited to:

- Environmental factors that vary for organisms of the same type such as the amount of food, amount of water, amount of exercise an animal gets, and chemicals in the water.
- Observable inherited traits of organisms in varied environmental conditions such as height, weight, coloration, number of leaves, condition of fur, size of leaves, number of fruit, and number of offspring.

Benchmark 4L.4.2.1.2

Obtain information from various media sources to determine that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms.** (P: 8, CC: 1, CI: LS3) Emphasis of the practice is to compare and/or combine information across texts and other reliable media. Emphasis is on organisms other than humans and the patterns in traits between offspring and their parents or among siblings.

Item Specifications:

P: 8 Obtaining, evaluating, and communicating information

Obtaining information from various media sources may include, but is not limited to:

- Comparing and contrasting information across the sources and texts provided to determine which are most relevant to explaining the phenomenon.
- Evaluating and integrating information across the sources (e.g., text, graphs, animations, and diagrams) to address a scientific question.
- Combining information from various sources to explain phenomena.
- Obtaining scientific information through various formats such as tables, diagrams, and/or graphs.

CC: 1 Patterns

Patterns may include, but are not limited to:

- Similarities and differences in traits between offspring and parents.

CI: LS3 Heredity: Inheritance and variation of traits

Variation of inherited traits in plants and animals may include, but is not limited to:

- Similarities in the traits of a parent and the traits of an offspring (e.g., tall plants typically have tall offspring).
- Similarities in traits among siblings (e.g., siblings often resemble each other).
- Differences in traits in a group of similar organisms (e.g., dogs come in many shapes and sizes; a field of corn plants have plants of different heights).
- Differences in traits of parents and offspring (e.g., offspring do not look exactly like their parents).
- Differences in traits among siblings (e.g., kittens from the same mother may not look exactly like their mother).

Items will **not** assess genetic mechanisms of inheritance and prediction of traits.

Items are limited to nonhuman examples.

Benchmark 4P.1.1.1.1

Ask questions to determine cause and effect relationships of electric and magnetic interactions between two objects not in contact with each other. (P: 1, CC: 2, CI: PS2) Examples of an electric force may include the force on hair from an electrically-charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force may include the force between two permanent magnets, the force between an electromagnet and steel paper clips, and the force exerted by one magnet versus the force exerted by two magnets. Examples of cause and effect relationships may include how the distance between objects affects the strength of the force and how the orientation of magnets affects the direction of the magnetic force.

Item Specifications:

P: 1 Asking questions (for science) and defining problems (for engineering)

Asking questions may include, but is not limited to:

- Identifying questions about what would happen if a variable were changed.
- Identifying testable and non-testable questions.
- Evaluating what questions can be investigated and predicting possible outcomes.
- Identifying evidence necessary to answer a question.
- Describing or identifying problems that can be solved.

CC: 2 Cause and effect: Mechanism and explanation

No clarification needed.

CI: PS2 Motion and stability: Forces and interactions

Electric and magnetic interactions between two objects not in contact may include, but is not limited to:

- Sizes of the forces on the two interacting objects due to the distance between the two objects.
- Relative orientation of two magnets and whether the force between the magnets is attractive or repulsive.
- The force a magnet exerts on other objects.
- Static electricity.

Benchmark 4P.1.1.2.1

Define a simple design problem that can be solved by applying scientific ideas about magnets.* (P: 1, CC: 2, CI: PS2, ETS2) Examples of problems may include constructing a latch to keep the door shut and creating a device to keep two moving objects from touching each other.

Item Specifications:

P: 1 Asking questions (for science) and defining problems (for engineering)

Defining problems may include, but is not limited to:

- Identifying evidence necessary to solve a problem.
- Describing or identifying problems that can be solved.
- Identifying possible constraints and/or specifications for a solution to a problem.
- Describing human needs and/or local or global issues that are reflected in the problem.

CC: 2 Cause and effect: Mechanism and explanation

No clarification needed.

CI: PS2 Motion and stability: Forces and interactions, ETS2 Links among engineering, technology, science, and society

Scientific ideas about magnets may include, but are not limited to:

- The relative orientation of two magnets and whether the force between the magnets is attractive or repulsive.
- The force a magnet exerts on other objects.

Benchmark 5E.2.2.1.2

Use data to describe patterns in the daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.** (P: 5, CC: 1, CI: ESS1) Examples of patterns may include the number of daylight hours over the course of a year, selected stars that are visible only in particular months, and the length and direction of shadows over a year.

Item Specifications:

P: 5 Using mathematics and computational thinking

Using data may include, but is not limited to:

- Deciding if qualitative or quantitative data are best to identify a pattern.
- Organizing simple data sets to reveal patterns and identify features such as maximum, minimum, range, average, and median.
- Using appropriate tools to measure quantities to address scientific questions and problems.
- Creating or using graphical representations or simple algorithms.

CC: 1 Patterns

Patterns may include, but are not limited to:

- Patterns of change that can be used to make predictions.

CI: ESS1 Earth's place in the universe

Daily changes in shadows, day and night, and seasonal appearance of stars may include, but are not limited to:

- Data pertaining to daily and seasonal changes caused by the Earth's rotation and orbit around the Sun.
- Length and direction of shadows observed several times during one day.
- Duration of daylight, as determined by sunrise and sunset times.
- Presence or absence of selected stars and/or groups of stars (i.e., constellations) that are visible in the night sky at different times of the year.
- Apparent motion of the Sun from east to west as Earth rotates on its axis.
- Length of the day gradually changing throughout the year as Earth orbits the Sun, with longer days in the summer and shorter days in the winter.
- Some stars and/or groups of stars (i.e., constellations) that can be seen in the sky all year.

Benchmark 5E.4.1.1.1

Use evidence to support an argument that the apparent brightness of the sun and stars is due to their relative distances from Earth. (P: 7, CC: 3, CI: ESS1) Evidence may include analogies of light bulbs and distances.

Item Specifications:

P: 7 Engaging in argument from evidence

Using evidence to support an argument may include, but is not limited to:

- Identifying evidence used in an argument.
- Comparing arguments based on an evaluation of the evidence presented in an explanation.
- Distinguishing between evidence and opinion.
- Supporting an argument with evidence, data, and/or a model provided.
- Using data to evaluate claims about cause and effect.

CC: 3 Scale, proportion, and quantity

Scale, proportion, and quantity may include, but are not limited to:

- Stars appearing small and dim, although they are large compared to Earth, due to distance from Earth.
- Similar stars varying in apparent brightness, indicating that they vary in distance from Earth.

CI: ESS1 Earth's place in the universe

Sun and stars may include, but are not limited to:

- The Sun and other stars being natural bodies in the sky that give off their own light.
- A luminous object close to a person appearing much brighter and larger than a similar object that is very far away from a person (e.g., nearby streetlights appear bigger and brighter than distant streetlights).
- The relative distance of the Sun and stars from Earth (e.g., although the Sun and other stars are far from the Earth, the stars are much farther away; the Sun is much closer to Earth than other stars).

Items will **not** assess size of stars.

Benchmark 5L.1.2.1.4

Plan and conduct an investigation to obtain evidence that plants get the materials they need for growth chiefly from air and water. (P: 3, CC: 5, CI: LS1) Examples of plants may include aquatic plants that grow without soil. Examples of observational evidence may include growth patterns for plants grown in different environments.

Item Specifications:

P: 3 Planning and carrying out investigations

Planning and conducting an investigation may include, but is not limited to:

- Evaluating appropriate methods and/or tools for collecting data.
- Making observations and/or measurements when collecting data that can serve as evidence for an explanation of a phenomenon.
- Predicting what would happen if a variable changes.
- Planning and conducting an investigation that produces data to serve as evidence in which variables are controlled and the number of trials are considered.
- Identifying variables as changed, stay the same, or measured.
- Carrying out descriptive, comparative, or experimental investigations.

CC: 5 Energy and matter: Flows, cycles, and conservation

Matter may include, but is not limited to:

- Observing the conservation of matter by tracking matter before and after processes and recognizing the total weight of substances does not change in a closed system.

CI: LS1 From molecules to organisms: Structures and processes

Plants and the materials needed for growth may include, but are not limited to:

- Growth measurement, both qualitative and quantitative (e.g., height, number of leaves, mass, length of roots, and other appropriate measurements).
- Soil not providing most of the material for plant growth (e.g., changes in weight of soil and a plant in a pot over time; hydroponic growth of plants).
- Plants' inability to grow without water.
- Plants' inability to grow without air.
- Air and water as the primary source of matter for growth.

Items will **not** access knowledge of nutrients, minerals, or fertilizer or the impact they have on plant growth.

Benchmark 5L.3.1.1.3

Create an electronic visualization of the movement of matter among plants, animals, decomposers, and the environment.** (P: 2, CC: 4, CI: LS2) Emphasis is on the idea that matter that is not food is changed by plants into matter that is food. Examples of systems through which matter cycles may include organisms, ecosystems, and the Earth. Examples of an electronic visualization may include a computer program, simulation, or animation.

Item Specifications:

P: 2 Developing and using models

Developing and using models may include, but is not limited to:

- Identifying limitations of models.
- Using models to describe or predict phenomena or scientific principles.
- Revising a model based on evidence that shows the relationships among variables.
- Using a model to test cause and effect relationships.
- Comparing and contrasting simple models.
- Using prototypes or conceptual models that use data, graphs, and/or diagrams.

The creation of an electronic visualization will be limited to the classroom level only.

CC: 4 Systems and system models

No clarification needed.

CI: LS2 Ecosystems: Interactions, energy, and dynamics

The movement of matter through the environment may include, but is not limited to:

- Plants as producers of food in an ecosystem.
- Relationships of organisms in food webs where some animals eat plants for food and other animals eat the animals that eat plants, while decomposers restore some materials back to the soil.
- The change of an aspect in an ecosystem by human or natural causes (e.g., organisms or environment) will affect other aspects in the ecosystem.

Benchmark 5L.4.1.2.1

Evaluate the merit of a solution to a problem caused by changes in plant and animal populations as a result of environmental changes.* (P: 7, CC: 4, CI: LS4, ETS1) Emphasis is on evaluating solutions (based on evidence and design criteria and constraints), not developing new solutions. Examples of environmental changes may include land characteristics, water distribution, temperature, food availability, or the presence of other organisms.

Item Specifications:

P: 7 Engaging in argument from evidence

Evaluating the merit of a solution to a problem may include, but is not limited to:

- Identifying evidence used to evaluate a solution.
- Comparing arguments based on the evidence presented in an explanation.
- Distinguishing between evidence and opinion.
- Supporting an argument with evidence, data, and/or a model provided.
- Using data to evaluate claims about cause and effect.

CC: 4 Systems and system models

Systems and system models may include, but are not limited to:

- A group of related parts (biotic and abiotic) that can make up a whole and carry out functions its individual parts cannot.

CI: LS4 Biological evolution: Unity and diversity, ETS1 Engineering design

Changes in plant and animal populations as a result of environmental changes may include, but are not limited to:

- Positive or negative effects on populations.
- Those caused by humans or natural processes, such as invasive species or change in land use.

Benchmark 5P.1.1.1.1

Ask investigatable questions and predict reasonable outcomes about the changes in energy, related to speed, that occur when objects interact. (P: 1, CC: 5, CI: PS3) Emphasis is on the change in energy due to a change in speed, not on the forces, as objects interact. Example of a question: Where and how do marbles move after a collision?

Item Specifications:

P: 1 Asking questions (for science) and defining problems (for engineering)

Asking investigatable questions may include, but is not limited to:

- Identifying questions about what would happen if a variable were changed.
- Identifying testable and non-testable questions.
- Evaluating what questions can be investigated and predicting possible outcomes.
- Identifying evidence necessary to answer a question.

CC: 5 Energy and matter: Flows, cycles, and conservation

Changes in energy may include, but are not limited to:

- The various ways to transfer energy between objects.

CI: PS3 Energy

Energy changes related to speed may include, but are not limited to:

- Measurements of an object's energy (e.g., relative motion and relative speed) before and/or after collision.
- The transfer of energy between colliding objects that results in a change in the motion of the objects.
- The transfer of energy when objects interact, resulting in sound and heat (e.g., rubbing hands together, hitting a drum, and clapping hands).
- The concept that the faster an object moves, the more energy it has.

Benchmark 5P.1.2.1.2

Conduct an investigation to determine whether the mixing of two or more substances results in new substances. (P: 3, CC: 2, CI: PS1) Emphasis is on conducting fair tests by controlling variables.

Item Specifications:

P: 3 Planning and carrying out investigations

Conducting an investigation may include, but is not limited to:

- Evaluating appropriate methods and/or tools for collecting data.
- Making observations and/or measurements during data collection that can serve as evidence for an explanation of a phenomenon.
- Describing the evidence that will be collected, including quantitative (e.g., weight and temperature) and qualitative (e.g., state of matter, color, texture, and odor) properties of the substances.
- Predicting what would happen if a variable changes.
- Planning and conducting an investigation that produces data to serve as evidence in which variables are controlled and the number of trials are considered.
- Identifying variables as changed, stay the same, or measured.
- Carrying out descriptive, comparative, or experimental investigations.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Chemical reactions resulting in products with properties different from the reactants.

CI: PS1 Matter and its interactions

The interaction of two or more substances may include, but is not limited to:

- Phase changes that do not result in new substances.
- Chemical reactions which result in change in color, production of gas, change in temperature, or formation of a solid.
- The need for more than one piece of evidence to identify a chemical reaction.

Benchmark 5P.1.2.1.3

Evaluate appropriate methods and tools to identify materials based on their properties prior to investigation. (P: 3, CC: 3, CI: PS1) Examples of materials to be identified may include baking soda and other powders, metals, minerals, and liquids. Examples of properties may include color, hardness, reflectivity, electrical conductivity, ability to conduct heat, response to magnetic forces, and solubility; density is not intended as an identifiable property.

Item Specifications:

P: 3 Planning and carrying out investigations

Evaluating appropriate methods and tools may include, but is not limited to:

- Evaluating appropriate methods and/or tools for collecting data.
- Making observations and/or measurements to collect data that can serve as evidence for an explanation of a phenomenon.
- Predicting what would happen if a variable changes.
- Using descriptive or comparative methods.
- Identifying the purpose of the investigation, which includes identifying which data should be collected to serve as the basis for evidence.

CC: 3 Scale, proportion, and quantity

Scale, proportion, and quantity may include, but is not limited to:

- The use of standard units to measure and describe physical quantities such as weight, temperature, and volume.

CI: PS1 Matter and its interactions

Identifying matter based on its properties may include, but is not limited to:

- Observable and measurable properties of materials.
- Properties such as color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility.

Items will **not** assess density or distinguish mass and weight.

Benchmark 5P.2.1.1.1

Analyze and interpret data to show that energy can be transferred from place to place by sound, light, heat, and electric currents. (P: 4, CC: 5, CI: PS3) Emphasis of the practice is on analyzing student observations and data to serve as evidence to support a claim.

Item Specifications:

P: 4 Analyzing and interpreting data

Analyzing and interpreting data may include, but is not limited to:

- Collecting categorical or numerical data for presentation in tables or various graphs to reveal patterns.
- Comparing and contrasting data collected by others to reveal similarities and differences.
- Analyzing and interpreting data using reasoning, mathematics, and/or computation.
- Analyzing data to refine a problem.
- Using representations such as maps, charts, graphs, and/or tables.

CC: 5 Energy and matter: Flows, cycles, and conservation

Energy may include, but is not limited to:

- The various ways energy can transfer between objects.

CI: PS3 Energy

The transfer of energy may include, but is not limited to:

- Light traveling from one place to another.
- Electric currents producing motion, sound, heat, or light.
- Sound traveling from one place to another.
- Heat passing from one object to another.
- Sound, heat, electric current, and light causing a different type of energy to be observed after an interaction (e.g., a specific sound may cause the movement of an object; an electrical current may be used to turn on a light).
- The relative presence of sound, light, electric current, or heat before and after an interaction (e.g., shining a light on an object can increase the temperature of the object; cold object warming in contact with a warmer object).

Benchmark 5P.2.2.1.1

Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved. (P: 5, CC: 3, CI: PS1) Examples of reactions or changes may include phase changes, dissolving, and mixing to form new substances. Mass and weight are not distinguished.

