# Grades 9–11 Science Stems and Proficiencies

## Earth and Space Science

### ESS1 - **The Earth and Earth materials, as we know them today, have developed over long periods of time, through constant change processes.**

1. ATMOSPHERE, CLIMATE, & WEATHER
   1) Explain how winds and ocean currents are produced on the Earth's surface.
   2) Explain heat and energy transfer in and out of the atmosphere and provide examples of its involvement in weather and climate.
   3) Describe how Earth's atmospheric composition has changed from the formation of the Earth through current time.
   4) Explain how Earth's features can affect wind and weather patterns by causing air to rise and increasing precipitation.

2. COMPOSITION & FEATURES OF EARTH MATERIALS
   1) Recognize that elements exist in fixed amounts and describe how they move through the solid Earth, oceans, atmosphere, and living things as part of geochemical cycles, such as the carbon and nitrogen cycles.
   2) Describe the conditions that enable the Earth to support life, such as the availability of water, the gravitational force, the EM field and the intensity of radiation from the Sun.
   3) Explain the concept of plate tectonics.
   4) Describe the movement of crustal plates and explain how the effects have altered the Earth's features.

3. FOSSILS AND GEOLOGIC TIME
   1) Identify and describe the methods used to measure geologic time, such as fossil identification, radioactive dating, and rock sequences;

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   | *2) Relate how geologic time is determined using various dating methods (e.g., radioactive, decay, rock sequences, fossil records).* |

4. OBSERVATION OF EARTH FROM SPACE

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   | *1) Provided with geologic data (including movement of plates) on a given locale, predict the likelihood for an earth event (e.g. volcanoes mountain ranges, islands, earthquakes, tides, tsunamis).* |

5. PROCESSES AND RATES OF CHANGE OF THE EARTH'S SURFACE
   1) Explain that the Earth is composed of interactive layers, which have distinct compositions, physical properties and processes.
   2) Relate plate movement to earthquakes and volcanic activity, and explain how it results in tectonic uplift and mountain building.
   3) Identify and describe the major external and internal sources of energy on Earth;

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   | *4) Provide supporting geologic/geographic evidence that supports the validity of the theory of plate tectonics.* |
   | *5) Trace the development of the theory of plate tectonics.* |
   | *6) Explain how internal and external sources of heat (energy) fuel geologic processes (e.g., rock cycle, plate tectonics, sea floor spreading).* |

6. ROCK CYCLE
   1) Explain that throughout the rock cycle, the total amount of the material remains the same.

7. WATER AND THE EARTH'S SURFACE
   1) Explain that water quality can be affected positively or negatively by outside sources.

## ESS2 - **The Earth is part of a solar system, made up of distinct parts, which have temporal and spatial interrelationships.**

1. EARTH, SUN AND MOON
   1) Explain how the Earth, Moon and Sun were formed.

2. ENERGY
   1) Identify the Earth's major external source of energy as solar energy.
   2) Explain how the inclination of incoming solar radiation can impact the amount of energy Earth receives on any given surface area.
   3) *Explain how internal and external sources of heat (energy) fuel geologic processes (e.g. rock cycle (plate tectonics, sea floor spreading).*

3. SOLAR SYSTEM
   1) Explain how gravitational force influenced the formations of the planets and their moons, and describe how these objects move in patterns under its continued influence;
   2) Explain how the Solar System formed from a giant cloud of gas and debris about 5 billion years ago.

4. VIEW FROM EARTH
   *None at this grade span.*

## ESS3 - **The origin and evolution of galaxies and the universe demonstrate fundamental principles of physical science across vast distances and time.**

1. SIZE AND SCALE
   1) Recognize electromagnetic waves can be used to locate objects in the universe, and track their movement.
   2) Define a light year.

