THE STANDARD

Molecules & Extended Structures

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

DCI

DISCIPLINARY CORE IDEA

PS1.A · Structure and Properties of Matter

> *Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).*

Everything is built from atoms. About a hundred different types exist, and they combine in characteristic ways. Sometimes they make small discrete molecules (water is 3 atoms, methanol is 6). Sometimes they make giant repeating structures that go on for billions of atoms (table salt, diamond). **The structure determines what the substance actually is.**

SEP

SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop a model to predict and/or describe phenomena.*

Students aren't memorizing what a water molecule looks like. They're building models that show how atoms connect, then using those models to describe a substance. The model is a thinking tool. If it can't predict or describe, it's just art. **If it can, the student is doing science.**

CCC

CROSSCUTTING CONCEPT

Scale, Proportion, and Quantity

> *Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.*

Atoms are too small to see, even under a microscope. The whole standard hinges on students reasoning about something they can't directly observe. **They scale up: a ball-and-stick model of one molecule represents the trillions of identical molecules in the cup of water in front of them.**

THE STANDARD

Chemical Reaction Data

Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

DCI
DISCIPLINARY CORE IDEA

PS1.A · Structure and Properties of Matter

> *Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.*

Every substance has a fingerprint of properties: density, melting point, solubility, flammability, odor. When two substances actually react, you don't get a mix of the originals. You get something new with different properties. PS1.A gives them the properties to measure. **PS1.B explains the atomic rearrangement behind the change.**

SEP
SCIENCE & ENGINEERING PRACTICE

Analyzing and Interpreting Data

> *Analyze and interpret data to determine similarities and differences in findings.*

Students aren't memorizing what counts as a reaction. They're comparing before/after data and arguing whether it supports a reaction or just a phase change. **Hand them a properties table and ask: what stayed the same, what changed, what does that tell us?**

CCC
CROSSCUTTING CONCEPT

Patterns

> *Macroscopic patterns are related to the nature of microscopic and atomic-level structure.*

The big idea: what you can see and measure (color change, bubbles, temperature swing, a new smell) comes from atoms rearranging underneath. Students don't need to see the atoms to know it happened. **They read the patterns in the data and connect them to a structural change they can't observe.**

THE STANDARD

Synthetic Materials

Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

DCI
DISCIPLINARY CORE IDEA

PS1.A · Structure and Properties of Matter

> *Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.*

Synthetic materials don't appear out of nowhere. Every plastic bottle, every pill, every polyester shirt started as something natural: oil pumped from the ground, natural gas, plant compounds, ore. A chemical process rearranges those atoms into a new substance with different properties. The new substance can do something the original couldn't. **Strength, flexibility, waterproofness, healing.**

SEP
SCIENCE & ENGINEERING PRACTICE

Obtaining, Evaluating, and Communicating Information

> *Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.*

Students aren't running a reaction in a beaker. They're reading. Articles, infographics, product labels, news pieces. The work is picking through information, deciding what's credible, and pulling out the through-line: natural resource in, chemical process happens, synthetic material out, society changes because of it. **Information literacy is the lab.**

CCC
CROSSCUTTING CONCEPT

Structure and Function

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

Synthetic materials are designed on purpose. Someone needed a fabric that wouldn't tear, so nylon got engineered. Someone needed a painkiller you could swallow, so aspirin got made. The properties of the material match the job it has to do. **Structure and function, but at the level of "why does this stuff exist at all?"**

THE STANDARD

Changes by Thermal Energy

Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

DCI
DISCIPLINARY CORE IDEA

PS1.A · Structure and Properties of Matter

> *Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.*

A pure substance is made of particles in motion. In a solid, they vibrate in place. In a liquid, they slide past each other but stay in contact. In a gas, they zoom around with space between them. Add thermal energy and particles move faster. **Add enough, and the substance changes state.**

SEP
SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop a model to predict and/or describe phenomena.*

Students aren't memorizing the three states. They're building a particle-level model that predicts what happens when heat goes in or out. The model has to show motion, spacing, and state. If their drawing can predict what ice does on the counter, they're doing science. **If it just labels three boxes, they're not.**

CCC
CROSSCUTTING CONCEPT

Cause and Effect

> *Cause and effect relationships may be used to predict phenomena in natural or designed systems.*

This standard is built on cause and effect. Thermal energy in is the cause. Faster particle motion, a temperature rise, or a phase change is the effect. **Students use the model to predict: if I add this much heat, what happens to the particles, what happens to the temperature, what happens to the state?**

THE STANDARD

Mass & Chemical Reactions

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.

DCI

DISCIPLINARY CORE IDEA

PS1.B · Chemical Reactions

> *Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. The total number of each type of atom is conserved, and thus the mass does not change.*

Atoms don't disappear. In a chemical reaction the atoms from the reactants regroup into new molecules, but every atom you started with is still there. Count hydrogen and oxygen on the reactant side, count them again on the product side. The numbers match. **That's why the mass before equals the mass after, as long as nothing escapes the system.**

SEP

SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop a model to describe unobservable mechanisms.*

Students aren't watching a reaction and calling it conservation. They're building a model that shows the same atoms on both sides, just regrouped. Before/after particle diagrams. Drag-and-drop atom sims. Gumdrops rearranged into new compounds. **If the model loses or invents an atom, the model is wrong, and that's the catch students have to find.**

CCC

CROSSCUTTING CONCEPT

Energy and Matter

> *Matter is conserved because atoms are conserved in physical and chemical processes.*

Matter is conserved because atoms are conserved. Students reason from something they can't see (atoms regrouping) to something they can measure (mass on a balance). When mass appears to change in an open container, the lens is: an atom went somewhere we didn't track. **The accounting works at the atomic scale, and the macroscopic measurement is the check.**

THE STANDARD

Endothermic & Exothermic

Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

DCI
DISCIPLINARY CORE IDEA

PS1.B · Chemical Reactions

> *Some chemical reactions release energy, others store energy.*

Some chemical processes release thermal energy (exothermic). Some absorb it (endothermic). Dissolving calcium chloride in water warms the water. Mixing baking soda and citric acid in water cools it. **The standard pairs that core chemistry with engineering: students design a device that uses one of those reactions on purpose, then test and rebuild it to hit a target temperature change.**

SEP
SCIENCE & ENGINEERING PRACTICE

Constructing Explanations and Designing Solutions

> *Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.*

Students aren't just running a reaction. They're designing a device against criteria and constraints, testing it, reading the data, and changing one variable to make the next version better. The SEP is the full design cycle, not a single build. **Their notebook should show a v1, a test, a decision, and a v2.**

CCC
CROSSCUTTING CONCEPT

Energy and Matter

> *The transfer of energy can be tracked as energy flows through a designed or natural system.*

Energy doesn't appear or vanish. It flows. The reactants hold chemical energy in their bonds. When atoms rearrange, some of that energy becomes thermal energy that moves into (or out of) the water and the bag. Students track that flow with a thermometer. **The temperature reading IS the energy story.**

THE STANDARD

Newton's Third Law & Collisions

Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.

DCI
DISCIPLINARY CORE IDEA

PS2.A · Forces and Motion

> *For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).*

When two objects interact, they push on each other with equal force in opposite directions. Always. The car pushes the wall, the wall pushes back just as hard. The forces in the pair are simultaneous, equal in size, opposite in direction, and they act on different objects. That last part is the one students miss. **The two forces aren't on the same thing.**

SEP
SCIENCE & ENGINEERING PRACTICE

Constructing Explanations and Designing Solutions

> *Apply scientific ideas or principles to design an object, tool, process or system.*

Students aren't just learning a law. They're using it to design a solution. The standard pairs the physics with engineering: pick a collision problem (a fragile cargo, a passenger, a phone), then design a device that reduces the force during impact. The science idea drives the design choice. **If the design doesn't connect back to force pairs, it's craft time.**

CCC
CROSSCUTTING CONCEPT

Systems and System Models

> *Models can be used to represent systems and their interactions, such as inputs, processes and outputs, and energy and matter flows within systems.*

A collision is a system with two objects, the force pair between them, and whatever you build to sit between them. Students model that system with a sketch or diagram showing the force arrows, the objects, and where the design feature lives. The model is the thinking tool. **It shows where energy and force flow during the moment of impact.**

THE STANDARD

Changes in an Object's Motion

Plan 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.