Item Specifications:

P: 5 Using mathematics and computational thinking

Measuring and graphing quantities may include, but is not limited to:

- Organizing simple data sets to reveal patterns and identify features such as maximum, minimum, range, average, and median.
- Using appropriate tools to measure quantities such as area, volume, and weight to address scientific problems.
- Collecting categorical or numerical data for presentation in tables or various graphs to reveal patterns.

CC: 3 Scale, proportion, and quantity

Scale, proportion, and quantity may include, but are not limited to:

- Standard units used to measure and describe physical quantities such as weight, time, temperature, and volume.

CI: PS1 Matter and its interactions

Evidence that matter is conserved when heating, cooling, or mixing substances may include, but is not limited to:

- Weight of substances before and after they are heated, cooled, or mixed, including any new substances produced by a reaction.
- The use of measurements and calculations to describe that the total weights of the substances did not change, regardless of the reaction or changes in properties observed.

Benchmark 5P.3.1.1.1

Develop and refine a model to describe that matter is made of particles too small to be seen. (P: 2, CC: 3, CI: PS1) Examples of evidence supporting a model may include adding air to expand a basketball, compressing air in a syringe, dissolving sugar in water, and evaporating salt water.

Item Specifications:

P: 2 Developing and using models

Developing and refining a model may include, but is not limited to:

- Identifying limitations of models.
- Using models to describe or predict phenomena or scientific principles.
- Revising a model based on evidence that shows the relationships among variables.
- Using a model to test cause and effect relationships.
- Comparing and contrasting simple models.
- Using conceptual models that use data, graphs, and/or diagrams.

CC: 3 Scale, proportion, and quantity

No clarification needed.

CI: PS1 Matter and its interactions

Evidence supporting the model of matter may include, but is not limited to:

- The behavior of a collection of many tiny particles of matter and observable phenomena involving matter (e.g., an expanding balloon, evaporating liquids, substances that dissolve in a solvent, and effect of wind).
- Weight or effects on other objects.
- The behavior and properties of gases, liquid, and solids.

Items will **not** assess the atomic scale mechanism of evaporation and condensation or define the unseen particles.

Benchmark 5P.3.1.1.2

Use models to describe that energy in animals' food (used for body repair, growth, and motion and to maintain body warmth) was once energy from the sun. (P: 2, CC: 5, CI: PS3) Examples of models may include diagrams and flow charts.

Item Specifications:

P: 2 Developing and using models

Using models may include, but is not limited to:

- Identifying limitations of models.
- Using models to describe or predict phenomena or scientific principles.
- Revising a model based on evidence that shows the relationships among variables.
- Using a model to test cause and effect relationships.
- Comparing and contrasting simple models.
- Using conceptual models that use data, graphs, and/or diagrams.

CC: 5 Energy and matter: Flows, cycles, and conservation

Energy may include, but is not limited to:

- The various ways that energy can transfer between objects and organisms.

CI: PS3 Energy

The transfer of energy may include, but is not limited to:

- The relationship between plants and the energy they get from sunlight to produce food.
- The relationship between food, energy, and materials that animals require for bodily functions (e.g., body repair, growth, motion, and body warmth maintenance).
- The relationship between animals and the food they eat, which is either other animals or plants (or both), to obtain energy for bodily functions and materials for growth and repair.
- Energy from the Sun being transferred to animals. This occurs through a series of events that begins when plants produce food and then are eaten by animals.

Benchmark 5P.3.2.1.1

Construct an explanation based on evidence relating the speed of an object to the energy of that object. (P: 6, CC: 5, CI: PS3) The emphasis of the practice is on students identifying the evidence that supports particular points in the explanation. Examples of evidence may include the damage and the height attained when going up a ramp.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Constructing an explanation may include, but is not limited to:

- Using evidence to analyze explanations that describe and predict phenomena.
- Evaluating data and evidence to construct an evidence-based model or explanation.
- Identifying variables and incorporating the resulting observations into an explanation of a phenomenon.
- Evaluating various explanations for an investigation or phenomena for consistency with the evidence.
- Identifying the evidence that supports an explanation.

CC: 5 Energy and matter: Flows, cycles, and conservation

Energy may include, but is not limited to:

- The various ways energy can transfer between objects.

CI: PS3 Energy

Relating speed of an object to the amount of energy of that object may include, but is not limited to:

- Qualitative indicators of the amount of energy of the object, as determined by a transfer of energy from that object (e.g., more or less sound produced in a collision, more or less heat produced when objects rub together, relative speed of a ball that was stationary following a collision with a moving object, and more or less distance a stationary object is moved).
- The concept that the faster a given object is moving, the more observable impact it can have on another object (e.g., a fast-moving ball striking an object, such as a gong or wall, makes more noise than does the same ball moving slowly and striking the same object).

Benchmark 5P.3.2.2.1

Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.* (P: 6, CC: 5, CI: PS3, ETS1, ETS2) Examples of devices may include electric circuits that convert electrical energy into motion, light, or sound; and a passive solar heater that converts light into heat. Examples of constraints may include the materials, cost, or time to design the device.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Applying scientific ideas to design, test, and refine a device may include, but is not limited to:

- Comparing multiple solutions to a problem to evaluate criteria and constraints of a design solution.
- Applying scientific concepts to solve design problems.
- Using evidence to evaluate multiple solutions to a design problem.

CC: 5 Energy and matter: Flows, cycles, and conservation

Energy may include, but is not limited to:

- The various ways energy can transfer between objects.

CI: PS3 Energy, ETS1 Engineering design, ETS2 Links among engineering, technology, science, and society

Energy conversion and engineering design may include, but are not limited to:

- Specifying the initial and final forms of energy (e.g., electrical energy, motion, light, sound, and heat).
- Describing the device and how the energy will be transformed (e.g., a light bulb to convert electrical energy into light energy; a motor to convert electrical energy into energy of motion).

Benchmark 6E.1.1.1.1

Ask questions that arise from observations of patterns in the movement of night sky objects to test the limitations of a solar system model. (P: 1, CC: 1, CI: ESS1) Emphasis is on students questioning the limitations of their own models and questioning the kinds of revisions needed to account for new data. Examples of observations may include the student's own observations or observations made by others. Examples of night sky objects include the Moon, constellations, and planets.

Item Specifications:

P: 1 Asking questions

Asking questions may include, but is not limited to:

- Evaluating questions from observations of models, phenomena, or data, unexpected results, or seeking additional information.
- Identifying or clarifying questions about an explanation or evidence for an argument.
- Identifying and evaluating testable or relevant questions or problems.
- Identifying evidence necessary to answer a question or solve a problem.
- Analyzing questions that challenge a data set.

CC: 1 Patterns

Patterns may include, but are not limited to:

- Relationships of bodies within the solar system.
- The use of graphs and charts.

CI: ESS1 Earth's place in the universe

Movement of night sky objects may include, but is not limited to:

- The tilt of Earth's axis of rotation as it applies to objects in the night sky.

Benchmark 6E.1.1.1.2

Ask questions to examine an interpretation about the relative ages of different rock layers within a sequence of several rock layers. (P: 1, CC: 1, CI: ESS1) Emphasis is on the interpretation of rock layers using geologic principles like superposition and cross-cutting relationships.

Item Specifications:

P: 1 Asking questions

Asking questions may include, but is not limited to:

- Evaluating questions from observations of models, phenomena, or data, unexpected results, or seeking additional information.
- Identifying or clarifying questions about an explanation.
- Identifying or clarifying evidence for an argument.
- Identifying and evaluating testable or relevant questions or problems.
- Identifying evidence necessary to answer a question or solve a problem.
- Analyzing questions that challenge an argument or a data set.

CC: 1 Patterns

Patterns in rock layers may include, but are not limited to:

- Assuming that natural laws operate today as in the past.

CI: ESS1 Earth's place in the universe

Relative ages of rock layers may include, but are not limited to:

- Analyses of rock layers and the fossil record that provide only relative dates, not an absolute scale.
- The fossil record, including index fossils, documenting the existence, diversity, extinction, and change of life forms throughout the history of life on Earth.
- Major events in Earth's history (e.g., formation of mountain chains or ocean basins, volcanic eruptions, lava flows, glaciations, or asteroid impacts).
- The principle of original horizontality.

Assessment does **not** include recalling the names of specific eras, periods, or epochs and events within them.

Benchmark 6E.1.1.1.3

Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. (P: 1, CC: 7, CI: ESS3) Emphasis is on the major role that human activities play in causing the rise in global temperatures. Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities.

Item Specifications:

P: 1 Asking questions

Asking questions may include, but is not limited to:

- Evaluating questions from observations of models, phenomena, or data, unexpected results, or seeking additional information.
- Identifying or clarifying questions about an explanation.
- Identifying or clarifying evidence for an argument.
- Evaluating questions to determine relationships between dependent and independent variables.
- Identifying and evaluating testable or relevant questions or problems.
- Identifying evidence necessary to answer a question or solve a problem.
- Analyzing questions that challenge an argument or a data set.
- Describing human needs and/or local or global issues that are reflected in the problem.

CC: 7 Stability and change

Changes in global temperature may include, but are not limited to:

- Evidence that stability might be disturbed either by sudden events or gradual changes that accumulate over time.
- Reducing climate change and reducing human vulnerability to climate changes depends on understanding climate science, engineering capabilities, and human behavior and then applying that knowledge to make wise decisions.

CI: ESS3 Earth and human activity

Evidence of the factors that have caused the rise in global temperatures may include, but is not limited to:

- Global warming, greenhouse gases, and greenhouse effect.
- Human activities, such as the release of greenhouse gases from burning fossil fuels.
- The influence of natural processes and/or human activities on a gradual or sudden change in global temperatures in natural systems (e.g., glaciers and arctic ice; plant and animal seasonal movements and life cycle activities).

Benchmark 6E.1.2.1.1

Collect data and use digital data analysis tools to identify patterns to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.** (P: 3, CC: 2, CI: ESS2) Emphasis is on how weather at a fixed location changes in response to moving air masses and to interactions at frontal boundaries between air masses. Examples of weather data may include temperature, air pressure, precipitation, and wind. Examples of data analysis may include weather maps, diagrams, and visualizations or may be obtained through laboratory experiments (such as with condensation).

Item Specifications:

P: 3 Planning and carrying out investigations

Collecting data and using digital data analysis tools may include, but is not limited to:

- Planning or revising an experiment or design to produce data needed to support a claim or answer a scientific question.
- Identifying variables as dependent, independent, or controlled.
- Evaluating and using needed tools, measurements, and data.
- Evaluating the accuracy of various data collection methods.
- Analyzing and interpreting results of an investigation.
- Descriptive, comparative, or experimental investigations.

CC: 2 Cause and effect

No clarification needed.

CI: ESS2 Earth's systems

Motions and interactions of air masses may include, but are not limited to:

- The relationship between the distribution and movement of air masses and landforms (e.g., mountains and deserts) and ocean temperatures and currents.
- High and low pressure systems, global winds, jet stream, Coriolis effect, warm and cold fronts, heat transfer (conduction, convection, and radiation), land/sea breeze, or density differences in air masses.
- The expected relationships between weather patterns and the location or movement of air masses (e.g., cold fronts may be characterized by thunderstorms).
- Heat energy from oceans effect on weather patterns.

Items will **not** assess the names of air masses (e.g., continental and polar), cloud types, or weather symbols used on weather maps, or the reported diagrams from weather stations.

Benchmark 6E.2.1.1.1

Analyze and interpret data to determine similarities and differences among features and processes occurring on solar system objects. (P: 4, CC: 3, CI: ESS1) Examples of objects may include moons, planets, comets, or asteroids. Example features may include characteristics of an object's atmosphere, surface, or interior. Examples of processes may include erosion, deposition, cratering, or volcanism.

Item Specifications:

P: 4 Analyzing and interpreting data

Analyzing and interpreting data may include, but is not limited to:

- Identifying linear and nonlinear relationships and/or relationships of space and time.
- Applying concepts of statistics and probability such as mean, median, mode, and range, identifying outliers, and using digital tools when feasible.
- Recognizing limitations of data or graphical displays and recommending improvements of precision, accuracy, and/or methods (e.g., multiple trials).
- Using data as evidence for phenomena.
- Comparing and contrasting different sets of data or graphical displays.
- Distinguishing between correlation and causation.

CC: 3 Scale, proportion, and quantity

Scale may include, but is not limited to:

- Patterns at various scales identifying characteristics of solar system objects, such as features, composition, size, location, or motion.
- Observations at one scale may differ from observations at another scale (e.g., surface features and number or diameter of satellites).
- Mathematical or proportional relationships between characteristics of solar system objects.

CI: ESS1 Earth's place in the universe

Features and processes of solar system objects may include, but are not limited to:

- Features and processes of the Sun.
- Distance from the Sun, diameter, surface features, structure, and composition (e.g., ice vs. rock vs. gas).

Items will **not** assess recalling facts about properties of individual planets and other solar system bodies.

Benchmark 6E.2.1.1.2

Analyze and interpret data on the distribution of fossils, rocks, continental shapes, and seafloor structures to provide evidence of past plate motions. (P: 4, CC: 1, CI: ESS2) Examples of data may include similarities of rock and fossil types on different continents, the shapes of the continents (including the continental shelves), and the locations of ocean floor features such as ridges and trenches.

Item Specifications:

P: 4 Analyzing and interpreting data

Analyzing and interpreting data may include, but is not limited to:

- Constructing, analyzing, and/or interpreting graphical displays such as maps, charts, graphs, and/or tables.
- Identifying linear and nonlinear relationships and/or relationships of space and time.
- Applying concepts of statistics and probability such as mean, median, mode, and range, identifying outliers, and using digital tools when feasible.
- Recognizing limitations of data or graphical displays and recommending improvements of precision, accuracy, and/or methods (e.g., multiple trials).
- Using data as evidence for phenomena.
- Comparing and contrasting different sets of data or graphical displays.
- Distinguishing between correlation and causation.

CC: 1 Patterns

Patterns may include, but are not limited to:

- Analyzing and interpreting the change of plate locations under the assumption that natural laws operate today as in the past.

CI: ESS2 Earth's systems

Evidence of plate motions may include, but is not limited to:

- Ancient land and water patterns illustrate how Earth's plates have moved, collided, and spread apart.
- Tectonic processes continually generate new sea floor at ridges and destroy old sea floor at trenches.
- Continental shapes and seafloor structures such as plate boundaries, mountain building, volcanoes, and rift valleys.
- Differences between oceanic and continental crust and the resulting interactions.
- The plastic nature of the mantle and the brittle nature of the lithosphere.

Items do **not** assess paleomagnetic anomalies in oceanic and continental crust without supporting information.

Benchmark 6E.2.1.1.3

Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.* (P: 4, CC: 1, CI: ESS3, ETS1) Examples of natural hazards may be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events. Examples of data may include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies may include building tornado shelters or barriers to protect from flooding.

Item Specifications:

P: 4 Analyzing and interpreting data

Analyzing and interpreting data may include, but is not limited to:

- Constructing, analyzing, and/or interpreting graphical displays such as maps, charts, graphs, and/or tables.
- Identifying linear and nonlinear relationships and/or relationships of space and time.
- Applying concepts of statistics and probability such as mean, median, mode, and range, identifying outliers, and using digital tools when feasible.
- Recognizing limitations of data or graphical displays and recommending improvements of precision, accuracy, and/or methods (e.g., multiple trials).
- Using data as evidence for phenomena.
- Comparing and contrasting different sets of data or graphical displays.
- Distinguishing between correlation and causation.
- Defining an optimal operational range for a design solution.

CC: 1 Patterns

Patterns may include, but are not limited to:

- Patterns in datasets such as location relative to geographic or geologic features, frequency, severity, types of damage, timing, predictive events, and phenomena (e.g., aftershocks and flash floods) associated with natural hazards.

CI: ESS3 Earth and human activity, ETS1 Engineering design

Data on natural hazards may include, but is not limited to:

- The history of natural hazards in a region, combined with an understanding of related geologic forces, can help forecast the locations and likelihoods of future events.
- The prediction of areas that are most and least susceptible to natural hazard events.
- Evidence that some natural hazards, such as volcanic eruptions and severe weather, can be predicted.
- Evidence that some natural hazards, such as earthquakes, occur suddenly and with no notice and are not predictable.

