Mathematics, Modeling, Laboratory Practices, and Timeline

Mathematics Skills Supporting Mastery of K-5 *Energy, Matter, and Force and Motion* Benchmarks

The mathematics skills listed below are not intended to be taught separately from science instruction. Rather, they identify mathematical concepts and practices that support student understanding of energy, matter, and force and motion at the point of learning. Students apply these skills while investigating phenomena, collecting and analyzing data, recognizing patterns, constructing explanations, and communicating scientific ideas. Mastery of these mathematics skills supports deeper understanding of the science benchmarks but does not replace mastery of benchmark content.

Mathematics Skill	**Description in *Energy, Matter, and Force and Motion* Context**	**Examples in *Energy, Matter, and Force and Motion* Context**	**Alignment to the B.E.S.T. Mathematics Benchmarks**
Counting and Comparing Quantities	Count, classify, compare, and order observations and measurements.	Compare which object moves farther; compare hotter and cooler objects; compare numbers of sound-producing objects; compare amounts of light observed; compare masses of objects; or compare the number of materials classified as mixtures or pure substances.	MA.K.NSO.1.1 MA.K.NSO.1.4 MA.1.NSO.1.4 MA.2.NSO.1.3 MA.3.NSO.1.3 MA.3.FR.2.1 MA.4.NSO.1.3 MA.4.NSO.1.5 MA.4.FR.1.4 MA.5.NSO.1.4
Comparing Relative Quantities	Recognize more/less, greater/smaller, faster/slower, and hotter/cooler relationships.	More force → greater changes in motion; more sunlight → greater heating.	MA.K.NSO.1.4 MA.1.NSO.1.4 MA.2.NSO.1.3 MA.3.NSO.1.3 MA.3.FR.2.1 MA.4.NSO.1.5 MA.5.NSO.1.4 MA.5.AR.3.2
Measurement and Use of Tools	Measure length, mass, volume, elapsed time, and temperature using appropriate tools and appropriate units.	Measure the distance an object moves, the time required for motion, or temperature changes during investigations; measure volume using appropriate measurement tools; measure mass using a balance; or measure temperature changes during heating investigations.	MA.K.M.1.3 MA.1.M.1.2 MA.1.M.2.1 MA.2.M.2.1 MA.2.M.1.1 MA.3.M.1.2 MA.4.M.1.1 MA.5.M.1.1 MA.5.GR.2.1

Mathematics Skill	**Description in *Energy, Matter, and Force and Motion* Context**	**Examples in *Energy, Matter, and Force and Motion* Context**	**Alignment to the B.E.S.T. Mathematics Benchmarks**
Using Units	Use correct units.	Measuring motion in centimeters, elapsed time in seconds, and temperature in degrees.	MA.1.M.1.1 MA.2.M.1.1 MA.3.M.1.2 MA.4.M.1.2 MA.5.M.1.1
Organizing and Representing Data	Organize observations and measurements using tables, picture graphs, bar graphs, charts, and line plots.	Bar graph of motion distance, record temperature measurements in a table, create a bar graph comparing volume measurements, or organize collision observations in a chart.	MA.K.DP.1.1 MA.1.DP.1.1 MA.2.DP.1.1 MA.3.DP.1.1 MA.4.DP.1.1 MA.5.DP.1.1
Using Tables and Graphs	Interpret information from tables, charts, graphs, and displays.	Compare motion data, compare energy observations, or compare matter properties.	MA.1.DP.1.1 MA.1.DP.1.2 MA.2.DP.1.1 MA.2.DP.1.2 MA.3.DP.1.1 MA.3.DP.1.2 MA.4.DP.1.1 MA.4.DP.1.2 MA.5.DP.1.1 MA.5.DP.1.2
Ordering and Sequencing Data	Arrange observations and measurements in a logical order.	Order objects by temperature, mass, or motion distance.	MA.K.NSO.2.3 MA.K.M.1.2 MA.K.GR.1.3 MA.1.NSO.1.4 MA.1.M.1.2 MA.1.GR.1.1 MA.2.NSO.1.3 MA.2.DP.1.1 MA.3.NSO.1.3 MA.3.M.1.1 MA.3.DP.1.1 MA.4.NSO.1.3 MA.4.NSO.1.5 MA.4.NSO.2.6 MA.5.NSO.1.4 MA.5.GR.3.1

Mathematics Skill	Description in *Energy, Matter, and Force and Motion* Context	Examples in *Energy, Matter, and Force and Motion* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Identifying Patterns	Analyze observations and data to identify patterns, relationships, and trends.	Greater force → greater changes in motion, more sunlight → higher temperatures, longer heating → greater temperature changes, or similar materials show similar observable properties.	MA.K.DP.1.1 MA.1.DP.1.2 MA.2.DP.1.2 MA.3.DP.1.2 MA.4.DP.1.2 MA.5.DP.1.2
Describing Change Over Time	Observe, measure, and describe how variables change over time.	Temperature increases or decreases, shadows change position during the day, motion changes over time, or matter changes during heating or cooling.	MA.3.M.1.2 MA.4.M.2.1 MA.5.M.1.1
Data Analysis and Interpretation	Analyze observations, measurements, tables, graphs, and investigations to draw conclusions and support explanations.	Analyze energy-source comparisons, determine which material is best suited for a task, compare results from collision investigations, or explain patterns in temperature data.	MA.K.M.1.2 MA.K.DP.1.1 MA.1.M.1.2 MA.1.DP.1.1 MA.1.DP.1.2 MA.2.DP.1.1 MA.2.DP.1.2 MA.3.DP.1.1 MA.3.DP.1.2 MA.4.AR.3.2 MA.4.DP.1.1 MA.4.DP.1.2 MA.4.DP.1.3 MA.5.DP.1.1 MA.5.DP.1.2

Mathematics Skill	Description in *Energy, Matter, and Force and Motion* Context	Examples in *Energy, Matter, and Force and Motion* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Quantitative Reasoning	Use measurements and numerical information to support claims and explanations.	Use volume measurements to compare objects, use temperature data to explain changes in matter, use distance and time observations to compare motion, or compare energy sources using evidence.	MA.K.M.1.2 MA.K.DP.1.1 MA.1.M.2.1 MA.1.DP.1.1 MA.1.DP.1.2 MA.2.M.2.1 MA.2.DP.1.1 MA.2.DP.1.2 MA.3.M.1.2 MA.3.M.2.2 MA.3.DP.1.1 MA.3.DP.1.2 MA.4.M.2.1 MA.4.DP.1.1 MA.4.DP.1.2 MA.4.DP.1.3 MA.5.GR.3.2 MA.5.DP.1.1 MA.5.DP.1.2
Mathematical Communication	Use data, measurements, tables, graphs, and mathematical representations to communicate scientific findings.	Present collision investigation results, explain energy-transfer patterns using a graph, or use measurement data to justify a material choice.	MA.K.M.1.2 MA.K.DP.1.1 MA.1.M.1.2 MA.1.DP.1.1 MA.1.DP.1.2 MA.2.DP.1.1 MA.2.DP.1.2 MA.3.DP.1.1 MA.3.DP.1.2 MA.4.DP.1.1 MA.4.DP.1.2 MA.4.DP.1.3 MA.5.DP.1.1 MA.5.DP.1.2

Modeling Skills Supporting Mastery of K-5 *Energy, Matter, and Force and Motion* Benchmarks

The modeling skills listed below are designed to support student understanding of physical science concepts through the use of drawings, diagrams, physical representations, and systems models that are appropriate for each grade level. As students progress, the complexity of the models increases to match developmental expectations and content demands. Students use models to represent structures, processes, interactions, and cause-and-effect relationships that may be difficult to observe directly. These skills help students communicate ideas, test explanations, and develop a deeper understanding of physical systems.

Modeling Skill	Description	Energy, Matter, and Force and Motion Specific Examples
Identifying System Parts	Identify the components of a system and describe how they work together.	Solar-powered water pump, simple machine system, plant-energy system, or battery-wire-bulb system.
Using Drawings and Diagrams	Create drawings and diagrams to represent observations, structures, and processes.	Draw energy transfers, states of matter, force interactions, or shadow patterns.
Representing Energy Flow	Use arrows and diagrams to represent energy transfers and transformations within systems.	Sunlight → solar panel → pump or battery → bulb.
Cause-and-Effect Modeling	Model how one change leads to another within a physical system.	Greater force → greater change in motion, heating → temperature change, or sunlight → plant growth.
Modeling Matter	Use drawings, diagrams, and physical representations to explain the structure and behavior of matter.	Particle models of solids, liquids, and gases; or models of mixtures and pure substances.
Constructing Physical Models	Build and use physical models to represent objects, systems, and scientific ideas.	Ramps, simple machines, particle models, solar-energy systems, or force investigations.
Systems Modeling	Use models to show how energy, matter, or forces move through a system.	Energy-flow diagrams, simple machine systems, irrigation systems, or photosynthesis models.
Comparing Models	Compare models with real-world objects, systems, and events.	Diagram versus actual circuit or particle model versus observed matter.
Evaluating Model Limitations	Recognize that models simplify real objects, systems, and processes.	Particle drawings, force diagrams, or energy-flow models.
Observational Models	Develop models based on observations collected during investigations.	Draw shadow changes, particle behavior, object motion, magnetic interactions, or energy transfers.
Using Arrows to Represent Forces	Use arrows to represent pushes, pulls, directions of motion, and force interactions.	Pushes, pulls, balanced forces, unbalanced forces, magnetic attraction and repulsion, or object motion.

Laboratory Practices Supporting Mastery of K-5 *Energy, Matter, and Force and Motion* Benchmarks

The laboratory practices listed below identify the investigative skills students use while learning physical science concepts. Through observation, measurement, data collection, analysis, and evidence-based explanation, students develop scientific habits of mind and learn how scientific knowledge is generated through investigations of natural phenomena.

Laboratory Practices	**Description of what students must be able to do**	**Examples in *Energy, Matter, and Force and Motion* Context**
Asking Testable Questions	Ask questions that can be investigated through observation, measurement, and testing.	How does the amount of sunlight affect temperature? How does the surface affect the motion of a toy car?
Planning and Carrying Out Investigations	Conduct observations and investigations to collect information about physical phenomena.	Test how different forces affect motion or investigate changes in matter when materials are heated or cooled.
Making Observations	Use senses and tools to observe properties, motion, energy changes, and interactions.	Observe melting ice, moving objects, magnetic interactions, or changes in temperature.
Measuring and Recording Data	Measure and record qualitative and quantitative observations using appropriate tools and units.	Record distance traveled, temperature changes, mass, volume, or time data.
Using Scientific Tools	Select and use tools safely and appropriately during investigations.	Use thermometers, balances, rulers, measuring cups, graduated cylinders, timers, and magnets.
Organizing and Representing Data	Organize observations and measurements using tables, charts, graphs, drawings, or other representations.	Create a data table showing the distance traveled by different objects or chart temperature changes over time.
Identifying Patterns	Analyze observations and data to identify patterns and relationships.	Recognize that greater forces produce greater changes in motion or that heating often increases temperature.
Using Models	Develop and use drawings, diagrams, physical models, and representations to explain scientific ideas.	Create particle models of matter, energy-flow diagrams, or force-and-motion diagrams.
Constructing Explanations	Use observations, measurements, and evidence to explain scientific phenomena.	Explain why some changes create new substances, why objects move differently, or how energy is transferred.
Engaging in Evidence-Based Argumentation	Use evidence from investigations to support claims and compare explanations.	Use investigation data to support a claim about the best material for a task or how force affects motion.
Communicating Results	Share observations, explanations, models, and conclusions using oral, written, and visual formats.	Present investigation findings using charts, diagrams, drawings, or written explanations.
Following Safety Procedures	Follow laboratory and classroom safety practices during investigations.	Safely handle materials, measure liquids, use thermometers, and conduct investigations responsibly.

Timeline of Key Accomplishments Supporting Mastery of K-5 *Energy, Matter, and Force and Motion* Benchmarks

This timeline provides historical and conceptual context for the Grades K-5 Energy, Matter, and Force and Motion benchmarks by highlighting key scientific ideas that support foundational understanding of energy, matter, and force and motion. It is not intended for memorization of names or dates, but rather to illustrate how scientific understanding develops over time through evidence, models, and refinement of ideas. Students at this level recognize that scientific knowledge is built from observations, improved with new evidence, and represented through models, forming the basis for the more advanced concepts they will encounter in Grades 6-12.

Historical developments often reflect changes in scientific models and explanations as new evidence becomes available. Students recognize that scientific understanding grows through the continual testing, revision, and refinement of models over time.

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
400 BC	Early idea of matter as tiny particles	Introduces the idea that matter is composed of extremely small particles.	Democritus
Ancient Times-1600s	Observations of magnetic materials and compass use	Demonstrates that magnets can exert forces without touching objects.	Various cultures and natural philosophers
1500s-1600s	Studies of motion begin	Shows motion can be observed and described.	Galileo Galilei
1600s	Study of gravity and falling objects	Explains why objects fall and move.	Galileo Galilei
1600s-1700s	Forces and motion explained	Demonstrates how forces affect the motion of objects and provides a framework for understanding motion and interactions.	Isaac Newton
1700s	Heat identified as a form of energy	Shows that heat can be transferred and can cause changes in matter.	Joseph Black, Benjamin Thompson (Count Rumford), and other contributing scientists
1700s-1800s	Measurement tools developed	Allows for the measurement of temperature and other physical properties to compare changes in matter and energy.	Various scientists and instrument makers
1700s-1800s	Study of electricity	Established understanding of electrical energy and laid the foundation for circuits and electrical technology.	Benjamin Franklin, Michael Faraday, and other contributing scientists

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
1700s-1800s	Evidence supporting particle models of matter grows	Supports understanding that matter is made of tiny particles that move differently in solids, liquids, and gases.	Daniel Bernoulli and other contributing scientists
Early 1800s	Relationship between electricity and magnetism discovered	Demonstrated that electricity and magnetism are connected and laid the foundation for electric motors, generators, and many modern technologies.	Hans Christian Ørsted, André-Marie Ampère, Michael Faraday, and other contributing scientists
1800s	Energy conservation developed	Demonstrates that energy can be transferred and transformed but is not created or destroyed.	James Prescott Joule, Hermann von Helmholtz, and other contributing scientists
1800s	Simple machines and forces studied	Explains how tools help move objects.	Various scientists
Late 1800s	Electric lighting developed	Connects energy to everyday use and demonstrates the transformation of electrical energy into light and heat.	Thomas Edison, Lewis H. Latimer, and other contributing scientists
Late 1800s-early 1900s	Advanced electrical technologies for railway transportation and communication	Demonstrates how electrical technology can be used in transportation systems to communicate with and control moving trains.	Granville T. Woods and other engineers
Late 1800s-1900s	Electrical systems expanded	Explains how electricity can be generated, transmitted, and used in homes.	Nikola Tesla, Lewis H. Latimer, and other contributing scientists and engineers
Early 1800s-Early 1900s	Scientific atomic theory developed	Supports understanding that matter is made of atoms.	John Dalton and other contributing scientists
Early 1900s	Atomic structure discovered and modeled	Supports understanding that atoms contain smaller components and can be represented using scientific models.	J.J. Thomson, Ernest Rutherford, Niels Bohr, and other contributing scientists
1900s-1950s	Modern appliances developed	Shows energy use in daily life systems and demonstrates energy transformations in technologies.	Various scientists and engineers

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
1905	Energy-Matter Relationship Explored	Helped scientists better understand energy transformations and the relationship between matter and energy.	Albert Einstein
Early-mid 1900s	Contributions to aviation and flight	Demonstrates applications of forces, motion, energy, and engineering to controlled flight.	Bessie Coleman and Gen. Daniel “Chappie” James, Jr.
1940s-1960	Precision electrical resistors developed and improved	Demonstrates how electrical components can control the flow of electrical energy and how electrical energy can be transferred through devices and systems.	Otis Boykin
1950s-Present	Renewable energy growth	Demonstrates how energy from renewable resources can be converted and used to meet human needs.	Multiple scientists and engineers, including those involved in solar-energy development in Florida.
1958-Present	Space exploration technologies developed and refined	Demonstrates applications of energy, forces, motion, materials, and simple machines in real-world systems.	NASA scientists, engineers, and astronauts, including contributions from Florida-based space exploration programs.
2000s-Present	Digital tools and sensors	Supports measurement and investigations in class and allows scientists to collect and analyze increasingly precise data.	Modern scientists and engineers

Mathematics, Modeling, Laboratory Practices, and Timeline

Mathematics Skills Supporting Mastery of K-5 *Planet Earth and Space* Benchmarks

The mathematics skills listed below are not intended to be taught separately from science instruction. Rather, they identify mathematical concepts and practices that support student understanding of Planet Earth and Space concepts at the point of learning. Students apply these skills while investigating phenomena, collecting and analyzing data, recognizing patterns, constructing explanations, and communicating scientific ideas. Mastery of these mathematics skills supports deeper understanding of the science benchmarks but does not replace mastery of benchmark content.