2. STARS AND GALAXIES
   1) Identify the characteristics common to most stars in the universe.
   2) Describe the ongoing processes involved in star formation, their life cycles and their destruction.
   3) *Explain the relationships between or among the energy produced from nuclear reactions, the origin of elements, and the life cycles of stars.*

3. UNIVERSE
   1) Explain that current scientific evidence supports the Big Bang Theory as a probable explanation of the origin of the universe, and describe the theory;
   2) Explain the evidence that suggests the universe is expanding;

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| *3)* | *Provide scientific evidence that supports or refutes the "Big Bang" theory of how the universe was formed;* |
| *4)* | *Based on the nature of electromagnetic waves, explain the movement and location of objects in the universe or their composition (e.g., red shift, blue shift, line spectra);* |
| *5)* | *Explain how scientific theories about the structure of the universe have been advanced through the use of sophisticated technology (e.g., space probes; visual, radio and x-ray telescopes).* |

## ESS4 – **The growth of scientific knowledge in Earth Space Science has been advanced through the development of technology and is used (alone or in combination with other sciences) to identify, understand, and solve local and global issues.**

1. DESIGN TECHNOLOGY
   1) Describe ways in which technology has increased our understanding of the universe.
   2) Understand that technology is designed with a particular function in mind, and principles of Earth Space science are useful in creating technology for the Earth space sciences

2. TOOLS
   1) Describe the use and benefits of Land based Light Telescopes, radio telescopes, spectrophotometers, satellites, manned exploration, probes, and robots to the study of Earth Space Science.
   2) Explain how scientists study the Earth using computer-generated models and observations from both land based sites and satellites, and describe the value of using these tools in unison.

3. SOCIAL ISSUES (LOCAL AND GLOBAL)
   USES OF EARTH MATERIALS
   1) Differentiate between and provide examples of renewable and nonrenewable sources of energy, and explain the advantages and limitations of each.
   2) Describe the means for transforming a natural material, such as iron ore, into useful products during different historical periods, such as the Stone Age, Iron Age, Renaissance, the Industrial Period and the current Age of Information.

   ENVIRONMENTAL CHANGE
   1) Explain how the use of technologies at a local level, such as burning of fossil fuels for transportation or power generation, may contribute to global environmental problems

4. CAREER TECHNICAL EDUCATION CONNECTIONS
   1) Explain the kinds of applications of knowledge and skills necessary for jobs/careers specific to Earth or space sciences

# Life Science

## LS 1 – All living organisms have identifiable structures and characteristics that allow for survival (organisms, populations, & species).

1. CLASSIFICATION
   1) Describe how organisms are classified into a hierarchy of groups and subgroups, which are based on similarities that reflect their evolutionary relationships.
   2) Explain that organisms that possess similar DNA code are more closely related than those in which DNA varies greatly.
   3) Identify plants and animals according to binomial nomenclature.
   4) Differentiate between prokaryotic and eukaryotic cells according to general structure and degrees of complexity.

2. LIVING THINGS AND ORGANIZATION
   1) Identify the structures of different types of cell parts/organelles and explain the functions they perform.
   2) Recognize how cell functions are regulated through changes in the activity of the functions performed by proteins, and through the selective expression of individual genes; and explain how this regulation allows cells to respond to their environment and to control and coordinate cell growth and division.
   3) Recognize how an organism's organization and complexity accommodate its need for obtaining, transforming, transporting, releasing, and eliminating the matter and energy used to sustain it.
   4) Explain how the processes of photosynthesis and cellular respiration are interrelated and contribute to biogeochemical cycles.
   5) Describe the structures of proteins and their role in cell function.
   6) Describe the chemical reactions involved in cell functions using examples from the nervous, immune and endocrine systems in multicellular animals.
   7) Recognize that because all matter tends toward more disorganized states, living systems need a continuous input of energy to maintain their chemical and physical organizations.
   *8) Use data and observation to make connections between, to explain, or to justify how specific cell organelles produce/regulate what the cell needs or what a unicellular or multi-cellular organism needs for survival (e.g., protein synthesis, DNA transport, nerve cells).*

3. REPRODUCTION
   1) Describe the chemical and structural properties of DNA and explain its role in identifying the characteristics of an organism.
   2) Recognize that new heritable characteristics can only result from new combinations of existing genes or from mutations of genes in an organism's sex cells, and explain why other changes in an organism cannot be passed on.
   3) Describe the alternation of generations, life cycles with haploid and diploid phases in living organisms, such as bacteria, plants and animals.
   *4) Explain or justify with evidence how the alteration of the DNA sequence may produce new gene combinations that make little difference, enhance capabilities, or can be harmful to the organism (e.g., selective breeding, genetic engineering, mutations).*

## LS 2 – Energy flows and matter recycles through an ecosystem.

1. ENVIRONMENT
   1) Explain how the amount of life an environment can sustain is restricted by the availability of matter and energy, and the ability of the ecosystem to recycle materials.