Technologies may include, but are not limited to:

- Global (such as satellite systems to monitor weather or forest fires).
- Local (such as building, bridge, or road designs to resist earthquakes, warning sirens for severe weather, or reservoirs to mitigate droughts).

Benchmark 6E.3.1.1.1

Develop and use scale models of solar system objects to describe the sizes of objects, the location of objects, and the motion of the objects; and include the role that gravity and inertia play in controlling that motion. (P: 2, CC: 3, CI: ESS1) Emphasis is on the regularity of the motion and accounting for Earth-based visual observations of the motion of these objects in our sky. Emphasis is also on recognizing the limitations of any of the models. Examples may include physical models (such as the analogy of distance along a football field or computer visualizations of orbits) or conceptual models (such as mathematical proportions relative to the size of familiar objects such as students' school or state). Not included are Kepler's Laws and retrograde motion of planets.

Item Specifications:

P: 2 Developing and using models

Developing and using models may include, but is not limited to:

- Recognizing advantages and limitations of models.
- Evaluating or comparing existing models.
- Comparing and contrasting two or more models.
- Developing or using simple models with uncertain or less predictable factors.
- Developing or using models to show relationships among variables, including those variables that are not observable but predict observable phenomena.
- Using models to make predictions and explanations or generate data.
- Revising models based on new information, including change of a variable or system component.
- Using diagrams, graphs, data sets, numerical representations, analogies, or computer simulations.

CC: 3 Scale, proportion, and quantity

Scale, proportion, and quantity may include, but are not limited to:

- Patterns at various scales identifying characteristics of solar system objects, such as features, composition, size, location, or motion that may be assessed apart from gravity and inertia.
- Observations at one scale differing from observations at another scale (e.g., surface features and number or diameter of satellites).
- Mathematical or proportional relationships between characteristics of solar system objects (e.g., orbit, mass, and distance from Sun).

CI: ESS1 Earth's place in the universe

The solar system may include, but is not limited to:

- The Sun and a collection of objects, including planets, their moons, comets, and asteroids that are held in orbit around the Sun by gravity and inertia.
- Formation of the solar system from a disk of dust and gas, drawn together by gravity.

The role of gravity and inertia may include, but is not limited to:

- Gravity as a function of distance and mass.
- Gravitational forces keep smaller objects in orbit around larger objects in the solar system.

Benchmark 6E.3.1.1.2

Develop a model, based on observational evidence, to describe the cycling and movement of Earth's rock material and the energy that drives these processes. (P: 2, CC: 5, CI: ESS2) Emphasis of the practice is on using observations of processes like weathering and erosion of soil and rock, deposition of sediment, and crystallization of lava to inform model development. Emphasis of the core idea is on how these processes operate over geologic time to form rocks and minerals through the cycling of Earth's materials. Examples of models may be conceptual or physical.

Item Specifications:

P: 2 Developing and using models

Developing and using models may include, but is not limited to:

- Recognizing advantages and limitations of models.
- Evaluating or comparing existing models.
- Comparing and contrasting two or more models.
- Developing or using simple models with uncertain or less predictable factors.
- Developing or using models to show relationships among variables, including those variables that are not observable but predict observable phenomena.
- Using models to make predictions and explanations or generate data.
- Revising models based on new information, including change of a variable or system component.
- Using diagrams, graphs, data sets, numerical representations, analogies, or computer simulations.

CC: 5 Energy and matter: Flows, cycles, and conservation

Energy that drives these processes may include, but is not limited to:

- Internal heat energy from Earth that drives such processes as melting, crystallization, deformation, and atomic rearrangement of rock elements, moves rock material to Earth's surface, and moves the lithospheric plates.
- Energy from the Sun and the force of gravity that drive the movement of wind and water, causing physical and chemical weathering, erosion, and sedimentation.

CI: ESS2 Earth's systems

Cycling and movement of Earth's rock material may include, but is not limited to:

- Rocks that cycle between igneous, sedimentary, or metamorphic rocks.
- Physical and chemical changes that occur during Earth processes such as melting, cooling, sedimentation, weathering, crystallization, recrystallization, erosion, deformation, heat, pressure, and cementation.
- Use of grain size and texture to indicate the conditions under which rock formed.
- Mineral properties such as streak, hardness, luster, and density.
- The flow of energy that transforms rock and mineral types on the surface and inside Earth.
- Earth materials such as lava, magma, or soil.

Items do **not** assess memorization of specific rock or mineral names.

Benchmark 6E.3.1.1.3

Develop a model, based on observational and experimental evidence, to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity. (P: 2, CC: 5, CI: ESS2) Emphasis of the practice is on developing a way to represent the mechanisms of water changing state, the global movements of water and energy, and on how the observational and experimental evidence supports the model. Examples of models may be conceptual or physical.

Item Specifications:

P: 2 Developing and using models

Developing and using models may include, but is not limited to:

- Recognizing advantages and limitations of models.
- Evaluating or comparing existing models.
- Comparing and contrasting two or more models.
- Developing or using simple models with uncertain or less predictable factors.
- Developing or using models to show relationships among variables, including those variables that are not observable but predict observable phenomena.
- Using models to make predictions and explanations or generate data.
- Revising models based on new information, including change of a variable or system component.
- Using diagrams, graphs, data sets, numerical representations, analogies, or computer simulations.

CC: 5 Energy and matter: Flows, cycles, and conservation

Energy that drives these processes may include, but is not limited to:

- Energy transfer as conduction, convection, or radiation.
- Heat energy stored in oceans.

CI: ESS2 Earth's systems

Cycling of water may include, but is not limited to:

- Water exists as solid, liquid, or gas, with phase change driven by transfer of energy.
- Evaporation, transpiration, respiration, condensation, precipitation, infiltration, groundwater, aquifers, runoff, glaciers, surface water, or reservoirs such as oceans, lakes, and rivers.
- Distribution of materials and purification of water.

Items will **not** assess quantitative understanding of the latent heats of vaporization and fusion.

Benchmark 6E.3.2.1.1

Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history. (P: 6, CC: 3, CI: ESS1) Emphasis is on how analyses of rock formations and the fossils they contain are used to establish relative ages of major events in Earth's history. Examples of major events may include the evolution or extinction of particular organisms, the formation of mountain chains and the formation of ocean basins. Not included is using radioactive decay to age date rocks.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Constructing explanations may include, but is not limited to:

- Using multiple sources of evidence, including text, models, data, or graphical representations, to construct, revise, or evaluate an explanation.
- Using qualitative or quantitative relationships between variables to construct, revise, or evaluate an explanation that predicts or describes phenomena.
- Applying scientific theories and concepts to construct, revise, or evaluate explanations of phenomena.

CC: 3 Scale, proportion, and quantity

Scale, proportion, and quantity may include, but is not limited to:

- Using a combination of the order of rock layers, the fossil record, and evidence of major geologic events and the relative ordering of events to construct a model of Earth's history.

CI: ESS1 Earth's place in the universe

Evidence for Earth's history may include, but is not limited to:

- Using the geologic time scale interpreted from rock strata as a way to organize Earth's history (analyzing rock strata and the fossil record provides only relative dates, not an absolute age).
- The assumption that natural laws operate today as in the past.

Items do **not** include recalling the names of specific eras, periods, or epochs and events within them.

Benchmark 6E.3.2.1.2

Construct a scientific explanation based on evidence for how the uneven distribution of Earth's mineral, energy, or groundwater resources is the result of past geological processes. (P: 6, CC: 2, CI: ESS3) Emphasis is on how these resources are limited and typically non-renewable on a human timeframe. Examples of uneven distribution of resources may include petroleum (like in the North Dakota Bakken Shale), metal ores (like iron in the rocks of Minnesota's Iron Range), or groundwater in the different regions of Minnesota.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Constructing explanations may include, but is not limited to:

- Using multiple sources of evidence, including text, models, data, or graphical representations, to construct, revise, or evaluate an explanation.
- Using qualitative or quantitative relationships between variables to construct, revise, or evaluate an explanation that predicts or describes phenomena.
- Applying scientific theories and concepts to construct, revise, or evaluate explanations of phenomena.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Theories and laws affecting the natural world operate today as they did in the past and will continue to do so in the future.

CI: ESS3 Earth and human activity

Earth's resources and their origin may include, but are not limited to:

- Resources obtained from Earth's biosphere.
- Petroleum, coal, metal ores, and soil.
- Groundwater as a resource that can be replenished on human timescales, with limited distribution due to geologic processes.
- Specific conditions for formation, which may be rare in Earth's history.
- Evaluation of evidence from past geologic processes such as volcanic activity and sedimentary processes.
- Specific environmental conditions, including certain areas and/or times that resulted in uneven distribution of resources.
- Renewable energy resources such as hydropower, tidal, wind, hydrothermal, and biofuels made available by past geological events.
- Use of Minnesota and regional resources, when possible.

Benchmark 6E.3.2.1.3

Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.* (P: 6, CC: 2, CI: ESS3, ETS1) Emphasis of the practice is on applying scientific principles about Earth's natural processes (like how water moves through the ground and air) to designing solutions to problems caused by human activity. Emphasis of the core idea is on how human activity impacts Earth's environments. Examples of parts of the design process may include assessing the kinds of solutions that are feasible and designing and evaluating solutions that may reduce those impacts. Examples of human activities that impact the environment may include withdrawing too much water from aquifers, altering stream flow by building dams or levees, increasing runoff caused by impermeable surfaces like parking lots, or adding undesirable materials to the air, water, or land.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Designing solutions may include, but is not limited to:

- Evaluating and/or designing, constructing, or testing a design of an object, tool, or system.
- Engaging in or evaluating a design cycle, including aspects such as prioritizing criteria, recognizing constraints, making tradeoffs, testing, revising, and retesting.
- Generating or critiquing multiple solutions to a problem.
- Determining criteria and constraints such as individual or societal needs and wants and economic conditions (e.g., costs of building and maintaining the solution).
- Monitoring effects on the environment such as measuring levels of pollution or biodiversity of an ecosystem.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Distinguishing between causation and correlation.

CI: ESS3 Earth and human activity, ETS1 Engineering design

Human impact on the environment may include, but is not limited to:

- Land usage (e.g., urban development, agriculture, mining, forestry, dam building, or the removal of wetlands).
- Human activities that have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species.
- Changes to Earth's environments that can have different impacts (negative and positive) for different living things.

Benchmark 6E.4.1.1.1

Construct an argument, supported by evidence, for how geoscience processes have changed Earth's surface at varying time and spatial scales. (P: 7, CC: 3, CI: ESS2) Emphasis is on how processes like erosion, deposition, mountain building, and volcanism affect the surface of Earth. Some processes, like mountain building, take a long time. Other processes, like landslides, happen quickly. Examples may include how weathering, erosion and glacial activity have shaped the surface of Minnesota.

Item Specifications:

P: 7 Engaging in argument from evidence

Constructing an argument may include, but is not limited to:

- Identifying and evaluating evidence that supports or refutes a claim.
- Evaluating or critiquing arguments and/or supporting evidence.
- Identifying flaws in reasoning and suggesting improvements.
- Comparing and analyzing differing arguments on the same topic.
- Using multiple sources of evidence, including text, models, data, or graphical representations.

CC: 3 Scale, proportion, and quantity

Scale, proportion, and quantity may include, but are not limited to:

- Earth's processes, ranging from large to microscopic, that work together to change Earth's surface.
- Changes that occur at varying time and spatial scales.

CI: ESS2 Earth's systems

Geoscience processes may include, but are not limited to:

- Plate movement, mountain building, distribution of continents, glaciation, surface weathering, erosion, movement, and deposition of sediment at a range of scales.
- Rapid catastrophic events such as earthquakes, volcanoes, or meteor impacts.
- Landscape features such as lakes, river valleys, cliffs, moraines, and floodplains.
- 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.
- Multiple processes that can act at varying time and spatial scales to impact a given area.
- Processes within the geosphere, hydrosphere, atmosphere, and biosphere that work together to change Earth's surface.

Benchmark 6E.4.2.2.1

Communicate how a series of models, including those used by Minnesota American Indian tribes and communities and other cultures, are used to explain how motion in the Earth-Sun-Moon system causes the cyclic patterns of lunar phases, eclipses and seasons. (P: 8, CC: 1, CI: ESS1) Examples of cultures may include those within the local context of the learning community and within the context of Minnesota. Emphasis is on students questioning the limitations of their models and revising them to account for new observations. Models may be physical, graphical or conceptual.

Item Specifications:

P: 8 Obtaining, evaluating, and communicating information

Communicating may include, but is not limited to:

- Analyzing evidence, including text, models, data, visual displays, or graphical representations, to determine central ideas and/or information.
- Evaluating evidence and its presentation for accuracy, credibility, or bias.
- Comparing information from multiple sources.
- Communicating scientific information using credible evidence.

CC: 1 Patterns

Patterns may include, but are not limited to:

- The analysis and interpretation of historical models of observable patterns which can be used to predict relationships of seasons, moon phases, and eclipses.
- Apparent motion of the Sun, the Moon, and stars in the sky that can be observed, described, predicted, and explained with models.
- Relative sizes and distances in the Earth-Sun-Moon system.

CI: ESS1 Earth's place in the universe

Motion and patterns in the Earth-Sun-Moon system may include, but are not limited to:

- Lunar phases, solar/lunar eclipses, seasons, rotation, revolution, solstice, and equinox.
- The tilt of Earth's axis of rotation.
- Solar energy and its interactions with Earth and Moon.

Benchmark 7L.1.1.1.1

Ask questions about the processes and outcomes of various methods of communication between cells of multicellular organisms. (P: 1, CC: 6, CI: LS1) Examples of questions about processes and outcomes may include questions about disruptions to normal communication processes in the human body, such as in cancer, diabetes, paralysis, or other disorders.

Item Specifications:

P: 1 Asking questions (for science) and defining problems (for engineering)

Asking questions may include, but is not limited to:

- Evaluating questions from observations of models, phenomena, or data, unexpected results, or seeking additional information.
- Identifying or clarifying questions about an explanation.
- Identifying or clarifying evidence for an argument.
- Evaluating questions to determine relationships between dependent and independent variables.
- Identifying and evaluating testable or relevant questions or problems.
- Identifying evidence necessary to answer a question or solve a problem.
- Analyzing questions that challenge an argument or a data set.

CC: 6 Structure and function

Structure and function may include, but is not limited to:

- Structure and function of body organization, including cells, tissues, organs, and organ systems, as it relates to cell communication.
- Cell parts that carry out specific functions for communication between cells.

CI: LS1 From molecules to organisms: Structures and processes

Communication between cells may include, but is not limited to:

- Sense receptors responding to different inputs then transmitting them as signals that travel along nerve cells to the brain.
- The fight against infectious or noninfectious disease.
- The brain processing signals which results in immediate behavior or creation of memory.

Benchmark 7L.1.1.1.2

Ask questions that arise from careful observations of phenomena or models to clarify and/or seek additional information about how changes in genes can affect organisms. (P: 1, CC: 6, CI: LS3) Examples of changes may include neutral, harmful, or beneficial effects to the structure and function of the organism.

Item Specifications:

P: 1 Asking questions (for science) and defining problems (for engineering)

Asking questions may include, but is not limited to:

- Evaluating questions from observations of models, phenomena, or data, unexpected results, or seeking additional information.
- Identifying or clarifying questions about an explanation.
- Identifying or clarifying evidence for an argument.
- Evaluating questions to determine relationships between dependent and independent variables.
- Identifying and evaluating testable or relevant questions or problems.
- Identifying evidence necessary to answer a question or solve a problem.
- Analyzing questions that challenge an argument or a data set.
- Using scientific knowledge to evaluate a design problem with multiple criteria and constraints and/or identify limits of possible solutions.

CC: 6 Structure and function

Structure and function may include, but is not limited to:

- The structure of DNA and its function.

CI: LS3 Heredity: Inheritance and variation of traits

Changes in genes may include, but are not limited to:

- Mutations that can result in changes to the structure and function of proteins, which can affect the structures and function of the organism and change traits.

Items will **not** assess specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.