DCI
DISCIPLINARY CORE IDEA

PS2.A · Forces and Motion

> *The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size.*

Whether an object's motion changes depends on two things: the total force pushing or pulling on it, and how much mass it has. Bigger total force in one direction means a bigger change in motion. Bigger mass means it takes more force to get the same change. **Balanced forces leave motion alone.**

SEP
SCIENCE & ENGINEERING PRACTICE

Planning and Carrying Out Investigations

> *Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.*

Students aren't running a teacher demo. They're designing the experiment. They pick the independent variable (force or mass), the dependent variable (the change in motion), the controls, the tools, and how many trials they need. The plan is the work. **If the plan can't be repeated by another group, it isn't done.**

CCC
CROSSCUTTING CONCEPT

Stability and Change

> *Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.*

Motion that isn't changing is stability. Motion that is changing is change. This standard sits right on the seam. **Students look at what's keeping motion steady (balanced forces) and what's nudging it off course (unbalanced forces), then trace the cause back to force and mass.**

THE STANDARD

Electric & Magnetic Force Strength

Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

DCI
DISCIPLINARY CORE IDEA

PS2.B · Types of Interactions

> *Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.*

Electric forces and magnetic forces can pull objects together or push them apart, and their strength isn't fixed. It depends on how much charge or current is involved, how strong the magnet is, and how far apart the interacting objects sit. Same force, dialed up or down depending on the conditions. **That's the move students are reasoning about.**

SEP
SCIENCE & ENGINEERING PRACTICE

Asking Questions and Defining Problems

> *Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources.*

Students aren't running every experiment themselves. They're looking at a phenomenon or a dataset and asking questions that could actually be tested with classroom tools. **"What happens if we add more coils?" "What if the magnet is farther away?" The work is interrogating the data, identifying the variables, and writing the question worth investigating.**

CCC
CROSSCUTTING CONCEPT

Cause and Effect

> *Cause and effect relationships may be used to predict phenomena in natural or designed systems.*

Every question in this standard is a cause-and-effect question. Change the current, the force changes. Change the distance, the force changes. Students are building a habit: when something gets stronger or weaker, ask what variable was responsible. **That habit transfers to every science domain they'll touch after this.**

THE STANDARD

Gravitational Interactions

Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

DCI
DISCIPLINARY CORE IDEA

PS2.B · Types of Interactions

> *Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass (e.g., Earth and the sun).*

Gravity isn't an Earth-only thing. Every object with mass pulls on every other object with mass. We just don't notice most of those pulls because the masses involved are too small. When one object is huge (Earth, the Sun, Jupiter), the pull is obvious. Two pencils on a desk pull on each other too. **The effect is just way too tiny to see.**

SEP
SCIENCE & ENGINEERING PRACTICE

Engaging in Argument from Evidence

> *Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.*

Students aren't memorizing that "gravity depends on mass." They're being handed evidence sets (orbital data, falling-object data, tidal patterns) and asked to build a claim, back it with the data, and present it so a peer can push back. The argument is the science. **A claim without evidence isn't an argument, it's a guess.**

CCC
CROSSCUTTING CONCEPT

Systems and System Models

> *Models can be used to represent systems and their interactions, such as inputs, processes and outputs, and energy and matter flows within systems.*

A gravitational system is the Sun and its planets. Or Earth and the Moon. Or Earth and a dropped apple. Students treat each as a system: which objects are interacting, which masses are involved, and what the pull does to the motion. **The system model is the frame that makes the evidence add up.**

THE STANDARD

Noncontact Forces

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.

DCI

DISCIPLINARY CORE IDEA

PS2.B · Types of Interactions

> *Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).*

Some forces work without contact. A magnet pulls a paperclip across a gap. A charged balloon tugs a stream of water without touching it. Earth pulls a dropped pencil to the floor. The explanation isn't magic. It's a field. A field is a region around an object where another object can feel a force. **The space isn't empty.**

SEP

SCIENCE & ENGINEERING PRACTICE

Planning and Carrying Out Investigations

> *Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.*

Students aren't just watching a demo. They're running an investigation and then turning around and critiquing how it was set up. Did the procedure actually produce evidence a field exists? Were the variables controlled? Would a skeptical classmate buy the data? Running the experiment is half the work. **Evaluating the design is the other half.**

CCC

CROSSCUTTING CONCEPT

Cause and Effect

> *Cause and effect relationships may be used to predict phenomena in natural or designed systems.*

Fields cause forces. That's the whole cause-and-effect chain. A magnetic field is the cause. A paperclip jumping toward the magnet is the effect. Students use that pattern to predict what will happen when the field is stronger, when distance increases, or when something blocks the path. **If they can predict, they understand the cause.**

THE STANDARD

Kinetic Energy of an Object

Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

DCI
DISCIPLINARY CORE IDEA

PS3.A · Definitions of Energy

> *Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.*

Anything moving has kinetic energy. Two things change how much: how heavy it is and how fast it's going. Heavier means more. Faster also means more, but speed has an outsized effect. Doubling the mass doubles the energy. Doubling the speed does a lot more than that. The relationship with mass is a straight line. **The relationship with speed bends upward.**

SEP
SCIENCE & ENGINEERING PRACTICE

Analyzing and Interpreting Data

> *Construct and interpret graphical displays of data to identify linear and nonlinear relationships.*

Students aren't reading about the relationship between mass, speed, and kinetic energy. They're collecting data, plotting it, and reading the relationship off the graph. Two graphs, two stories. One should come out as a straight line. One should curve. **The shape of the line is the answer.**

CCC
CROSSCUTTING CONCEPT

Scale, Proportion, and Quantity

> *Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.*

The standard runs on proportional thinking. If you double the mass, what happens to the energy? If you double the speed? The answers aren't the same, and that gap is the whole point. **Students compare magnitudes and notice when a quantity scales linearly versus when it scales faster than that.**

THE STANDARD

Distance & Potential Energy

Develop 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.

DCI
DISCIPLINARY CORE IDEA

PS3.A · Definitions of Energy

> *A system of objects may also contain stored (potential) energy, depending on their relative positions.*

Energy doesn't only live in motion. When two objects pull or push on each other across a distance, the system stores energy in their arrangement. Lift a ball higher above Earth and you store more gravitational potential energy. Push two like-pole magnets closer and you store more magnetic potential energy. **Change the arrangement, change the stored energy.**

SEP
SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop a model to describe unobservable mechanisms.*

Students build models to show something they can't see: stored energy. The model can be a drawing, a diagram, a labeled photo, or a written description. **What makes it count as a model is that it shows the two objects, the distance between them, and how the stored energy changes when that distance changes.**

CCC
CROSSCUTTING CONCEPT

Systems and System Models

> *Models can be used to represent systems and their interactions, such as inputs, processes, and outputs, and energy and matter flows within systems.*

The energy isn't in the ball. It's in the ball-and-Earth system. That shift, from "the object has energy" to "the system stores energy in the arrangement," is the whole point. **Students stop tracking single objects and start tracking pairs and the space between them.**

THE STANDARD

Thermal Energy Transfer

Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

DCI
DISCIPLINARY CORE IDEA

PS3.A · Definitions of Energy

> *Temperature is a measure of the average kinetic energy of particles of matter.*

Thermal energy moves from hot to cold on its own. Always. A warm cup of coffee gives up its heat to the cool room. An ice cube pulls heat in from the air around it. **The standard pairs that core idea with engineering: students design a device that either slows that flow down (an insulated cup) or speeds it up (a solar cooker), then test and rebuild it.**

SEP
SCIENCE & ENGINEERING PRACTICE

Constructing Explanations and Designing Solutions

> *Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system.*

Students aren't running a one-shot experiment. They're designing a device against criteria and constraints, testing it with a thermometer, reading the data, and changing one variable to make the next version better. **Their notebook should show a v1, a test, a decision, and a v2.**

CCC
CROSSCUTTING CONCEPT

Energy and Matter

> *The transfer of energy can be tracked as energy flows through a designed or natural system.*

Energy doesn't disappear when something cools off. It flows. Out of the hot water, through the cup walls, into the room air. Students track that flow with a thermometer. **The temperature reading over time IS the energy story, and a good design either blocks the flow or opens a faster path for it.**

THE STANDARD

Temperature & Energy

Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

DCI
DISCIPLINARY CORE IDEA

PS3.A · Definitions of Energy

> *Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.*

Temperature measures how fast particles are moving on average. But how much energy it takes to change that temperature depends on what the substance is and how much of it you have. Water needs a lot of energy to warm up by one degree. Metal needs much less. **A big pot takes longer to heat than a small one.**

SEP
SCIENCE & ENGINEERING PRACTICE

Planning and Carrying Out Investigations

> *Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.*

Students aren't running a recipe lab where the procedure is handed to them. They're planning the investigation themselves. They pick the variables, decide what to control, choose the tools, and decide how much data they need. **The teacher's job is to keep them honest, not to hand them a worksheet.**