Mathematics Skill	**Description in *Planet Earth and Space* Context**	**Examples in *Planet Earth and Space* Context**	**Alignment to the B.E.S.T. Mathematics Benchmarks**
Count, Sort, and Classify	Organize Earth materials, weather observations, and natural resources based on observable characteristics.	Sort rocks by texture, classify clouds by appearance, or group natural resources.	MA.K.DP.1.1 MA.K.M.1.2 MA.K.GR.1.3 MA.1.GR.1.1 MA.2.GR.1.2 MA.3.GR.1.2 MA.4.GR.1.1 MA.5.GR.1.1 MA.5.GR.1.2
Measurement and Comparison	Use appropriate tools and units to measure and compare Earth and weather data.	Compare rainfall amounts, measure air temperature, or compare landform characteristics.	MA.K.NSO.2.3 MA.K.M.1.3 MA.1.M.1.2 MA.2.M.1.1 MA.3.M.1.1 MA.3.M.1.2 MA.4.M.1.1 MA.4.M.1.2 MA.5.M.1.1
Identify Patterns	Analyze observations and data to identify patterns, trends, and relationships in Earth and space systems.	Daily weather observations, seasonal changes, or patterns in cloud formation.	MA.K.DP.1.1 MA.1.DP.1.2 MA.2.DP.1.2 MA.3.AR.3.3 MA.3.DP.1.2 MA.4.AR.3.2 MA.4.DP.1.2 MA.5.AR.3.1 MA.5.AR.3.2 MA.5.DP.1.2

Mathematics Skill	**Description in *Planet Earth and Space* Context**	**Examples in *Planet Earth and Space* Context**	**Alignment to the B.E.S.T. Mathematics Benchmarks**
Represent and Interpret Data	Organize and interpret data using tables, charts, graphs, and pictorial displays.	Create weather charts, graph temperatures, or organize fossil observations.	MA.K.DP.1.1 MA.1.DP.1.1 MA.1.DP.1.2 MA.2.DP.1.1 MA.2.DP.1.2 MA.3.DP.1.1 MA.3.DP.1.2 MA.4.DP.1.1 MA.4.DP.1.2 MA.5.DP.1.1 MA.5.DP.1.2
Data Analysis and Interpretation	Analyze observations, measurements, tables, charts, graphs, maps, and investigations to draw conclusions and support explanations.	Analyze weather data to identify trends, compare climate information for different regions, interpret fossil evidence to infer past environments, or compare rainfall data among locations.	MA.K.M.1.2 MA.K.DP.1.1 MA.1.M.1.2 MA.1.DP.1.1 MA.1.DP.1.2 MA.2.DP.1.1 MA.2.DP.1.2 MA.3.DP.1.1 MA.3.DP.1.2 MA.4.AR.3.2 MA.4.DP.1.1 MA.4.DP.1.2 MA.4.DP.1.3 MA.5.DP.1.1 MA.5.DP.1.2
Describe Change Over Time	Observe, measure, compare, and explain changes occurring over different time scales.	Daily weather changes, seasonal patterns, shoreline changes, or fossil evidence of environmental change.	MA.K.M.1.2 MA.1.DP.1.1 MA.2.DP.1.1 MA.2.DP.1.2 MA.3.DP.1.1 MA.3.DP.1.2 MA.4.DP.1.1 MA.4.M.2.1 MA.5.DP.1.1
Compare Relative Quantities	Use greater than, less than, more, less, higher, lower, warmer, cooler, and similar comparisons.	Compare temperatures, rainfall, elevations, or cloud cover.	MA.K.NSO.1.4 MA.K.M.1.2 MA.1.NSO.1.4 MA.2.NSO.1.3 MA.3.NSO.1.3 MA.3.FR.2.1 MA.4.NSO.1.5 MA.5.NSO.1.4

Mathematics Skill	**Description in *Planet Earth and Space* Context**	**Examples in *Planet Earth and Space* Context**	**Alignment to the B.E.S.T. Mathematics Benchmarks**
Spatial Reasoning	Use maps, globes, diagrams, and models to identify locations and patterns.	Locate mountains and oceans; identify latitude relationships and compare locations across hemispheres; trace waterways; identify climate zones; trace hurricane paths; compare locations on maps and globes; or analyze relationships among latitude, climate, and biomes.	MA.K.NSO.1.3 MA.1.M.1.1 MA.2.AR.3.1 MA.2.M.1.1 MA.3.AR.3.3 MA.3.M.1.2 MA.4.AR.3.2 MA.5.AR.3.1 MA.5.AR.3.2 MA.5.GR.4.1 MA.5.GR.4.2
Quantitative Reasoning	Use measurements and numerical information to compare observations and support scientific explanations.	Compare precipitation amounts, compare temperatures among climate zones, or use weather records to explain climate patterns.	MA.K.M.1.2 MA.K.DP.1.1 MA.1.M.2.1 MA.1.DP.1.1 MA.1.DP.1.2 MA.2.M.2.1 MA.2.DP.1.1 MA.2.DP.1.2 MA.3.M.1.2 MA.3.M.2.2 MA.3.DP.1.1 MA.3.DP.1.2 MA.4.M.2.1 MA.4.DP.1.1 MA.4.DP.1.2 MA.4.DP.1.3 MA.5.GR.3.1 MA.5.GR.3.2 MA.5.DP.1.1 MA.5.DP.1.2
Sequencing and Ordering	Arrange events and observations in logical order.	Sequence stages of the water cycle, order weather observations, or organize evidence of Earth changes.	MA.K.NSO.1.3 MA.K.NSO.2.3 MA.1.NSO.1.4 MA.1.M.1.2 MA.2.NSO.1.3 MA.3.NSO.1.3 MA.3.FR.2.1 MA.4.NSO.1.3 MA.4.NSO.1.5 MA.4.FR.1.4 MA.5.NSO.1.4

Mathematics Skill	Description in *Planet Earth and Space* Context	Examples in *Planet Earth and Space* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Mathematical Communication	Use numerical data, tables, charts, graphs, and maps to communicate scientific findings.	Present climate comparisons using graphs, maps, weather charts, or data tables to communicate scientific findings; display fossil evidence in chart or diagram form.	MA.K.M.1.2 MA.K.DP.1.1 MA.1.M.1.2 MA.1.DP.1.1 MA.1.DP.1.2 MA.2.DP.1.1 MA.2.DP.1.2 MA.3.DP.1.1 MA.3.DP.1.2 MA.4.DP.1.1 MA.4.DP.1.2 MA.4.DP.1.3 MA.5.DP.1.1 MA.5.DP.1.2

Modeling Skills Supporting Mastery of K-5 *Planet Earth and Space* Benchmarks

The modeling skills listed below support student understanding of Earth and space science concepts through the use of drawings, diagrams, maps, globes, physical representations, and systems models that are appropriate for each grade level. As students progress through the grades, the complexity of the models increases to align with developmental expectations and content demands. Students use models to represent structures, processes, interactions, and patterns that may be difficult to observe directly. These skills help students communicate ideas, test explanations, and develop a deeper understanding of Earth and space systems.

Modeling Skill	Description	*Planet Earth and Space* Specific Examples
Using Physical Models	Use tangible models to represent Earth features and processes.	Earth layer models, landform models, or water cycle models.
Using Diagrams and Drawings	Create and interpret visual representations of Earth systems.	Drawings of waterways, weather systems, or Earth materials.
Modeling Systems	Use models to identify system components and explain interactions among parts of Earth and space systems.	Geosphere-hydrosphere interaction, water cycle models, or weather system models.
Representing Change Over Time	Use models to describe Earth processes that occur over time.	Erosion models, fossil sequence models, or weather observation records.
Comparing Models and Observations	Compare model predictions with observations.	Compare a water cycle model to real-world observations.
Revising Models Using Evidence	Refine models based on new observations and evidence.	Improve Earth system diagrams after investigations.
Using Models to Explain Phenomena	Use models to communicate scientific explanations.	Explain weathering, erosion, Earth layers, or climate zones through models.
Using Models to Make Predictions	Use observations and models to predict future events of systems behavior.	Predict weather patterns, changes in coastlines, movement of water through a watershed, or seasonal changes.
Using Maps and Globes	Use maps, globes, and spatial representations to identify locations, surface features, and Earth patterns.	Locate oceans and mountains, trace waterways, or identify climate zones.
Cause-and-Effect Modeling	Use models to explain how one change in a system leads to another.	Water → erosion, wind → dune formation, or Sun → evaporation.
Using Spatial Models	Use maps, diagrams, globes, and other spatial representations to show locations, movements, and relationships.	Climate-zone maps. waterway diagrams, or Earth-Sun observations.
Evaluating Model Limitations	Recognize that models simplify real systems and may not show every detail.	Water cycle diagrams, globe representation, or Earth layer models

Laboratory Practices Supporting Mastery of K-5 *Planet Earth and Space* Benchmarks

The laboratory practices listed below identify the investigative skills students use while learning Earth and space science concepts. Through observation, measurement, data collection, analysis, and evidence-based explanation, students develop scientific habits of mind and learn how scientific knowledge is generated through investigations of natural phenomena.

Laboratory Practices	**Description of what students must be able to do**	***Planet Earth and Space* focused example**
Asking Questions	Generate questions about Earth materials, weather, and Earth processes.	Ask how water changes Earth's surface.
Planning and Conducting Investigations	Carry out investigations to collect evidence.	Investigate erosion using water and soil.
Making Observations	Use senses and tools to gather information.	Observe rocks, weather conditions, or clouds.
Measuring and Collecting Data	Gather quantitative and qualitative data.	Measure rainfall and temperature.
Organizing and Analyzing Data	Identify patterns and trends from collected data.	Compare daily weather observations.
Constructing Explanations	Use evidence to explain observations.	Explain how fossils provide evidence of past environments.
Communicating Results	Share findings using words, drawings, graphs, and models.	Present water cycle or weather investigations.
Using Scientific Tools	Use scientific tools correctly and appropriately to collect observations and measurements.	Rain gauges, thermometers, wind vanes, hygrometers, or barometers.
Using Scientific Tools Safely	Properly use investigation materials and tools.	Safely use thermometers and weather instruments.
Identifying Patterns	Analyze observations and measurements to identify recurring patterns and relationships.	Patterns in weather, seasonal changes, climate trends, or fossil distribution.
Using Models	Develop and use models to represent Earth materials, systems, processes, and patterns.	Water cycle models, Earth-layer diagrams, or Earth-system interaction models.
Engaging in Evidence-Based Argumentation	Use observations and data to support claims and compare explanations.	Use fossil evidence to infer past environments, use weather data to justify predictions, or compare resource classifications using evidence.

Timeline of Key Accomplishments Supporting Mastery of K-5 *Planet Earth and Space* Benchmarks

This timeline provides historical and conceptual context for the Grades K-5 Planet Earth and Space benchmarks by highlighting key scientific ideas that support foundational understanding of Earth materials, Earth systems, weather, climate, and Earth history. It is not intended for memorization of names or dates, but rather to illustrate how scientific understanding develops over time through evidence, models, and refinement of ideas. Students at this level recognize that scientific knowledge is built from observations, improved with new evidence, and represented through models, forming the foundation for the more advanced concepts they will encounter in Grades 6–12.

Historical developments often reflect changes in scientific models and explanations as new evidence becomes available. Students recognize that scientific understanding grows through the continual testing, revision, and refinement of models over time.

Time Period	**Accomplishment or Discovery**	**Why it matters for *Planet Earth and Space***	**Important People Involved**
Ancient Civilizations	Systematic observations of the Sun, Moon, stars, seasons, and weather	Demonstrates that patterns in the sky and weather can be observed and used to make predictions.	Many cultures worldwide, including the Egyptians and Ancient Jews
300 BC-200 AD	Earth recognized as spherical; early measurements of Earth's size	Established Earth's shape and scale as foundational planetary properties.	Aristotle and Eratosthenes
1500s-1600s	Improved observations of celestial objects and planetary motion.	Helped explain patterns observed in the sky and improved understanding of Earth's place in space.	Nicolaus Copernicus, Galileo Galilei, and Johannes Kepler
1600s	Principles of stratigraphy	Provided rules for interpreting rock layers and relative age relationships.	Nicolas Steno
1600s-1700s	Scientific weather observations become more systematic	Demonstrated that weather can be observed, measured, recorded, and compared over time.	Various scientists
Late 1600s-1700s	Laws of motion and gravity developed	Explained forces governing planetary motion and provides a foundation for understanding Earth's relationship with other objects in space.	Isaac Newton
Late 1700s	Uniformitarianism proposed	Demonstrated that the same natural processes observed today have shaped Earth over long periods of time.	James Hutton

Time Period	Accomplishment or Discovery	Why it matters for *Planet Earth and Space*	Important People Involved
1700s-1800s	Weather instruments improved and became widely used	Allowed more accurate measurements of temperature, precipitation, air pressure, and wind.	Various scientists and instrument makers
1769-1770	Produced one of the first maps of the Gulf Stream.	Improved navigation and demonstrated how scientific observations can be used to understand large-scale Earth systems.	Benjamin Franklin Timothy Folger
Early-Mid 1800s	Geologic time concepts and relative dating developed	Organized Earth's history using rock layers and fossils.	Charles Lyell
Late 1800s	Fossil classification and correlation improved	Revealed evidence of changing environments and organisms through time.	Georges Cuvier and William Smith
Late 1800s-Early 1900s	Scientific observations and mathematical calculations of the Earth and sky, which helped people better understand the movement and patterns of the Sun, Moon, and stars.	Demonstrated how systematic observations, mathematical calculations, and recorded data can be used to study celestial patterns and Earth-space relationships.	Benjamin Banneker
Early 1900s	Seismic wave studies revealed Earth's internal layers	Provided evidence for the structure of Earth's interior.	Richard Oldham
Early 1900s	Radioactive dating methods developed	Improved understanding of the age of rocks and Earth history.	Ernest Rutherford and other scientists
1910s-1930s	Continental drift hypothesis proposed	Introduced the idea that continents move over time.	Alfred Wegener
1940s-1950s	Mapping the ocean floor expanded	Revealed major features of Earth's surface beneath the oceans.	Marie Tharp and Bruce Heezen
1950s-1960s	Seafloor spreading proposed	Provided evidence explaining how Earth's surface can change over time.	Harry Hess and Robert S. Dietz
1950s-Present	Development of space sciences and exploration	Demonstrated how mathematical calculations, scientific observations, and technological models are used to understand Earth and objects in space.	Katherine Johnson, Dorothy Vaughan, and Mary W. Jackson
1956-1980s	Satellite navigation technologies	Demonstrated how mathematical calculations and satellites can be used to model the Earth's shape and contribute to modern GPS technology.	Gladys West

Time Period	Accomplishment or Discovery	Why it matters for *Planet Earth and Space*	Important People Involved
1958-Present	Developed and refined Space exploration technologies	Demonstrated how observations, measurements, models, and technology were used to study Earth, the Solar System, and beyond.	NASA scientists, engineers, and astronauts, including Mae C. Jemison
1960s-1970s	Plate tectonic theory developed	Unified explanations for earthquakes, volcanoes, mountains, and surface change.	J. Tuzo Wilson and other contributing scientists
1960s-Present	Weather satellites launched and improved	Enabled large-scale observations of clouds, storms, and weather patterns around Earth.	NASA, NOAA, and international space agencies
1960s-Present	Earth system science develops	Demonstrated that the geosphere, hydrosphere, atmosphere, and biosphere interact as interconnected systems.	NASA Earth Science Program and Earth system scientists
1969	Apollo 11 Launch from Kennedy Space Center	Demonstrated the capability for human exploration beyond Earth and provided scientific information about the Moon and planetary systems. Apollo 11 launched from Kennedy Space Center in Florida.	Neil Armstrong Buzz Aldrin Michael Collins NASA
1970s-1980s	Satellite observations expanded study of Earth systems	Improved understanding of interactions among Earth's atmosphere, oceans, land, and living things.	NASA and International space agencies
1983-Present	Collected environmental data furthering the study of Earth's atmosphere and conducted experiments supporting life sciences.	During his missions, he helped deploy satellites, conduct scientific experiments, and supported Department of Defense research projects.	Guion "Guy" Bluford
1992-Present	Transformed and advanced humanity's ambitions with space exploration.	Demonstrated how scientific experiments conducted in space helped scientists better understand how living things respond to conditions beyond Earth.	Mae C. Jemison
Late 1900s	Modern climate and ocean circulation models developed	Improved understanding of long-term weather and climate patterns.	Henry Stommel and other Earth scientists
Late 1900s to Present	Expanded Earth and environmental research using observations and models	Demonstrated how field observations, satellite data, and scientific models can be used to study Earth's systems and environmental change.	Contemporary Earth and environmental scientists

Time Period	Accomplishment or Discovery	Why it matters for *Planet Earth and Space*	Important People Involved
2000s-Present	Global hazard monitoring systems expanded	Improved tracking of hurricanes, floods, earthquakes, volcanoes, and other natural hazards.	NOAA, USGS, and international agencies
2000s-Present	Earth system models refined	Helped scientists study interactions among the geosphere, hydrosphere, atmosphere, and biosphere.	Interdisciplinary scientists
2000s-Present	Advances in Earth observation technologies	Improved monitoring of weather, water, landforms, natural resources, and environmental change.	Earth observation scientists
2000s-Present	Planetary geology and Earth observation expanded through integrated field, satellite, and modeling studies	Advanced the study of Earth and planetary processes through observations, satellite data, and models, improving environmental monitoring and supporting future exploration of Earth's oceans and Mars.	Jessica A. Watkins and other geologists

Mathematics, Modeling, Laboratory Practices, and Timeline

Mathematics Skills Supporting Mastery of K-5 *Life* Benchmarks

The mathematics skills listed below are not intended to be taught separately from science instruction. Rather, they identify mathematical concepts and practices that support student understanding of life science concepts at the point of learning. Students apply these skills while investigating phenomena, collecting and analyzing data, recognizing patterns, constructing explanations, and communicating scientific ideas. Mastery of these mathematics skills supports deeper understanding of the science benchmarks but does not replace mastery of benchmark content.

Mathematics Skill	Description in *Life* Context	Examples in *Life* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Counting and Classification	Sort, group, count, and classify living things based on observable characteristics.	Sorting plants by leaf shape or classifying animals by body coverings.	MA.K.DP.1.1 MA.K.NSO.1.1 MA.1.NSO.1.1 MA.1.GR.1.1 MA.2.GR.1.2 MA.3.GR.1.2 MA.4.GR.1.1 MA.5.GR.1.1 MA.5.GR.1.2
Measurement	Measure and compare biological structures and changes over time.	Measuring plant growth or comparing animal lengths.	MA.K.NSO.2.3 MA.K.M.1.2 MA.1.M.1.1 MA.1.M.1.2 MA.2.M.1.1 MA.2.M.1.2 MA.3.M.1.1 MA.3.M.1.2 MA.3.M.2.2 MA.4.M.1.1 MA.4.M.1.2 MA.5.M.1.1
Data Collection and Representation	Collect, record, display, and interpret biological observations and data.	Creating picture graphs of animal groups or recording weekly plant growth.	MA.K.DP.1.1 MA.1.DP.1.1 MA.2.DP.1.1 MA.3.DP.1.1 MA.4.DP.1.1 MA.5.DP.1.1 MA.1.DP.1.2 MA.2.DP.1.2 MA.3.DP.1.2 MA.4.DP.1.2 MA.4.DP.1.3 MA.5.DP.1.2

Mathematics Skill	**Description in *Life* Context**	**Examples in *Life* Context**	**Alignment to the B.E.S.T. Mathematics Benchmarks**
Comparing Quantities	Compare biological quantities using greater than, less than, equal to, and differences.	Comparing numbers of seeds that germinated.	MA.K.NSO.1.4 MA.1.NSO.1.4 MA.1.NSO.2.3 MA.2.NSO.1.3 MA.2.NSO.2.3 MA.3.NSO.1.3 MA.4.NSO.1.3 MA.4.NSO.1.5 MA.4.FR.1.4 MA.5.NSO.1.4
Patterns	Identify patterns in life cycles, growth, inheritance, and environmental responses.	Observing seasonal migration patterns or sequencing life cycle stages.	MA.K.DP.1.1 MA.1.DP.1.2 MA.2.DP.1.2 MA.3.AR.3.3 MA.3.DP.1.2 MA.4.AR.3.2 MA.4.DP.1.2 MA.5.AR.3.1 MA.5.AR.3.2 MA.5.DP.1.2
Graphical Representation	Use tables, charts, and graphs to display biological data.	Bar graphs of heart-rate investigations or plant growth.	MA.K.DP.1.1 MA.1.DP.1.1 MA.2.DP.1.1 MA.3.DP.1.1 MA.4.DP.1.1 MA.5.DP.1.1
Data Analysis and Interpretation	Analyze observations, measurements, tables, charts, graphs, and investigations to identify patterns, support explanations, and make evidence-based conclusions about living organisms and biological systems.	Analyze plant growth data, compare inheritance patterns, interpret population changes, analyze organism response investigations, or compare ecosystem observations.	MA.K.DP.1.1 MA.K.M.1.2 MA.1.DP.1.1 MA.1.DP.1.2 MA.1.M.1.1 MA.1.M.1.2 MA.2.DP.1.1 MA.2.DP.1.2 MA.2.M.1.1 MA.2.M.1.2 MA.2.M.1.3 MA.3.DP.1.1 MA.3.DP.1.2 MA.3.M.1.1 MA.3.M.1.2 MA.4.DP.1.1 MA.4.DP.1.2 MA.4.M.1.1 MA.4.DP.1.3 MA.5.DP.1.1 MA.5.DP.1.2

Mathematics Skill	**Description in *Life* Context**	**Examples in *Life* Context**	**Alignment to the B.E.S.T. Mathematics Benchmarks**
Quantitative Reasoning	Use numerical information to compare organisms, populations, structures, environmental conditions, and biological processes.	Compare growth rates, compare population sizes, compare resource availability, compare trait frequencies, or compare environmental measurements.	MA.K.NSO.2.3 MA.1.NSO.1.4 MA.1.M.1.2 MA.2.NSO.1.3 MA.2.M.1.2 MA.3.FR.2.1 MA.3.NSO.1.3 MA.3.M.1.2 MA.4.NSO.1.3 MA.4.NSO.1.5 MA.4.FR.1.4 MA.5.NSO.1.4 MA.5.DP.1.1 MA.5.DP.1.2
Systems Analysis	Use quantitative and observational data to analyze relationships among interacting parts of biological systems.	Analyze food web interactions, compare body system functions, investigate ecosystem changes, or analyze organism-environment interactions.	MA.K.DP.1.1 MA.K.M.1.2 MA.1.DP.1.1 MA.2.DP.1.1 MA.2.M.1.1 MA.3.DP.1.1 MA.3.DP.1.2 MA.3.M.1.1 MA.4.DP.1.2 MA.4.FR.2.4 MA.5.DP.1.2 MA.5.NSO.2.5

Modeling Skills Supporting Mastery of K-5 *Life* Benchmarks

The modeling skills listed below support student understanding of life science concepts through the use of drawings, diagrams, physical representations, and systems models that are appropriate for each grade level. As students progress through the grades, the complexity of the models increases to align with developmental expectations and content demands. Students use models to represent structures, processes, interactions, and relationships that may be difficult to observe directly. These skills help students communicate ideas, test explanations, and develop a deeper understanding of living systems.