Benchmark 7L.1.2.1.1

Conduct an investigation to provide evidence that living things are made of cells, either one cell or many different numbers and types of cells. (P: 3, CC: 3, CI: LS1) Emphasis is on developing evidence that living things are made of cells, distinguishing between living and non-living things, and understanding that living things may be made of one cell or of many and varied cells.

Item Specifications:

P: 3 Planning and carrying out investigations

Conducting an investigation may include, but is not limited to:

- Planning or revising an experiment or design to produce data needed to support a claim or answer a scientific question.
- Identifying variables as dependent, independent, or controlled.
- Testing design solutions under a range of conditions.
- Analyzing and interpreting results of an investigation.
- Using descriptive, comparative, or experimental investigations.

CC: 3 Scale, proportion, and quantity

Scale, proportion, and quantity may include, but are not limited to:

- Proportional model of an organism.
- Phenomena that are observable at one scale but are not observable at another scale.

CI: LS1 From molecules to organisms: Structures and processes

Evidence that living things are made of cells may include, but is not limited to:

- Observations of single-celled organisms and different types of cells in multicelled organisms.
- Absence of cells in nonliving things, including viruses.
- Prokaryotic and eukaryotic cells.

Benchmark 7L.2.1.1.1

Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.** (P: 4, CC: 2, CI: LS2) Emphasis is on cause and effect relationships between resources and growth of individual organisms and the number or organisms in ecosystems during periods of abundant and scarce resources. Examples may include populations of MN deer, moose, wolf, scavengers or aquatic populations in Lake Superior or algal blooms in lakes and ponds. Examples of evidence may include the use of flow charts to organize and sequence the algorithm, and to show relationships.

Item Specifications:

P: 4 Analyzing and interpreting data

Analyzing and interpreting data may include, but is not limited to:

- Constructing, analyzing, and/or interpreting graphical displays such as maps, charts, graphs, and/or tables.
- Identifying linear and nonlinear relationships and/or relationships of space and time.
- Applying concepts of statistics and probability such as mean, median, mode, and range, identifying outliers, and using digital tools when feasible.
- Recognizing limitations of data or graphical displays and recommending improvements of precision, accuracy, and/or methods (e.g., multiple trials).
- Using data as evidence for phenomena.
- Comparing and contrasting different sets of data or graphical displays.
- Distinguishing between correlation and causation.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Requiring identification of possible effects of scarcity or abundance of resources in an ecosystem.

CI: LS2 Ecosystems: Interactions, energy, and dynamics

Effects of resource availability on an ecosystem may include, but is not limited to:

- An organism's and/or a population's dependence on interactions with biotic and abiotic factors.
- Competition for limited resources that affects growth and reproduction of individual organisms and populations.
- Effects of resource availability on traits of organisms.
- Population factors such as size, reproduction rate, or growth information.

Supporting information will be provided if non-Minnesota examples are used.

Benchmark 7L.2.1.1.2

Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth. (P: 4, CC: 1, CI: LS4) Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.

Item Specifications:

P: 4 Analyzing and interpreting data

Analyzing and interpreting data may include, but is not limited to:

- Constructing, analyzing, and/or interpreting graphical displays such as maps, charts, graphs, and/or tables.
- Identifying linear and nonlinear relationships and/or relationships of space and time.
- Recognizing limitations of data or graphical displays and recommending improvements of precision, accuracy, and/or methods (e.g., multiple trials).
- Using data as evidence for phenomena.
- Comparing and contrasting different sets of data or graphical displays.
- Distinguishing between correlation and causation.

CC: 1 Patterns

Patterns may include, but are not limited to:

- The assumption that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.

CI: LS4 Biological evolution: Unity and diversity

The fossil record may include, but is not limited to:

- Evidence of the existence, diversity, extinction, and change of many life forms and their environments throughout Earth's history.
- The comparison of anatomical similarities between organisms to infer lines of evolutionary descent.
- Age of fossils determined using relative placement of sedimentary rock layers or through radiometric dating.
- Patterns that provide evidence for mass extinctions.
- Patterns that show the long-term increase in diversity and complexity of organisms on Earth.
- The assumption that natural laws operate today as they would have in the past.

Items will **not** assess the memorization of names of individual species or geological eras in the fossil record.

Items will **not** assess detailed knowledge of radiometric dating techniques.

Benchmark 7L.2.1.1.3

Analyze visual data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.** (P: 4, CC: 1, CI: LS4) Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing their macroscopic appearances on diagrams or pictures.

Item Specifications:

P: 4 Analyzing and interpreting data

Analyzing and interpreting data may include, but is not limited to:

- Constructing, analyzing, and/or interpreting graphical displays such as maps, charts, graphs, and/or tables.
- Identifying linear and nonlinear relationships and/or relationships of space and time.
- Using data as evidence for phenomena.
- Comparing and contrasting different sets of data or graphical displays.
- Distinguishing between correlation and causation.

CC: 1 Patterns

Patterns may include, but are not limited to:

- Patterns in anatomical structures used to determine which species are most closely related.

CI: LS4 Biological evolution: Unity and diversity

Embryological development may include, but is not limited to:

- Anatomical similarities between organisms that infer lines of evolutionary descent.
- Features such as gill slits, limbs, and tails.

Item comparisons are limited to gross appearance of anatomical structures in embryological development.

Benchmark 7L.2.2.1.1

Use an algorithm to explain how natural selection may lead to increases and decreases of specific traits in populations.** (P: 5, CC: 2, CI: LS4) Emphasis is on using proportional reasoning to develop mathematical models, probability statements, or simulations to support explanations of trends in changes to populations over time.

Item Specifications:

P: 5 Using mathematics and computational thinking

Using an algorithm may include, but is not limited to:

- Applying mathematical concepts and/or processes such as ratio, rate, percent, basic operations, and simple algebraic formulas.
- Generating or analyzing data sets for patterns or trends using scientific instruments (e.g., thermometers, probes, etc.), digital tools, or mathematical measurements.
- Using mathematics and/or computational thinking to predict or support explanations.
- Constructing an explanation using a series of steps.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Changes in populations or environments may have more than one cause.
- Overall trends in the distribution of traits.

CI: LS4 Biological evolution: Unity and diversity

Natural selection leading to increases and decreases of traits may include, but is not limited to:

- Variations that exist within populations and can affect an organism's ability to survive and reproduce.
- Species changing over time in response to changes in environmental conditions through adaptation by natural selection acting over generations.
- Changes in the distribution of traits within a population resulting from survival and reproduction in a new environment.
- Extinction of a species when the environmental shifts are too extreme or rapid.
- The use of data or simulations to observe population and/or environmental changes (e.g., climate and resource availability) over time.

Items will **not** include Hardy Weinberg calculations.

Benchmark 7L.3.1.1.1

Develop and use a model to describe the function of a cell as a whole and describe the way cell parts contribute to the cell's function. (P: 2, CC: 6, CI: LS1) Emphasis is on the cell functioning as a whole system and the primary role of identified parts of the cell, specifically the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.

Item Specifications:

P: 2 Developing and using models

Developing and using a model may include, but is not limited to:

- Recognizing advantages and limitations of models.
- Evaluating or comparing existing models.
- Comparing and contrasting two or more models.
- Developing or using models to show relationships among variables, including those variables that are not observable but predict observable phenomena.
- Using models to make predictions and explanations or generate data.
- Revising models based on new information, including change of a variable or system component.
- Diagrams, graphs, data sets, numerical representations, analogies, or computer simulations.

CC: 6 Structure and function

Structure and function may include, but are not limited to:

- Analyzing complex natural structures/systems to determine how they function.

CI: LS1 From molecules to organisms: Structures and processes

Functions of cells may include, but are not limited to:

- Functions of cells such as photosynthesis, cellular respiration, and cell division.
- Comparison of functioning between different types of cells.

The ways cell parts contribute to the cell's function may include, but are not limited to:

- Parts that work separately or together to maintain a cell's internal processes.
- The cell membrane forming the boundary that controls what enters and leaves the cell.
- Mitochondria are involved in cellular respiration.
- Plant cells contain cell walls, which provide structure to the plant, and chloroplasts, which make food through photosynthesis.
- The relationship of the cell membrane and cell wall in plant cells.
- The nucleus contains the genetic information of the cell.

Benchmark 7L.3.1.1.2

Develop and use a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. (P: 2, CC: 5, CI: LS1) Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released. Examples may include models of sugar breakdown into molecules of glucose that power our bodies, or protein breakdown into amino acids that are later reassembled to create body structures.

Item Specifications:

P: 2 Developing and using models

Developing and using a model may include, but is not limited to:

- Recognizing advantages and limitations of models.
- Evaluating or comparing existing models.
- Comparing and contrasting two or more models.
- Developing or using simple models with uncertain or less predictable factors.
- Developing or using models to show relationships among variables, including those variables that are not observable but predict observable phenomena.
- Using models to make predictions and explanations or generate data.
- Revising models based on new information, including change of a variable or system component.
- Using diagrams, graphs, data sets, numerical representations, analogies, or computer simulations.

CC: 5 Energy and matter: Flows, cycles, and conservation

Energy and matter may include, but are not limited to:

- Conservation of matter.
- Energy release with food molecule rearrangement, which may be used to support life processes within the organism.

CI: LS1 From molecules to organisms: Structures and processes

Describing how food is rearranged through chemical reactions may include, but is not limited to:

- Food (glucose) undergoing chemical reactions with oxygen, releasing stored energy, and producing carbon dioxide and water during cellular respiration.

Items will **not** assess chemical formulas or equations for photosynthesis or respiration.

Benchmark 7L.3.1.1.3

Develop and use a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. (P: 2, CC: 5, CI: LS2) Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems.

Item Specifications:

P: 2 Developing and using models

Developing and using a model may include, but is not limited to:

- Recognizing advantages and limitations of models.
- Evaluating or comparing existing models.
- Comparing and contrasting two or more models.
- Developing or using simple models with uncertain or less predictable factors.
- Developing or using models to show relationships among variables, including those variables that are not observable but predict observable phenomena.
- Using models to make predictions and explanations or generate data.
- Revising models based on new information, including change of a variable or system component.
- Using diagrams, graphs, data sets, numerical representations, analogies, or computer simulations.

CC: 5 Energy and matter: Flows, cycles, and conservation

Energy and matter may include, but are not limited to:

- Conservation of matter.
- Conservation of energy, including energy changing form.
- The transfer of matter and energy through the ecosystem.
- Relative amounts of energy transferred between trophic levels using models such as energy pyramids.

CI: LS2 Ecosystems: Interactions, energy, and dynamics

Cycling of matter and flow of energy in an ecosystem may include, but is not limited to:

- Food webs as models that demonstrate how matter and energy are transferred between producers (organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food—within an ecosystem.
- Transfers of matter into and out of the physical environment (such as atmosphere and soil) occur at every level (particle level to environmental level).
- Decomposers recycling nutrients from dead plant and animal matter back into the soil and water.
- Plants and algae forming the lowest level of the food web, supporting all life in the ecosystem.
- Nonliving parts of an ecosystem such as sunlight, soil, water, minerals, or air.
- Minnesota ecosystems.
- Photosynthesis within a food web to show energy transfer and matter cycling.

Items will **not** include the use of chemical reactions to describe the processes.

Benchmark 7L.3.1.1.4

Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. (P: 2, CC: 2, CI: LS3) Emphasis is on using models, such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variations.

Item Specifications:

P: 2 Developing and using models

Developing and using a model may include, but is not limited to:

- Recognizing advantages and limitations of models.
- Evaluating or comparing existing models.
- Comparing and contrasting two or more models.
- Developing or using simple models with uncertain or less predictable factors.
- Developing or using models to show relationships among variables, including those variables that are not observable but predict observable phenomena.
- Using models to make predictions and explanations or generate data.
- Revising models based on new information, including change of a variable or system component.
- Using diagrams, graphs, data sets, numerical representations, analogies, or computer simulations.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Relationships between type of reproduction and resulting genetic variation.

CI: LS3 Heredity: Inheritance and variation of traits

Asexual reproduction may include, but is not limited to:

- Offspring getting genetic information from only one parent.
- Offspring and parents having identical chromosomes.

Sexual reproduction may include, but is not limited to:

- Sperm and egg cells that contain half of the organism's genetic information.
- Offspring having two sources of genetic information (i.e., two sets of chromosomes each containing one allele) that contribute to each final pair of chromosomes in the offspring.
- Each parent contributing half of the genes acquired (at random) by the offspring.
- Offspring having genetic variation.
- Use of the terms homozygous and heterozygous.

Benchmark 7L.3.2.1.1

Construct an explanation based on evidence for how environmental and genetic factors influence the growth of organisms and/or populations. (P: 6, CC: 2, CI: LS1, ETS2) Examples of environmental factors may include local environmental conditions such as availability of food, light, space, and water. Examples of genetic factors may include large breed cattle and species of grass affecting growth of organisms. Examples of evidence may include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds. Examples of human activity may include agricultural practices, phosphorus and nitrogen loading in lakes, hybridization and breeding practices.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Constructing an explanation may include, but is not limited to:

- Using multiple sources of evidence, including text, models, data, or graphical representations, to construct, revise, or evaluate an explanation.
- Using qualitative or quantitative relationships between variables to construct, revise, or evaluate an explanation that predicts or describes phenomena.
- Applying scientific theories and concepts to construct, revise, or evaluate explanations of phenomena.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Identifying and differentiating between causation and correlation.
- Describing the impact of changing environmental or genetic factors on growth.
- Using probability to describe a cause and effect relationship.
- Identifying patterns in nature and events that occur together.

CI: LS1 From molecules to organisms: Structures and processes, ETS2 Links among engineering, technology, science, and society

Environmental and genetic factors that influence growth may include, but are not limited to:

- Animals engaging in behaviors that increase the odds of reproduction.
- Plant reproduction that may depend on animal behavior or specialized features to reproduce.
- Organism growth affected by both genetic and environmental factors.
- Environmental factors such as temperature and soil composition.
- Selective breeding of organisms for human use, gene therapy, or genetic modification.
- The idea that an organism's body is an environment, with environmental factors such as antibiotics.
- General ideas of probability that can be used to describe the contributions of specific causes or factors to organism growth.
- The role of cell division in the growth of organisms.

Items do **not** include genetic mechanisms, gene regulation, or biochemical processes.

Benchmark 7L.3.2.1.2

Construct an explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. (P: 6, CC: 2, CI: LS1) Emphasis of the core idea is on plants and algae using energy from light to make sugars (food for themselves and as an energy source for other organisms) from carbon dioxide (from air) and water; and in the process release oxygen.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Constructing an explanation may include, but is not limited to:

- Using multiple sources of evidence, including text, models, data, or graphical representations, to construct, revise, or evaluate an explanation.
- Using qualitative or quantitative relationships between variables to construct, revise, or evaluate an explanation that predicts or describes phenomena.
- Applying scientific theories and concepts to construct, revise, or evaluate explanations of phenomena.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- The ability to identify and differentiate between causation and correlation.
- The impact of environmental changes on the cycling of matter or flow of energy.
- The transfer of energy drives the motion and/or cycling of matter.

CI: LS1 From molecules to organisms: Structures and processes

The role of photosynthesis in the cycling of matter and flow of energy may include, but is not limited to:

- Chloroplasts as the organelles that carry out the process of photosynthesis in eukaryotic cells.
- The process of photosynthesis as energy input from light, molecules of carbon dioxide (from many sources), and water are used by plants, algae (including phytoplankton), and many microorganisms to make sugars (food) and oxygen.
- Sugars being used immediately or stored for growth or later use.
- Animals obtaining food from eating plants, algae, and photosynthetic microorganisms or eating other animals.
- Animals taking in food and oxygen to provide energy and materials for growth and survival.
- Products of photosynthesis becoming reactants in cellular respiration.
- Inputs and outputs of the process of photosynthesis.

Items do **not** assess the biochemical mechanisms of photosynthesis or require students to know chemical symbols or the balanced equation for photosynthesis.