CCC
CROSSCUTTING CONCEPT

Scale, Proportion, and Quantity

> *Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.*

This standard runs on proportional reasoning. Double the mass, you roughly need double the energy for the same temperature change. Swap water for sand, and a small amount of energy moves the temperature a lot more. **Students reason about ratios between energy in, mass, and temperature change without doing the formal calculations.**

THE STANDARD

Kinetic Energy Transfer

Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

DCI
DISCIPLINARY CORE IDEA

PS3.B · Conservation of Energy and Energy Transfer

> *When the motion energy of an object changes, there is inevitably some other change in energy at the same time.*

When an object speeds up or slows down, energy doesn't appear or vanish. It moves. A rolling ball that comes to a stop didn't lose its kinetic energy. The energy transferred somewhere else, usually to thermal energy and sound through friction. **Every change in motion is matched by a change in energy somewhere in the system.**

SEP
SCIENCE & ENGINEERING PRACTICE

Engaging in Argument from Evidence

> *Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon.*

Students aren't just observing a ball slow down. They're building an argument: claim, evidence, reasoning. The claim is that energy transferred. The evidence is what they measured or observed. The reasoning is how that evidence supports the claim. **They construct it, present it, and defend it.**

CCC
CROSSCUTTING CONCEPT

Energy and Matter

> *Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion).*

Energy shows up in different forms. Kinetic energy in moving objects, thermal energy in warmer surfaces, sound energy in the air. Students track energy as it changes form. The total stays the same. **Only the address changes.**

THE STANDARD

Waves & Energy

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.

DCI
DISCIPLINARY CORE IDEA

PS4.A · Wave Properties

> *A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.*

A wave is a repeating pattern. Three numbers describe it. Wavelength is the distance from one crest to the next. Frequency is how many waves pass a point each second. Amplitude is the height from the rest line up to the crest. Of those three, amplitude is the one tied to energy. **Bigger amplitude means more energy carried by the wave.**

SEP
SCIENCE & ENGINEERING PRACTICE

Using Mathematics and Computational Thinking

> *Use mathematical representations to describe and/or support scientific conclusions and design solutions.*

Students aren't just watching waves. They're measuring them, plotting them, and using simple math to connect numbers to behavior. A labeled diagram, a wavelength-vs-frequency ratio, a quick plot of amplitude against energy. **The math is the lens that turns "the wave got bigger" into "the amplitude doubled, so the energy went up."**

CCC
CROSSCUTTING CONCEPT

Patterns

> *Graphs and charts can be used to identify patterns in data.*

Waves are patterns by definition. Every wave repeats. Once students start sketching and graphing them, the same shape shows up in a slinky, a rope, a sound wave, and a water ripple. Recognizing that shared pattern is the whole point. **Different sources, same math.**

THE STANDARD

Wave Transmission

Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

DCI
DISCIPLINARY CORE IDEA

PS4.A · Wave Properties

> *A sound wave needs a medium through which it is transmitted.*

When a wave hits something, one of three things happens. It bounces back (reflected), it sinks in and turns into heat or motion (absorbed), or it passes through (transmitted). What the material is made of decides which one wins. A mirror reflects light. Black paint absorbs it. Glass lets it through. **The same three options apply to sound, water waves, and every other wave students will meet.**

SEP
SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop and use a model to describe phenomena.*

Students aren't memorizing a list of materials. They're building a model (a drawing, a sim, a written description) that shows where a wave hits, where it goes, and why. The model is the thinking. **If a student can sketch the wave path at a window and label which part bounces, which part heats up the glass, and which part keeps going, they're doing the standard.**

CCC
CROSSCUTTING CONCEPT

Structure and Function

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

The behavior is the function. The material is the structure. Smooth and hard reflects. Soft and porous absorbs. Clear and even transmits. Once a student sees that the inside of a material is what dictates wave behavior, they can predict it for a material they've never met. **That's the whole point of Structure and Function.**

THE STANDARD

Digital vs Analog Signals

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.

DCI
DISCIPLINARY CORE IDEA

PS4.C · Information Technologies and Instrumentation

> *Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.*

Signals carry information. Analog signals carry it as a smooth wave that can take any value, like a needle wiggling in a groove on a record. Digital signals carry it as a string of discrete pulses, usually just two values (on or off, 1 or 0). When a signal travels, noise gets added. Digital signals can be cleaned up by snapping each pulse back to its nearest value. Analog signals can't. **The noise stays.**

SEP
SCIENCE & ENGINEERING PRACTICE

Obtaining, Evaluating, and Communicating Information

> *Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings.*

Students aren't building a phone. They're pulling information from a few different places (a short reading, a diagram, a video clip, a side-by-side audio sample) and stitching it into one clear argument. The claim is already given: digital is more reliable. **Their job is to back it up with evidence from multiple sources and explain it in their own words.**

CCC
CROSSCUTTING CONCEPT

Structure and Function

> *Structures can be designed to serve particular functions.*

A signal's structure (continuous wave vs. discrete pulses) is what determines its function (degrades over distance vs. regenerates cleanly). Engineers picked digital for most modern communication because the structure was designed for the job. **The "shape" of the signal is the whole reason it works.**

THE STANDARD

Evidence of Living Things

Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.

DCI

DISCIPLINARY CORE IDEA

LS1.A · Structure and Function

> *All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular).*

Every living thing is built from cells. Some organisms are one cell and that one cell does everything. Others, like a human, are roughly 37 trillion cells doing different jobs. The cell is the smallest unit that's actually alive. Below that you have molecules. Above that you have tissues and organs. **The cell is where life starts.**

SEP

SCIENCE & ENGINEERING PRACTICE

Planning and Carrying Out Investigations

> *Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of an investigation.*

Students aren't reading about cells. They're putting something living under a microscope and producing their own evidence. The investigation is the point. **They plan it, run it, record what they see, and use what they see to argue that a thing they thought was a single object is actually made of smaller units.**

CCC

CROSSCUTTING CONCEPT

Scale, Proportion, and Quantity

> *Phenomena that can be observed at one scale may not be observable at another scale.*

Cells are too small to see with the naked eye. A typical cell is 10 to 100 micrometers across. The whole standard depends on students recognizing that a phenomenon hidden at one scale (a leaf, a pond, the inside of their cheek) becomes obvious at another (under 100x magnification). **Different scale, different evidence.**

THE STANDARD

Cell Parts & Functions

Develop and use a model to describe the function of a cell as a whole and ways the parts of cells contribute to the function.

DCI
DISCIPLINARY CORE IDEA

LS1.A · Structure and Function

> *Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell.*

A cell is the smallest thing that's alive. Inside it, tiny parts called organelles each do a specific job: the nucleus stores DNA, the mitochondria release energy from food, the cell membrane controls what gets in and out. No single part is the cell. **The cell is what all the parts do together.**

SEP
SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop and use a model to describe phenomena.*

Students aren't memorizing organelle definitions off a diagram. They're building a model of a cell and using it to explain how the cell stays alive. The model has to show what each part does, not just label what each part is. **If the model can describe how the cell functions, the student is doing the science.**

CCC
CROSSCUTTING CONCEPT

Structure and Function

> *Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function.*

Cells are microscopic. Students will never see a mitochondrion with their own eyes. The whole standard runs on the idea that structure tells you function. **The shape of a part, where it sits in the cell, what surrounds it, all of that is a clue to what the part does for the cell as a whole.**

THE STANDARD

Interacting Body Systems

Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

DCI
DISCIPLINARY CORE IDEA

LS1.A · Structure and Function

> *In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.*

Your body is not one machine. It is a stack of subsystems, each built from groups of cells that took on a specific job. Cells of one type form tissues. Tissues form organs. Organs group into systems. Every system depends on the others to do its work. **Nothing in the body runs alone.**

SEP
SCIENCE & ENGINEERING PRACTICE

Engaging in Argument from Evidence

> *Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon.*

This standard is built on argument, not labeling. Students aren't naming the parts of the heart. They're making a case. They use evidence, like heart rate data or a flow chart, to argue that two or more systems are interacting. **The claim has to be supported, not just stated.**

CCC
CROSSCUTTING CONCEPT

Systems and System Models

> *Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.*

A system has subsystems. Subsystems are part of a larger system. The body is the clearest example a student will ever meet. Zoom in: an organ is a system. Zoom out: the whole body is a system. Both views are true at the same time. **That's the lens the standard wants students using.**

THE STANDARD

Plant & Animal Reproduction

Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.