Modeling Skill	Description	*Life* Specific Examples
Observational Modeling	Create drawings and representations based on observations.	Drawing plant parts or modeling animal life cycles.
Structure-Function Modeling	Use models to explain how structures perform specific functions.	Modeling flower structures or illustrating skeletal support.
System Modeling	Illustrate how parts of a biological system work together.	Digestive system diagrams or food transport models.
Flow Modeling	Represent movement of matter, energy, or resources.	Modeling nutrient movement through the body or energy flow from plants to animals.
Classification Models	Use charts and graphic organizers to categorize organisms.	Vertebrate-invertebrate classification charts.
Predictive Models	Use models to make predictions.	Predicting plant growth under different environmental conditions.
Physiological Systems Modeling	Use models to represent structures and interactions within living systems.	Digestive system diagrams, circulatory system models, plant transport models, or organ system interactions.
Life Cycle Modeling	Use models to represent growth, development, and reproduction over time.	Butterfly life cycle, frog development, plant life cycles, or human growth models.
Heredity and Trait Modeling	Use models to represent inherited traits and variation among organisms.	Family trait charts, trait comparison diagrams, inheritance models.
Ecological Systems Modeling	Use models to identify components, boundaries, and interactions within ecosystems.	Food webs, habitat models, ecosystem interaction diagrams, or producer-consumer-decomposer models.

Laboratory Practices Supporting Mastery of K-5 *Life* Benchmarks

The laboratory practices listed below identify the investigative skills students use while learning life science concepts. Through observation, measurement, data collection, analysis, and evidence-based explanation, students develop scientific habits of mind and learn how scientific knowledge is generated through investigations of living systems and biological phenomena.

Laboratory Practices	Description of what students must be able to do	*Life* focused example
Planning and Conducting Investigations	Make observations and carry out investigations of living systems.	Investigate plant growth under different conditions.
Collecting Data	Use appropriate tools to gather observations and measurements.	Measure plant height or observe life cycle stages.
Recording Observations	Use drawings, tables, journals, and charts to document evidence.	Maintain a seed growth journal.
Analyzing Data	Organize and interpret data to identify patterns.	Compare growth rates among plants.
Using Evidence	Use observations and data to support explanations.	Explain why one plant grew larger than another.
Developing and Using Models	Create and revise models to explain biological systems.	Construct food web or life cycle models.
Using Technology and Tools	Use age-appropriate scientific tools safely and effectively.	Hand lenses, digital microscopes, balances, or thermometers.
Practicing Safety	Follow safety procedures while investigating living organisms and biological materials.	Handling plants, soil, organisms, or classroom specimens appropriately.
Defining Systems and System Boundaries	Identify components of a biological system and determine which interactions are included in an investigation.	Define components of a terrarium ecosystem, identify parts of a plant system, or define an organism and its environment.
Monitoring Change Over Time	Observe and record biological changes occurring over days, weeks, months, or seasons.	Plant growth investigations, life-cycle observations, population monitoring, or seasonal organism changes.
Comparing Explanations	Evaluate multiple explanations using evidence gathered from investigations and observations.	Compare explanations for plant growth differences, compare causes of ecosystem changes, or evaluate evidence for inherited traits.

Timeline of Key Accomplishments Supporting Mastery of K-5 *Life* Benchmarks

This timeline provides historical and conceptual context for the K-5 Life Science standards by highlighting important developments in the study of living things. It is not intended for memorization of names or dates, but rather to illustrate how scientific knowledge develops through observations, evidence, investigations, and improved technologies. Students at this level recognize that scientific knowledge is built from observations, improved with new evidence, and represented through models, forming the foundation for the more advanced concepts they will encounter in Grades 6–12.

Historical developments often reflect changes in scientific models and explanations as new evidence becomes available. Students recognize that scientific understanding grows through the continual testing, revision, and refinement of models over time.

Time Period	**Accomplishment or Discovery**	**Why it matters for *Life***	**Important People Involved**
400 B.C.	Early classification of living things	Organized living organisms based on shared characteristics.	Aristotle
1660s	Early observations of cells using microscopes	Establishes that previously unseen structures, now known as cells, could be observed in living and nonliving materials.	Robert Hooke
1670s	Observation of microorganisms	Revealed the existence of microscopic life.	Antonie van Leeuwenhoek
1700s	Development of modern classification system	Provides a framework for organizing living things based on shared characteristics.	Carl Linnaeus
1800s	Scientific evidence that microorganisms can cause disease	Supports understanding of microorganisms and their relationship to health and disease.	Louis Pasteur, Robert Koch, and other contributing scientists
1838-1839	Development of Cell Theory	Established that plants and animals are made of cells.	Matthias Schleiden and Theodor Schwann
1855	Cells arise from preexisting cells	Completed the foundational principles of Cell Theory.	Rudolf Virchow
1859	Theory of Natural Selection	Helps explain how inherited variation and environmental pressures contribute to adaptations and changes in populations over generations.	Charles Darwin
1860s	Pasteurization	Demonstrated the importance of microorganisms in food and health.	Louis Pasteur
1865	Laws of Heredity	Established foundational principles of inheritance	Gregor Mendel

Time Period	Accomplishment or Discovery	Why it matters for *Life*	Important People Involved
Late 1800s - Early 1900s	Agricultural and plant science advanced through research	Demonstrates how systematic study of plants, soils, and agricultural practices can be used to understand living systems and improve human use of biological resources.	George Washington Carver
Late 1800s - Early 1900s	Studies of animal behavior expanded through systematic observation	Demonstrated that careful observation and experimentation can be used to investigate how animals behave and interact with their environments.	Charles Henry Turner
Early 1900s	Research on cells expanded	Advanced understanding of how cells participate in early development of organisms.	Ernest Everett Just
1930s - 1940s	Blood and plasma preservation techniques developed	Advanced understanding and application of knowledge about blood and the human body.	Charles R. Drew
1942-1945	Developed the process that became frozen concentrated orange juice.	USDA Laboratory in Winter Haven, Florida provided concentrated orange juice to provide Vitamin C to troops in World War II and later transformed Florida's citrus industry.	Louis G. MacDowell Edwin L. Moore Cedric Atkins
1953	Structure of DNA described	Provides a foundation for understanding heredity and inheritance.	James Watson, Francis Crick, Rosalind Franklin, Maurice Wilkins, and other contributing scientists
1900s - Present	Development of ecosystem and systems ecology concepts	Supports understanding of interactions among organisms and environments.	Eugene Odum and other ecologists
1990 - 2003	The Human Genome Project	Expanded understanding of genes and heredity.	U.S. Department of Energy, National Institutes of Health, and contributing scientists
2000s	Microbiome research	Revealed the importance of microorganisms in human health and ecosystems.	Jeffrey Gordon and other contributing scientists

Mathematics, Modeling, Laboratory Practices, and Timeline

Mathematics Skills Supporting Mastery of 6-8 *Energy, Matter, and Force and Motion* Benchmarks

The mathematics skills listed below are not intended to be taught separately from science instruction. Rather, they identify mathematical concepts and practices that support student understanding of energy, matter, and force and motion concepts at the point of learning. Students apply these skills while investigating phenomena, collecting and analyzing data, identifying patterns, constructing explanations, and communicating scientific ideas. Mastery of these mathematics skills supports deeper understanding of the science benchmarks but does not replace mastery of benchmark content.

Mathematics Skill	**Description in *Energy, Matter, and Force and Motion* Context**	**Examples in *Energy, Matter, and Force and Motion* Context**	**Alignment to the B.E.S.T. Mathematics Benchmarks**
Measurements and Units	Use appropriate tools and units to measure physical quantities such as mass, volume, density, and time; calculate derived quantities such as speed and density.	Distance, time, mass, volume, force, speed, or density measurements.	MA.6.AR.3.2 MA.6.AR.3.3 MA.6.AR.3.5 MA.6.GR.2.3 MA.7.AR.3.3 MA.7.GR.2.3 MA.8.AR.3.5 MA.8.NSO.1.4 MA.8.NSO.1.5 MA.8.NSO.1.6
Proportional Reasoning	Recognize and interpret relationships between variables that change in proportion.	Relationships among distance, time, speed, mass, force, or density.	MA.6.AR.3.2 MA.6.AR.3.5 MA.7.AR.4.3 MA.7.AR.4.5 MA.8.AR.3.1 MA.8.AR.3.2 MA.8.AR.3.5
Algebraic Reasoning	Use formulas to calculate unknown quantities and interpret relationships between variables.	Density calculations, speed calculations, or solving for unknown quantities.	MA.6.AR.1.1 MA.6.AR.1.3 MA.6.AR.1.4 MA.6.AR.2.2 MA.6.AR.2.3 MA.7.AR.2.2 MA.8.AR.2.1 MA.8.AR.2.3
Graphical Representation and Interpretation	Construct and interpret graphs to identify patterns and trends in data.	Distance-time graphs, position-time graphs, phase-change graphs, or graphical patterns in data.	MA.6.GR.1.1 MA.6.GR.1.2 MA.6.GR.1.3 MA.7.AR.4.3 MA.7.DP.1.5 MA.8.F.1.3

Mathematics Skill	**Description in *Energy, Matter, and Force and Motion* Context**	**Examples in *Energy, Matter, and Force and Motion* Context**	**Alignment to the B.E.S.T. Mathematics Benchmarks**
Data Analysis and Pattern Recognition	Analyze data sets to identify trends, relationships, and variability.	Motion data, density data, repeated measurements, and phase-change patterns.	MA.6.DP.1.1 MA.6.DP.1.2 MA.7.DP.1.1 MA.7.DP.1.2 MA.7.DP.2.4 MA.8.DP.1.1 MA.8.DP.1.2 MA.8.DP.1.3
Spatial and Conceptual Reasoning	Use visual and spatial reasoning to interpret models and diagrams.	Particle diagrams, energy-flow diagrams, force vectors, and system representations.	MA.6.GR.2.4 MA.7.GR.2.1 MA.8.GR.2.1 MA.8.GR.2.2 MA.8.GR.2.3 MA.8.GR.1.1
Scale and Scientific Quantities	Work with very large and very small quantities using ratios, rates, and scientific notation when appropriate.	Ratios, rates, scientific notation, and large or small scientific quantities.	MA.6.AR.3.1 MA.6.AR.3.2 MA.7.AR.3.1 MA.8.NSO.1.4 MA.8.NSO.1.5 MA.8.NSO.1.6

Modeling Skills Supporting Mastery of 6-8 *Energy, Matter, and Force and Motion* Benchmarks

The modeling skills listed below support student understanding of physical science concepts through the use of diagrams, graphs, mathematical representations, physical models, and conceptual models of systems. Students use models to represent structures, processes, interactions, and relationships that may not be directly observable. These skills help students communicate ideas, test explanations, make predictions, and develop understanding of physical systems.

Modeling Skill	**Description**	***Energy, Matter, and Force and Motion* Specific Examples**
Using Models to Represent Systems	Use diagrams, graphs, and physical models to represent scientific ideas and systems.	Particle models, energy-flow diagrams, force-interaction representations, or system models.
Identifying System Components and Boundaries	Recognize components within a system and distinguish between inputs and outputs.	Open and closed systems, system boundaries, inputs, outputs, or energy transfers.
Conceptual Modeling	Use simplified models to explain structure, relationships, and processes.	Energy transformations, particle organization, atomic structure, or force interactions.
Graphical Modeling	Represent relationships between variables visually and interpret their meaning.	Distance-time graphs, position-time graphs, temperature-time graphs, trends, or relationships.
Using Models to Explain Relationships	Use models to explain cause-and-effect relationships within systems.	Energy-particle relationships, force-motion relationships, or system interactions.
Evaluating Models	Evaluate strengths, limitations, assumptions, and sources of uncertainty in models.	Strengths, limitations, assumptions, or uncertainties of scientific models.
Using Models to Make Predictions	Use models and patterns to predict outcomes when variables change.	Motion predictions, phase changes, force interactions, or system responses to changing variables.

Laboratory Practices Supporting Mastery of 6-8 *Energy, Matter, and Force and Motion* Benchmarks

The laboratory practices listed below identify the investigative skills students use while learning physical science concepts. Through observation, measurement, data collection, analysis, modeling, and evidence-based explanation, students develop scientific habits of mind and learn how scientific knowledge is generated through investigations of physical phenomena.

Laboratory Practices	**Description of What Students Must be Able to Do**	***Energy, Matter, and Force and Motion* Focused Examples**
Designing and Conducting Investigations	Plan and carry out controlled investigations to explore scientific concepts.	Investigations of forces, motion, energy transfer, density, or phase changes.
Collecting Accurate and Reliable Data	Use tools and procedures to obtain consistent and accurate measurements.	Measurements of time, distance, mass, volume, force, temperature, or other physical quantities.
Analyzing and Interpreting Data	Organize, graph, and interpret data to identify patterns and relationships.	Motion graphs, density data, phase-change data, or physical science investigations.
Engaging in Argument from Evidence	Use data to support explanations and evaluate conclusions.	Evidence-based explanations of physical and chemical phenomena.
Applying Scientific Reasoning	Apply cause-and-effect reasoning and scientific concepts to explain observations.	Energy transfer, particle interactions, force-motion relationships, or system behavior.
Evaluating Investigations and Results	Reflect on methods, identify sources of error, and suggest improvements.	Sources of error, reliability of results, or investigation improvements.
Using Tools and Technology	Use tools, devices, and simulations to collect and analyze data.	Digital tools, sensors, simulations, or technology-supported data collection.
Developing and Using Models	Use models to explain observations and predict outcomes.	Particle, energy, force, or system models.
Practicing Lab Safety	Follow safe procedures when conducting investigations with materials and equipment.	Safe use of materials, equipment, tools, or laboratory procedures.

Timeline of Key Accomplishments Supporting Mastery of 6-8 *Energy, Matter, and Force and Motion* Benchmarks

This timeline provides historical and conceptual context for the Grades 6-8 standards by highlighting key scientific ideas that support foundational understanding for energy, matter, and force and motion. It is not intended for memorization of names or dates, but rather to illustrate how scientific understanding develops over time through evidence, models, and refinement of ideas. Students at this level should recognize that scientific knowledge is built from observations, improved with new evidence, and represented through models, forming the basis for the more advanced concepts they will encounter in Grades 9-12.

Historical developments often reflect changes in scientific models and explanations as new evidence becomes available. Students should recognize that scientific understanding grows through the continual testing, revision, and refinement of models over time.

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
~400 BC	Early idea that matter is made of tiny particles	Introduces the idea that all matter is composed of small units, supporting atomic models.	Democritus
1500s-1600s	Observations of moving objects and forces	Establishes that motion can be described and studied using evidence.	Galileo Galilei
1600s	Early descriptions of gravity and motion	Introduces the idea that forces cause motion and act between objects.	Isaac Newton
1660s	Definition of elements as basic substances	Supports classification of matter as elements, compounds, and mixtures.	Robert Boyle
Late 1600s	Laws of motion and forces	Foundational for understanding motion and forces.	Isaac Newton
1700s-1800s	Heat is recognized as energy transfer	Supports understanding of conduction, convection, and radiation.	Benjamin Thompson (Count Rumford)
1700s-1800s	Light and sound identified as waves	Supports wave energy transfer concepts.	Thomas Young
Late 1700s-Early1800s	Law of Conservation of Mass established	Reinforces that matter is not created or destroyed.	Antoine Lavoisier
Early 1800s	Atomic theory describing atoms as building blocks of matter	Foundational for understanding atoms, molecules, and compounds.	John Dalton
1800s	Organization of elements based on patterns of properties	Supports understanding of classification and relationships of elements organized within the periodic table.	Dmitri Mendeleev
1800s	Relationship between energy and motion identified	Supports understanding of kinetic and potential energy concepts.	Émilie du Châtelet

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
1800s	Discovery of electromagnetic spectrum beyond visible light	Supports an understanding of visible light as part of a larger system.	William Herschel, James Clerk Maxwell, and Heinrich Hertz
Mid-1800s	Established the conservation of energy	Reinforces transformation and conservation of energy.	James Prescott Joule and Hermann von Helmholtz
1800s-1900s	Graphical representation of motion relationships developed	Supports interpreting motion graphs.	Various scientists and engineers
1800s-1900s	Wave properties (wavelength and frequency) described	Supports relationships between wave properties and energy.	Heinrich Hertz
1900s-present	Development of scientific instruments and measurements	Supports accurate data collection and investigations.	Various scientists and engineers
1900s-present	Use of models and simulations to explain systems	Reinforces role and limitations of models.	Albert Einstein, Niels Bohr, and many modern scientists and engineers
2000-present	Increased use of digital tools and data analysis	Supports graphing, simulation, and system modeling in classrooms.	Various research and education teams

Mathematics, Modeling, Laboratory Practices, and Timeline

Mathematics Skills Supporting Mastery of 6-8 *Planet Earth and Space* Benchmarks

The mathematics skills listed below are not intended to be taught separately from science instruction. Rather, they identify mathematical concepts and practices that support student understanding of Planet Earth and Space concepts at the point of learning. Students apply these skills while investigating phenomena, collecting and analyzing data, identifying patterns, constructing explanations, and communicating scientific ideas. Mastery of these mathematics skills supports deeper understanding of the science benchmarks but does not replace mastery of benchmark content.