Benchmark 7L.3.2.1.3

Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships. (P: 6, CC: 1, CI: LS4) Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Constructing an explanation may include, but is not limited to:

- Using multiple sources of evidence, including text, models, data, or graphical representations, to construct, revise, or evaluate an explanation.
- Using qualitative or quantitative relationships between variables to construct, revise, or evaluate an explanation that predicts or describes phenomena.
- Applying scientific theories and concepts to construct, revise, or evaluate explanations of phenomena.

CC: 1 Patterns

Patterns may include, but are not limited to:

- Patterns in the fossil record (e.g., presence, location, and inferences possible in lines of evolutionary descent for multiple specimens).
- Patterns observed at multiple spatial and time scales (e.g., DNA sequences, embryological development, and fossil records) provide evidence for causal relationships relating to biological evolution and common ancestry.

CI: LS4 Biological evolution: Unity and diversity

Using anatomical similarities and differences to infer evolutionary relationships among organisms may include, but is not limited to:

- Predominant traits in a population resulting from natural and/or artificial selection.
- Change in species over time in response to changes in environmental conditions.
- Traits that support successful survival and reproduction in the new environment becoming more common.
- The use of shared anatomic features, fossil evidence, or genetic makeup to infer lines of evolutionary descent and/or determine or compare the relationships or relatedness of organisms (modern and extinct).

Benchmark 7L.3.2.1.4

Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. (P: P: 6, CC: 2, CI: LS4) Emphasis is on using simple probability statements and proportional reasoning to construct explanations.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Constructing an explanation may include, but is not limited to:

- Using multiple sources of evidence, including text, models, data, or graphical representations, to construct, revise, or evaluate an explanation.
- Using qualitative or quantitative relationships between variables to construct, revise, or evaluate an explanation that predicts or describes phenomena.
- Applying scientific theories and concepts to construct, revise, or evaluate explanations of phenomena.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Differentiation between causation and correlation.
- The relationships between traits and the probability of survival and reproduction of a given organism in a specific environment.

CI: LS4 Biological evolution: Unity and diversity

Genetic variations of traits increasing the probability of surviving and reproducing may include, but is not limited to:

- Both natural and artificial selection.
- Species changing over time in response to changes in environmental conditions.
- Traits that support successful survival and reproduction in the new environment becoming more common.
- The effects of a specific environment (e.g., food availability, predators, nesting site availability, light availability, etc.) on the probability of an organism surviving and reproducing.
- Mutations resulting in changes to individuals or, over time, an entire population.
- Any population in a given environment contains a variety of inheritable genetic traits.
- Morphological (e.g., body shape, wing pattern, and bone structure), physiological (e.g., disease resistance, heart rate, and photosynthesis), or behavioral (e.g., feeding, mating, and defense) traits.

Benchmark 7L.4.1.1.1

Support or refute an explanation by arguing from evidence for how the body is a system of interacting subsystems composed of groups of cells. (P: 7, CC: 4, CI: LS1) Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples may include arguments that deal with the interaction of subsystems within a system and the normal functioning of those systems.

Item Specifications:

P: 7 Engaging in argument from evidence

Arguing from evidence may include, but is not limited to:

- Analyzing evidence, including text, models, data, visual displays, or graphical representations, to determine central ideas and/or information.
- Evaluating evidence and its presentation for accuracy, credibility, or bias.
- Comparing information from multiple sources.
- Communicating scientific information using credible evidence.

CC: 4 Systems and system models

Evidence for how the body is a system of interacting subsystems composed of groups of cells may include, but is not limited to:

- Groups of specialized cells working together to form tissues (e.g., types of cells found in different tissues such as nervous, muscular, epithelial, etc. and their functions).
- Specialized tissues making up each organ and working together for the organ to function (e.g., the heart contains muscle and connective and epithelial tissues that allow the heart to pump blood).
- Interactions of organs within an organ system (e.g., the heart and blood vessels work together to pump blood throughout the body).
- Interactions of body systems within an organism (e.g., the digestive, circulatory, and respiratory systems work together to provide needed materials to the body for energy, growth, and repair).

CI: LS1 From molecules to organisms: Structures and processes

Systems and system models may include, but are not limited to:

- Components and interactions of systems.
- Systems may have subsystems and be a part of larger complex systems (e.g., organ systems make up an organism and are made of tissues, which are made of cells).
- Features of a system that are not observable.

Items will **not** assess differentiating between or identifying types of cells or tissues.

Items are limited to circulatory, excretory, digestive, respiratory, muscular, and nervous systems.

Benchmark 7L.4.1.1.2

Support or refute an explanation by arguing from evidence and scientific reasoning for how animal behavior and plant structures affect the probability of successful reproduction. (P: 7, CC: 2, CI: LS1) Examples of behaviors that affect the probability of animal reproduction may include nest building to protect young, herding of animals to protect young from predators, and vocalization and/or colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction may include transferring pollen or seeds, and creating conditions for seed germination and growth. Examples of plant structures may include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.

Item Specifications:

P: 7 Engaging in argument from evidence

Arguing from evidence may include, but is not limited to:

- Analyzing evidence, including text, models, data, visual displays, or graphical representations, to determine central ideas and/or information.
- Evaluating evidence and its presentation for accuracy, credibility, or bias.
- Comparing information from multiple sources.
- Communicating scientific information using credible evidence.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Differentiation between causation and correlation.
- Phenomena having more than one cause and some cause and effect relationships in systems that can only be described using probability.
- Relationships between specialized plant structures and the probability of successful reproduction of plants that have those structures.
- Relationships between animal behaviors and the probability of successful reproduction of animals that exhibit those behaviors.

CI: LS1 From molecules to organisms: Structures and processes

Animal behavior and plant structures affecting reproduction may include, but are not limited to:

- Genetic and environmental factors that may affect an organism's reproduction.
- Migration.
- Protection of territory.

Benchmark 7L.4.1.2.1

Construct an argument supported by empirical evidence that changes in physical or biological components of an ecosystem affect populations.* (P: 7, CC: 7, CI: LS2) Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations and on evaluating empirical evidence supporting arguments about changes and/or impacts to ecosystems. Examples of physical components may include human-built structures like urban developments, or dams.

Item Specifications:

P: 7 Engaging in argument from evidence

Arguing from evidence may include, but is not limited to:

- Analyzing evidence, including text, models, data, visual displays, or graphical representations, to determine central ideas and/or information.
- Evaluating evidence and its presentation for accuracy, credibility, or bias.
- Comparing information from multiple sources.
- Communicating scientific information using credible evidence.

CC: 7 Stability and change

Stability and change may include, but are not limited to:

- Changes in natural or designed systems over time.
- Even small changes in one part of a system might cause large changes in another part.
- Disruption by either sudden events or gradual changes that accumulate over time.
- Consideration of the causal and correlational patterns of the changes.

CI: LS2 Ecosystems: Interactions, energy, and dynamics

Changes in components of an ecosystem and their effects on populations may include, but are not limited to:

- Organisms and populations are dependent on their environmental interactions both with other living things and with nonliving factors, any of which can limit their growth, survival, or reproductive likelihood.
- Access to and competition for resources (e.g., food, water, oxygen, etc.) limiting organism and population growth.
- Disruptions to any part of an ecosystem that can lead to shifts in all of its populations.
- All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of both people and the natural environment.
- Migration of species into or out of an area or formation of a new species.
- Magnitude of the changes in the physical or biological components of an ecosystem, such as data about rainfall, pollution, fires, predator removal, or species introduction.
- Magnitude of the changes in populations, such as population size, types of species present, or relative prevalence of a species within the ecosystem.

Benchmark 7L.4.1.2.2

Evaluate competing design solutions for maintaining biodiversity or ecosystem services.* (P: 7, CC: 2, CI: LS2, ETS2) Emphasis is on evaluating a solution that reduces environmental harm while still benefiting humans. Examples of ecosystem services (natural processes within ecosystems that humans also benefit from) may include water purification as it cycles through Earth's systems, nutrient recycling, climate stabilization, decomposition of wastes, and pollination. Examples of design solution constraints may include scientific, economic, and social considerations.

Item Specifications:

P: 7 Engaging in argument from evidence

Arguing from evidence may include, but is not limited to:

- Analyzing evidence, including text, models, data, visual displays, or graphical representations, to determine central ideas and/or information.
- Evaluating evidence and its presentation for accuracy, credibility, or bias.
- Comparing information from multiple sources.
- Communicating scientific information using credible evidence.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Differentiation between causation and correlation.
- Small changes in one part of a system might cause large changes in another part.
- Phenomena may have more than one cause and some cause and effect relationships in systems can only be described using probability.
- Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

CI: LS2 Ecosystems: Interactions, energy, and dynamics

Maintaining biodiversity or ecosystem services may include, but is not limited to:

- Changes in biodiversity influencing humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on (e.g., water purification and recycling).
- Why biodiversity or ecosystem services are necessary to maintain a healthy ecosystem.
- Evidence such as variety of species or factors that affect the stability of the biodiversity of an ecosystem.
- In order to design better technologies, new science may need to be explored (e.g., materials research prompted by desire for better batteries or solar cells; biological questions raised by medical problems).
- All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of both people and the natural environment.
- The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus, technology use varies from region to region and over time.
- Technologies that are beneficial for a certain purpose that may later be found to have had unforeseen impacts (e.g., health-related and environmental). In such cases, new regulations on use or new technologies (to mitigate the impacts or eliminate them) may be required.

Benchmark 7L.4.2.2.1

Gather multiple sources of information and communicate how Minnesota American Indian tribes and communities and other cultures use knowledge to predict or interpret patterns of interactions among organisms across multiple ecosystems. (P: 8, CC: 1, CI: LS2, ETS2) Examples of cultures may include those within the local context of the learning community and within the context of Minnesota. Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions may include competition, predation and mutualisms.

Item Specifications:

P: 8 Obtaining, evaluating, and communicating information

Gathering and communicating information may include, but is not limited to:

- Analyzing evidence, including text, models, data, visual displays, or graphical representations, to determine central ideas and/or information.
- Evaluating evidence and its presentation for accuracy, credibility, or bias.
- Comparing information from multiple sources.
- Communicating scientific information using credible evidence.

CC: 1 Patterns

Patterns may include, but are not limited to:

- Rates of change (e.g., the growth rates of plants under different conditions) and other numerical relationships that provide information about patterns of interactions.
- Patterns that can help identify cause and effect relationships.
- Graphs, charts, and mathematical representations that may identify patterns in data.
- Similarity between interactions among organisms across multiple ecosystems.

CI: LS2 Ecosystems: Interactions, energy, and dynamics, ETS2 Links among engineering, technology, science, and society

Interactions among organisms may include, but are not limited to:

- Growth of organisms and population increases that are limited by access to resources (e.g., food, water, oxygen, etc.).
- Competition between or within species.
- Specific competitive, predatory, and mutually-beneficial interactions that vary across ecosystems but can share patterns.
- Food webs as models that demonstrate how matter and energy are transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem.
- Ecosystem characteristics that vary over time. Disruptions to any part of an ecosystem can lead to shifts in all of its populations.

Benchmark 8P.1.1.1.1

Ask questions about locations of common elements on the periodic table to note patterns in the properties of similarly grouped elements. (P: 1, CC: 1, CI: PS1) Emphasis is on the similar properties within columns of the periodic table. Examples of questions that students may think to ask may include how are the properties of elements in a column similar and different.

Item Specifications:

P: 1 Asking questions (for science) and defining problems (for engineering)

Asking questions may include, but is not limited to:

- Evaluating questions from observations of models, phenomena, or data, unexpected results, or seeking additional information.
- Identifying or clarifying questions about an explanation
- Identifying or clarifying evidence for an argument.
- Identifying and evaluating testable or relevant questions.
- Identifying evidence necessary to answer a question.
- Analyzing questions that challenge an argument or a data set.

CC: 1 Patterns

Patterns may include, but are not limited to:

- The relationship between common properties and the electrons in the outermost energy level, excluding transition metals or lanthanide and actinide series.
- Tables of melting points, boiling points, and/or conductivity.

CI: PS1 Matter and its interactions

Elements' location on the periodic table and patterns of properties may include, but are not limited to:

- Comparisons of metals vs. nonmetals.
- Comparisons between group 1A (Alkali metals), group 7A (halogens), and group 8A (noble gases).
- Chemical and physical properties such as phase of matter, reaction with water, and conductivity of heat and/or electricity.

Items that assess valence electrons will be limited to identifying the groups on the periodic table.

Benchmark 8P.1.1.1.2

Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. (P: 1, CC: 2, CI: PS2) Examples of data may include the number of turns of wire in a coil, the strength of magnets, and the current through the wire and their effect on the speed of rotation in a simple motor.

Item Specifications:

P: 1 Asking questions (for science) and defining problems (for engineering)

Asking questions may include, but is not limited to:

- Evaluating questions from observations of models, phenomena, or data, unexpected results, or seeking additional information.
- Identifying or clarifying questions about an explanation or evidence for an argument.
- Evaluating questions to determine relationships between dependent and independent variables.
- Identifying and evaluating testable or relevant questions.
- Identifying evidence necessary to answer a question.
- Analyzing questions that challenge an argument or a data set.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Magnitude, distance, and relative orientation can all have an effect on electromagnetic forces.

CI: PS2 Motion and stability: Forces and interactions

Electric and magnetic forces may include, but are not limited to:

- Attractive or repulsive forces, whose size depends on the magnitudes of electric charges, electric currents, or electric or magnetic field strengths, and the distance or orientation between the interacting objects.
- Use of devices such as electromagnets, electric motors, or generators.

Benchmark 8P.1.2.1.1

Plan and conduct an investigation of changes in pure substances when thermal energy is added or removed and relate those changes to particle motion. (P: 3, CC: 2, CI: PS1) Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs.

Item Specifications:

P: 3 Planning and carrying out investigations

Planning and conducting an investigation may include, but is not limited to:

- Planning or revising an experiment or design to produce data needed to support a claim or answer a scientific question.
- Identifying variables as dependent, independent, or controlled.
- Evaluating and using needed tools, measurements, and data.
- Evaluating the accuracy of various data collection methods.
- Analyzing and interpreting results of an investigation.
- Carrying out descriptive, comparative, or experimental investigations.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include but, is not limited to:

- The relationship between the addition or removal of thermal energy from a substance and the change in the average kinetic energy of the particles in the substance.

CI: PS1 Matter and its interactions

Particle motion may include, but is not limited to:

- Liquid particles constantly in contact with each other:
- Gas particles widely spaced except when they happen to collide.
- Solid particles closely spaced, which vibrate in position but do not change relative locations.
- Changes of state that occur with variations in temperature or pressure can be investigated using models of matter.
- Change in particle arrangement resulting in change in density.

Relationship between thermal energy and pure substances may include, but is not limited to:

- Motion of particles in a system and the kinetic energy of the particles in the system.
- Average kinetic energy of the particles and the temperature of the system.
- Transfer of thermal energy (or heat) resulting in change in kinetic energy or state of matter.

Benchmark 8P.1.2.1.2

Plan and conduct an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. (P: 3, CC: 7, CI: PS2) Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.

Item Specifications:

P: 3 Planning and carrying out investigations

Planning and conducting an investigation may include, but is not limited to:

- Planning or revising an experiment or design to produce data needed to support a claim or answer a scientific question.
- Identifying variables as dependent, independent, or controlled.
- Evaluating and using needed tools, measurements, and data.
- Evaluating the accuracy of various data collection methods.
- Analyzing and interpreting results of an investigation.
- Carrying out descriptive, comparative, or experimental investigations.

CC: 7 Stability and change

No further clarification is needed.

CI: PS2 Motion and stability: Forces and interactions

Motion of an object may include, but is not limited to:

- Determination by the sum of the forces acting on it.
- Unbalanced forces resulting in change in motion.
- Relationships between mass, force, and change of motion.
- Measurements using the metric system.
- Acceleration as related to Newton's Second Law.
- Inertia as related to Newton's First Law.
- Simple algebraic calculations.

Benchmark 8P.1.2.1.3

Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. (P: 3, CC: 2, CI: PS2) Examples of this phenomenon may include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations may include first-hand experiences or simulations.