DCI
DISCIPLINARY CORE IDEA

LS1.B · Growth and Development of Organisms

> *Animals engage in characteristic behaviors that increase the odds of reproduction. Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.*

Reproduction isn't automatic. Animals do specific things (build nests, sing, display, defend young, herd) that raise the odds their offspring survive long enough to reproduce themselves. Plants can't move, so they grew structures (bright flowers, nectar, scent, hooked seeds, fruit, nut shells) that get animals to do the moving for them. **Both sides are running the same play: increase the probability that the next generation actually shows up.**

SEP
SCIENCE & ENGINEERING PRACTICE

Engaging in Argument from Evidence

> *Use an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.*

Students aren't writing a definition of reproduction. They're making an argument. They pick a behavior or a plant structure, then use evidence (what they observed, what they read, what the data shows) and scientific reasoning to defend a claim about how that trait boosts reproductive success. Counter-evidence is fair game. **The argument has to hold up.**

CCC
CROSSCUTTING CONCEPT

Cause and Effect

> *Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.*

Nothing here is a guarantee. A peacock with a bigger tail doesn't always win the mate. A dandelion seed doesn't always land somewhere it can grow. These are cause-and-effect relationships expressed as probability: this trait makes successful reproduction more likely, not certain. **Students need to reason in odds, not absolutes.**

THE STANDARD

Influencing Organism Growth

Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

DCI
DISCIPLINARY CORE IDEA

LS1.B · Growth and Development of Organisms

> *Genetic factors as well as local conditions affect the growth of the adult plant.*

Every organism starts with a genetic blueprint inherited from its parents. That blueprint sets the range of what's possible. But where the organism actually lands inside that range comes down to environment: food, water, light, space, temperature. A Great Dane puppy will never grow Chihuahua-sized, but a malnourished Great Dane won't hit its breed potential either. Genes set the ceiling. **Environment decides how close you get to it.**

SEP
SCIENCE & ENGINEERING PRACTICE

Constructing Explanations and Designing Solutions

> *Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.*

Students aren't memorizing that "genes and environment both matter." They're building an explanation supported by evidence. They look at data, identify patterns, and write a claim with reasoning. The explanation is the deliverable. If it cites evidence and connects cause to effect, it counts as science. **If it's a guess with no data behind it, it doesn't.**

CCC
CROSSCUTTING CONCEPT

Cause and Effect

> *Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.*

This whole standard is a cause-and-effect detective story with two suspects. Why is this plant taller than that one? Could be genes. Could be sunlight. Could be both. **Students learn that one effect (growth) can have multiple causes acting at the same time, and untangling them takes careful comparison.**

THE STANDARD

Role of Photosynthesis

Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

DCI
DISCIPLINARY CORE IDEA

LS1.C · Organization for Matter and Energy Flow in Organisms

> *Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen.*

Plants are not eating the soil. They pull carbon dioxide out of the air, water up through their roots, and energy from sunlight, then build sugar (glucose) and release oxygen. The carbon in a tree's trunk came from the sky, not the dirt. **That sugar runs the plant or gets stored for later.**

SEP
SCIENCE & ENGINEERING PRACTICE

Constructing Explanations and Designing Solutions

> *Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.*

Students aren't memorizing a reaction. They're making a claim about where matter goes and where energy goes, and then backing it up with evidence they can point to: bubble counts on a water plant, a color change in an indicator, a starch test on a leaf. **The explanation has to track both the matter and the energy.**

CCC
CROSSCUTTING CONCEPT

Energy and Matter

> *Within a natural system, the transfer of energy drives the motion and/or cycling of matter.*

Energy moves the matter. Light energy flips the system on. Carbon and oxygen atoms get reshuffled into new molecules. The energy ends up locked inside the sugar's chemical bonds, and the matter shows up as plant body or oxygen in the air. **One process, two stories: where the atoms went, where the energy went.**

THE STANDARD

Food & Chemical Reactions

Develop 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.

DCI
DISCIPLINARY CORE IDEA

LS1.C · Organization for Matter and Energy Flow in Organisms

> *Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy.*

Food isn't a magic energy potion. It's matter. Carbs, fats, and proteins are big molecules that get broken apart in digestion, shipped to cells, and either burned for energy or rebuilt into new molecules the body needs. Same atoms, new arrangement. **The chicken sandwich a student ate at lunch is, at the molecular level, becoming part of their muscles, hormones, and ATP.**

SEP
SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop a model to describe unobservable mechanisms.*

Students aren't memorizing the digestive tract. They're building a model that shows an unobservable process: food molecules getting broken down, transported, and rearranged inside cells. The model is how they make the invisible visible. **If it can describe what's happening to the matter, it's doing its job.**

CCC
CROSSCUTTING CONCEPT

Energy and Matter

> *Matter is conserved because atoms are conserved in physical and chemical processes.*

Atoms in the food don't vanish and atoms in the body don't appear from nowhere. Every carbon atom in a slice of pizza either ends up exhaled as CO_2, stored as fat or muscle, or used in a new molecule. Matter is tracked. Energy is tracked. **Nothing leaks out of the system.**

THE STANDARD

Stimuli & Sensory Receptors

Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

DCI

DISCIPLINARY CORE IDEA

LS1.D · Information Processing

> *Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.*

Your senses are not generalists. Each receptor is built to respond to one kind of input. Eye receptors react to light. Ear receptors react to vibrations. Tongue and nose receptors react to specific chemicals. Skin receptors react to pressure, temperature, and damage. The receptor catches the signal. Nerves carry it to the brain. **The brain decides: act now, or store it as a memory.**

SEP

SCIENCE & ENGINEERING PRACTICE

Obtaining, Evaluating, and Communicating Information

> *Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.*

Students are not designing an experiment here. They are gathering information from multiple sources, checking whether those sources hold up, and pulling the pieces into one clear story about how the body senses and responds. **The skill is sorting good evidence from sloppy claims, then communicating what they found.**

CCC

CROSSCUTTING CONCEPT

Cause and Effect

> *Cause and effect relationships may be used to predict phenomena in natural systems.*

This standard runs on cause and effect. A specific stimulus causes a specific receptor to fire. That signal causes a specific brain response. Change the stimulus, the response changes. Damage the receptor, the response stops. **Students trace those chains and use them to predict what will happen next.**

THE STANDARD

Resource Availability

Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

DCI
DISCIPLINARY CORE IDEA

LS2.A · Interdependent Relationships in Ecosystems

> *Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Growth of organisms and population increases are limited by access to resources.*

Every living thing needs resources to survive. Food, water, shelter, space, sunlight. When those resources are plentiful, populations grow. When they run low, growth slows, organisms compete, and numbers drop. **The size of a population is tied directly to what the ecosystem can supply.**

SEP
SCIENCE & ENGINEERING PRACTICE

Analyzing and Interpreting Data

> *Analyze and interpret data to provide evidence for phenomena.*

Students aren't memorizing definitions of "carrying capacity." They're reading actual population graphs and rainfall charts and predator-prey curves. The skill is looking at data, spotting the pattern, and using it as evidence. **If they can point to the dip and explain what caused it, they're doing science.**

CCC
CROSSCUTTING CONCEPT

Cause and Effect

> *Cause and effect relationships may be used to predict phenomena in natural or designed systems.*

This standard runs on cause and effect. Rain drops, wildflowers bloom less. Wolves disappear, deer explode. Food runs out, populations crash. **Students trace the cause back to the effect using the data in front of them, then use that pattern to predict what happens next.**

THE STANDARD

Interactions in Ecosystems

Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

DCI
DISCIPLINARY CORE IDEA

LS2.A · Interdependent Relationships in Ecosystems

> *Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.*

Organisms interact in a small number of repeating ways. They compete for the same resource. They eat each other. They help each other. One uses another without affecting it. One uses another and harms it. The species change from ecosystem to ecosystem, but the categories don't. **A predator-prey relationship in the Serengeti works the same way as a predator-prey relationship in the Pacific.**

SEP
SCIENCE & ENGINEERING PRACTICE

Constructing Explanations and Designing Solutions

> *Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena.*

Students aren't just naming relationships. They're building an explanation that uses what they've seen in one ecosystem to predict what they'll see in another. **If they understand the pattern, they can look at a new ecosystem they've never studied and call the shot: "this is competition," "this is mutualism." That's the work.**

CCC
CROSSCUTTING CONCEPT

Patterns

> *Patterns can be used to identify cause and effect relationships.*

Patterns are the lens. Once students can spot a category of interaction in one place, they recognize it everywhere. The same five relationship types appear in deserts, oceans, forests, and savannas. Different cast, same script. **That repeating structure is what makes prediction possible.**

THE STANDARD

Matter & Energy in Ecosystems

Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

DCI
DISCIPLINARY CORE IDEA

LS2.B · Cycle of Matter and Energy Transfer in Ecosystems

> *Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem.*

Two different things happen at the same time in every ecosystem. Matter (carbon, nitrogen, water) cycles between living and nonliving parts over and over. Energy flows one way, from the sun, into producers, into consumers, and out as heat at every step. **Food webs are the model that shows both.**

SEP
SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop a model to describe phenomena.*