Mathematics Skill	**Description in *Planet Earth and Space* Context**	**Examples in *Planet Earth and Space* Context**	**Alignment to the B.E.S.T. Mathematics Benchmarks**
Spatial Reasoning and Scale	Understand relative size, distance, and scale in Earth and space systems.	Comparing the thickness of Earth's layers, Solar System distances, relative sizes of planets, stars, galaxies, and large-scale structures in the Universe.	MA.6.GR.1.1 MA.6.GR.1.2 MA.7.AR.3.3 MA.7.GR.1.5 MA.8.GR.2.2
Proportional Relationships	Identify relationships between variables.	Relationships among depth, pressure, and temperature in Earth; mass, distance, and gravity in the Solar System; and orbital distance and orbital period relationships.	MA.6.AR.3.2 MA.6.AR.3.5 MA.7.AR.4.1 MA.7.AR.4.2 MA.7.AR.4.3 MA.7.AR.4.5 MA.8.AR.3.1 MA.8.AR.3.2 MA.8.AR.3.5
Graphical Representation and Interpretation	Represent and interpret graphs showing Earth processes and system changes.	Temperature-depth graphs, climate data, tide charts, planetary motion data, H-R diagrams, and graphical representations of relationships among stellar properties.	MA.6.DP.1.4 MA.6.DP.1.5 MA.7.AR.4.1 MA.7.AR.4.3 MA.7.DP.1.5 MA.8.AR.3.4 MA.8.F.1.3 MA.8.DP.1.1 MA.8.DP.1.2
Data Analysis and Pattern Recognition	Identify patterns in environmental and astronomical data.	Weather and climate data, rainfall patterns, temperature trends, eclipse patterns, planetary motion, lunar phases, tide patterns, and stellar data.	MA.6.DP.1.2 MA.6.DP.1.4 MA.6.DP.1.6 MA.7.DP.1.1 MA.7.DP.1.2 MA.7.DP.1.5 MA.8.DP.1.1 MA.8.DP.1.2 MA.8.DP.1.3

Mathematics Skill	Description in *Planet Earth and Space* Context	Examples in *Planet Earth and Space* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Measurements and Units	Use appropriate measurements, tools and standard units for Earth and space investigations.	Measurements of temperature, distance, mass, volume, time, atmospheric conditions, light years, astronomical units, and orbital periods.	MA.6.AR.3.2 MA.6.AR.3.5 MA.7.AR.3.3 MA.8.NSO.1.4 MA.8.NSO.1.5 MA.8.NSO.1.6
Geometric Reasoning	Use geometric relationships to understand shapes, movement, and spatial relationships.	Planetary orbits, Earth-Sun-Moon geometry, moon phases, tilt and rotation of planets, and eclipse alignment.	MA.6.GR.1.1 MA.6.GR.1.2 MA.7.GR.1.3 MA.7.GR.1.4 MA.7.GR.1.5 MA.8.GR.1.1 MA.8.GR.1.2 MA.8.GR.1.4 MA.8.GR.1.5 MA.8.GR.1.6 MA.8.GR.2.2
Patterns and Periodicity	Identify, represent, and analyze recurring patterns and cycles in Earth and space systems.	Lunar phases, eclipses, tides, planetary motion, seasons, rotation and revolution, and recurring weather or climate patterns.	MA.6.DP.1.4 MA.7.AR.4.1 MA.7.AR.4.3 MA.8.F.1.3

Modeling Skills Supporting Mastery of 6-8 *Planet Earth and Space* Benchmarks

The modeling skills listed below support student understanding of Earth and space science concepts through the use of diagrams, scale models, graphical representations, conceptual models, and system models. Students use models to represent structures, processes, interactions, and relationships that may not be directly observable. These skills help students communicate ideas, test explanations, make predictions, and develop understanding of Earth and space systems.

Modeling Skill	**Description**	***Planet Earth and Space* Specific Examples**
System Modeling	Represent interactions between Earth systems.	Atmosphere-hydrosphere interaction, Sun-Earth-Moon system interactions, Earth-system interactions, or gravitational systems.
Scale Modeling	Represent large-scale systems using simplified models.	Solar system scale models, Earth-layer models, galaxy models, or large-scale Universe representations.
Conceptual Modeling	Represent processes such as plate movement or energy transfer.	Convection models, plate tectonic models, matter-cycle models, seasons, or lunar phases.
Graphical Modeling	Interpret and create graphs showing system changes.	Climate graphs, seafloor-spreading patterns, orbital relationships, H-R diagrams, light spectra, or stellar life-cycle models.
Using Models to Explain Processes	Use models to explain cause-and-effect relationships.	Explaining tides, eclipses, seasons, planetary motion, matter cycling, or plate interactions using scientific models.
Evaluating Models	Identify strengths and limitations of models.	Evaluating strengths, limitations, assumptions, or scale constraints of Earth and space science models.
Predicting Using Models	Use models to predict changes in systems.	Predicting weather patterns, planetary motion, eclipse occurrence, tidal patterns, or seasonal changes.

Laboratory Practices Supporting Mastery of 6-8 *Planet Earth and Space* Benchmarks

The laboratory practices listed below identify the investigative skills students use while learning Earth and space science concepts. Through observation, measurement, data collection, analysis, modeling, and evidence-based explanation, students develop scientific habits of mind and learn how scientific knowledge is generated through investigations of Earth and space phenomena.

Laboratory Practices	Description of What Students Must be Able to Do	*Planet Earth and Space* Focused Examples
Designing Investigations	Plan investigations of Earth or space systems.	Investigations of weathering, erosion, heat transfer, Earth systems, lunar phases, or Solar System phenomena.
Collecting Data	Use tools to gather observations and measurements.	Weather observations, lunar phases, star positions, shadows, Earth-system measurements, or planetary data.
Analyzing Data	Interpret patterns and relationships.	Climate data, seismic evidence, planetary motion, stellar data, lunar cycles, eclipse timing, or tidal patterns.
Using Evidence	Support explanations with data.	Evidence-based explanations of Earth history, soil formation, plate tectonics, lunar phases, tides, seasons, or planetary motion.
Model-Based Inquiry	Use models to simulate systems.	Plate tectonic models, Earth-system simulations, Solar System models, orbital simulations, or stellar life-cycle models.
Evaluating Results	Identify errors and refine investigations.	Improving accuracy of data collection.
Using Technology	Use digital tools and simulations.	Satellite imagery, digital mapping tools, remote sensing data, simulations, or astronomical observations.
Practicing Lab Safety	Follow safe procedures during investigations.	Safe handling of materials in erosion or heat investigations.

Timeline of Key Accomplishments Supporting Mastery of 6-8 *Planet Earth and Space* Benchmarks

This timeline provides historical and conceptual context for the Grades 6-8 standards by highlighting key scientific ideas that support foundational understanding for planet Earth and space. It is not intended for memorization of names or dates, but rather to illustrate how scientific understanding develops over time through evidence, models, and refinement of ideas. Students at this level should recognize that scientific knowledge is built from observations, improved with new evidence, and represented through models, forming the basis for the more advanced concepts they will encounter in Grades 9-12.

Historical developments often reflect changes in scientific models and explanations as new evidence becomes available. Students should recognize that scientific understanding grows through the continual testing, revision, and refinement of models over time.

Time Period	**Accomplishment or Discovery**	**Why it matters for *Planet Earth and Space***	**Important People Involved**
Ancient Times	Earth and sky observations	Foundation of astronomy and Earth system understanding.	Many cultures worldwide, including the Egyptians and Ancient Jews
Ancient Times	Motion of the Sun, Moon, and stars recorded	Supports understanding of recurring patterns used in astronomy.	Many cultures worldwide, including the Egyptians and Ancient Jews
1088	First documented use of magnetic needles for navigation	Advanced scientific understanding of Earth's magnetic field to improve the accuracy of navigation.	Shen Kuo
Ancient Times-1600s	Magnetic compasses developed and used for navigation	Demonstrates that Earth's magnetic properties can be observed and used to determine direction, providing an early practical application of Earth's magnetic field.	Ancient inventors and navigators
1500s-1600s	Heliocentric model of the Solar System	Shifted understanding of planetary motion.	Nicolaus Copernicus and Galileo Galilei
1600s	Telescopic observations of planets and moons	Supports observational evidence in astronomy.	Galileo Galilei
1600s	Laws of Planetary Motion	Established motion of planets within solar systems.	Johannes Kepler
1700s-1800s	Study of rock layers and fossils	Basis for Earth history and layering.	James Hutton and Charles Lyell
1800s	Discovery of the role of greenhouse gases in Earth's atmosphere	Foundation for climate understanding.	John Tyndall

Time Period	Accomplishment or Discovery	Why it matters for *Planet Earth and Space*	Important People Involved
Early 1900s	Discovery of Earth's internal structure	Foundation for plate tectonics and geosphere.	Inge Lehmann
1900s	Climate pattern analysis	Links energy transfer to weather and climate.	Various scientists
1900s	Development of the Hertzsprung-Russell (H-R) diagram	Supports classification and life cycles of stars.	Ejnar Hertzsprung and Henry Norris Russell
1910s-1970s	Development of Plate Tectonic Theory	Unified explanations for continental movement, earthquakes, volcanoes, mountain building, and seafloor spreading.	Alfred Wegener, Harry Hess, J. Tuzo Wilson, and other contributing scientists
1920s	Expanding universe discovery	Understanding galaxies beyond the Milky Way.	Edwin Hubble
1950s-present	Satellite technology	Enables Earth and space observations.	NASA and NOAA
1950s-1960s	Space exploration begins	Expands understanding of the Solar System.	NASA and USSR scientists
1969	Apollo 11 Launch from Kennedy Space Center	Demonstrated the capability for human exploration beyond Earth and provided scientific information about the Moon and planetary systems. Apollo 11 launched from Kennedy Space Center in Florida.	Neil Armstrong Buzz Aldrin Michael Collins NASA
1990s	Discovery of exoplanets	Expands knowledge of planetary systems beyond our own.	Michel Mayor and Didier Queloz
2000s-present	Advanced telescopes and satellites	Enables study of distant space and Earth systems.	Global research teams

Mathematics, Modeling, Laboratory Practices, and Timeline

Mathematics Skills Supporting Mastery of 6-8 *Planet Earth and Space* Benchmarks

The mathematics skills listed below are not intended to be taught separately from science instruction. Rather, they identify mathematical concepts and practices that support student understanding of Planet Earth and Space concepts at the point of learning. Students apply these skills while investigating phenomena, collecting and analyzing data, identifying patterns, constructing explanations, and communicating scientific ideas. Mastery of these mathematics skills supports deeper understanding of the science benchmarks but does not replace mastery of benchmark content.

Mathematics Skill	Description in *Planet Earth and Space* Context	Examples in *Planet Earth and Space* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Spatial Reasoning and Scale	Understand relative size, distance, and scale in Earth and space systems.	Comparing the thickness of Earth's layers, Solar System distances, relative sizes of planets, stars, galaxies, and large-scale structures in the Universe.	MA.6.GR.1.1 MA.6.GR.1.2 MA.7.AR.3.3 MA.7.GR.1.5 MA.8.GR.2.2
Proportional Relationships	Identify relationships between variables.	Relationships among depth, pressure, and temperature in Earth; mass, distance, and gravity in the Solar System; and orbital distance and orbital period relationships.	MA.6.AR.3.2 MA.6.AR.3.5 MA.7.AR.4.1 MA.7.AR.4.2 MA.7.AR.4.3 MA.7.AR.4.5 MA.8.AR.3.1 MA.8.AR.3.2 MA.8.AR.3.5
Graphical Representation and Interpretation	Represent and interpret graphs showing Earth processes and system changes.	Temperature-depth graphs, climate data, tide charts, planetary motion data, H-R diagrams, and graphical representations of relationships among stellar properties.	MA.6.DP.1.4 MA.6.DP.1.5 MA.7.AR.4.1 MA.7.AR.4.3 MA.7.DP.1.5 MA.8.AR.3.4 MA.8.F.1.3 MA.8.DP.1.1 MA.8.DP.1.2

Mathematics Skill	Description in *Planet Earth and Space* Context	Examples in *Planet Earth and Space* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Data Analysis and Pattern Recognition	Identify patterns in environmental and astronomical data.	Weather and climate data, rainfall patterns, temperature trends, eclipse patterns, planetary motion, lunar phases, tide patterns, and stellar data.	MA.6.DP.1.2 MA.6.DP.1.4 MA.6.DP.1.6 MA.7.DP.1.1 MA.7.DP.1.2 MA.7.DP.1.5 MA.8.DP.1.1 MA.8.DP.1.2 MA.8.DP.1.3
Measurements and Units	Use appropriate measurements, tools and standard units for Earth and space investigations.	Measurements of temperature, distance, mass, volume, time, atmospheric conditions, light years, astronomical units, and orbital periods.	MA.6.AR.3.2 MA.6.AR.3.5 MA.7.AR.3.3 MA.8.NSO.1.4 MA.8.NSO.1.5 MA.8.NSO.1.6
Geometric Reasoning	Use geometric relationships to understand shapes, movement, and spatial relationships.	Planetary orbits, Earth-Sun-Moon geometry, moon phases, tilt and rotation of planets, and eclipse alignment.	MA.6.GR.1.1 MA.6.GR.1.2 MA.7.GR.1.3 MA.7.GR.1.4 MA.7.GR.1.5 MA.8.GR.1.1 MA.8.GR.1.2 MA.8.GR.1.4 MA.8.GR.1.5 MA.8.GR.1.6 MA.8.GR.2.2
Patterns and Periodicity	Identify, represent, and analyze recurring patterns and cycles in Earth and space systems.	Lunar phases, eclipses, tides, planetary motion, seasons, rotation and revolution, and recurring weather or climate patterns.	MA.6.DP.1.4 MA.7.AR.4.1 MA.7.AR.4.3 MA.8.F.1.3

Modeling Skills Supporting Mastery of 6-8 *Planet Earth and Space* Benchmarks

The modeling skills listed below support student understanding of Earth and space science concepts through the use of diagrams, scale models, graphical representations, conceptual models, and system models. Students use models to represent structures, processes, interactions, and relationships that may not be directly observable. These skills help students communicate ideas, test explanations, make predictions, and develop understanding of Earth and space systems.

Modeling Skill	Description	*Planet Earth and Space* Specific Examples
System Modeling	Represent interactions between Earth systems.	Atmosphere-hydrosphere interaction, Sun-Earth-Moon system interactions, Earth-system interactions, or gravitational systems.
Scale Modeling	Represent large-scale systems using simplified models.	Solar system scale models, Earth-layer models, galaxy models, or large-scale Universe representations.
Conceptual Modeling	Represent processes such as plate movement or energy transfer.	Convection models, plate tectonic models, matter-cycle models, seasons, or lunar phases.
Graphical Modeling	Interpret and create graphs showing system changes.	Climate graphs, seafloor-spreading patterns, orbital relationships, H-R diagrams, light spectra, or stellar life-cycle models.
Using Models to Explain Processes	Use models to explain cause-and-effect relationships.	Explaining tides, eclipses, seasons, planetary motion, matter cycling, or plate interactions using scientific models.
Evaluating Models	Identify strengths and limitations of models.	Evaluating strengths, limitations, assumptions, or scale constraints of Earth and space science models.
Predicting Using Models	Use models to predict changes in systems.	Predicting weather patterns, planetary motion, eclipse occurrence, tidal patterns, or seasonal changes.

Laboratory Practices Supporting Mastery of 6-8 *Planet Earth and Space* Benchmarks

The laboratory practices listed below identify the investigative skills students use while learning Earth and space science concepts. Through observation, measurement, data collection, analysis, modeling, and evidence-based explanation, students develop scientific habits of mind and learn how scientific knowledge is generated through investigations of Earth and space phenomena.

Laboratory Practices	**Description of What Students Must be Able to Do**	***Planet Earth and Space* Focused Examples**
Designing Investigations	Plan investigations of Earth or space systems.	Investigations of weathering, erosion, heat transfer, Earth systems, lunar phases, or Solar System phenomena.
Collecting Data	Use tools to gather observations and measurements.	Weather observations, lunar phases, star positions, shadows, Earth-system measurements, or planetary data.
Analyzing Data	Interpret patterns and relationships.	Climate data, seismic evidence, planetary motion, stellar data, lunar cycles, eclipse timing, or tidal patterns.
Using Evidence	Support explanations with data.	Evidence-based explanations of Earth history, soil formation, plate tectonics, lunar phases, tides, seasons, or planetary motion.
Model-Based Inquiry	Use models to simulate systems.	Plate tectonic models, Earth-system simulations, Solar System models, orbital simulations, or stellar life-cycle models.
Evaluating Results	Identify errors and refine investigations.	Improving accuracy of data collection.
Using Technology	Use digital tools and simulations.	Satellite imagery, digital mapping tools, remote sensing data, simulations, or astronomical observations.
Practicing Lab Safety	Follow safe procedures during investigations.	Safe handling of materials in erosion or heat investigations.

Timeline of Key Accomplishments Supporting Mastery of 6-8 *Planet Earth and Space* Benchmarks

This timeline provides historical and conceptual context for the Grades 6-8 standards by highlighting key scientific ideas that support foundational understanding for planet Earth and space. It is not intended for memorization of names or dates, but rather to illustrate how scientific understanding develops over time through evidence, models, and refinement of ideas. Students at this level should recognize that scientific knowledge is built from observations, improved with new evidence, and represented through models, forming the basis for the more advanced concepts they will encounter in Grades 9-12.

Historical developments often reflect changes in scientific models and explanations as new evidence becomes available. Students should recognize that scientific understanding grows through the continual testing, revision, and refinement of models over time.