Item Specifications:

P: 3 Planning and carrying out investigations

Planning and conducting an investigation may include, but is not limited to:

- Planning or revising an experiment or design to produce data needed to support a claim or answer a scientific question.
- Identifying variables as dependent, independent, or controlled.
- Evaluating and using needed tools, measurements, and data.
- Evaluating the accuracy of various data collection methods.
- Testing design solutions under a range of conditions.
- Analyzing and interpreting results of an investigation.
- Carrying out descriptive, comparative, or experimental investigations.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Gravitational forces and the relationship between distance and mass of objects.

CI: PS2 Motion and stability: Forces and interactions

Forces between objects exerted by fields may include, but are not limited to:

- Electric, magnetic, electromagnetic, and gravitational forces.
- Distance between objects, mass of the objects, charge or magnetic orientation of the objects, and/or magnitude of charge or magnetic strength.
- Magnetic field or gravitational field of the Earth.
- Measurements of electric, gravitational, or magnetic forces.

Items are limited to electric, magnetic, and gravitational fields.

Benchmark 8P.1.2.1.4

Plan and conduct an investigation to determine how the temperature of a substance is affected by the transfer of energy, the amount of mass, and the type of matter. (P: 3, CC: 2, CI: PS3) Emphasis is on conceptualizing temperature as the average kinetic energy of a substance's particles. Examples of investigations may include comparing final water temperatures after different masses of ice melt in equal volumes of water with the same initial temperature, and temperature changes of different materials with the same mass as they heat or cool in the environment.

Item Specifications:

P: 3 Planning and carrying out investigations

Planning and conducting an investigation may include, but is not limited to:

- Planning or revising an experiment or design to produce data needed to support a claim or answer a scientific question.
- Identifying variables as dependent, independent, or controlled.
- Evaluating and using needed tools, measurements, and data.
- Evaluating the accuracy of various data collection methods.
- Analyzing and interpreting results of an investigation.
- Carrying out descriptive, comparative, or experimental investigations.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Proportional relationships (e.g. expansion and contractions of materials) among different types and quantities of a substance.

CI: PS3 Energy

Effects of transfer of energy, mass, or type of matter on temperature of a substance may include, but are not limited to:

- The relationship between the temperature and the total energy of a system, which depends on the type, state, and amount of matter present.
- The amount of energy needed to change the temperature of a sample, which depends on the nature of the matter, size of the sample, and environment.

Benchmark 8P.2.1.1.1

Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. (P: 4, CC: 1, CI: PS1) Examples of reactions may include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride. Examples of properties may include density, melting point, boiling point, solubility, flammability, and odor.

Item Specifications:

P: 4 Analyzing and interpreting data

Analyzing and interpreting data may include, but is not limited to:

- Constructing, analyzing, and/or interpreting graphical displays such as maps, charts, graphs, and/or tables.
- Identifying linear and nonlinear relationships and/or relationships of space and time.
- Applying concepts of statistics and probability such as mean, median, mode, and range, identifying outliers, and using digital tools when feasible.
- Recognizing limitations of data or graphical displays and recommending improvements of precision, accuracy, and/or methods (e.g., multiple trials).
- Using data as evidence for phenomena.
- Comparing and contrasting different sets of data or graphical displays.
- Distinguishing between correlation and causation.

CC: 1 Patterns

Patterns may include, but are not limited to:

- Similarities and differences in physical and chemical properties of each substance before and after the interaction.

CI: PS1 Matter and its interactions

Properties of substances before and after a chemical reaction may include, but are not limited to:

- Changes in the properties of substances related to the rearrangement of atoms of reactants and products.
- Numerical data.
- Conservation of mass.

Benchmark 8P.2.1.1.2

Construct and interpret graphical displays of data to describe the relationship of kinetic energy to the mass and speed of an object. (P: 4, CC: 3, CI: PS3) Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples may include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a Wiffle ball versus a tennis ball.

Item Specifications:

P: 4 Analyzing and interpreting data

Constructing and interpreting graphical displays of data may include, but is not limited to:

- Constructing, analyzing, and/or interpreting graphical displays such as maps, charts, graphs, and/or tables.
- Identifying linear and nonlinear relationships and/or relationships of space and time.
- Applying concepts of statistics and probability such as mean, median, mode, and range, identifying outliers, and using digital tools when feasible.
- Recognizing limitations of data or graphical displays and recommending improvements of precision, accuracy, and/or methods (e.g., multiple trials).
- Using data as evidence for phenomena.
- Comparing and contrasting different sets of data or graphical displays.
- Distinguishing between correlation and causation.

CC: 3 Scale, proportion, and quantity

Scale, proportion, and quantity may include, but are not limited to:

- Proportional relationships between kinetic energy, mass, and speed.

CI: PS3 Energy

The relationship of kinetic energy to mass and speed may include, but is not limited to:

- Kinetic energy, which is proportional to the mass of the moving object and the square of its speed.

Benchmark 8P.2.2.1.1

Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. (P: 5, CC: 1, CI: PS4) Emphasis is on describing waves (standard repeating waves) with both qualitative and quantitative thinking. Not included are electromagnetic waves.

Item Specifications:

P: 5 Using mathematics and computational thinking

Using mathematical representations may include, but is not limited to:

- Applying mathematical concepts and/or processes such as ratio, rate, percent, basic operations, and simple algebraic formulas.
- Generating or analyzing data sets for patterns or trends using scientific instruments (e.g., thermometers, probes, etc.), digital tools, or mathematical measurements.
- Using mathematics to predict or support explanations.
- Creating algorithms to solve a problem.

CC: 1 Patterns

Patterns may include, but are not limited to:

- A proportional relationship between energy of the wave and the square of the amplitude.
- A proportional relationship between the amount of energy transferred by waves in a given time to the frequency (e.g., if twice as many water waves hit the shore each minute, then twice as much energy will be transferred to the shore).
- Changes in the energy of the wave if any one of the parameters of the wave is changed.

CI: PS4 Waves and their applications in technologies for information transfer

Waves may include, but are not limited to:

- Identification of characteristics in a simple mathematical wave model.
- Representation of repeating quantities.
- Frequency, as the number of times the pattern repeats in a given amount of time (e.g., beats per second).
- Amplitude, as the maximum extent of the repeating quantity from rest position (e.g., height or depth of a water wave from average sea level).
- Wavelength, as a certain distance in which the quantity repeats its value (e.g., the distance between the tops of a series of water waves).
- Identification of the ways wave characteristics correspond with physical observations (e.g., frequency corresponds to sound pitch and amplitude corresponds to sound volume).

Items do **not** include electromagnetic waves and is limited to standard repeating waves.

Benchmark 8P.2.2.1.2

Create a computer program to illustrate the transfer of energy within a system where energy changes form.**
(P: 5, CC: 7, CI: PS3) Emphasis of the programming skills is the use of sequences, events and conditionals. Examples of a system may include a roller coaster, a pendulum, an electric water heater, and a solar electric collector.

Item Specifications:

Not assessed on MCA-IV.

Benchmark 8P.3.1.1.1

Develop models to describe the atomic composition of simple molecules and crystals. (P 2, CC: 3, CI: PS1) Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules may include ammonia and methane. Examples of crystal structures may include sodium chloride or quartz, pyrite or diamonds. Does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete description of all individual atoms in a complex molecule or crystal structure.

Item Specifications:

P: 2 Developing and using models

Developing models may include, but is not limited to:

- Recognizing advantages and limitations of models.
- Evaluating or comparing existing models.
- Comparing and contrasting two or more models.
- Developing or using simple models with uncertain or less predictable factors.
- Developing or using models to show relationships among variables, including those variables that are not observable but predict observable phenomena.
- Using models to make predictions and explanations or generate data.
- Revising models based on new information, including change of a variable or system component.
- Using diagrams, graphs, data sets, numerical representations, analogies, or computer simulations.

CC: 3 Scale, proportion, and quantity

Scale, proportion, and quantity may include, but are not limited to:

- Behavior of a large sample depends on its structure at a particle level, which is too small to see.

CI: PS1 Matter and its interactions

Atomic composition of simple molecules and crystals may include, but is not limited to:

- Models showing atomic composition of simple molecules and extended structures that vary in complexity.
- Identifications of relevant components, including individual atoms, molecules, and extended structures with repeating subunits or substances (e.g., solids, liquids, and gases at the macro level).
- Individual atoms, from two to thousands, combine to form molecules, which can be made of the same type or different types of atom.
- Some molecules can connect to each other.
- In some molecules, the same atoms of different elements repeat; in other molecules, the same atom of a single element repeats.

Benchmark 8P.3.1.1.2

Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. (P: 2, CC: 5, CI: PS1) Emphasis is on law of conservation of matter. Examples of models may include physical models, digital formats, or drawings, which represent atoms. Not included are atomic masses, balancing symbolic equations, or intermolecular forces.

Item Specifications:

P: 2 Developing and using models

Developing models may include, but is not limited to:

- Recognizing advantages and limitations of models.
- Evaluating or comparing existing models.
- Comparing and contrasting two or more models.
- Developing or using simple models with uncertain or less predictable factors.
- Developing or using models to show relationships among variables, including those variables that are not observable but predict observable phenomena.
- Using models to make predictions and explanations or generate data.
- Revising models based on new information, including change of a variable or system component.
- Using diagrams, graphs, data sets, numerical representations, analogies, or computer simulations.

CC: 5 Energy and matter: Flows, cycles, and conservation

No clarification needed.

CI: PS1 Matter and its interactions

Chemical reactions may include, but are not limited to:

- The use of a particle representation to balance a chemical reaction.
- Equal numbers and types of atoms in reactants and products.

Benchmark 8P.3.1.1.3

Develop and revise a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. (P: 2, CC: 5, CI: PS3) Emphasis is on relative amounts potential energy and not on calculations of potential energy. Examples of objects within systems interacting at varying distances may include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models may include representations, diagrams, pictures, and written descriptions of systems.

Item Specifications:

P: 2 Developing and using models

Developing and revising models may include, but is not limited to:

- Recognizing advantages and limitations of models.
- Evaluating or comparing existing models.
- Comparing and contrasting two or more models.
- Developing or using simple models with uncertain or less predictable factors.
- Developing or using models to show relationships among variables, including those variables that are not observable but predict observable phenomena.
- Using models to make predictions and explanations or generate data.
- Revising models based on new information, including change of a variable or system component.
- Using diagrams, graphs, data sets, numerical representations, analogies, or computer simulations.

CC: 5 Energy and matter: Flows, cycles, and conservation

Energy may include, but is not limited to:

- The transfer of energy into or out of a system when force is applied to change distance of objects (e.g., moving attracting objects farther apart or moving repelling objects closer together).

CI: PS3 Energy

Objects interacting at a distance may include, but are not limited to:

- The possible transfer of energy to or from an object when each object exerts a force on the other from a distance.
- A system of two stationary objects that interact through electric, magnetic, or gravitational forces.

Items are limited to two objects and electric, magnetic, and gravitational interactions.

Benchmark 8P.3.1.1.4

Develop and use a model to qualitatively describe that waves are reflected, absorbed, or transmitted through various materials. (P: 2, CC: 4, CI: PS4) Emphasis is on both light and mechanical waves. Examples of models may include drawings, simulations, a storyboard/diagram and written descriptions.

Item Specifications:

P: 2 Developing and using models

Developing and using models may include, but is not limited to:

- Recognizing advantages and limitations of models.
- Evaluating or comparing existing models.
- Comparing and contrasting two or more models.
- Developing or using simple models with uncertain or less predictable factors.
- Developing or using models to show relationships among variables, including those variables that are not observable but predict observable phenomena.
- Using models to make predictions and explanations or generate data.
- Revising models based on new information, including change of a variable or system component.
- Using diagrams, graphs, data sets, numerical representations, analogies, or computer simulations.

CC: 4 Systems and system models

Systems may include, but are not limited to:

- Waves interacting with various materials.

CI: PS4 Waves and their applications in technologies for information transfer

Waves may include, but are not limited to:

- Waves that travel through matter (e.g., sound or water waves) and those that can travel through space (e.g., light waves).
- Various materials through which waves are reflected, absorbed, or transmitted.
- Relevant characteristics of the wave before and after it has interacted with a material (e.g., frequency, amplitude, and wavelength).
- Position of the source of the wave.
- The boundary of two transparent materials causing bending of light. Items may not assess the term refraction.

Items are limited to qualitative applications pertaining to light and mechanical waves.

Benchmark 8P.3.2.1.1

Construct an explanation based on evidence and scientific principles of a common phenomenon that can be explained by the motions of molecules. (P: 6, CC: 3, CI: PS1) Emphasis of the core idea is on the movement of small particles (atoms or molecules) can explain the behavior of macroscopic phenomena. Examples of phenomena may include expansion of balloons, diffusion of odors, and pressure changes in gases due to heating and cooling.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Constructing explanations may include, but is not limited to:

- Using multiple sources of evidence, including text, models, data, or graphical representations, to construct, revise, or evaluate an explanation.
- Using qualitative or quantitative relationships between variables to construct, revise, or evaluate an explanation that predicts or describes phenomena.
- Applying scientific theories and concepts to construct, revise. or evaluate explanations of phenomena.

CC: 3 Scale, proportion, and quantity

Scale, proportion, and quantity may include, but are not limited to:

- Proportional relationships (e.g., the size of a balloon at room temperature compared to the size of the same balloon in the freezer).

CI: PS1 Matter and its interactions

Motion of molecules may include, but is not limited to:

- Phase changes, description of motion of particles, water cycle, and arrangement of particles.

Benchmark 8P.3.2.2.1

Construct, test and modify a device that either releases or absorbs thermal energy by chemical processes.* (P: 6, CC: 5, CI: PS1, ETS1) Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of chemical reactions include dissolving ammonium chloride or calcium chloride in water.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Constructing, testing, and modifying may include, but is not limited to:

- Evaluating and/or designing, constructing, or testing the design of an object, tool, or system.
- Engaging in or evaluating a design cycle, including aspects such as prioritizing criteria, recognizing constraints, making tradeoffs, testing, revising, and retesting.
- Generating or critiquing multiple solutions to a problem.
- Using constraints, such as amount and cost of materials or safety.
- Describing how the transfer of thermal energy between the device and other components within the system will be tracked and used to solve the given problem.
- Analyzing the parts of the problem to be solved by the device.

CC: 5 Energy and matter: Flows, cycles, and conservation

No clarification needed.

CI: PS1 Matter and its interactions, ETS1 Engineering design

Chemical processes may include, but are not limited to:

- Chemical reactions that release or store energy.

Benchmark 8P.3.2.2.2

Design a solution to a problem involving the motion of two colliding objects using Newton's 3rd Law.* (P: 6, CC: 4, CI: PS2, ETS1) Examples of practical problems may include the impact of one dimensional collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Designing a solution may include, but is not limited to:

- Evaluating and/or designing, constructing, or testing the design of an object, tool, or system.
- Engaging in or evaluating a design cycle, including aspects such as prioritizing criteria, recognizing constraints, making tradeoffs, testing, revising, and retesting.
- Generating or critiquing multiple solutions to a problem.
- Recognizing constraints such as cost, mass and speed of objects, time, or materials.

CC: 4 Systems and system models

No clarification needed.

CI: PS2 Motion and stability: Forces and interactions, ETS1 Engineering design

No clarification needed.

Benchmark 8P.3.2.2.3

Design, construct, and test a device that either minimizes or maximizes thermal energy transfer.* (P: 6, CC: 5, CI: PS3, ETS1) Emphasis is on using scientific principles to design the device. Examples of devices may include an insulated box, a solar cooker, and a Styrofoam cup.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Constructing, testing, and modifying may include, but is not limited to:

- Evaluating and/or designing, constructing, or testing the design of an object, tool, or system.
- Engaging in or evaluating a design cycle, including aspects such as prioritizing criteria, recognizing constraints, making tradeoffs, testing, revising, and retesting.
- Generating or critiquing multiple solutions to a problem.
- Applying design constraints such as materials, safety, time, or cost.
- Using change in temperature as a measure of success.
- Incorporating design criteria such as the minimum or maximum temperature difference that the device is required to maintain, the amount of time that the device is required to maintain this difference, or whether the device is intended to maximize or minimize the transfer of thermal energy.

CC: 5 Energy and matter: Flows, cycles, and conservation

No clarification needed.