Students aren't memorizing food chains. They're building a model that shows who eats whom, where atoms travel, and where energy is leaking out as heat. The model has to do work. **If it can't trace a carbon atom or show why the top of the pyramid is narrow, it isn't done yet.**

CCC
CROSSCUTTING CONCEPT

Energy and Matter

> *The transfer of energy can be tracked as energy flows through a natural system.*

Energy and matter behave differently in the same system. Energy enters as light, gets passed along food chains, and exits as heat. Matter doesn't exit. It cycles. The same carbon atom can be in a leaf, then a deer, then a fungus, then the soil, then back in the air. **Two patterns, one ecosystem.**

THE STANDARD

Effects of Ecosystem Change

Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

DCI
DISCIPLINARY CORE IDEA

LS2.C · Ecosystem Dynamics, Functioning, and Resilience

> *Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.*

Ecosystems are not still pictures. They shift. A drought, a fire, a flood, a new predator, a disease, the loss of one plant species. Any of those changes can push populations up, down, or sideways across the whole system. **Change one piece and the whole web feels it.**

SEP
SCIENCE & ENGINEERING PRACTICE

Engaging in Argument from Evidence

> *Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.*

Students aren't telling a story about an ecosystem. They're building an argument, with data, that a specific change caused specific population shifts. Empirical evidence is the job. A claim without numbers behind it doesn't count. A graph without a claim doesn't either. **Both, together, are the work.**

CCC
CROSSCUTTING CONCEPT

Stability and Change

> *Small changes in one part of a system might cause large changes in another part.*

Stability looks like a forest that seems the same year after year. Change looks like that forest a year after a wildfire. **The standard pushes students to see that "stable" ecosystems are actually balancing many small forces, and that one disruption can swing the whole balance into a different state.**

THE STANDARD

Designs for Biodiversity

Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

DCI
DISCIPLINARY CORE IDEA

LS2.C · Ecosystem Dynamics, Functioning, and Resilience

> *Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.*

Biodiversity is the variety of life: genes, species, and whole ecosystems. The more variety an ecosystem holds, the more it can absorb shocks and keep running. Humans get tangible benefits from those running ecosystems, called ecosystem services. Pollination, clean water, fertile soil, flood control, oxygen, climate regulation. **When biodiversity drops, those services start to drop with it.**

SEP
SCIENCE & ENGINEERING PRACTICE

Engaging in Argument from Evidence

> *Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.*

Students aren't picking the "right" answer. They're evaluating several real options against criteria they helped build, weighing trade-offs, and arguing for one with evidence. The work is the comparison, not the conclusion. A student who picks Solution A with weak reasoning hasn't met the standard. **A student who picks Solution B and can defend why against the others has.**

CCC
CROSSCUTTING CONCEPT

Stability and Change

> *Small changes in one part of a system might cause large changes in another part.*

Ecosystems look steady until they aren't. A small change (one missing pollinator, one warmer summer, one new road through a habitat) can cascade into big change. **Students reason about what stays stable, what shifts, and which design solutions push the system back toward stability instead of past a tipping point.**

THE STANDARD

Mutations

Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.

DCI
DISCIPLINARY CORE IDEA

LS3.A · Inheritance of Traits

> *Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.*

Genes sit on chromosomes inside cells. Each gene chiefly codes for a specific protein, and proteins do most of the actual work: building structures, running reactions, sending signals. A mutation is a change in the gene's sequence. Sometimes that change alters the protein. Sometimes the altered protein changes a trait. **Harmful, beneficial, or neutral, depending on what the protein does and what changed.**

SEP
SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop and use a model to describe phenomena.*

Students aren't memorizing mutation types. They're building a model that links three layers: the gene sequence, the protein it codes for, and the trait the organism shows. **A working model lets them describe why one change in the DNA can ripple all the way up to something visible, or not ripple at all.**

CCC
CROSSCUTTING CONCEPT

Structure and Function

> *Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts.*

This standard is pure structure-and-function. The shape of a protein determines what it can do. A change in the gene can change the protein's structure. A different structure can mean a different function. **The model has to make that chain visible at a scale students can't directly observe.**

NGSS MS-LS3-2

THE STANDARD

Models for Genetic Variation

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.

DCI

DISCIPLINARY CORE IDEA

LS1.B · Growth and Development of Organisms (secondary)

> *Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring.*

One parent or two. That single difference drives everything else. Asexual reproduction copies one parent's genes directly into the offspring, so the offspring is genetically identical. Sexual reproduction takes half the genes from each parent and shuffles them together, so the offspring has a brand-new combination. **Same biological goal, two completely different genetic outcomes.**

SEP

SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop and use a model to describe phenomena.*

Students aren't memorizing a definition of meiosis. They're building models (Punnett squares, diagrams, simulations) that show how genes move from parents to offspring. The model has to predict or describe a real cross. **If a Punnett square can't show why two brown-eyed parents could have a blue-eyed child, the student doesn't understand the gene transmission yet.**

CCC

CROSSCUTTING CONCEPT

Cause and Effect

> *Cause and effect relationships may be used to predict phenomena in natural systems.*

This standard is built on a clean cause-and-effect chain. The cause is the reproduction type (one parent vs two). The effect is the genetic outcome (identical vs varied). **Students trace the chain in both directions: predict the offspring from the parents, and reason backward from offspring variation to what kind of reproduction produced it.**

THE STANDARD

Patterns in the Fossil Record

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 under the assumption that natural laws operate today as in the past.

DCI
DISCIPLINARY CORE IDEA

LS4.A · Evidence of Common Ancestry and Diversity

> *The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.*

The fossil record is the collection of fossils sorted by age, mostly by which rock layer they sit in. It documents which organisms existed, how diverse they were, which ones went extinct, which ones persisted with changes, and which ones first appear later in the record. Same natural laws then as now. **The patterns are there to read.**

SEP
SCIENCE & ENGINEERING PRACTICE

Analyzing and Interpreting Data

> *Analyze and interpret data to determine similarities and differences in findings.*

Students aren't memorizing geological eras or species names. They're looking at fossil data (positions, body plans, ages) and pulling patterns out of it. The work is making sense of a dataset, not reciting a timeline. **If they can describe what they see and what it implies, they're doing the science.**

CCC
CROSSCUTTING CONCEPT

Patterns

> *Graphs, charts, and images can be used to identify patterns in data.*

Patterns are the entire game here. Older layers below, younger layers above. Simple body plans first, more complex anatomical structures later. Whole groups appearing, persisting, disappearing. **The fossil record is a dataset, and the students' job is to spot the patterns the data keeps repeating.**

THE STANDARD

Comparative Anatomy

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.

DCI
DISCIPLINARY CORE IDEA

LS4.A · Evidence of Common Ancestry and Diversity

> *Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent.*

Bodies carry evidence. The bones in a human arm, a bat wing, a whale flipper, and a cat leg follow the same basic blueprint, even though they do completely different jobs. Modern organisms and fossil organisms show the same kind of overlap. Those shared structures point to shared ancestors. **The anatomy itself is the evidence.**

SEP
SCIENCE & ENGINEERING PRACTICE

Constructing Explanations and Designing Solutions

> *Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events.*

Students aren't memorizing which species are related to which. They're applying a scientific idea (shared anatomy points to shared ancestry) to a real comparison and building an explanation. **The work is "here's what I see, here's what it means, here's why." If they can construct that, they're doing the science.**

CCC
CROSSCUTTING CONCEPT

Patterns

> *Patterns can be used to identify cause and effect relationships.*

Patterns are the whole point. The same arm bones show up across species that look nothing alike. The same leftover hip bones show up in animals that don't have legs. The pattern repeats across modern bodies and fossil ones. **Students use the pattern to figure out cause: shared structure traces back to shared ancestry.**

THE STANDARD

Comparative Embryology

Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.

DCI
DISCIPLINARY CORE IDEA

LS4.A · Evidence of Common Ancestry and Diversity

> *Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy.*

Adult animals can look nothing alike. A fish, a chicken, a lizard, and a human are wildly different as full-grown organisms. But rewind to early development and their embryos look strikingly similar. Same general body plan, same tail, same pharyngeal arches in the neck region. **Those shared early features are evidence that these species share an ancestor far back in time.**

SEP
SCIENCE & ENGINEERING PRACTICE

Analyzing and Interpreting Data

> *Analyze displays of data to identify linear and nonlinear relationships.*

Students aren't doing live embryology. They're looking at pictures and diagrams of embryos side by side and pulling patterns out of what they see. Which features show up in every embryo? Which species look most alike at the earliest stage? **The data is visual, and the job is to read it carefully and explain what the pattern means.**

CCC
CROSSCUTTING CONCEPT

Patterns

> *Graphs, charts, and images can be used to identify patterns in data.*

Patterns are the whole game here. The more similar two embryos look in early development, the more closely related the species tend to be. **Students compare images, group what matches with what, and use that pattern to make a relatedness claim they couldn't make from the adult forms alone.**

THE STANDARD

Genetic Variation for Survival

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.