Time Period	Accomplishment or Discovery	Why it matters for *Planet Earth and Space*	Important People Involved
Ancient Times	Earth and sky observations	Foundation of astronomy and Earth system understanding.	Many cultures worldwide, including the Egyptians and Ancient Jews
Ancient Times	Motion of the Sun, Moon, and stars recorded	Supports understanding of recurring patterns used in astronomy.	Many cultures worldwide, including the Egyptians and Ancient Jews
1088	First documented use of magnetic needles for navigation	Advanced scientific understanding of Earth's magnetic field to improve the accuracy of navigation.	Shen Kuo
Ancient Times-1600s	Magnetic compasses developed and used for navigation	Demonstrates that Earth's magnetic properties can be observed and used to determine direction, providing an early practical application of Earth's magnetic field.	Ancient inventors and navigators
1500s-1600s	Heliocentric model of the Solar System	Shifted understanding of planetary motion.	Nicolaus Copernicus and Galileo Galilei
1600s	Telescopic observations of planets and moons	Supports observational evidence in astronomy.	Galileo Galilei
1600s	Laws of Planetary Motion	Established motion of planets within solar systems.	Johannes Kepler
1700s-1800s	Study of rock layers and fossils	Basis for Earth history and layering.	James Hutton and Charles Lyell
1800s	Discovery of the role of greenhouse gases in Earth's atmosphere	Foundation for climate understanding.	John Tyndall

Time Period	Accomplishment or Discovery	Why it matters for *Planet Earth and Space*	Important People Involved
Early 1900s	Discovery of Earth's internal structure	Foundation for plate tectonics and geosphere.	Inge Lehmann
1900s	Climate pattern analysis	Links energy transfer to weather and climate.	Various scientists
1900s	Development of the Hertzsprung-Russell (H-R) diagram	Supports classification and life cycles of stars.	Ejnar Hertzsprung and Henry Norris Russell
1910s-1970s	Development of Plate Tectonic Theory	Unified explanations for continental movement, earthquakes, volcanoes, mountain building, and seafloor spreading.	Alfred Wegener, Harry Hess, J. Tuzo Wilson, and other contributing scientists
1920s	Expanding universe discovery	Understanding galaxies beyond the Milky Way.	Edwin Hubble
1950s-present	Satellite technology	Enables Earth and space observations.	NASA and NOAA
1950s-1960s	Space exploration begins	Expands understanding of the Solar System.	NASA and USSR scientists
1969	Apollo 11 Launch from Kennedy Space Center	Demonstrated the capability for human exploration beyond Earth and provided scientific information about the Moon and planetary systems. Apollo 11 launched from Kennedy Space Center in Florida.	Neil Armstrong Buzz Aldrin Michael Collins NASA
1990s	Discovery of exoplanets	Expands knowledge of planetary systems beyond our own.	Michel Mayor and Didier Queloz
2000s-present	Advanced telescopes and satellites	Enables study of distant space and Earth systems.	Global research teams

Mathematics, Modeling, Laboratory Practices, and Timeline

Mathematics Skills Supporting Mastery of 6-8 *Life* Benchmarks

The mathematics skills listed below are not intended to be taught separately from science instruction. Rather, they identify mathematical concepts and practices that support student understanding of life science concepts at the point of learning. Students apply these skills while investigating phenomena, collecting and analyzing data, identifying patterns, constructing explanations, and communicating scientific ideas. Mastery of these mathematics skills supports deeper understanding of the science benchmarks but does not replace mastery of benchmark content.

Mathematics Skill	Description in *Life* Context	Examples in *Life* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Pattern Recognition	Identify patterns in biological systems and processes.	Population growth trends, inheritance patterns, or food web dynamics.	MA.6.AR.3.3 MA.6.DP.1.2 MA.7.AR.4.1 MA.8.DP.1.2 MA.8.F.1.3
Cause-and-Effect Relationships	Analyze relationships among variables.	Environmental change yields population change.	MA.6.AR.1.1 MA.6.AR.1.3 MA.6.AR.1.4 MA.6.AR.2.2 MA.6.AR.2.3 MA.7.AR.2.2 MA.7.AR.4.1 MA.7.AR.4.2 MA.8.AR.2.1 MA.8.AR.2.3 MA.8.DP.1.2 MA.8.F.1.3
Proportional Reasoning	Understand relationships between quantities.	Nutrient intake versus energy output or predator-prey relationships.	MA.6.AR.3.2 MA.6.AR.3.5 MA.7.AR.4.2 MA.7.AR.4.3 MA.7.AR.4.4 MA.7.AR.4.5 MA.8.AR.3.1 MA.8.AR.3.2 MA.8.AR.3.5

Mathematics Skill	Description in *Life* Context	Examples in *Life* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Graphical Representation and Interpretation	Interpret graphs and data sets.	Population graphs or enzyme activity versus temperature.	MA.6.GR.1.1 MA.6.GR.1.2 MA.6.GR.1.3 MA.6.DP.1.4 MA.6.DP.1.5 MA.7.AR.4.3 MA.7.DP.1.5 MA.8.DP.1.1 MA.8.DP.1.2 MA.8.F.1.3
Scale and Organization	Understand the hierarchical organization of life.	Cell builds tissue which builds organs that are organized into systems.	MA.6.GR.1.1 MA.6.GR.1.2 MA.6.GR.1.3 MA.7.AR.3.3 MA.7.GR.1.5 MA.8.GR.2.2 MA.8.NSO.1.4 MA.8.NSO.1.5 MA.8.NSO.1.6
Data Analysis	Identify trends and draw conclusions from biological data.	Ecosystem data or growth rates.	MA.6.DP.1.1 MA.6.DP.1.2 MA.7.DP.1.1 MA.7.DP.1.2 MA.8.DP.1.1 MA.8.DP.1.2 MA.8.DP.1.3
Comparative Reasoning	Compare systems, organisms, and processes.	Plant versus animal cells or energy flow in ecosystems.	MA.6.AR.3.5 MA.6.DP.1.2 MA.7.DP.1.2 MA.7.DP.1.3 MA.7.DP.1.4 MA.7.DP.1.5 MA.8.NSO.1.4 MA.8.DP.2.3
Trend Analysis	Analyze changes over time using biological data.	Population change, disease incidence, or environmental change.	MA.6.DP.1.1 MA.6.DP.1.6 MA.7.DP.1.4 MA.7.DP.1.5 MA.8.AR.3.2 MA.8.AR.3.4 MA.8.AR.3.5 MA.8.F.1.2 MA.8.F.1.3 MA.8.DP.1.2

Mathematics Skill	Description in *Life* Context	Examples in *Life* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Quantitative Comparison	Compare biological quantities, rates, and measurements.	Food-label comparisons, disease-prevalence data, or population measurements.	MA.6.AR.3.5 MA.6.AR.3.2 MA.7.DP.1.3 MA.7.AR.3.2 MA.7.AR.3.3 MA.7.AR.4.1 MA.7.DP.1.5 MA.8.NSO.1.4 MA.8.F.1.2 MA.8.DP.1.1 MA.8.DP.1.2

Modeling Skills Supporting Mastery of 6-8 *Life* Benchmarks

The modeling skills listed below support student understanding of life science concepts through the use of diagrams, conceptual models, graphical representations, and systems models. Students use models to represent structures, processes, interactions, and relationships that may not be directly observable. These skills help students communicate ideas, test explanations, make predictions, and develop understanding of living systems.

Modeling Skill	Description	*Life* Specific Examples
Structural Modeling	Represent biological structures and organization.	Cell diagrams, body systems, or plant structures.
Process Modeling	Represent biological processes over time.	Photosynthesis cycle or cellular respiration.
System Modeling	Represent interactions within systems.	Ecosystem models or nutrient cycles.
Energy and Matter Flow Modeling	Trace movement of energy and matter.	Food webs or carbon cycle.
Genetic Modeling	Represent inheritance patterns.	Punnett squares or trait diagrams.
Behavioral Modeling	Represent organism response.	Stimulus-response models.
Model Evaluation	Identify strengths and limitations.	Comparing diagrams versus real biological systems.
Predictive Modeling	Use models to predict changes.	Population changes due to environment.
Defining Systems and Boundaries	Identify components and interactions within biological systems and distinguish system boundaries.	Defining an ecosystem, identifying inputs and outputs in a body system, or distinguishing organism and environment.
Using Models to Explain Relationships	Use models to explain biological cause-and-effect relationships.	Explaining food web interactions, nutrient cycling, or body-system interactions.
Interaction Modeling	Represent interactions among organisms, systems, and environments.	Food webs, symbiosis models, body-system interactions, or ecosystem relationships.

Laboratory Practices Supporting Mastery of 6-8 *Life* Benchmarks

The laboratory practices listed below identify the investigative skills students use while learning life science concepts. Through observation, measurement, data collection, analysis, modeling, and evidence-based explanation, students develop scientific habits of mind and learn how scientific knowledge is generated through investigations of living systems and biological phenomena.

Laboratory Practices	**Description of What Students Must be Able to Do**	***Life* Focused Examples**
Designing Investigations	Plan biological investigations.	Testing plant growth conditions.
Collecting Data	Gather observations and measures.	Recording heart rate or plant growth.
Analyzing Data	Identify patterns and relationships.	Population data trends or enzyme activity.
Using Evidence	Support explanations with data.	Explaining ecosystem changes.
Comparative Investigations	Compare conditions or organisms.	Light versus no-light plant growth.
Model-Based Investigation	Use models to simulate systems.	Ecosystem simulations.
Evaluating Results	Identify errors and refine investigation.	Improving experimental design.
Using Technology	Use tools to collect and analyze data.	Microscopes or digital probes.
Argument from Evidence	Construct claims based on data.	Explaining adaptation or survival outcomes.
Constructing Explanations	Develop evidence-based explanations connecting observations, data, and biological concepts.	Explaining ecosystem changes, organism responses, or body-system interactions using collected evidence.

Timeline of Key Accomplishments Supporting Mastery of 6-8 *Life* Benchmarks

This timeline provides historical and conceptual context for the Grades 6-8 standards by highlighting key scientific ideas that support foundational understanding for life science. It is not intended for memorization of names or dates, but rather to illustrate how scientific understanding develops over time through evidence, models, and refinement of ideas. Students at this level should recognize that scientific knowledge is built from observations, improved with new evidence, and represented through models, forming the basis for the more advanced concepts they will encounter in Grades 9-12.

Historical developments often reflect changes in scientific models and explanations as new evidence becomes available. Students should recognize that scientific understanding grows through the continual testing, revision, and refinement of models over time.

Time Period	**Accomplishment or Discovery**	**Why it matters for *Life***	**Important People Involved**
1600s	Discovery and Observation of Cells	Foundation of cell theory.	Robert Hooke and Anton van Leeuwenhoek
1800s	Cell Theory established	All living things are made of cells.	Matthais Jakob Shleiden, Theodor Schwann, and Rudolf Ludwig Carl Virchow
1800s	Early understanding of photosynthesis and respiration	Explains how organisms obtain and use energy, supporting energy flow in ecosystems.	Jan Ingenhousz and Julius von Sachs
1800s	Foundations of Ecology and Ecosystem Interactions	Provides a foundation for understanding interactions and energy flow in ecosystems.	Alexander von Humboldt
1800s	Explanation of how living things change over time	Explains how organisms change over time in response to environmental conditions.	Charles Darwin
1800s	Laws of inheritance	Predicting traits.	Gregor Mendel
1800s	Germ Theory and the role of microorganisms	Established that microorganisms affect living systems, health, and disease.	Louis Pasteur and Robert Koch
1900s	Deoxyribonucleic acid (DNA) identified as genetic material	Explained how hereditary information is stored and transmitted.	Rosalind Franklin, James Watson, and Francis Crick
1900s	Ecosystem theory	Interactions among organisms	Various ecologists
1900s	Homeostasis and body system regulation	Explains how organisms maintain internal balance and coordinate system functions.	Walter Cannon
1900s	Discovery of vitamins and essential nutrients	Improved understanding of nutrition and body-system function.	Various scientists

Time Period	Accomplishment or Discovery	Why it matters for *Life*	Important People Involved
1900s–early 2000s	Explanation of how traits in populations change over time based on genetic variation	Explains how changes in inherited traits influence populations over time.	Theodosius Dobzhansky and Ernst Mayr
Late 1900s	Understanding variation within populations	Explains how differences among individuals affect survival and population change over time.	Various scientists
1900s-present	Energy flow and nutrient cycling	Foundation of ecology	Odum and various scientists
Late 1900s-present	Biotechnology	Applications of genetics	Various scientists
Late 1900s-present	Advances in aquaculture and precision agriculture	Enables producers to monitor living organisms and environmental conditions to improve food production and resource management	Various scientists
2000s-present	Environmental science	Anthropogenic impact on ecosystems	Various scientists

Mathematics, Modeling, Laboratory Practices, and Timeline

Mathematics Skills Supporting Mastery of 9-12 *Energy, Matter, and Force and Motion* Benchmarks

The mathematics skills listed below are not intended to be taught separately from science instruction. Rather, they identify mathematical concepts and practices that support student understanding of energy, matter, and force and motion concepts at the point of learning. Students apply these skills while investigating phenomena, collecting and analyzing data, identifying patterns, constructing explanations, evaluating evidence, and communicating scientific ideas. Mastery of these mathematics skills supports deeper understanding of the science benchmarks but does not replace mastery of benchmark content.

Mathematics Skill	**Description in *Energy, Matter, and Force and Motion* Context**	**Examples in *Energy, Matter, and Force and Motion* Context**	**Alignment to the B.E.S.T. Mathematics Benchmarks**
Applications of Algebraic Reasoning	Rearrange equations and mathematical formulas, isolate variables, and substitute values correctly to solve an unknown.	From $P = \frac{W}{t}$, solve for work: $W = Pt$	MA.912.AR.1.1 MA.912.AR.1.2 MA.912.AR.9.1 MA.912.AR.9.2 MA.912.AR.9.3
Proportional Relationships	Identify when relationships are proportional, inversely proportional, quadratic, or exponential.	Doubling height doubles gravitational potential energy. Increasing distance decreases gravitational or electrostatic force according to inverse-square relationships.	MA.7.AR.4.1 MA.7.AR.4.2 MA.7.AR.4.3 MA.8.AR.3.1 MA.912.AR.8.3 MA.912.F.1.8 MA.912.AR.5.4 MA.912.F.1.1 MA.912.F.1.6
Represent Data Graphically and Interpret its Meaning	Create and interpret energy graphs; identify patterns like conservation or changes in rates.	Plotting kinetic energy vs. velocity and interpreting the curve.	MA.912.AR.2.5 MA.912.AR.4.3 MA.912.F.1.3 MA.912.F.1.6 MA.912.F.1.7 MA.912.F.1.8
Dimensional Analysis	Use dimensional analysis and conversion factors to verify units, convert measurements, analyze relationships among quantities, and solve multistep problems involving physical and chemical systems.	Converting 1500 W to 1.5kW; converting joules to kilojoules in energy calculations; converting pressure, temperature, and volume units in gas-law problems; verifying that calculated quantities have appropriate units.	MA.5.M.1.1 MA.6.AR.3.2 MA.912.NSO.1.1 MA.912.AR.2.1 MA.912.AR.2.2 MA.912.F.1.8

Mathematics Skill	Description in *Energy, Matter, and Force and Motion* Context	Examples in *Energy, Matter, and Force and Motion* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Mathematical Modeling and Rate Analysis	Use equations, graphs, geometry, and rates of change to analyze physical systems and predict outcomes.	Interpret the slope of position-time and velocity-time graphs. Use graphical relationships to calculate work, power, and energy changes.	MA.912.C.4.2 MA.912.GR.3.4 MA.912.T.1.2 MA.912.AR.2.5 MA.912.AR.3.8 MA.912.AR.1.1 MA.912.AR.1.2
Data Analysis	Analyze variation, identify patterns, and compute averages from repeated measurements.	Averaging multiple temperature-change measurements in a calorimetry experiment.	MA.5.DP.1.2 MA.6.DP.1.2 MA.6.DP.1.6 MA.8.DP.1.2 MA.912.DP.5.4
Error Analysis and Uncertainty	Evaluate measurement uncertainty, sources of error, and limitations of data.	Compare theoretical and measured efficiency values	MA.912.DP.1.4 MA.912.FL.1.1 MA.912.FL.2.3
Scientific Notation and Orders of Magnitude	Represent, compare, and calculate with very large and very small quantities.	Atomic radius; wavelengths of electromagnetic radiation; Avogadro's number; nuclear energy calculations.	MA.8.NSO.1.4 MA.8.NSO.1.5 MA.8.NSO.1.6 MA.912.NSO.1.1 MA.912.NSO.1.2 MA.912.NSO.1.3
Statistical Analysis and Trends	Analyze distributions, identify trends, evaluate relationships between variables, and draw conclusions from data sets.	Determine whether a relationship is linear, quadratic, or exponential. Evaluate trends in radioactive decay data. Analyze relationships among pressure, volume, and temperature. Identify correlations in energy efficiency investigations.	MA.912.F.1.8 MA.912.AR.5.3 MA.912.DP.1.2 MA.912.DP.2.4 MA.912.DP.2.8 MA.912.DP.2.9

Modeling Skills Supporting Mastery of 9-12 *Energy, Matter, and Force and Motion* Benchmarks

The modeling skills listed below support student understanding of physical science concepts through the use of diagrams, mathematical representations, computational simulations, conceptual models, and systems models. Students use models to represent structures, processes, interactions, and relationships that may not be directly observable. These skills help students communicate ideas, test explanations, make predictions, evaluate assumptions, and develop understanding of physical systems.

Modeling Skill	**Description**	***Energy, Matter, and Force and Motion* Specific Examples**
Defining Systems and Boundaries	Identify what is inside or outside a system and determine relevant energy inputs, outputs, and transfers.	Identify where energy enters or exits a system. Define a system as a roller coaster car only vs. a system as a car and the track it travels on.
Mathematical Modeling	Use equations and mathematical formulas to model relationships among variables, not just compute numeric answers.	Predict kinetic energy change when velocity doubles using $KE = \frac{1}{2}mv^2$.
Graphical Modeling	Construct and read graphs that show how energy changes over time, distance, or temperature. Use the slope or area of the graph to understand what is happening in the system, such as how fast energy is changing or how much work is done.	Interpret heating curve plateaus representing phase change.
Particle-Level Modeling	Use particle diagrams and models to represent atomic structure, molecular interactions, phase changes, bonding, and energy transfer.	Model gas particles during compression. Represent ionic and covalent bonding. Model phase changes, bonding, and energy transfer.
Qualitative or Conceptual Modeling	Use diagrams to explain energy storage, transfer, and changes	Particle diagrams to model thermal energy. Arrow diagrams showing energy flow strength.
Computational Modeling and Simulations	Use digital tools to model systems, vary parameters, and compare predictions to read data	Model pendulum energy using simulations. Spreadsheet modeling of household energy consumption.
Using Models to Make Predictions	Use models to predict energy changes based on variable manipulation and justify results.	Predict temperature change in calorimetry experiments. Predict how ramp height affects final speed.
Evaluating and Refining Models	Test models with data, revise assumptions, and identify limitations to increase accuracy.	Add friction to a “no-loss” roller coaster model. Modify heat-loss model when predictions don’t match measured temperatures.

Modeling Skill	Description	*Energy, Matter, and Force and Motion* **Specific Examples**
Evaluating Model Assumptions and Limitations	Identify assumptions, strengths, and limitations of models and determine when a model is useful or incomplete.	Compare the Bohr model and quantum mechanical model of the atom. Evaluate limitations of the ideal gas models. Explain why frictionless-motion models differ from real-world systems.
Systems Modeling	Analyze interacting systems using mathematical, conceptual, and computational models.	Model energy transfer among components of an ecosystem, electrical circuit, thermal system, mechanical system, or engineered energy-transfer system.

Laboratory Practices Supporting Mastery of 9-12 *Energy, Matter, and Force and Motion* Benchmarks

The laboratory practices listed below identify the investigative skills students use while learning physical science concepts. Through observation, measurement, data collection, analysis, modeling, and evidence-based explanation, students develop scientific habits of mind and learn how scientific knowledge is generated through investigations of physical phenomena and systems.