CI: PS3 Energy, ETS1 Engineering design

Thermal energy transfer may include, but is not limited to:

- Temperature as a measure of the average kinetic energy of particles of matter.
- The relationship between the temperature and the total thermal energy of a system depending on the types, states, and amounts of matter present.
- Energy spontaneously transferred out of hotter regions or objects and into colder ones.
- Different types of materials used in the design solution have properties (e.g., thickness, heat conductivity, and reflectivity) that can minimize or maximize thermal energy transfer.
- Conduction, convection, and radiation.

Benchmark 8P.4.1.1.1

Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. (P: 7, CC: 3, CI: PS2) Examples of evidence for arguments may include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system. Not included are Newton's Law of Gravitation or Kepler's Laws.

Item Specifications:

P: 7 Engaging in argument from evidence

Constructing and presenting arguments using evidence may include, but is not limited to:

- Identifying and evaluating evidence that supports or refutes a claim.
- Evaluating or critiquing arguments and/or supporting evidence.
- Identifying flaws in reasoning and suggesting improvements.
- Comparing and analyzing differing arguments on the same topic.
- Using multiple sources of evidence, including text, models, data, or graphical representations.

CC: 3 Scale, proportion, and quantity

No clarification needed.

CI: PS2 Motion and stability: Forces and interactions

Gravitational interactions may include, but are not limited to:

- The direction of the forces between objects in the system.
- Distance between objects.

Benchmark 8P.4.1.1.2

Compare and evaluate evidence to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. (P: 7, CC: 5, CI: PS3) Examples of empirical evidence used in the students' arguments may include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of an object.

Item Specifications:

P: 7 Engaging in argument from evidence

Comparing and evaluating evidence may include, but is not limited to:

- Identifying and evaluating evidence that supports or refutes a claim.
- Evaluating or critiquing arguments and/or supporting evidence.
- Identifying flaws in reasoning and suggesting improvements.
- Comparing and analyzing differing arguments on the same topic.
- Using multiple sources of evidence, including text, models, data, or graphical representations.

CC: 5 Energy and matter: Flows, cycles, and conservation

Energy may include, but is not limited to:

- Different forms of energy (e.g., energy in fields, thermal energy, energy of motion, light, and sound).

CI: PS3 Energy

Evidence of change in energy of an object may include, but is not limited to:

- A change in observable features of the object or surroundings, such as motion, position, temperature, or wave amplitude and frequency, before and after the interaction.

Benchmark 8P.4.2.1.1

Gather and evaluate information from multiple sources to describe that synthetic materials come from natural resources and impact society. (P: 8, CC: 6, CI: PS1) Emphasis of the practice is to synthesize information from multiple appropriate sources and assess the credibility, accuracy and possible bias of each publication. Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of materials may include plastic, new medicines, foods, and alternative fuels.

Item Specifications:

P: 8 Obtaining, evaluating, and communicating information

Gathering and evaluating information may include, but is not limited to:

- Analyzing evidence, including text, models, data, visual displays, or graphical representations, to determine central ideas and/or information.
- Evaluating evidence and its presentation for accuracy, credibility, or bias.
- Comparing information from multiple sources.
- Communicating scientific information using credible evidence.

CC: 6 Structure and function

Structure and function may include, but are not limited to:

- Structures designed to serve particular functions by taking into account properties of different materials and how those materials can be transformed, shaped, and used.

CI: PS1 Matter and its interactions

Synthetic materials coming from natural resources may include, but are not limited to:

- Pure substances having characteristic physical and chemical properties.
- Synthetic materials used by humans and the natural resources from which they come.
- Chemical processes that are used to create synthetic materials from natural resources (e.g., burning of limestone for the production of concrete).
- Societal needs for the synthetic material (e.g., the need for concrete as a building material).

Benchmark 8P.4.2.1.2

Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.** (P: 8, CC: 6, CI: PS4) Emphasis of the practice is on using information to support and clarify claims. Emphasis of the core idea is on understanding that waves (encoded both analog and digitally) can be used for communication purposes. Examples of encoding and transmitting information may include using fiber optic cable to transmit light pulses, radio wave pulses in Wi-Fi devices, and conversion of stored binary patterns to make sound or text on a computer screen.

Item Specifications:

P: 8 Obtaining, evaluating, and communicating information

Integrating qualitative scientific and technical information to support the claim may include, but is not limited to:

- Analyzing evidence, including text, models, data, visual displays, or graphical representations, to determine central ideas and/or information.
- Evaluating evidence and its presentation for accuracy, credibility, or bias.
- Comparing information from multiple sources.
- Communicating scientific information using credible evidence.

CC: 6 Structure and function

Structure and function may include, but is not limited to:

- Structures can be designed to serve particular functions.

CI: PS4 Waves and their applications in technologies for information transfer

Digitized and analog signals may include, but are not limited to:

- Digitized signals understood as wave pulses.
- Examples of technology such as audio recordings and digital probes, including thermometers and pH probes, that use digital coding and transmission.
- Specific features that make digital signals more reliable than analog signals, such as more reliable recording, storing for future recovery, and ability to transmit signals over long distances without significant degradation.
- Technologies that can extend the measurement, exploration, modeling, and computational capacity of scientific investigations.

Items do **not** include binary counting.

Items do **not** include the specific mechanism of any given device.

Benchmark 9L.1.1.1.1

Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. (P: 1, CC: 2, CI: LS3) Examples of relationships may include relationships between mutated DNA sequences or chromosomal deletions and their effect on traits.

Item Specifications:

P: 1 Asking questions (for science) and defining problems (for engineering)

Asking questions may include, but is not limited to:

- Evaluating questions from observations of models, theories, phenomena, or data, unexpected results, or seeking additional information.
- Evaluating questions to determine relationships, including quantitative relationships, between dependent and independent variables.
- Identifying and evaluating testable or relevant questions or problems.
- Identifying evidence necessary to answer a question or solve a problem.
- Evaluating questions that challenge the premise of an argument, or the interpretation of a data set.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Specific causes of DNA and chromosomal mutations and the effect on the resulting proteins and resulting traits.
- The relationship between mutagens in the environment (e.g., UV rays) and mutations.
- The relationship between inheriting specific alleles from each parent and the inherited trait.
- Identification of possible causal relationships.

CI: LS3 Heredity: Inheritance and variation of traits

The role of DNA and chromosomes in traits passed from parents to offspring may include, but is not limited to:

- Cells containing genetic information in the form of DNA molecules.
- Genes as regions of DNA that contain instructions that code for proteins.
- Mutations in DNA sequences or chromosomal mutations that may be helpful, harmful, or have no effect.
- Chromosomes containing a single very long DNA molecule, with each gene on a chromosome located on a particular segment of that DNA.

Items will **not** assess the steps of meiosis.

Benchmark 9L.1.2.1.1

Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. (P: 3, CC: 7, CI: LS1) Examples of investigations may include heart rate response to exercise, stomata response to moisture and temperature, and root development in response to water levels.

Item Specifications:

P: 3 Planning and carrying out investigations

Planning and conducting an investigation may include, but is not limited to:

- Planning investigations to produce data used in building and revising models, explaining phenomena, and testing design solutions.
- Identifying sources of error and evaluating control of variables.
- Planning collection of data, determining types of data needed for reliable measurements, considering limitations of data (e.g., number of trials, cost, risk, and time), and refining the design accordingly.
- Planning safe and ethical investigations, mindful of environmental, social, and personal impacts.
- Selecting and using appropriate tools to collect, record, analyze, and evaluate data.
- Making hypotheses about what happens to a dependent variable when an independent variable is manipulated.
- Carrying out descriptive, comparative, or experimental investigations.

CC: 7 Stability and change

Stability and change may include, but is not limited to:

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

CI: LS1 From molecules to organisms: Structures and processes

The feedback mechanisms that maintain homeostasis may include, but are not limited to:

- Stimulus and response.
- Positive or negative feedback.
- Feedback cycles.

Items will only assess the feedback mechanism and **not** the cellular processes (e.g., cellular respiration) involved in the feedback mechanism.

Benchmark 9L.2.1.1.1

Apply concepts of probability to explain and predict the variation and distribution of expressed traits in a population. (P: 4, CC: 3, CI: LS3) Examples of traits in human groups may include lactose intolerance, or high-altitude adaptation.

Item Specifications:

P: 4 Analyzing and interpreting data

Applying concepts of probability may include, but is not limited to:

- Using tools, technologies, and/or models (e.g., computational and mathematical) to make valid and reliable scientific claims.
- Applying concepts of statistics and probability using digital tools when feasible.
- Recognizing the limitations of data analysis, such as accuracy of population size estimates (e.g., mark and recapture and randomness of sampling).
- Comparing and contrasting data sets for consistency of measurements and observations.
- Evaluating the impact of new data.
- Using Punnett squares as data.

CC: 3 Scale, proportion, and quantity

Scale, proportion, and quantity may include, but are not limited to:

- Expressed traits at an organism or population level.
- Study of a population in an ecosystem vs. that same species globally.

CI: LS3 Heredity: Inheritance and variation of traits

The variation and distribution of expressed traits in a population may include, but are not limited to:

- The use of Punnett squares to predict traits.
- Analysis of population data as it relates to environmental change.
- Examples of traits from nonhuman groups.
- Variation and distribution of traits observed being dependent on both genetic and environmental factors (e.g., predation, food availability, or climate).

Items will **not** assess Hardy-Weinberg calculations.

Benchmark 9L.2.1.1.2

Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. (P: 4, CC: 1, CI: LS4) Emphasis is on analyzing shifts in the numerical distribution of traits and using these shifts as evidence to support explanations. Examples of advantageous traits may include antibiotic resistance in bacteria, or the coloration and camouflage of animals in response to changing environmental conditions.

Item Specifications:

P: 4 Analyzing and interpreting data

Applying concepts of statistics and probability may include, but is not limited to:

- Using tools, technologies, and/or models (e.g., computational and mathematical) to make valid and reliable scientific claims.
- Applying concepts of statistics and probability using digital tools when feasible.
- Identifying limitations of data analysis (e.g., measurement and sampling selection).
- Comparing and contrasting data sets for consistency of measurements and observations.
- Evaluating the impact of new data.

CC: 1 Patterns

Patterns may include, but are not limited to:

- Mathematical representations (e.g., graphs and population data) needed to identify some patterns.

CI: LS4 Biological evolution: Unity and diversity

Increase of organisms with advantageous heritable traits may include, but is not limited to:

- The impact of natural selection on the number of advantageous traits in a population.
- Traits that positively affect survival being more likely to be passed on and become more common in the population.
- The potential for a species to increase in number.
- Requirement of genetic variation of individuals in a species due to mutation and sexual reproduction.
- Competition for a limited supply of environmental resources needed for survival and reproduction.
- The proliferation of organisms that are better able to survive and reproduce in an environment.
- Biodiversity increasing by the formation of new species (speciation) and decreasing by the loss of species (extinction).

Benchmark 9L.2.2.1.1

Use a computational model to support or revise an evidence-based explanation for factors that have ecological and economic impacts on different- sized ecosystems, including factors caused by the practices of various human groups.** (P: 5, CC: 3, CI: LS2) Examples of ecological impacts might include changes in the carrying capacity, species numbers and/or types of organisms present in an environment. Examples of human practices can have positive or negative impacts, such as stream restoration versus deforestation as an ecological example. Examples of computational models may include online simulations of population dynamics, population ecology, or population growth.

Item Specifications:

P: 5 Using mathematics and computational thinking

Using a computational model may include, but is not limited to:

- Applying mathematical concepts and/or processes such as ratio, rate, percent, basic operations, and simple algebraic formulas.
- Generating or analyzing data sets for patterns or trends using scientific instruments (e.g., thermometers, probes, etc.), digital tools, or mathematical measurements.
- Using mathematics and/or computational thinking to predict or support explanations.
- Creating algorithms to solve a problem.
- Comparing proposed solutions to a problem.

CC: 3 Scale, proportion, and quantity

Scale, proportion, or quantity may include, but are not limited to:

- The significance of a phenomenon being dependent on the scale, proportion, and quantity at which it occurs.

CI: LS2 Ecosystems: Interactions, energy, and dynamics

Factors that have impacts on ecosystems may include, but are not limited to:

- Modest biological or physical changes as well as extreme changes (e.g., climate change).
- Those that affect biodiversity.

Benchmark 9L.2.2.1.2

Use a computational model to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.** (P: 5, CC: 5, CI: LS2) Examples of claims about matter cycles may include how carbon, nitrogen, or water cycles through the environment, and/or how disruptions to those systems affect matter cycling. Examples of energy flow may include the transfer of the sun's energy into and among organisms, and/or connections between fossil fuel burning and the carbon cycle. Examples of computational models may include online simulations and animated representations.

Item Specifications:

P: 5 Using mathematics and computational thinking

Using a computational model may include, but is not limited to:

- Applying mathematical concepts and/or processes such as ratio, rate, percent, basic operations, and simple algebraic formulas.
- Generating or analyzing data sets for patterns or trends using scientific instruments (e.g., thermometers, probes, etc.), digital tools, or mathematical measurements.
- Using mathematics and/or computational thinking to predict or support explanations.

CC: 5 Energy and matter

Energy and matter may include, but are not limited to:

- Any cycle of matter involves associated energy transfer.
- Conservation of energy and matter.

CI: LS2 Ecosystems: Interactions, energy, and dynamics

Cycling of matter and flow of energy may include, but are not limited to:

- Representations of energy flow and matter cycling such as food chains, food webs, and energy pyramids.
- The water cycle, carbon cycle (photosynthesis, cellular respiration, combustion, and decomposition), and nitrogen cycle (nitrogen fixation and decomposition).
- Emphasis on matter such as carbon, hydrogen, nitrogen, and oxygen.

Items are limited to proportional reasoning to describe the cycling of matter and flow of energy.

Items will **not** assess knowing chemical compounds or balancing equations.

Benchmark 9L.3.1.1.1

Develop and use a model to illustrate the levels of organization of interacting systems and how that translates into specific functions in multicellular organisms.** (P: 2, CC: 6, CI: LS1) Emphasis is on specific functions at the organ system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. Examples of models may include real (e.g. fish, birds, insects, etc.) or imaginary organisms with attention to the various structures and systems that assist the organism in performing necessary life functions.

Item Specifications:

P: 2 Developing and using models

Developing and using a model may include, but is not limited to:

- Evaluating advantages and limitations of models of the same process, mechanism, or system and selecting or revising a model that best fits the evidence or criteria.
- Developing, revising, and/or using a model based on evidence to show or predict relationships between systems or system components.
- Using multiple types of models to explain or predict phenomena.
- Using different model types based on advantages or limitations.
- Developing, using, and/or manipulating models, including mathematical and computational models, to generate data to support explanations, predict phenomena, analyze systems, test processes, and/or solve problems.

CC: 6 Structure and function

No clarification needed.

CI: LS1 From molecules to organisms: Structures and processes

Levels of organization of interacting systems may include, but are not limited to:

- A system consisting of different parts, but which is also a part of a larger system.

Items will **not** assess interactions and functions at the molecular or chemical reaction level.

Benchmark 9L.3.1.1.2

Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. (P: 2, CC: 2, CI: LS1) Examples of models may include diagrams and conceptual models.

Item Specifications:

P: 2 Developing and using models

Using a model may include, but is not limited to:

- Evaluating advantages and limitations of models of the same process, mechanism, or system and selecting or revising a model that best fits the evidence or criteria.
- Developing, revising, and/or using a model based on evidence to show or predict relationships between systems or system components.
- Using multiple types of models to explain or predict phenomena.
- Using different model types based on advantages or limitations.
- Developing, using, and/or manipulating models, including mathematical and computational models, to generate data to support explanations, predict phenomena, analyze systems, and/or test processes.

CC: 2 Cause and effect

Cause and effect may include, but is not limited to:

- Healthy cells being able to divide (under ideal conditions).
- Mutations causing a cell to become cancerous.
- Appropriate signals causing differentiation of stem cells into a specific cell type.
- Mutations resulting from errors in DNA replication.
- Division of nearby cells to replace dead somatic cells.

CI: LS1 From molecules to organisms: Structures and processes

Cell division (mitosis) and differentiation may include, but are not limited to:

- Use of mitosis in multicellular organisms for the purposes of growth and tissue repair.
- Use of cell division for asexual reproduction in some organisms.
- Production of two identical cells with the same number of chromosomes, identical to each other and to the parent cell.
- The role of DNA and chromosomes in the cell cycle.
- Signals turning on certain genes in a cell of a multicellular organism, causing it to differentiate.