DCI
DISCIPLINARY CORE IDEA

LS4.B · Natural Selection

> *Natural selection leads to the predominance of certain traits in a population, and the suppression of others.*

Inside any population, individuals are slightly different from one another. Some of those differences are inherited. When the environment makes certain traits more useful for staying alive and producing offspring, the individuals carrying those traits leave behind more descendants. Over generations, the common version of the trait shifts. **That shift is natural selection.**

SEP
SCIENCE & ENGINEERING PRACTICE

Constructing Explanations and Designing Solutions

> *Construct an explanation that includes qualitative or quantitative relationships between variables that describe phenomena.*

Students aren't memorizing "survival of the fittest." They're building an explanation grounded in data: trait variation existed, the environment favored one version, more of those individuals reproduced, the next generation looked different. **The explanation has to connect cause to effect with numbers or proportions, not just storytelling.**

CCC
CROSSCUTTING CONCEPT

Cause and Effect

> *Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.*

The cause-and-effect chain in natural selection runs through probability. A dark moth on a soot-covered tree isn't guaranteed to live. It just has a better chance than a light moth on the same tree. **Students reason about shifting odds across a population, not guaranteed outcomes for individuals.**

THE STANDARD

Inheritance of Desired Traits

Gather and synthesize information about technologies that have changed the way humans influence the inheritance of desired traits in organisms.

DCI
DISCIPLINARY CORE IDEA

LS4.B · Natural Selection

> *In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.*

Humans have been steering which traits get passed to the next generation for at least 10,000 years. Pick the cow that gives the most milk, breed it. Save seeds from the biggest corn cob, plant those next year. The genes that carry desired traits show up more often in offspring. **Newer technologies do the same job faster and more directly.**

SEP
SCIENCE & ENGINEERING PRACTICE

Obtaining, Evaluating, and Communicating Information

> *Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.*

Students aren't memorizing a list of breeding methods. They're pulling information from multiple sources, weighing how credible each source is, and synthesizing what they find into a clear explanation. **The skill is sorting reliable information from hype, then communicating what the evidence actually says.**

CCC
CROSSCUTTING CONCEPT

Cause and Effect

> *Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.*

Every technology in this standard is a cause that produces an effect on an organism's traits. Some effects show up in one generation (gene editing). Some take dozens (selective breeding). Some effects are predictable, some are probabilistic. **Students trace each cause to its effect and notice that the size and speed of the effect depend on the technology used.**

THE STANDARD

Natural Selection & Traits

Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

DCI
DISCIPLINARY CORE IDEA

LS4.C · Adaptation

> *Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.*

Populations change because their environment selects. Traits that help an organism survive and reproduce in that environment become more common in the next generation. Traits that hurt those odds become less common. Individuals don't change. The proportions inside the population do. **Run it across generations and the make-up of the population shifts.**

SEP
SCIENCE & ENGINEERING PRACTICE

Using Mathematics and Computational Thinking

> *Use mathematical representations to support scientific conclusions and design solutions.*

Students aren't deriving equations. They're using math to describe a trend. Percentages of light vs. dark beetles. Fractions of resistant bacteria. Simple probability of which moth a bird sees first. The math is the evidence trail. **It turns "more common over time" into something a student can point at.**

CCC
CROSSCUTTING CONCEPT

Cause and Effect

> *Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.*

Selection is a cause-and-effect relationship students can't predict for any one organism, but can predict in aggregate. Which exact moth gets eaten is probability. Which color is over-represented in the next generation is predictable. **Cause and effect at the population level lives in proportions, not individuals.**

THE STANDARD

Earth-Sun-Moon System

Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

DCI
DISCIPLINARY CORE IDEA

ESS1.A · The Universe and Its Stars

> *Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.*

The moon orbits Earth. Earth orbits the sun. Earth also spins on a tilted axis. Three motions running at once, all predictable. Lunar phases come from where the moon sits relative to Earth and the sun. Eclipses come from those three lining up. Seasons come from the tilt, not from how close Earth gets to the sun. **Same system, different cycles, all geometry.**

SEP
SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop and use a model to describe phenomena.*

Students aren't memorizing a phase chart. They're building a model (a ball and a flashlight, a diagram, a 3D sim) that shows where the moon and Earth and sun sit relative to each other. Then they use that model to predict what an observer on Earth would see. **If the model can explain a full moon and a solar eclipse and a Texas summer, it's doing real work.**

CCC
CROSSCUTTING CONCEPT

Patterns

> *Patterns can be used to identify cause-and-effect relationships.*

Every cycle in this standard is a pattern. Full moon every ~29.5 days. Solstice every six months. Eclipses on a longer rhythm. Patterns let students stop guessing and start predicting. Once they see the pattern, they can ask the better question: what's causing it? **That's the bridge from observation to mechanism.**

THE STANDARD

Gravity & Our Solar System

Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

DCI
DISCIPLINARY CORE IDEA

ESS1.A · The Universe and Its Stars

> *Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.*

Gravity is the glue. The sun's mass holds the planets in orbit. Planets hold their moons. The Milky Way's combined mass (stars, gas, dust, and dark matter) holds billions of stars in their long orbits around the galactic center. Same force, different scales. Nothing in space is just sitting still. **Everything is falling around something bigger.**

SEP
SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop and use a model to describe phenomena.*

Students aren't memorizing planet names. They're building a model that shows what gravity is doing across a whole system. The model has to work at two scales at once: the solar system (sun pulls planets) and the galaxy (collective mass pulls stars). **If the model can describe both, it's doing the work the standard asks for.**

CCC
CROSSCUTTING CONCEPT

Systems and System Models

> *Models can be used to represent systems and their interactions.*

A system has parts that interact. The solar system is a system. The galaxy is a bigger system that contains the solar system. The model students build is a system model. **It shows which parts interact, what's pulling on what, and why the whole thing doesn't fly apart.**

THE STANDARD

Scale Model of the Solar System

Analyze and interpret data to determine scale properties of objects in the solar system.

DCI
DISCIPLINARY CORE IDEA

ESS1.B · Earth and the Solar System

> *The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.*

The solar system is one star (the Sun), eight planets, a handful of dwarf planets, dozens of moons, an asteroid belt, comets, and the Kuiper belt. Everything orbits the Sun because the Sun's gravity holds it all in place. The planets are not interchangeable. **Each one is a specific size, a specific distance away, and made of specific stuff.**

SEP
SCIENCE & ENGINEERING PRACTICE

Analyzing and Interpreting Data

> *Analyze and interpret data to determine similarities and differences in findings.*

Students don't memorize planet facts. They work from real data: tables of diameters and orbital distances, photos from Cassini and New Horizons, drawings of planetary layers. **They look for similarities and differences, group objects that behave alike, and explain the patterns they find.**

CCC
CROSSCUTTING CONCEPT

Scale, Proportion, and Quantity

> *Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.*

The solar system is too big to see. A diagram in a textbook lies about scale, because if Earth is a pea, Neptune is over a mile away. **Students reason about proportions: how many Earths fit across Jupiter, how many AU out Neptune sits, how many times bigger the Sun is than everything else combined.**

THE STANDARD

Time Scale of Earth

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.

DCI
DISCIPLINARY CORE IDEA

ESS1.C · The History of Planet Earth

> *The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.*

Earth is about 4.6 billion years old. That's a number so big it stops feeling real. The geologic time scale is how scientists make it usable. Rock layers stack up over time, with the oldest on the bottom and the youngest on top. Inside those layers, fossils mark which life forms were around when. **Together, the rocks and the fossils give us a timeline.**

SEP
SCIENCE & ENGINEERING PRACTICE

Constructing Explanations and Designing Solutions

> *Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.*

Students aren't memorizing eras. They're building an explanation: how do we know Earth is this old, and how do we know when major events happened? The evidence is in the strata. **A good explanation cites the layers, the fossils inside them, and the logic that connects what's deeper to what's older.**

CCC
CROSSCUTTING CONCEPT

Scale, Proportion, and Quantity

> *Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.*

4.6 billion years is unimaginable on its own. Students have to scale it down to something they can hold: one meter of rope for a billion years, or one football field for all of Earth's history. The scale shift is the whole point. Students can't experience deep time directly. **They reason about it through proportional models.**

THE STANDARD

Cycling of Earth's Materials

Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.