Laboratory Practices	Description of What Students Must be Able to Do	*Energy, Matter, and Force and Motion* Focused Examples
Designing and Conducting Investigations	Plan and carry out controlled experiments that explore energy transfer, transformation, and conservation.	Design an experiment to test how mass affects kinetic energy (KE). Set up a calorimetry investigation to measure heat transfer.
Collecting Accurate and Reliable Data	Use appropriate tools to take precise measurements and collect data relevant to energy concepts.	Use motion detectors or photogates to collect speed data. Use thermometers or probes to measure temperature changes.
Analyzing and Interpreting Data	Organize data, create graphs, and use slopes or areas to make meaning of physical relationships.	Analyze a force-distance graph to calculate work. Interpret temperature-time curves to identify heat transfer patterns.
Applying Quantitative Reasoning	Use measurements, equations, and calculations to analyze experimental results and explain scientific phenomena.	Calculate work, power, and efficiency. Determine density, molar mass, or reaction yield. Calculate percent composition or percent error. Use gas-law equations to analyze laboratory data.
Engaging in Argument from Evidence	Use data to support claims about energy changes and evaluate competing explanations.	Argue whether energy was conserved in a collision using collected data. Justify differences between theoretical and measured efficiencies.
Evaluating and Refining Experimental Designs	Identify errors, improve procedures, and revise investigations to increase accuracy and reliability.	Suggest ways to reduce heat loss in a calorimetry experiment. Modify a ramp investigation to reduce timing error.
Using Digital Tools and Technology	Use sensors, software, spreadsheets, or simulations to collect, analyze, and model energy data.	Graph energy over time using digital tools. Use simulations to compare predicted vs. observed energy transformations.
Quantifying Uncertainty	Evaluate precision, accuracy, error, and uncertainty when interpreting results.	Determine percent error and evaluate whether differences between theoretical and measured values are significant.
Practicing Lab Safety	Use proper safety procedures when working with electrical systems, heat sources, and moving objects.	Safe handling of hot plates during thermal experiments. Proper setup and use of electrical circuits.

Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks

This timeline provides historical and conceptual context for the Grades 9-12 Energy, Matter, and Force and Motion benchmarks by highlighting major scientific discoveries, theories, and technological advances that shaped modern understanding of matter, energy, motion, forces, thermodynamics, electricity, waves, and atomic structure. It is not intended for memorization of names or dates, but rather to illustrate how scientific understanding develops over time through evidence, models, and refinement of ideas. Students at this level should recognize that scientific knowledge is built from observations, improved with new evidence, and represented through models.

Historical developments often reflect changes in scientific models and explanations as new evidence becomes available. Students should recognize that scientific understanding grows through the continual testing, revision, and refinement of models over time.

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
400 BC	Early Idea of "Atoms" as Indivisible Particles	Proposed that matter is composed of tiny particles called atoms, providing an early conceptual model that influenced later scientific investigations into the structure and properties of matter.	Democritus
1500s-1600s	Early Studies of Motion and Rejection of Aristotelian Physics	Introduced evidence-based investigations of motion and challenged long-standing explanations based on philosophy rather than observation.	Galileo Galilei
1609-1619	Kepler's Laws of Planetary Motion	Described mathematical patterns governing planetary motion and provided evidence that the movement of objects can be explained through predictable relationships. Established the foundation for understanding gravity, orbital motion, and later developments in mechanics.	Johannes Kepler
1630s-1640s	Experiments on Falling Objects and Inertia	Demonstrated that objects accelerate at predictable rates under gravity and established foundational ideas about inertia and motion.	Galileo Galilei

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
1661	First Modern Definition of an Element	Established the concept that elements are fundamental substances with unique properties, laying the foundation for modern chemistry and advancing scientific understanding of the composition and behavior of matter.	Robert Boyle
1662	Boyle's Law (Pressure–Volume Relationships)	Established the quantitative relationship between pressure and volume in gases, providing a foundation for understanding gas behavior, particle interactions, thermodynamic systems, and energy transfer involving matter.	Robert Boyle
1678	Formulation of Hooke's Law	Established the relationship between force and elastic energy in springs, which was foundational for understanding potential energy in mechanical systems.	Robert Hooke
1687	Publication of *Principia Mathematica*	Established mathematical laws describing force and motion, providing the foundation for classical mechanics and modern understanding of work, energy, and motion.	Isaac Newton
Early 1700s	Newton's Law of Cooling	Described how thermal energy is transferred between objects and their surroundings, providing a foundation for understanding heat transfer and thermal equilibrium.	Isaac Newton
1729	Early Observations Relating Light Intensity and Transmission	Established foundational ideas about how light intensity changes as it passes through materials, contributing to later understanding of light absorption, electromagnetic radiation, and the Beer-Lambert Law.	Pierre Bouguer

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
1730s-1740s	Translation and explanation of Newton's *Principia* and established the modern concept of kinetic energy	Translated Isaac Newton's *Philosophiæ Naturalis Principia Mathematica* from Latin into French and added detailed explanations, mathematical clarifications, and commentary that made Newton's ideas understandable. Clarified the idea that the energy of a moving object depends on the square of its velocity, not just its speed.	Émilie du Châtelet
1738	Bernoulli's Fluid Energy Relation	Demonstrated the relationship among pressure, velocity, and energy in moving fluids, forming the foundation for fluid dynamics and energy transfer in flowing systems.	Daniel Bernoulli
1752	Development of the lightening rod	One of the first technologies designed to control and safely transfer electrical energy.	Benjamin Franklin
1760	Quantitative Absorption Relationships	Basis for Beer–Lambert absorption; informs radiative transfer through air and water	Johann Heinrich Lambert
1761	Specific and Latent Heat Identified	Demonstrated that substances absorb and release energy during temperature changes and phase changes, establishing foundational concepts in thermal energy transfer and thermodynamics.	Joseph Black
1770s-1790s	Heat from Friction Experiments	Established that heat is a form of energy transfer, not a material.	Benjamin Thompson (Count Rumford)
1780s-1800s	Charles's Law	Demonstrated the relationship between temperature and volume in gases, advancing scientific understanding of particle motion, gas behavior, and thermodynamic systems.	Jacques Charles
1785	Coulomb's Law	Demonstrated how electric charges exert forces at a distance, forming the foundation for understanding electrostatic force and vector interactions.	Charles-Augustin de Coulomb

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
1800	Discovery of Infrared Radiation	Demonstrated that electromagnetic radiation extends beyond visible light and introduced the study of infrared energy. Advanced scientific understanding of radiation, thermal energy transfer, and the interaction of energy and matter.	William Herschel
1802-1808	Gay-Lussac's Gas Laws	Established quantitative relationships among gas pressure, temperature, and composition, strengthening scientific understanding of gas behavior, chemical reactions, and particle interactions.	Joseph Louis Gay-Lussac
1803	Modern Atomic Theory	Proposed that matter is composed of atoms with characteristic masses that combine in predictable ratios, providing a foundation for conservation of matter, chemical formulas, and stoichiometric relationships.	John Dalton
1808-1811	Avogadro's Hypothesis	Proposed that equal volumes of gases at the same temperature and pressure contain the same number of particles which is crucial for understanding molar volume and development of the mole concept.	Amedeo Avogadro
1821-1834	Electromagnetic Induction, Electric Motors, and Electrolysis	Discovered electromagnetic induction and the Law of Electrolysis which made electricity useful and understandable. Laid the groundwork for modern physics, chemistry, and technology.	Michael Faraday
1822	Fourier's Law of Heat Conduction and Fourier analysis	Quantifies heat conduction and provides mathematical tools for analyzing periodic phenomena, waves, and thermal systems.	Joseph Fourier
1824	Carnot Limit	Established the theoretical upper limit for the efficiency of heat engines, providing a foundation for understanding energy transformations, thermodynamic systems, and energy efficiency.	Sadi Carnot

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
1827	Ohm's Law	Established the quantitative relationship among voltage, current, and resistance, providing a foundation for understanding electrical energy transfer and circuit behavior.	Georg Ohm
1834	Clapeyron Relation	Described the relationship among pressure, temperature, and phase changes, improving scientific understanding of gases, thermodynamic systems, and energy transfer involving matter.	Benoît Clapeyron
1840s-1850s	Momentum and impulse concepts refined	Clarified mathematical relationships in collisions.	Gaspard-Gustave de Coriolis, William John Macquorn Rankine
1840s-1850s	Conservation of Energy Established	Demonstrated that energy can be transferred and transformed but is neither created nor destroyed. Unified mechanical, thermal, and other forms of energy into a single conservation framework that underlies modern physics and chemistry.	James Prescott Joule Julius Robert Mayer Hermann von Helmholtz
1850-1854	Clausius/Kelvin—First & Second Laws; entropy	Formal energy conservation and directionality; frames efficiency and waste heat in Earth and devices	Rudolph Clausius, William Thomson (Lord Kelvin)
1852	Extension leading to modern Beer-Lambert Law	Demonstrated that the absorption of electromagnetic energy by matter follows a predictable mathematical relationship and laid the foundation for modern spectrometry.	August Beer
1852-1859	Beer–Lambert Law and Greenhouse Gas Absorption	Demonstrated how matter absorbs specific wavelengths of electromagnetic radiation, strengthening understanding of light-matter interactions, spectroscopy, and energy transfer processes.	August Beer, John Tyndall
1859	Kirchhoff's Law of thermal radiation	Established the relationship between emission and absorption of thermal radiation, advancing understanding of energy transfer through radiation and thermal equilibrium.	Gustav Kirchhoff

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
1860s	Electromagnetic Field Theory and Maxwell's equations	Unified electricity and magnetism into a single theory and demonstrated that light is an electromagnetic wave. Established the foundation for understanding electromagnetic energy, waves, radiation, electric circuits, and modern communication technologies.	James Clerk Maxwell
1860s	Formation of thermodynamics (1st and 2nd laws)	Explains energy transfer, heat flow, and efficiency.	Rudolph Clausius Lord Kelvin (William Thomson)
1860s	Development of the Periodic Table	Organized elements by properties which became the basis for periodic trends, valence, and reactivity of elements.	Dmitri Mendeleev
1870s-1880s	Foundation of statistical mechanics and chemical thermodynamics	Developed mathematical methods that explain energy distribution, free energy, and equilibrium in physical systems, which has proved essential for modern energy modeling.	Josiah Willard Gibbs
1871-1908	Rayleigh and Mie Scattering	Explained how electromagnetic radiation interacts with particles of different sizes, improving understanding of light behavior, waves, and energy transfer through matter.	John William Strutt (Lord Rayleigh), Gustav Mie
1873-1878	Gibbs Free Energy Formalized	Provided a quantitative method for predicting whether physical and chemical processes occur spontaneously, strengthening understanding of energy transfer, equilibrium, and system stability.	Josiah Willard Gibbs
1879	Development of practical electric lighting	Connects to electricity, circuits, power calculations, and energy efficiency.	Thomas Edison
1879-1884	Stefan–Boltzmann Law	Demonstrated the relationship between an object's temperature and the amount of thermal radiation it emits, strengthening scientific understanding of energy transfer through radiation.	Josef Stefan, Ludwig Boltzmann
1880s-1890s	Alternating current (AC) systems developed	Foundation for modern electrical systems and power transmission.	Nikola Tesla

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
1880s-1890s	Development of vector mathematics	Enabled multi-directional force analysis.	Gibbs, Heaviside
1884	Le Châtelier's Principle	Predicts how systems shift when conditions change, which is essential for understanding equilibrium, reaction shifts, and industrial processes.	Henri Le Châtelier
1893	Wien's Displacement Law	Demonstrated the relationship between temperature and the wavelength of emitted radiation, strengthening scientific understanding of thermal energy and electromagnetic radiation.	Wilhelm Wien
1895-1914	Radioactivity Research	Showed that atoms are not indivisible which opened the door to atomic and nuclear physics and began the study of atomic and nuclear physics. Led to the understanding of nuclear energy, nuclear medicine, and research on atomic structure.	Marie Curie
1896	Arrhenius CO_2-Warming Calculation	Demonstrated that changes in the composition of matter can influence the absorption and transfer of radiant energy, strengthening scientific understanding of energy balance within physical systems.	Svante Arrhenius
1897	Discovery of the Electron	Determined that atoms have internal structure and charged particles.	Joseph John Thomson
1898	Discovery of Radium and Polonium	Provided evidence that atoms undergo nuclear changes and release energy, contributing to the development of nuclear physics and understanding of atomic structure.	Marie Curie
1900	Planck's Quantum Hypothesis (Energy Quantization)	Proposed that energy is emitted and absorbed in discrete packets called quanta. This discovery transformed scientific understanding of energy transfer and laid the foundation for quantum physics and modern atomic theory.	Max Planck

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
1903	Rocket Equation	Established the mathematical relationship among mass, velocity change, and propulsion, providing a foundation for understanding momentum conservation and spaceflight mechanics.	Konstantin Tsiolkovsky
1905	Mass-energy equivalence ($E = mc^2$) Photoelectric Effect Special Relativity	Connects mass and energy in extreme systems. Basis for solar photovoltaics and sensors. Enhanced understanding of motion at high speeds.	Albert Einstein
1905-1916	Photoelectric Effect Theory and Measurement	Demonstrated that electromagnetic radiation transfers energy in discrete quantities, providing evidence for quantum theory and modern understanding of energy transfer.	Albert Einstein, Robert Millikan
1905-1930	Development of Quantum Theory	Expanded understanding of atomic structure, energy levels, light-matter interactions, and particle behavior. These discoveries form the basis of modern atomic models, spectroscopy, semiconductors, lasers, and many modern technologies.	Albert Einstein, Niels Bohr, Erwin Schrödinger, Werner Heisenberg, Louis de Broglie
1909-1911	Nuclear Model of the Atom	Demonstrated that atoms contain a small, dense, positively charged nucleus, transforming scientific understanding of atomic structure and laying the foundation for nuclear physics.	Ernest Rutherford
1910	Elastic Rebound Theory	Explained how elastic potential energy can be stored and rapidly released within materials, providing evidence of energy transfer and conservation in physical systems.	Harry Fielding Reid
1911	Superconductivity	Demonstrated that electrical resistance can disappear under specific conditions, expanding understanding of electrical energy transfer and the properties of matter.	Heike Kamerlingh Onnes

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
1913	Bohr Model	Introduced quantized electron energy levels, providing a model that explained atomic emission spectra and strengthened scientific understanding of atomic structure and energy transitions.	Niels Bohr
1915-1935	Noether's Theorem	Every fundamental symmetry in nature corresponds to a conservation law to connect mathematics, physics, and the laws of nature.	Emmy Noether
1916-1930s	Modern Chemical Bonding Theory	Developed Lewis structures, electronegativity, and bonding models that are the core for molecules and reactions.	Gilbert N. Lewis Linus Pauling
1917-1919	Discovery of the Proton	Provided evidence that atomic nuclei contain positively charged particles, advancing scientific understanding of atomic structure, atomic number, and the organization of elements within the periodic table.	Ernest Rutherford
1920s	Quantum Mechanical Model	Replaced earlier atomic models with a probability-based model describing the behavior and location of electrons within atoms to improve scientific understanding of atomic structure, electron energy levels, chemical bonding, molecular geometry, periodic trends, and the interactions of matter at the atomic scale.	Erwin Schrödinger Werner Heisenberg
1920s-1940s	Advances in Fluid Dynamics and Drag	Advanced scientific understanding of how forces act on objects moving through fluids and how energy is transferred within flowing systems. Improved models of drag, lift, pressure, and motion and provided important applications of Newton's Laws, force interactions, and energy transfer in aviation, transportation, and engineered systems.	Ludwig Prandtl

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
1925	Hohmann Transfer	Provided an efficient method for transferring objects between orbits, applying principles of energy conservation, gravitational interactions, and motion.	Walter Hohmann
1932	Discovery of the Neutron	Identified the neutron as a fundamental particle within the atomic nucleus, completing the modern model of atomic structure to improve scientific understanding of isotopes, nuclear stability, radioactive decay, and nuclear reactions. Provided a foundation for modern nuclear physics and chemistry.	James Chadwick
1936-1943	Jet Propulsion and Orbital Mechanics	Advanced scientific understanding of how forces, momentum, energy transformations, and gravitational fields influence the motion of objects. Provided real-world applications of Newton's Laws, conservation principles, and mathematical modeling of motion.	Robert Goddard Hermann Oberth Werner von Braun
1938-1939	Nuclear Fission	Demonstrated that atomic nuclei can split into smaller nuclei, releasing large amounts of energy and additional particles to transform scientific understanding of atomic structure, nuclear reactions, and matter-energy relationships. Provided evidence that energy can be released through changes within the nucleus of an atom.	Otto Hahn Fritz Strassmann Lise Meitner Otto Frisch
1940s-1960s	Advances in Heat Transfer and Thermodynamics	Refined scientific models describing the transfer and transformation of energy within physical systems to advance and improve understanding of thermal energy, heat flow, efficiency, equilibrium, and the behavior of matter during energy exchanges.	Theodore von Kármán, H. Julian Allen, Ernst Eckert, and other thermodynamics and heat-transfer researchers

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
1942-1945	Scientific Director of the Manhattan Project	Applied scientific models of atomic structure and nuclear fission to develop the first large-scale nuclear technologies, demonstrating how changes within atomic nuclei can release enormous amounts of energy and strengthening scientific understanding of nuclear processes and matter-energy relationships.	J. Robert Oppenheimer
1950s	Discovery of DNA Structure	Demonstrated how the properties and behavior of matter are determined by atomic structure, chemical bonding, molecular geometry, and intermolecular forces.	Rosalind Franklin James Watson Francis Crick
1950s-1960s	Modern Understanding of Friction and Material Behavior	Advanced scientific understanding of friction, surface interactions, and material properties, leading to improved models of contact forces and energy dissipation.	Stephen Timoshenko
1954	Practical Silicon Solar Cell	Provided the first practical high-efficiency photovoltaic technology, demonstrating how matter can interact with electromagnetic radiation to convert solar energy into electrical energy.	Bell Laboratories (Daryl Chapin, Calvin Fuller, Gerald Pearson)
1954-1960	First HVDC Link	Demonstrated improved long-distance electrical power transmission through reduced energy losses, advancing understanding of electrical energy transfer, power systems, efficiency, and engineered energy infrastructure.	ASEA (Gotland HVDC Link); NASA
1957	Keeling Curve Record	Provided a continuous record of atmospheric carbon dioxide concentrations, demonstrating how long-term data collection supports the study of matter, energy transfer, and interactions within complex physical systems.	Charles D. Keeling

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
1957-1960	Sputnik and TIROS-1	Marked the beginning of the satellite era and expanded the ability to study energy, radiation, motion, and physical systems from space. Provided new measurements of Earth's atmosphere, temperature patterns, cloud systems, and energy transfer processes while demonstrating applications of forces, motion, orbital mechanics, and electrical power systems.	National Aeronautics and Space Administration (NASA); Union of Soviet Socialist Republics (USSR)
1958	Van Allen Belts and Solar Wind	Improved understanding of the interaction among charged particles, magnetic fields, and energy transfer in space environments.	James Van Allen, Eugene Parker
1960s-Present	Discovery of Quarks, Leptons, and Particle Models	Expanded scientific understanding of matter at the subatomic level by identifying fundamental particles and developing models that explain the structure of atoms, protons, neutrons, and nuclear interactions.	Murray Gell-Mann, George Zweig
1964	Quark Model	Provided a framework for explaining the internal structure of protons and neutrons, advancing scientific understanding of matter as subatomic particles.	Murray Gell-Mann
1970s-1990s	Growth of Renewable Energy Technologies	Expanded the use of technologies that convert energy from renewable sources into usable electrical energy, including solar, wind, and hydroelectric systems.	James Blyth, Elliott Berman, and numerous engineers and scientists contributing to modern renewable-energy technologies
1977	Radioisotope Thermoelectric Generators (RTGs) on Voyager Missions	Demonstrated how nuclear energy released through radioactive decay can be converted into electrical energy for long-duration space missions.	NASA; Jet Propulsion Laboratory (JPL)