Items will **not** assess specific gene control mechanisms.

Benchmark 9L.3.1.1.3

Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. (P: 2, CC: 4, CI: LS1) Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models may include diagrams, chemical equations, and conceptual models.

Item Specifications:

P: 2 Developing and using models

Using a model may include, but is not limited to:

- Evaluating advantages and limitations of models of the same process, mechanism, or system and selecting or revising a model that best fits the evidence or criteria.
- Developing, revising, and/or using a model based on evidence to show or predict relationships between systems or system components.
- Using multiple types of models to explain or predict phenomena.
- Using different model types based on advantages or limitations.
- Developing, using, and/or manipulating models, including mathematical and computational models, to generate data to support explanations, predict phenomena, analyze systems, and/or test processes.

CC: 4 Systems and system models

No clarification needed.

CI: LS1 From molecules to organisms: Structures and processes

Photosynthesis may include, but is not limited to:

- The equation for photosynthesis as: carbon dioxide + water + light energy --> glucose + oxygen
- The Sun being the ultimate source of energy needed for life.
- Photosynthetic organisms such as plants, algae, and phytoplankton.
- Storage of chemical energy in the plant.

Items will **not** assess these specific biochemical steps: light-dependent reactions, light-independent reactions, and Calvin Cycle.

Benchmark 9L.3.1.1.4

Use a model to illustrate that cellular respiration is a chemical process in which energy from food is used to create new compounds. (P: 2, CC: 5, CI: LS1) Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.

Item Specifications:

P: 2 Developing and using models

Using a model may include, but is not limited to:

- Evaluating advantages and limitations of models of the same process, mechanism, or system and selecting or revising a model that best fits the evidence or criteria.
- Developing, revising, and/or using a model based on evidence to show or predict relationships between systems or system components.
- Using multiple types of models to explain or predict phenomena.
- Using different model types based on advantages or limitations.
- Developing, using, and/or manipulating models, including mathematical and computational models, to generate data to support explanations, predict phenomena, analyze systems, and/or test processes.

CC: 5 Energy and matter

Energy and matter may include, but are not limited to:

- Conservation of matter (e.g., food going into an organism either remains in the organism or exits as waste).
- Conversion of energy to other forms (chemical energy in food is transferred to thermal [heat] energy or mechanical energy in organisms).
- Conservation of energy, which only moves between one place and another place, between objects and/or fields, or between systems.

CI: LS1 From molecules to organisms: Structures and processes

Cellular respiration may include, but is not limited to:

- The equation for cellular respiration as: glucose + oxygen --> carbon dioxide + water + ATP (energy).
- Chemical energy in the bonds of food molecules being released to maintain life processes.

Items will **not** include identification of the steps or specific processes involved in cellular respiration.

Benchmark 9L.3.2.1.1

Construct an explanation based on evidence for how the structure of DNA determines the structure of the proteins that carry out the essential functions of life. (P: 6, CC: 6, CI: LS1).

Item Specifications:

P: 6 Constructing explanations and designing solutions

Constructing an explanation may include, but is not limited to:

- Using multiple sources of evidence, including text, models, data, or graphical representations, to construct, revise, or evaluate an explanation.
- Using qualitative or quantitative relationships between variables to construct, revise, or evaluate an explanation that predicts or describes phenomena.
- Applying scientific theories and concepts to construct, revise, or evaluate explanations of phenomena.

CC: 6 Structure and function

Structure and function may include, but are not limited to:

- The relationship of structure and function in DNA, including replication, ordering of base pairs, and mutation of the DNA molecule.
- The relationship of structure and function in proteins, including transcription and translation.

CI: LS1 From molecules to organisms: Structures and processes

DNA and proteins may include, but are not limited to:

- The discovery of DNA and our current understanding of genetics resulting from the progression of contributions of many different scientists over the course of time.
- Basic molecular structure and primary function of nucleic acid.
- Identification of the relationships between DNA, genes, and chromosomes.
- The use of base pairing rules for DNA (A=T and C=G) and RNA (A=U and C=G).
- Protein shape and function dependent on the amino acid sequence.

Items will **not** assess identification of specific cell or tissue types, whole body systems, or specific protein structures and functions.

Benchmark 9L.3.2.1.2

Construct and revise an explanation based on evidence for how various elements combine with carbon to form molecules that form the basis for life on Earth. (P: 6, CC: 5, CI: LS1) Emphasis is on using evidence from models and simulations to support explanations. Examples of molecules may include proteins, lipids, carbohydrates and nucleic acids.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Constructing an explanation may include, but is not limited to:

- Using multiple sources of evidence, including text, models, data, or graphical representations, to construct, revise, or evaluate an explanation.
- Using qualitative or quantitative relationships between variables to construct, revise, or evaluate an explanation that predicts or describes phenomena.
- Applying scientific theories and concepts to construct, revise, or evaluate explanations of phenomena.

CC: 5 Energy and matter: Flows, cycles, and conservation

Energy and matter may include, but are not limited to:

- Energy existing within the molecular bonds of matter.
- Conservation of matter.

CI: LS1 From molecules to organisms: Structures and processes

Elements and molecules may include, but are not limited to:

- Elements such as carbon, oxygen, hydrogen, nitrogen, and phosphorous.
- Carbon forming the backbone of molecules such as carbohydrates, lipids, proteins, and nucleic acids that are formed from smaller building blocks.
- Elements combining through processes such as photosynthesis, cellular respiration, and protein synthesis.

Benchmark 9L.3.2.1.3

Construct and revise an explanation based on evidence about the role of photosynthesis and cellular respiration (including anaerobic processes) in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. (P: 6, CC: 7, CI: LS2) Emphasis is on the importance of biological processes in the global scale cycling of carbon and on a conceptual understanding of the role of aerobic and anaerobic respiration in different environments.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Constructing an explanation may include, but is not limited to:

- Using multiple sources of evidence, including text, models, data, or graphical representations, to construct, revise, or evaluate an explanation.
- Using qualitative or quantitative relationships between variables to construct, revise, or evaluate an explanation that predicts or describes phenomena.
- Applying scientific theories and concepts to construct, revise, or evaluate explanations of phenomena.

CC: 7 Stability and change

Stability and change may include, but are not limited to:

- Changes in the cycling of carbon induced by human activity, such as global climate change.
- Change and rates of change that can be quantified and modeled over very short or very long periods of time.

CI: LS2 Ecosystems: Interactions, energy, and dynamics

Photosynthesis, cellular respiration, and cycling of matter may include, but are not limited to:

- Photosynthesis, digestion of plant matter, cellular respiration, and decomposition as important components of the carbon cycle, in which carbon is exchanged between the biosphere, atmosphere, hydrosphere, and geosphere through chemical, physical, geological, and biological processes.
- Reactants and products of photosynthesis and cellular respiration, such as water, carbon dioxide, glucose, oxygen, and ATP (energy).
- Relationship between photosynthesis and cellular respiration.
- The impact of an increase or decrease of an input/reactant (or sunlight) on the processes.
- Anaerobic processes, such as fermentation.

Benchmark 9L.3.2.1.4

Construct an explanation based on evidence that the process of evolution primarily results from four factors: reproduction within a species, heritable genetic variation of individuals in that species, competition for limited resources, and increased survival and reproduction of the individuals best suited for the environment. (P: 6, CC: 2, CI: LS4) Emphasis is on using evidence to explain the influence each of the four factors has on the number, behavior, morphology, or physiology of organisms, in terms of their ability to compete for limited resources and subsequent survival of individuals and adaptation of their species. Examples of evidence may include mathematical models such as simple distribution graphs and proportional reasoning.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Constructing an explanation may include, but is not limited to:

- Using multiple sources of evidence, including text, models, data, or graphical representations, to construct, revise, or evaluate an explanation.
- Using qualitative or quantitative relationships between variables to construct, revise, or evaluate an explanation that predicts or describes phenomena.
- Applying scientific theories and concepts to construct, revise, or evaluate explanations of phenomena.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Differentiation between causation and correlation.
- Effects of environmental change on genetic diversity**.**

CI: LS4 Biological evolution: Unity and diversity

The process of evolution may include, but is not limited to:

- Sexual reproduction leading to heritable genetic variation of individuals in a species.
- Variation leading to competition for limited resources.
- Individuals best suited to the environment having increased survival and reproduction rates.
- The impact of natural selection on traits in a population.
- Traits that positively affect survival being more likely to be passed on, therefore becoming more common in the population.

Benchmark 9L.3.2.1.5

Construct an explanation based on evidence for how natural selection leads to the adaptation of populations. (P: 6, CC: 2, CI: LS4) Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems contribute to a change in gene frequency over time, leading to adaptation of populations. Examples of selective forces may include long-term climate change, or variations in seasonal temperatures, pH, light cycles, geographic barriers, or in response to the evolution of other organisms.

Item Specifications:

P: 6 Constructing explanations (for science) and designing solutions (for engineering)

Constructing an explanation may include, but is not limited to:

- Using multiple sources of evidence, including text, models, data, or graphical representations, to construct, revise, or evaluate an explanation.
- Using qualitative or quantitative relationships between variables to construct, revise, or evaluate an explanation that predicts or describes phenomena.
- Applying scientific theories and concepts to construct, revise, or evaluate explanations of phenomena.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Differentiation between causation and correlation.
- Effects of natural selection on a population.

CI: LS4 Biological evolution: Unity and diversity

Evidence for natural selection and adaptation may include, but is not limited to:

- Anatomical or embryological evidence of change over time.
- Comparison of DNA and amino acid sequences.
- Distribution of traits within a population.
- Human impact on biodiversity.

Benchmark 9L.4.1.1.1

Evaluate evidence for the role of group behavior on an individual's and species' chances to survive and reproduce. (P: 7, CC: 2, CI: LS2) Emphasis of the practice is on identifying evidence supporting the outcomes of group behavior, and developing logical and reasonable arguments based on evidence. Emphasis of the core idea is on distinguishing between group and individual behavior. Examples of group behavior may include herding, migratory behaviors, or various symbioses.

Item Specifications:

P: 7 Engaging in argument from evidence

Evaluating evidence may include, but is not limited to:

- Comparing and evaluating competing arguments, taking into account accepted explanations, and new evidence.
- Evaluating claims, evidence, and/or reasoning behind currently accepted explanations to determine the merits of arguments.
- Using a claim with supporting evidence and reasoning, determine if the evidence is logically consistent.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Differentiating between causation and correlation.
- Making and defending claims about cause and effect.

CI: LS2 Ecosystems: Interactions, energy, and dynamics

Evidence for the role of group behavior on organisms' survival may include, but is not limited to:

- Carrying capacity.
- Individual energy needs within an ecosystem and its impact on populations.
- Biological or physical disturbances within an ecosystem (including human activity) and their impact on the survival of a population.
- Predictions about group behaviors' impact on survival rates.
- Predictions about the impact of resource availability or environmental disturbances on entire species.
- Examples such as packs and prides vs. individual hunting predator/prey relationships.

Benchmark 9L.4.1.1.2

Make and defend a claim based on evidence that heritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. (P: 7, CC: 2, CI: LS3) Emphasis is on using data to support arguments for the ways variation occurs.

Item Specifications:

P: 7 Engaging in argument from evidence

Making and defending a claim based on evidence may include, but is not limited to:

- Comparing and evaluating competing arguments, taking into account accepted explanations, and new evidence.
- Evaluating claims, evidence, and/or reasoning behind currently accepted explanations to determine the merits of arguments.
- Using a claim with supporting evidence and reasoning, determine if the evidence is logically consistent.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Differentiation between causation and correlation.
- The ability to make and defend claims about cause and effect.
- Effects of mutations.

CI: LS3 Heredity: Inheritance and variation of traits

Heritable genetic variations may include, but are not limited to:

- Those caused by mutations that are helpful, harmful, or have no effect.
- Those caused by mutations such as insertion, deletion, or substitution.
- Those caused by crossing over and independent assortment of chromosomes during sexual reproduction.

Items will **not** assess the phases of meiosis or the biochemical mechanism of specific steps in the process.

Benchmark 9L.4.1.1.3

Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. (P: 7, CC: 2, CI: LS4) Emphasis is on determining cause and effect relationships for (1) how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and (2) how the rate of change of the environment affects distribution or disappearance of traits in species.

Item Specifications:

P: 7 Engaging in argument from evidence

Evaluating evidence may include, but is not limited to:

- Comparing and evaluating competing arguments, taking into account accepted explanations, and new evidence.
- Evaluating claims, evidence, and/or reasoning behind currently accepted explanations to determine the merits of arguments.
- Using a claim with supporting evidence and reasoning, determine if the evidence is logically consistent.

CC: 2 Cause and effect: Mechanism and explanation

Cause and effect may include, but is not limited to:

- Differentiation between causation and correlation.
- The ability to make and defend claims about cause and effect.
- Effects of mutations.

CI: LS4 Biological evolution: Unity and diversity

Changes in environmental conditions and their effects on species may include, but are not limited to:

- Effects of natural selection on a population.
- Adaptations and the distribution of traits within a population.
- Effects of climate changes on gene frequencies within populations.
- Environmental factors such as invasive species, pollution, volcanic eruptions, earthquakes, natural disasters, and other current environmental conditions.

Benchmark 9L.4.2.1.1

Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. (P: 8, CC: 1, CI: LS4) Emphasis is on conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence may include similarities in DNA sequences, the fossil record, artificial selection, anatomical structures, and the order of appearance of structures in embryological development.

Item Specifications:

P: 8 Obtaining, evaluating, and communicating information

Communicating scientific information may include, but is not limited to:

- Comparing and evaluating information in various formats to address a scientific question.
- Reading scientific text, tables, models, animations, simulations, diagrams, and graphs to identify the key ideas being presented.
- Evaluating the validity and reliability of claims, methods, or designs obtained from various sources.

CC: 1 Patterns

Patterns may include, but are not limited to:

- Using mathematical representations to identify and analyze patterns.
- Relating patterns at scale.
- Communicating that the patterns observed at multiple spatial and temporal scales provide evidence for causal relationships.

CI: LS4 Biological evolution: Unity and diversity

Evidence of biological evolution may include, but is not limited to:

- Geographical distribution of plants and animals.
- Homologous structures.
- DNA sequences varying among species but also having many similarities between species.
- Multiple DNA sequences coding for the same amino acid.
- Patterns in the fossil record (e.g., presence and location).

Benchmark 9L.4.2.2.1

Obtain and communicate information about how Minnesota American Indian tribes and communities and other cultures construct solutions to mitigate threats to biodiversity.* (P: 8, CC: 7, CI: LS2, ETS1) Examples of cultures may include those within the local context of the learning community and within the context of Minnesota. Examples of threats to biodiversity may include climate change, deforestation, urbanization, dam construction or removal, invasive species, human population growth, threatening/endangering species, agricultural practices, extraction and use of fossil fuels.

Item Specifications:

P: 8 Obtaining, evaluating, and communicating information

Obtaining and communicating information may include, but is not limited to:

- Comparing and evaluating information in various formats to address a scientific question or design problem.
- Reading scientific text, tables, models, animations, simulations, diagrams, and graphs to identify the key ideas being presented.
- Evaluating the validity and reliability of claims, methods, or designs obtained from various sources.

CC: 7 Stability and change

Stability and change may include, but are not limited to:

- Measuring and modeling changes over short and long periods of time.
- Designing systems for greater or lesser stability.

CI: LS2 Ecosystems: Interactions, energy, and dynamics, ETS1 Engineering design

Threats to biodiversity may include, but are not limited to:

- Past practices of environmental management and engineering.
- Extraction and use of natural resources, overpopulation, and overutilization.

Solutions to mitigate threats to biodiversity may include, but are not limited to:

- Identification of constraints (e.g., cost, safety, and reliability), as well as cultural and environmental impacts.
- Evaluation of ecosystem function and productivity.
- Ability to predict the effects of specific solutions on biodiversity.
- Information from studies conducted by Minnesota American Indian Tribes and various groups of immigrant (non-indigenous) cultures found in Minnesota.
- Natural or designed systems.