DCI
DISCIPLINARY CORE IDEA

ESS2.A · Earth's Materials and Systems

> *All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.*

Rocks aren't permanent. They're just one stage in a cycle. A volcanic rock can break down into sand. Sand can get buried and packed into sandstone. Sandstone can get cooked and squeezed into a different rock entirely. Cooked deeper, it melts into magma and starts the loop over. **Two energy sources drive the whole thing: the sun (weathering, water moving sediment) and Earth's internal heat (volcanoes, mountain-building, melting).**

SEP
SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop and use a model to describe phenomena.*

Students aren't memorizing a chart of rock names. They're building a model that shows how matter moves between forms and where the energy comes from at each step. The model is the thinking. **If a student can point at their diagram and trace one atom from a lava flow to a beach to a buried layer to magma again, they're doing the science.**

CCC
CROSSCUTTING CONCEPT

Stability and Change

> *Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.*

A rock looks stable. On a human timescale it basically is. Stretch the timescale to millions of years and that same rock is in motion: breaking down, getting buried, melting, recrystallizing. The cycle is what changes. The material is what stays. **Stability and change live in the same system, depending on how far back you zoom.**

THE STANDARD

Geoscience Processes

Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

DCI
DISCIPLINARY CORE IDEA

ESS2.A · Earth's Materials and Systems

> *The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.*

Earth's surface is never sitting still. Water, wind, and ice break rock down and move the pieces. Volcanoes pile new rock on top. Plates grind into each other and shove up mountains. Some changes finish in minutes (a landslide). Some take millions of years (a canyon). **Same planet, vastly different speeds and sizes.**

SEP
SCIENCE & ENGINEERING PRACTICE

Constructing Explanations and Designing Solutions

> *Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.*

Students aren't memorizing a list of processes. They're constructing an explanation: here's the evidence, here's the process that fits it, here's why this process explains the change at this scale. The explanation is the deliverable. **If they can back it up with evidence, they're doing the science.**

CCC
CROSSCUTTING CONCEPT

Scale, Proportion, and Quantity

> *Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.*

Every geoscience process runs on a different clock and across a different distance. A landslide finishes in seconds across a hillside. The Himalayas keep rising about 5 mm a year across a continent. **Students learn to ask "how fast?" and "how big an area?" before they explain anything.**

THE STANDARD

Past Plate Motions

Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.

DCI
DISCIPLINARY CORE IDEA

ESS1.C · The History of Planet Earth

> *Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches.*

Earth's outer shell is broken into giant plates that move slowly on the hotter, softer rock beneath them. They've been moving for hundreds of millions of years. The continents we see today used to be stuck together in different arrangements. The proof isn't just one thing. **It's matching fossils, matching rocks, matching coastlines, and a long ridge running down the middle of the Atlantic Ocean.**

SEP
SCIENCE & ENGINEERING PRACTICE

Analyzing and Interpreting Data

> *Analyze and interpret data to provide evidence for phenomena.*

Students aren't taking plate tectonics on faith. They're looking at maps, fossil charts, and seafloor data, then arguing what those patterns mean. The data is the case. **If they can't connect a pattern in the data to a claim about plate motion, the claim doesn't hold.**

CCC
CROSSCUTTING CONCEPT

Patterns

> *Patterns in rates of change and other numerical relationships can provide information about natural systems.*

The whole standard runs on patterns. Coastlines that fit. Fossils that show up on opposite continents and nowhere else. Rock layers that match across an ocean. A ridge running straight down the Atlantic. None of those patterns mean much alone. **Together they tell one story.**

THE STANDARD

Cycling of Water

Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

DCI

DISCIPLINARY CORE IDEA

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

> *Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. Global movements of water and its changes in form are propelled by sunlight and gravity.*

Water doesn't get used up. It moves. The same molecules cycle between ocean, atmosphere, land, and living things. The Sun heats water until it evaporates, and plants release water vapor through their leaves. Vapor rises, cools, and condenses into clouds. **Gravity pulls it back down as rain or snow, and then keeps pulling it across the land into rivers, lakes, and underground.**

SEP

SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop a model to describe unobservable mechanisms.*

Students aren't memorizing a six-step cycle diagram. They're building a model that shows where water goes, what state it's in at each stop, and what's making it move. The model has to make an invisible process visible. **If it can't explain why water moves, it's not done.**

CCC

CROSSCUTTING CONCEPT

Energy and Matter

> *Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.*

The whole standard is matter cycling because energy flows. Sunlight is the energy that lifts water into the air. Gravity is the force that pulls it back down. Take either one away and the cycle stops. **Students should be able to point at any arrow in their model and say what's driving it.**

THE STANDARD

Interactions of Air Masses

Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

DCI
DISCIPLINARY CORE IDEA

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

> *The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.*

Air doesn't just sit there. Huge bodies of air (air masses) form over oceans or continents, pick up the temperature and moisture of whatever they sit above, then move. When two different air masses meet, weather happens at the boundary. Add in pressure differences, and you get wind, clouds, rain, and storms. **The atmosphere is a system with patterns, but the patterns aren't perfectly predictable, which is why forecasts come in percentages.**

SEP
SCIENCE & ENGINEERING PRACTICE

Planning and Carrying Out Investigations

> *Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.*

Students aren't memorizing front symbols. They're collecting weather data over time and using it to back up a claim. The investigation is the point. Temperature, pressure, humidity, wind. Track them. **Look for what changed when, and connect the change to what was moving through the atmosphere.**

CCC
CROSSCUTTING CONCEPT

Cause and Effect

> *Cause and effect relationships may be used to predict phenomena in natural or designed systems.*

Cause and effect runs the whole standard. A cold air mass shoves into a warm one, the warm air gets forced upward, water vapor cools and condenses, clouds and rain follow. Students trace the chain: pressure change here, weather change there. **The reasoning isn't "what happened?" It's "what caused what?"**

THE STANDARD

Unequal Heating of Earth

Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

DCI

DISCIPLINARY CORE IDEA

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

> *Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.*

Sunlight hits Earth unevenly. The equator gets a direct overhead angle, the poles get a low slanted angle, and that mismatch sets the whole system in motion. Warm air rises near the equator, cooler air sinks near the poles, and Earth's rotation bends the moving air sideways. The same uneven heating drives ocean currents, which carry warm and cold water around the planet. **Together these flows decide what climate a region gets.**

SEP

SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop and use a model to describe phenomena.*

Students aren't memorizing a list of wind belts. They're building a model (a diagram, a map, a globe with arrows) that shows how heat input and Earth's spin produce circulation patterns. Then they use the model to describe a real climate. **The model has to do work: predict where wind goes, explain why a place is wet or dry, connect a current to a coastline.**

CCC

CROSSCUTTING CONCEPT

Systems and System Models

> *Models can be used to represent systems and their interactions, such as inputs, processes and outputs, and energy, matter, and information flows within systems.*

Atmosphere and ocean act as one big system with inputs (sunlight), processes (rising, sinking, deflecting, flowing), and outputs (regional climates). Students treat the planet as a system and trace energy and matter moving through it. **The model is the system in miniature.**

THE STANDARD

Earth's Resource Distribution

Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.

DCI
DISCIPLINARY CORE IDEA

ESS3.A · Natural Resources

> *Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.*

Earth's resources aren't sprinkled evenly. Oil, copper, iron, fresh groundwater, fertile soil. They concentrate in specific places because of specific geologic stories. **Where you find a resource is a clue about what was happening at that spot millions, sometimes billions, of years ago.**

SEP
SCIENCE & ENGINEERING PRACTICE

Constructing Explanations and Designing Solutions

> *Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.*

Students aren't memorizing where the oil fields are. They're constructing an explanation: here's the evidence (a resource map, a tectonic map, a rock layer description), here's the geologic process that fits, here's the reasoning that connects them. **Evidence in, explanation out.**

CCC
CROSSCUTTING CONCEPT

Cause and Effect

> *Cause and effect relationships may be used to predict phenomena in natural or designed systems.*

Every resource concentration has a cause behind it. Ancient swamp here, coal seam now. Subduction zone here, copper deposit now. **Students learn to read a map the way a detective reads a scene: this effect, what caused it?**

THE STANDARD

Forecast Catastrophic Events

Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

DCI
DISCIPLINARY CORE IDEA

ESS3.B · Natural Hazards

> *Mapping 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.*

Natural hazards leave fingerprints. Earthquakes cluster along plate boundaries. Hurricanes spin up over warm ocean water in seasonal windows. Volcanoes give off gas and small quakes before they erupt. When you map where hazards have happened and understand the geologic or atmospheric forces driving them, you can forecast where and when they're likely to happen again. Forecasting isn't fortune-telling. **It's pattern reading.**

SEP
SCIENCE & ENGINEERING PRACTICE

Analyzing and Interpreting Data

> *Analyze and interpret data to determine similarities and differences in findings.*