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
1991	Commercial Li-ion batteries	Enabled efficient storage and transfer of electrical energy through electrochemical processes, transforming portable electronics, renewable energy systems, electric transportation, and modern energy technologies.	Akira Yoshino, Yoshio Nishi, and Sony researchers
1995-Present	Solar and Heliospheric Observatory (SOHO) and Modern Missions	Improved scientific understanding of solar energy, electromagnetic radiation, and particle interactions through continuous observations of the Sun.	European Space Agency (ESA); NASA
2000s-Present	CERES, Argo, Modern Remote Sensing, and Computational Models	Advanced satellite observations, ocean-monitoring systems, and computational models to provide precise measurements of energy transfer, radiation, heat storage, and physical system interactions to allow the investigation of complex systems, analysis of large data sets, and the development of evidence-based explanations of physical phenomena.	NASA, NOAA, International Argo Program, and international research teams
2000-Present	Digital Sensors, Computational Modeling, and Simulation Technologies	Advanced sensors, data collection systems, computational models, and simulations allow scientists and students to investigate energy, matter, forces, motion, and complex systems with greater precision and accuracy.	Scientists, engineers, software developers, and research teams worldwide
2012	Discovery of Higgs Boson	Confirmed a fundamental component of the Standard Model of particle physics and improved understanding of the origin of particle mass.	CERN scientists; ATLAS and CMS research collaborations
2018-Present	Parker Solar Probe	Provides direct measurements of energy transfer, electromagnetic radiation, magnetic fields, and charged particles in the Sun's outer atmosphere, improving scientific understanding of solar energy, plasma behavior, and particle interactions in space systems.	NASA

Time Period	Accomplishment or Discovery	Why it matters for *Energy, Matter, and Force and Motion*	Important People Involved
2020s-Present	Artemis Program	Applies principles of energy transfer, thermodynamics, radiation protection, electrical systems, propulsion, and life-support engineering within modern deep-space exploration systems.	NASA

Mathematics, Modeling, Laboratory Practices, and Timeline

Mathematics Skills Supporting Mastery of 9-12 *Planet Earth and Space* Benchmarks

The mathematics skills listed below are not intended to be taught separately from science instruction. Rather, they identify mathematical concepts and practices that support student understanding of Planet Earth and Space concepts at the point of learning. Students apply these skills while investigating phenomena, collecting and analyzing data, identifying patterns, constructing explanations, evaluating evidence, and communicating scientific ideas. Mastery of these mathematics skills supports deeper understanding of the science benchmarks but does not replace mastery of benchmark content.

Mathematics Skill	Description in *Planet Earth and Space* Context	Examples in *Planet Earth and Space* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Applications of Algebraic Reasoning	Use algebraic relationships to represent Earth and space processes, compare rates of change, and compute quantities related to energy transfer, gravity, orbital motion, matter cycling, and Earth system interactions.	Calculate rates of plate movement using distance and time data. Determine changes in temperature or sea level over time using linear models. Solve equations related to radioactive decay and half-life in geologic dating. Calculate orbital velocity changes associated with distance from a gravitational source.	MA.912.AR.1.1 MA.912.AR.1.2 MA.912.AR.5.7 MA.912.C.5.3
Proportional Relationships	Apply ratios, rates, and proportional reasoning to analyze Earth and space system data and scale relationships across spatial and temporal ranges.	Compare sediment deposition rates in different environments. Scale geologic time to timelines or diagrams. Relate energy input to temperature change in atmospheric or ocean systems. Compare relative scales of planets, stars, galaxies, and the observable universe. Relate wavelength and frequency across the electromagnetic spectrum.	MA.6.AR.3.5 MA.7.AR.4.1 MA.7.AR.4.2 MA.7.AR.4.3 MA.8.AR.3.1 MA.912.AR.8.3 MA.912.F.1.5

Mathematics Skill	Description in *Planet Earth and Space* Context	Examples in *Planet Earth and Space* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Represent Data Graphically and Interpret its Meaning	Construct and interpret graphs to identify trends, cycles, and patterns in Earth system data across time and space.	Plot global temperature or precipitation trends. Interpret ocean floor age versus distance from mid-ocean ridges. Analyze seismic wave travel-time graphs. Interpret Hertzsprung-Russell diagrams. Analyze galaxy redshift versus distance graphs. Examine light curves and spectral data from astronomical observations.	MA.912.AR.2.4 MA.912.AR.2.5 MA.912.DP.1.1 MA.912.DP.2.1 MA.912.F.1.3 MA.912.F.1.6 MA.912.F.1.7 MA.912.F.1.8
Dimensional Analysis	Use unit conversions and dimensional reasoning to ensure consistency and interpret physical meaning in Earth and space science calculations.	Convert between kilometers, meters, and centimeters for crustal thickness. Convert years to millions of years for geologic timescales. Check unit consistency in energy or heat-flow calculations. Convert among astronomical units, light-years, and parsecs. Interpret scales used in planetary and galactic distances.	MA.4.M.1.2 MA.5.M.1.1 MA.6.AR.3.2 MA.6.AR.3.5 MA.7.AR.3.2 MA.7.AR.4.5 MA.912.AR.5.3 MA.912.F.1.8 MA.912.GR.2.2 MA.912.GR.2.6 MA.912.NSO.1.1
Applications of Geometric Reasoning	Use geometry and spatial reasoning to analyze Earth structures, spatial patterns, celestial systems, and physical features.	Interpret cross-sections of rock layers and faults. Measure angles of fault lines or slopes from diagrams. Analyze latitude-longitude relationships and Earth-scale geometry. Interpret orbital diagrams and planetary alignments. Compare spatial relationships among Solar System objects.	MA.912.GR.4.1 MA.912.GR.3.3 MA.912.GR.4.3 MA.912.GR.4.4 MA.912.GR.4.6 MA.912.T.1.2

Mathematics Skill	Description in *Planet Earth and Space* Context	Examples in *Planet Earth and Space* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Data Analysis	Analyze Earth and space science datasets to identify correlations, variability, uncertainty, and evidence-based conclusions.	Compare datasets showing hazard frequency and magnitude. Evaluate uncertainty in atmospheric measurements. Analyze distributions of earthquakes, volcanoes, or weather events. Analyze astronomical survey data to identify patterns in galaxy distribution.	MA.912.AR.5.3 MA.912.DP.1.4 MA.912.DP.2.1 MA.912.DP.2.2 MA.912.DP.2.3
Temporal Reasoning	Use mathematical reasoning to compare Earth and space processes operating across vastly different timescales.	Compare rates of erosion versus plate motion. Distinguish short-term weather data from long-term temperature records. Compare rates of geologic processes operating over thousands, millions, and billions of years. Compare stellar life-cycle timescales. Relate light-travel time to observations of cosmic history.	MA.4.M.1.2 MA.5.M.1.1 MA.6.AR.3.5 MA.912.AR.2.4 MA.912.F.1.3 MA.912.F.1.6
Spatial Reasoning	Interpret spatial datasets and maps to identify Earth and space system patterns.	Interpret GIS maps showing earthquake and volcano distributions. Analyze tectonic plates relationships. Compare geographic patterns of climate zones, ocean currents, and atmospheric circulation. Analyze the hierarchical organization of Earth, the Solar System, the Milky Way galaxy, and the observable universe. Interpret distributions of galaxies, clusters, filaments, and voids.	MA.912.AR.5.7 MA.912.C.5.3 MA.912.AR.2.4 MA.912.F.1.3 MA.912.F.1.6

Modeling Skills Supporting Mastery of 9-12 *Planet Earth and Space* Benchmarks

The modeling skills listed below support student understanding of Earth and space science concepts through the use of diagrams, mathematical representations, computational simulations, conceptual models, and systems models. Students use models to represent structures, processes, interactions, and relationships that may not be directly observable. These skills help students communicate ideas, test explanations, make predictions, evaluate assumptions, and develop understanding of Earth and space systems.

Modeling Skill	Description	*Planet Earth and Space* Specific Examples
Defining Systems and Boundaries	Identify components of Earth and space systems, determine boundaries, inputs, outputs, and interactions, and justify model simplifications.	Define boundaries of the hydrologic cycle within a watershed. Identify components of a tectonic plate boundary region. Define boundaries of the Solar System, planetary systems, or galaxies. Identify inputs, outputs, and interactions within Earth-Sun systems.
Mathematical Modeling	Represent Earth and space processes using equations, proportional relationships, rates, proportional relationships, and quantitative relationships.	Model radioactive decay using half-life equations. Calculate rates of seafloor spreading. Quantify heat flow from Earth's interior. Model orbital motion using gravitational relationships. Represent redshift-distance relationships mathematically.
Graphical Modeling	Use graphs to represent relationships, trends, cycles, and changes in Earth and space system data.	Graph earthquake depth versus distance from plate boundaries. Plot temperature or precipitation trends. Analyze ocean crust age versus distance from mid-ocean ridges. Interpret Hertzsprung-Russell diagrams. Graph relationships among redshift, distance, and motion.
Qualitative or Conceptual Modeling	Use diagrams, flowcharts, and verbal explanations to represent systems, processes, and interactions.	Conceptual models of mantle convection. Diagrams showing energy transfer among Earth's spheres. Feedback diagrams illustrating radiation balance or biogeochemical cycles. Models of Solar System formation. Models of stellar evolution. Models of cosmic expansion.

Modeling Skill	Description	*Planet Earth and Space* Specific Examples
Computational Modeling and Simulations	Use computer-based models and simulations to analyze processes that cannot be directly observed or experimentally reproduced.	Simulate atmospheric circulation patterns. Model tsunami propagation across ocean basins. Explore ocean circulation models. Simulate orbital motion. Model galaxy formation and distribution. Explore space-weather interactions.
Using Models to Make Predictions	Apply models to predict outcomes and evaluate predictions using available evidence.	Predict future plate positions using current plate velocities. Forecast storm paths using atmospheric models. Anticipate erosion patterns based on slope and water flow. Predict orbital positions. Forecast space-weather impacts. Predict future stellar evolution stages.
Evaluating and Refining Models	Assess model accuracy, assumptions, and uncertainty using observational evidence.	Compare earthquake-model predictions with observed seismic data. Refine ocean circulation models using updated measurements. Evaluate hazard models. Compare Solar System formation models with new observations. Refine cosmological models using astronomical evidence.
Systems Modeling	Represent interactions among Earth and space systems to examine feedbacks and emergent patterns.	Model interactions among the atmosphere, hydrosphere, geosphere, and biosphere. Model climate-system feedbacks. Model Earth-Sun-space interactions. Model interactions among stars, planets, radiation, and planetary environments. Model galaxy and large-scale cosmic systems. Model solar activity, radiation, and magnetosphere interactions.

Laboratory Practices Supporting Mastery of 9-12 *Earth and Space* Benchmarks

The laboratory practices listed below identify the investigative skills students use while learning Earth and space science concepts. Through observation, measurement, data collection, analysis, modeling, and evidence-based explanation, students develop scientific habits of mind and learn how scientific knowledge is generated through investigations of Earth and space phenomena and systems.

Laboratory Practices	**Description of What Students Must be Able to Do**	***The Earth and Space* Focused Examples**
Designing and Conducting Investigations	Plan and carry out investigations that model, measure, or simulate Earth and space processes.	Design an investigation modeling how temperature affects density-driven convection in fluids.
Collecting Accurate and Reliable Data	Use appropriate tools, techniques, and protocols to gather precise and reproducible Earth and space system data.	Collect temperature, depth, and time measurements from a density-column model. Compare astronomical observations collected from multiple instruments or wavelengths.
Analyzing and Interpreting Data	Organize, analyze, and interpret Earth and space science data to identify patterns, trends, relationships, and variability.	Analyze seismic-wave travel-time data; analyze galaxy redshift data; interpret spectra from stars and galaxies.
Engaging in Argument from Evidence	Construct, evaluate, and communicate explanations supported by data, observations, and scientific reasoning.	Use rock-layer and fossil evidence to support geologic-age claims. Use redshift and cosmic-background-radiation evidence to support explanations of cosmic expansion.
Constructing Explanations	Develop evidence-based explanations connecting observations, data, models, and scientific concepts.	Explain plate movement, climate trends, stellar evolution, galaxy distributions, or Earth-apace interactions using collected evidence.
Evaluating and Refining Experimental Designs	Assess effectiveness of investigation methods and revise procedures to improve reliability and accuracy.	Revise an erosion investigation after identifying uncontrolled changes in slope angle.
Using Digital Tools and Technology	Apply digital tools to collect, visualize, model, or analyze Earth and space science data.	Use Geographic Information Systems (GIS) maps, satellite imagery, astronomical databases, simulation software, spacecraft data, or telescope observations.
Evaluating Indirect Evidence	Use multiple lines of evidence to investigate systems and processes that cannot be directly observed.	Infer Earth's interior using seismic evidence, galaxy structure using redshift surveys, and stellar properties using spectra and luminosity data.
Practicing Lab Safety	Follow safety protocols appropriate for Earth and space science investigations involving equipment, materials, or simulations.	Safely handle heating elements and fluids during mantle convection modeling activities.

Timeline of Key Accomplishments Supporting Mastery of 9-12 *Earth and Space* Benchmarks

This timeline provides historical and conceptual context for the Grades 9-12 standards by highlighting key scientific ideas that support foundational understanding for planet Earth and space. It is not intended for memorization of names or dates, but rather to illustrate how scientific understanding develops over time through evidence, models, and refinement of ideas. Students at this level should recognize that scientific knowledge is built from observations, improved with new evidence, and represented through models.

Historical developments often reflect changes in scientific models and explanations as new evidence becomes available. Students should recognize that scientific understanding grows through the continual testing, revision, and refinement of models over time.

Time Period	Accomplishment or Discovery	Why it matters for *Earth and Space*	Important People Involved
300 BC-200 AD	Earth recognized as spherical; early measurements of Earth's size	Established Earth's shape, scale, and gravity as foundational planetary properties	Aristotle Eratosthenes
1500s-1600s	Heliocentric Model	Established the Sun-centered Solar System framework	Nicolaus Copernicus Galileo Galilei
Early 1600s	Kepler's Laws of Planetary Motion	Explained mathematical relationships governing planetary orbits	Johannes Kepler
1600s	Principles of stratigraphy	Provided rules for interpreting rock layers and relative age	Nicolas Steno
Late 1600s-1700s	Laws of Motion and Gravity	Explained forces governing planetary motion and Earth processes	Isaac Newton
Late 1700s	Uniformitarianism	Linked present-day processes to Earth's deep past	James Hutton
Early-Mid 1800s	Geologic Time Scale (relative dating)	Organized Earth's history using rock layers and fossils	Charles Lyell
1800s	Spectroscopy	Allowed determination of composition and motion of distant objects using light.	Joseph von Fraunhofer Gustav Kirchhoff
Late 1800s	Early fossil classification and correlation	Revealed changes in environments through time	Georges Cuvier William Smith
Early 1900s	Seismic wave analysis	Revealed Earth's layered internal structure	Richard Oldham
Early 1900s	Hertzsprung-Russell Diagram	Revealed relationships among stellar temperature, luminosity, and evolution	Ejnar Hertzsprung Henry Norris Russell
Early 1900s	Discovery of radioactive decay	Enabled absolute dating of rocks and events	Ernest Rutherford
1910s-1930s	Continental drift hypothesis	Introduced large-scale surface motion of continents	Alfred Wegener
1920s	Milky Way and External Galaxies Identified	Demonstrated that galaxies exist beyond the Milky Way	Edwin Hubble

Time Period	Accomplishment or Discovery	Why it matters for *Earth and Space*	Important People Involved
1920s-1930s	Expanding Universe	Provided evidence that the universe is expanding	Edwin Hubble
1940s-1960s	Mapping of the ocean floor and mid-ocean ridges	Provided critical evidence supporting seafloor spreading and plate tectonics	Marie Tharp Bruce Heezen
1950s	Early Rocket Launches from Cape Canaveral	Established Florida as the nation's primary launch site and enabled the development of modern spaceflight and satellite technologies.	NASA, U.S. military and aerospace scientists and engineers
1950s-1960s	Seafloor spreading	Explained the formation of ocean basins	Harry Hess Robert S. Dietz
1950s-1960s	Mathematical Calculations Supporting Human Spaceflight	Provided critical orbital calculations supporting early crewed space missions and space exploration	Katherine Johnson
1957-Present	Space Age and Satellite Observation	Enabled direct exploration of Earth and space and global Earth-system modeling	International Space Agencies
1960s	Evidence for Seafloor Spreading and Plate Motion	Confirmed plate motion and ocean crust age patterns	Frederick Vine Drummond Matthews
1960s	Establishment of Kennedy Space Center	Created NASA's primary launch center for human spaceflight and space exploration programs. Since the Apollo era, Kennedy Space Center has been the primary launch site for major U.S. human spaceflight missions.	NASA John F. Kennedy
1960s	Cosmic Microwave Background Radiation	Provided critical evidence supporting modern cosmological models	Arno Penzias Robert Wilson
1969	Apollo 11 Launch from Kennedy Space Center	Demonstrated the capability for human exploration beyond Earth and provided scientific information about the Moon and planetary systems. Apollo 11 launched from Kennedy Space Center in Florida.	Neil Armstrong Buzz Aldrin Michael Collins NASA
1960s-1970s	Geodynamo theory of magnetic field	Explained magnetic field generation and planetary protection	Walter Elsasser
1960s-1970s	Plate tectonic theory	Unified earthquakes, volcanoes, mountains, and plate motion	J. Tuzo Wilson

Time Period	Accomplishment or Discovery	Why it matters for *Earth and Space*	Important People Involved
1960s-1980s	Discovery and Analysis of Pulsars and Compact Stellar Objects	Expanded scientific understanding of stellar remnants and extreme space environments	Jocelyn Bell Burnell
1970s-Present	Satellite Observation of Earth and Earth Systems from Florida-Based Launch Programs	Enabled global analysis of atmospheric, oceanic, and land processes	NASA and International space agencies
1970s-Present	Advances in Dark Matter Research and Galaxy Dynamics	Strengthened evidence for unseen matter influencing galaxy motion	Vera Rubin
Late 1900s	Ocean circulation models	Explained global heat redistribution by oceans	Henry Stommel
Late 1900s	Radiation balance and greenhouse processes quantified	Clarified regulation of Earth's temperature	Svante Arrhenius
1981-2011	Space Shuttle Program	Enabled long-term human spaceflight, satellite deployment, scientific research, and construction of major space infrastructure through 135 missions launched from Kennedy Space Center.	NASA Space Shuttle astronauts and engineers
1983	First African American in Space	Expanded participation in human spaceflight and contributed to Space Shuttle missions	Guion Bluford
1983	First American Woman in Space	Expanded participation in space science and exploration	Sally Ride
1987-1992	First African American Woman in Space	Expanded participation in human space exploration and demonstrated contributions of diverse scientists and astronauts to space research	Mae Jemison
Late 1900s-2000s	Tracing the Movement of Matter Through Earth Systems	Showed how essential elements move through Earth systems	Multiple Earth system scientists
1990s	Space Exploration and Optical Systems Research	Advanced spacecraft operations and optical technologies used in space investigations	Ellen Ochoa
1990s-Present	Space Telescopes and Large Sky Surveys	Expanded understanding of stars, galaxies, and large-scale cosmic structure	Multiple International Collaborations
1990s-Present	Space Telescopes and Modern Astronomical Surveys	Expanded understanding of stars, galaxies, and cosmic structure	Nancy Grace Roman

Time Period	Accomplishment or Discovery	Why it matters for *Earth and Space*	Important People Involved
2000s	Global hazard monitoring networks	Improved tracking and assessment of natural hazards	USGS, NOAA, and various global agencies
2000s-Present	Earth system models	Integrated atmosphere, oceans, land, and biosphere	Interdisciplinary Earth scientists
2000s-Present	High-resolution remote sensing and Geologic Information Systems (GIS)	Enhanced analysis of Earth processes and changes	Earth observation scientists
2020	Return of Human Launches from Florida Through Commercial Crew Missions	Marked the return of human orbital launches from Florida and demonstrated new partnerships among NASA and commercial aerospace organizations.	NASA Commercial Crew partners
2022-Present	Artemis Program Launches from Kennedy Space Center	Supports scientific investigation of the Moon and preparation for future human exploration of Mars and deep space. Artemis missions launch from Kennedy Space Center.	NASA Artemis scientists and engineers

Mathematics, Modeling, and Laboratory Practices

Mathematics Skills Supporting Mastery of 9-12 *Life* Benchmarks

The mathematics skills listed below are not intended to be taught separately from science instruction. Rather, they identify mathematical concepts and practices that support student understanding of Life concepts at the point of learning. Students apply these skills while investigating phenomena, collecting and analyzing data, identifying patterns, constructing explanations, evaluating evidence, and communicating scientific ideas. Mastery of these mathematics skills supports deeper understanding of the science benchmarks but does not replace mastery of benchmark content.

Mathematics Skill	Description in *Life* Context	Examples in *Life* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Applications of Algebraic Reasoning	Rearrange equations and symbolic relationships to solve for unknown biological quantities and rates.	Calculating ATP yield from cellular respiration pathways; determining recombination frequency and genetic map distance; calculating population growth rates, carrying capacity, migration effects, trophic-transfer efficiency, decomposition rates, nutrient transfer, biomass changes, microbial generation times, and physiological metrics such as body mass index (BMI), heart-rate recovery, metabolic rate, blood glucose levels, and respiration rates.	MA.912.AR.1.1 MA.912.AR.1.2 MA.912.AR.5.5 MA.912.C.5.3
Proportional Relationships	Identify and apply proportional, inverse, and exponential relationships in biological systems.	Enzyme activity increasing proportionally with substrate concentration (to saturation); surface area-to-volume relationships in cells. Relating surface area-to-volume ratio changes to transport efficiency and cell-size limitations. Relating trophic-transfer efficiency to energy availability across food webs.	MA.7.AR.4.1 MA.7.AR.4.2 MA.7.AR.4.3 MA.8.AR.3.1 MA.912.AR.8.3 MA.912.AR.5.4 MA.912.GR.4.3

Mathematics Skill	Description in *Life* Context	Examples in *Life* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Represent Data Graphically and Interpret its Meaning	Create and interpret graphs to identify biological trends, rates, and equilibrium points.	Graphing population size versus time; interpreting enzyme activity versus temperature curves; reading survivorship curves. Interpreting predator-prey graphs, migration maps, survivorship curves, and population growth models. Interpreting blood glucose graphs, heart rate data, growth curves, immune response data, and nutrient intake trends. Interpreting fungal population curves, decomposition trends, nutrient-cycle data, and symbiotic growth comparisons. Interpreting microbial population graphs, epidemiological data, nutrient-cycle trends, fermentation results, and environmental monitoring datasets.	MA.912.AR.2.4 MA.912.AR.2.5 MA.912.DP.1.1 MA.912.DP.2.1 MA.912.F.1.3 MA.912.F.1.6 MA.912.F.1.7 MA.912.F.1.8 MA.912.GR.7.5
Dimensional Analysis	Convert and interpret biological units correctly and consistently.	Converting among nanometers, micrometers, millimeters, and centimeters when analyzing cells, organelles, and magnification; calculating respiration, photosynthesis, diffusion, enzyme activity, or population-growth rates by applying consistent units across multiple variables and time scales.	MA.4.M.1.2 MA.5.M.1.1 MA.6.AR.3.2 MA.6.AR.3.5 MA.7.AR.3.2 MA.7.AR.3.3 MA.7.AR.4.5 MA.912.AR.5.3 MA.912.F.1.8 MA.912.GR.2.2 MA.912.GR.2.6 MA.912.NSO.1.1 MA.912.NSO.1.2
Applications of Geometric Reasoning	Use geometric relationships to explain structure-function relationships.	Calculating surface area-to-volume ratios and geometric scaling relationships of cells, tissues, organs, and organisms; modeling leaf architecture, alveolar folding, vascular branching, and root-network geometry to evaluate diffusion efficiency, resource transport, metabolic constraints, and structure-function relationships across biological systems.	MA.912.GR.4.3 MA.912.GR.4.4 MA.912.GR.4.5 MA.912.GR.4.6

Mathematics Skill	Description in *Life* Context	Examples in *Life* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Data Analysis	Analyze variation, compute descriptive statistics, and interpret biological variability and patterns.	Determining means and ranges of heart-rate data; analyzing biodiversity indices across ecosystems. Analyzing inheritance ratios, mutation frequencies, cancer incidence rates, and photosynthesis experiments. Analyzing population trends in mammals, migration data in birds, fish abundance surveys, amphibian decline datasets, and invasive species impacts. Analyzing disease incidence, nutrition data, physiological measurements, microbiome datasets, and population health trends. Analyzing fungal growth rates, decomposition rates, nutrient cycling data, mycorrhizal effects on plant growth, and invasive-species impacts. Analyzing microbial growth curves, disease-transmission trends, nutrient-cycling data, wastewater treatment performance, and biodiversity datasets.	MA.912.AR.5.3 MA.912.DP.1.4 MA.912.DP.2.1 MA.912.DP.2.2 MA.912.DP.2.3
Spatial Data Analysis	Interpret maps, geographic datasets, and spatial patterns to explain organism distribution, habitat use, and biodiversity.	Comparing species distributions across biomes; analyzing habitat fragmentation maps; interpreting migration pathways. Analyzing fungal distribution patterns, mycorrhizal networks, invasive fungal spread, and succession patterns across ecosystems. Analyzing microbial distributions across ecosystems, disease outbreaks, bioremediation sites, and environmental gradients.	MA.912.DP.1.1 MA.912.DP.1.2 MA.912.DP.2.2 MA.912.DP.2.3 MA.912.DP.3.1

Mathematics Skill	Description in *Life* Context	Examples in *Life* Context	Alignment to the B.E.S.T. Mathematics Benchmarks
Quantitative Health Analysis	Analyze health and physiological data to identify trends, relationships, and evidence-based explanations.	Analyzing heart rate, blood pressure, oxygen consumption, blood glucose, and metabolic data across multiple time points; comparing nutrient intake, energy expenditure, and physiological indicators to established health benchmarks; and evaluating trends, rates of change, correlations, and variability to develop evidence-based explanations of homeostasis, fitness, disease risk, and overall health outcomes.	MA.912.DP.1.2 MA.912.DP.1.3 MA.912.DP.1.5 MA.912.DP.2.1 MA.912.DP.2.4 MA.912.DP.2.5 MA.912.DP.2.6 MA.912.DP.2.7

Modeling Skills Supporting Mastery of 9-12 *Life* Benchmarks

The modeling skills listed below support student understanding of life science concepts through the use of diagrams, mathematical representations, computational simulations, conceptual models, and systems models. Students use models to represent structures, processes, interactions, and relationships that may not be directly observable. These skills help students communicate ideas, test explanations, make predictions, evaluate assumptions, and develop understanding of Earth and space systems.

Modeling Skill	Description	*Life* Specific Examples
Defining Systems and Boundaries	Identify relevant components, interactions, and limits of biological systems.	Defining a system as a single cell, tissue, organ system, organism, population, or ecosystem; identifying relevant biotic and abiotic components and interactions within system boundaries.
Mathematical Modeling	Use equations and quantitative relationships to represent biological processes.	Modeling population growth using exponential or logistic equations; calculating allele frequencies with Hardy-Weinberg relationships; modeling rates of photosynthesis, respiration, nutrient cycling, or disease spread using quantitative data.
Graphical Modeling	Use graphs to represent change, equilibrium, and feedback in biological systems.	Interpreting predator-prey cycles, population growth curves, survivorship curves, biomass distribution across trophic levels, migration patterns, and food-web interactions using graphical representations.
Qualitative or Conceptual Modeling	Use diagrams and conceptual representations to explain biological mechanisms.	Diagrams of cell membranes to model transport; food-web models; gene-expression pathways; flow diagrams of nutrient cycling.
Computational Modeling and Simulations	Use digital simulations to test variables and explore complex biological systems.	Using simulations to model disease spread, population dynamics, gene inheritance patterns, ecosystem responses to environmental change, and climate impacts on biodiversity.
Historical Modeling	Analyze how scientific models have changed over time as new evidence becomes available.	Comparing historical and modern models of cells, heredity, disease transmission, biological classification, and DNA structure.

Modeling Skill	Description	*Life* Specific Examples
Using Models to Make Predictions	Apply models to predict biological outcomes under changed conditions.	Predicting population responses to habitat fragmentation, invasive species, disease outbreaks, altered predator abundance, environmental stress, nutritional deficiencies, physiological disturbances, fungal succession, decomposition rates, microbial growth, nutrient cycling, and ecosystem change.
Evaluating and Refining Models	Compare model predictions with evidence and revise assumptions.	Comparing predicted and observed population trends, ecosystem responses, fungal growth patterns, nutrient-cycling processes, microbial growth, disease transmission, and physiological responses; revising models based on evidence.
Systems Modeling	Represent interactions among biological, ecological, and environmental systems to examine feedbacks and emergent patterns.	Modeling interactions among cells, organisms, populations, ecosystems, and Earth systems; linking nutrient cycling, biodiversity, productivity, microbial processes, fungal interactions, and interconnected human body systems.
Molecular Modeling	Use structural representations to explain molecules, macromolecules, and cellular processes.	Modeling DNA replication, protein synthesis, membrane structure, ATP cycling, and signal transduction pathways.
Physiological Systems Modeling	Use models to represent interactions among organ systems and feedback mechanisms that maintain homeostasis.	Modeling thermoregulation, blood-glucose regulation, cardiovascular-respiratory interactions, immune responses, hormone regulation, and feedback mechanisms that maintain homeostasis.

Laboratory Practices Supporting Mastery of 9-12 *Life* Benchmarks

The laboratory practices listed below identify the investigative skills students use while learning life science concepts. Through observation, measurement, data collection, analysis, modeling, and evidence-based explanation, students develop scientific habits of mind and learn how scientific knowledge is generated through investigations of Earth and space phenomena and systems.

Laboratory Practices	Description of What Students Must be Able to Do	*Life* Focused Examples
Designing and Conducting Investigations	Plan and conduct controlled experiments addressing biological questions.	Design an experiment testing enzyme activity at different temperatures.
Collecting Accurate and Reliable Data	Use appropriate tools and methods to collect biological data precisely.	Measure cell size using microscopes; collect population data using quadrats or transects.
Analyzing and Interpreting Data	Organize data, create graphs, identify biological patterns and ecological relationships, and evaluate evidence supporting scientific explanations.	Analyze photosynthesis rate data; interpret population growth curves.
Engaging in Argument from Evidence	Use data to support claims and evaluate alternative explanations.	Justify causes of population decline using biodiversity and environmental data.
Evaluating and Refining Experimental Designs	Identify sources of error and improve investigations for reliability.	Modify sampling methods to reduce bias in ecological studies.
Using Digital Tools and Technology	Employ software, probes, databases, or simulations to analyze biological data.	Use digital sensors to measure respiration rates; analyze genetics data using databases. Using bioinformatics databases, chromosome mapping software, or molecular simulations to analyze genetic information. Using wearable devices, digital sensors, medical datasets, nutrition databases, and physiological simulations. Using environmental sensors, GIS mapping tools, nutrient-cycle datasets, fungal-growth simulations, and digital microscopy images.
Constructing Explanations	Develop evidence-based explanations connecting observations, data, and biological principles.	Explaining changes in ecosystem productivity, disease spread, growth responses, or organism interactions using collected data.
Practicing Lab Safety	Follow safety procedures when working with biological materials and equipment.	Safe handling of microscopes, biological samples, and lab chemicals.

Timeline of Key Accomplishments Supporting Mastery of 9-12 *Life* Benchmarks

This timeline provides historical and conceptual context for the Grades 9-12 standards by highlighting key scientific ideas that support foundational understanding for life science. It is not intended for memorization of names or dates, but rather to illustrate how scientific understanding develops over time through evidence, models, and refinement of ideas. Students at this level should recognize that scientific knowledge is built from observations, improved with new evidence, and represented through models, forming the basis for the more advanced concepts.

Historical developments often reflect changes in scientific models and explanations as new evidence becomes available. Students should recognize that scientific understanding grows through the continual testing, revision, and refinement of models over time.

Time Period	Accomplishment or Discovery	Why it matters for *Life*	Important People Involved
400 B.C.	Early Biological Classification	Systematic observation and organization of living organisms.	Aristotle
1628	Circulation of Blood	Established understanding of blood movement through the body.	William Harvey
1648	Early Plant Physiology Experiments	Demonstrated that plant growth could be studied experimentally and quantitatively, helping establish modern plant biology.	Jan van Helmont
1665	Discovery of Cells	Established cells as the fundamental units of life	Robert Hooke
1676	First Observations of Microorganisms	Opened scientific study of microscopic life, including fungi.	Antonie van Leeuwenhoek
1735	Modern Classification System	Standardized biological classification	Carl Linnaeus
1779	Plant Photosynthesis Investigations	Demonstrated that plants release oxygen in the presence of light, providing foundational evidence for understanding photosynthesis.	Jan Ingenhousz
1796	First Vaccination	Foundation of immunology and disease prevention	Edward Jenner
1804	Plant Nutrition Research	Demonstrated that plant growth depends on carbon dioxide, water, and mineral nutrients, helping establish the chemical basis of photosynthesis and plant nutrition.	Nicolas-Théodore de Saussure
1838-1839	First and Second Tenets of Cell Theory	Established the theory that all plants and animals are made of cells	Matthias Schleiden and Theodor Schwann

Time Period	**Accomplishment or Discovery**	**Why it matters for *Life***	**Important People Involved**
1855	Third Tenet of Cell Theory	Established the principle which states that all cells arise from preexisting cells	Rudolf Virchow
1859	Natural Selection	Provided the scientific explanation for how variation and differential survival and reproduction can lead to changes in populations over time.	Charles Darwin
1861	Biogenesis Demonstrated	Helped establish scientific understanding of growth and reproduction in living organisms.	Louis Pasteur
1861-1880s	Germ Theory Established	Demonstrated that microorganisms cause disease and transformed medicine and public health.	Louis Pasteur and Robert Koch
1862	Discovery of Pasteurization	Revolutionized food safety by demonstrating that heating liquids could eliminate harmful microorganisms	Louis Pasteur
1865	Laws of Heredity	Founding of modern genetics	Gregor Mendel
1899	Homogenization	First patented machine to produce homogenized milk	Auguste Gaulin
1900s-1920s	Discovery and Experimental Investigation of Plant Hormones (auxins)	Established chemical regulation of plant growth and development.	Frits Went and other contributing scientists
1910-1915	Chromosome Theory and the Development of Gene Mapping	Demonstrated that genes are carried on chromosomes through his *Drosophila* studies, discovered genetic linkage, and showed that some genes are inherited together because they are located on the same chromosome.	Thomas Hunt Morgan
1920s	Food Chains and Food Web Research	Helped to explain energy transfer and ecological relationships among organisms within ecosystems.	Charles Elton
1921	Discovery of Insulin	Revolutionized treatment of diabetes	Frederick Banting and Charles Best
1928	Discovery of Penicillin	Demonstrated the importance of fungi in medicine.	Alexander Fleming
1930s-1960s	Homeostasis and Physiological Regulation	Expanded understanding of feedback mechanisms that regulate internal conditions and maintain stable body-system function.	Walter Cannon and other contributing scientists

Time Period	Accomplishment or Discovery	Why it matters for *Life*	Important People Involved
1950s	Calvin Cycle Discovered	Explained how plants convert carbon dioxide into sugars during photosynthesis.	Melvin Calvin
1950s-Present	Mycorrhizal Ecology	Revealed the critical roles fungi play in nutrient cycling and plant productivity.	John Laker Harley and other contributing scientists
1952	Photo 51	Provided key information that was essential for developing a model of DNA	Rosalind Franklin
1953	DNA Structure	Explained how genetic information is stored, replicated, and transmitted among organisms.	James Watson, Francis Crick, and Rosalind Franklin
1962	Silent Spring Published	Demonstrated how environmental contaminants influence animal populations and ecosystems.	Rachel Carson
1970	Discovery of Cyclins and Cell-Cycle Regulation Mechanisms	Provided evidence that cell division is controlled by regulatory proteins that coordinate progression through the cell cycle.	Leland Hartwell, Paul Nurse, and Tim Hunt
1971	Proposal of the Two-Hit Hypothesis for Cancer Development	Helped explain how changes in genes that regulate cell division contribute to cancer.	Alfred Knudson
1970s	Discovery of Restriction Enzymes and Recombinant DNA	Established the foundation of modern molecular biology and genetic engineering.	Hamilton Smith, Daniel Nathans, and Werner Arber
1977	Three-Domain Classification System and Discovery of Archaea	Expanded biological classification using molecular evidence and reorganized major groups of life.	Carl Woese
1980s-1990s	Discovery of Tumor Suppressor Genes and Proto-Oncogenes	Demonstrated how disruptions in cell-cycle control can lead to uncontrolled cell division and disease.	Robert Weinberg, Bert Vogelstein, and other contributing scientists
1990-2003	The Human Genome Project	Mapped and sequenced all human genes	U.S. Department of Energy and National Institutes of Health
2000s	Microbiome Research	Expanded understanding of human-micro interactions	Jeffrey Gordon and other contributing scientists
2001	Nobel Prize Recognition for Discoveries of Cell-Cycle Regulation	Confirmed the importance of cyclins, checkpoints, and regulatory proteins in controlling cell division.	Leland Hartwell, Tim Hunt, and Paul Nurse

Time Period	Accomplishment or Discovery	Why it matters for *Life*	Important People Involved
2012	CRISPR Gene Editing	Enabled precise modification of DNA and expanded applications of biotechnology, genetics, agriculture, and medicine.	Jennifer Doudna and Emmanuelle Charpentier