Students aren't memorizing hazard facts. They're pulling data (maps, magnitudes, dates, tracks) and looking for similarities and differences. Where do earthquakes cluster? Which months do hurricanes hit? What signals showed up before Mt. St. Helens blew? The data is messy on purpose. **Finding the pattern is the science.**

CCC
CROSSCUTTING CONCEPT

Patterns

> *Graphs, charts, and images can be used to identify patterns in data.*

Patterns are the whole game here. A single earthquake is a data point. A map of a thousand earthquakes is a story about plate boundaries. **The CCC pushes students to stop seeing hazards as random and start seeing them as patterned, repeatable, and forecast-able to a degree.**

THE STANDARD

Minimizing Human Impact

Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

DCI
DISCIPLINARY CORE IDEA

ESS3.C · Human Impacts on Earth Systems

> *Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.*

Human activities change the environment in measurable ways. Water gets withdrawn from aquifers. Land gets converted from wetland to pavement. Pollutants enter air, water, and soil. As population and per-person consumption grow, the impacts usually grow with them. The exception is when the activity or technology is engineered to reduce that impact. **The standard is about that engineering work.**

SEP
SCIENCE & ENGINEERING PRACTICE

Constructing Explanations and Designing Solutions

> *Apply scientific principles to design an object, tool, process or system.*

Students aren't writing an opinion piece on the environment. They're applying scientific principles to design a method. That method has to do two things: monitor a specific impact with measurements, and minimize that impact with a testable solution. **If the design can't be measured or tested, it's not engineering yet.**

CCC
CROSSCUTTING CONCEPT

Cause and Effect

> *Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.*

Cause and effect is the lens. Students have to connect a specific human activity to a specific environmental change, then connect their solution to a specific reduction in that change. Correlation is not enough. Two things changing at the same time doesn't prove one caused the other. **The design has to isolate the cause it's targeting.**

THE STANDARD

Populations & Earth's Systems

Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

DCI

DISCIPLINARY CORE IDEA

ESS3.C · Human Impacts on Earth Systems

> *Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.*

Two numbers shape how humans push on Earth's systems. The first is how many people there are. The second is how much each person uses on average. Both have climbed for most of recent history, and the impacts (on land, water, air, and other species) typically climb with them. **Technology can bend the curve in either direction.**

SEP

SCIENCE & ENGINEERING PRACTICE

Engaging in Argument from Evidence

> *Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.*

Students aren't sharing opinions about population. They're building an argument from data. That means a claim, evidence pulled from a real database, and reasoning that connects the two. The argument has to be defensible. **"I think" is not the same thing as "the data shows."**

CCC

CROSSCUTTING CONCEPT

Cause and Effect

> *Cause and effect relationships may be used to predict phenomena in natural or designed systems.*

This standard is a cause-and-effect machine. More people plus more per-person consumption tends to mean more land cleared, more water pulled, more energy used, more waste produced. The cause-and-effect chain is what students trace. **Spotting where the chain branches or weakens is part of the work.**

THE STANDARD

Changing Global Temperatures

Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

DCI
DISCIPLINARY CORE IDEA

ESS3.D · Global Climate Change

> *Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.*

Earth's average surface temperature has risen about 1.3°C since 1880. The evidence comes from many independent sources: weather stations, satellites, ocean buoys, ice cores, tree rings. Human activities, especially burning coal, oil, and natural gas, have raised atmospheric CO2 from about 280 ppm before 1850 to over 430 ppm today. More greenhouse gases trap more heat. **That is the major driver of the current warming.**

SEP
SCIENCE & ENGINEERING PRACTICE

Asking Questions and Defining Problems

> *Ask questions to identify and clarify evidence of an argument.*

Students aren't memorizing climate facts. They're asking questions about the evidence: where did this data come from, what does it actually show, how do we know one cause from another. A good question is a thinking tool. **It separates what the data tells us from what we assume.**

CCC
CROSSCUTTING CONCEPT

Stability and Change

> *Stability might be disturbed either by sudden events or gradual changes that accumulate over time.*

Earth's climate has been relatively stable for thousands of years. That stability is being disturbed. The change isn't sudden like a volcano. It's a gradual accumulation across a century that adds up to something the geological record hasn't shown at this rate before. **Stability and change is the frame for reading the graphs.**

THE STANDARD

Defining Design Problems

Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

DCI
DISCIPLINARY CORE IDEA

ETS1.A · Defining and Delimiting Engineering Problems

> *The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.*

Engineering doesn't start with building. It starts with defining the problem precisely. Criteria are what success looks like, written so you can measure it. Constraints are the limits the solution has to live inside. Sloppy criteria and constraints lead to sloppy designs. **Tight ones make the work testable.**

SEP
SCIENCE & ENGINEERING PRACTICE

Asking Questions and Defining Problems

> *Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.*

Students aren't picking a project and running. They're rewriting a vague problem into a specific one. They name what the solution must do, what it can't do, and what limits the materials, time, safety, or environment put on it. **The problem statement is the deliverable.**

CCC
CROSSCUTTING CONCEPT

Influence of Science, Engineering, and Technology on Society and the Natural World

> *All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.*

Every design choice ripples outward. A new product uses resources, affects people, and changes the natural environment. Students consider those impacts up front, not after the prototype is built. **The constraints on a real design include "what does this do to the people and the planet around it?"**

THE STANDARD

Evaluating Design Solutions

Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

DCI
DISCIPLINARY CORE IDEA

ETS1.B · Developing Possible Solutions

> *There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.*

Once you've nailed down the criteria and constraints, you almost always end up with more than one possible design. Evaluation is how you decide which one actually wins. It's not a vibe check. **It's a systematic process: score each design against each criterion, line up the trade-offs, and let the data point at the best fit.**

SEP
SCIENCE & ENGINEERING PRACTICE

Engaging in Argument from Evidence

> *Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.*

Students aren't picking the design they personally like. They're arguing from evidence. Each design gets rated against agreed-upon criteria, the scores get compared, and students defend a choice using the numbers and the trade-offs. The argument is the whole point. **If they can't justify it, they haven't done the work.**

CCC
CROSSCUTTING CONCEPT

Influence of Science, Engineering, and Technology on Society and the Natural World

> *All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.*

Every design decision sends ripples outward. The lunchbox a company picks affects what gets bought, what materials get used, what ends up in a landfill. Students see that "best design" isn't just a classroom call. **It shapes what people use, what the environment absorbs, and what gets made next.**

THE STANDARD

Comparing Design Solutions

Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

DCI
DISCIPLINARY CORE IDEA

ETS1.B · Developing Possible Solutions

> *There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.*

When you test three designs, you rarely get one clear winner. Design A handles load like a champ but costs too much. Design B is cheap but flexes under weight. Design C is light but slow to build. The work isn't picking a winner. **The work is reading the data, naming what each one did well, and combining those strengths into a v4 that beats all three.**

SEP
SCIENCE & ENGINEERING PRACTICE

Analyzing and Interpreting Data

> *Analyze and interpret data to determine similarities and differences in findings.*

Students aren't picking favorites or going with gut feel. They're analyzing test data, finding the similarities and differences across designs, and using those patterns to decide what to keep, what to drop, and what to combine. **The data drives the redesign, not the prettiest prototype.**

CCC
CROSSCUTTING CONCEPT

(not specified)

> *Engineering standards typically do not specify a single CCC.*

Patterns show up across the test results. One design fails the same way every trial. Another excels under one condition and tanks under another. Spotting those patterns is what tells you which features are real strengths and which were lucky one-offs. **No pattern, no useful redesign.**

THE STANDARD

Iterative Testing & Modification

Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

DCI
DISCIPLINARY CORE IDEA

ETS1.B · Developing Possible Solutions

> *A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. Models of all kinds are important for testing solutions.*

Engineering doesn't happen in one shot. You build a version, test it, study what the data tells you, and change one thing. Then you test again. Each round (each iteration) makes the design a little better. The goal isn't a perfect solution. **It's the best one you can land on inside the criteria, constraints, and time you've got.**

SEP
SCIENCE & ENGINEERING PRACTICE

Developing and Using Models

> *Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.*

Students aren't sketching a final design and calling it engineering. They're building a model (physical, drawn, or digital) for the purpose of generating data. The model exists to get tested. The data from that test points to the next change. **The model is a question, not an answer.**

CCC
CROSSCUTTING CONCEPT

(not specified)

> *Engineering standards typically do not specify a single CCC.*

NGSS doesn't list a single crosscutting concept for engineering standards. The one that fits best here is the Influence of Engineering, Technology, and Science on Society and the Natural World. **Iterative design is how every tool, gadget, and process around students got refined: try, measure, change, retry, until it's good enough to ship.**