2) Describe how the interrelationships and interdependencies among organisms generate stable ecosystems that fluctuate around a state of rough equilibrium for hundreds or thousands of years.
3) Identify the factors in an ecosystem that can affect its carrying capacity.
4) Analyze and describe how environmental disturbances, such as climate changes, natural events, human activity and the introduction of invasive species, can affect the flow of energy or matter in an ecosystem.

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| *5) Using data from a specific ecosystem, explain relationships or make predictions about how environmental disturbance (human impact or natural events) affects the flow of energy or cycling of matter in an ecosystem.* |
| *6) Explain or evaluate potential bias in how evidence is interpreted in reports concerning a particular environmental factor that impacts the biology of humans.* |

2. FLOW OF ENERGY
   1) Use examples from local ecosystems to describe the relationships among organisms at the different trophic levels.

3. RECYCLING OF MATERIALS
   1) Explain that as matter and energy flow through different levels of organization in living systems and between living systems and the environment, elements, such as carbon and nitrogen, are recombined in different ways.

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| *2) Trace the cycling of matter (e.g., carbon cycle) and the flow of energy in a living system from its source through its transformation in cellular, biochemical processes (e.g., photosynthesis, cellular respiration, fermentation).* |

## LS 3 - Groups of organisms show evidence of change over time (e.g. evolution, natural selection, structures, behaviors, and biochemistry).

1. CHANGE
   1) Identify ways humans can impact and alter the stability of ecosystems, such as habitat destruction, pollution, and consumption of resources; and describe the potentially irreversible effects these changes can cause.
   2) Identify ways of detecting, and limiting or reversing environmental damage.
   3) Analyze the aspects of environmental protection, such as ecosystem protection, habitat management, species conservation and environmental agencies and regulations; and evaluate and justify the need for public policy in guiding the use and management of the environment.

2. EVIDENCE OF EVOLUTION
   1) Explain the currently accepted theory for the development of life on Earth, including the history of its origin and the evolutionary process.
   2) Recognize that the abilities and behaviors an organism has, and likelihood of its survival strongly depend on its heritable characteristics, which can be biochemical and anatomical.
   3) Explain the contributions of Darwin, Malthus, Wallace and Russell to the advancement of life science.
   4) Explain evolution in terms of how the Earth's present-day life forms evolved from earlier, distinctly different species as a consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection.

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| *5)* | *Explain how evidence from technological advances supports or refutes the genetic relationships among groups of organisms (e.g., DNA analysis, protein analysis).* |
| *6)* | *Given information about living or extinct organisms, cite evidence to explain the frequency of inherited characteristics of organisms in a population, OR explain the evolution of varied structures (with defined functions) that affected the organisms' survival in a specific environment (e.g., giraffe, wind pollination of flowers).* |

3. NATURAL SELECTION
   1) Explain the concept of natural selection.
   2) Explain the diversity and unity of past and present life forms on Earth using currently accepted theories.
   3) Recognize how a species chance of survival increases with each variation of an organism within the species, and explain how, in the event of a major global change, the great diversity of species on Earth, the greater the chance for survival of life.
   4) Analyze present day data and research in areas, including antibiotic resistance in bacteria, changes in viral genomes, such as bird flu, DNA sequencing, and relate it to the concepts of natural selection.
   5) Identify and describe ways genes may be changed and combined to create genetic variation within a species.
   6) Explain that gene mutations and new combinations may have a variety of effects on the organism, including positive and negative ones, or none at all.
   7) Explain the concepts of Mendelian genetics.
   8) Use pedigree charts and Punnett Squares to determine patterns of inheritance.

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| *9)* | *Given a scenario, provide evidence that demonstrates how sexual reproduction results in a great variety of possible gene combinations and contributes to natural selection (e.g., Darwin's finches, isolation of a species, Tay Sach's disease).* |

## LS4 - Humans are similar to other species in many ways, and yet are unique among Earth's life forms.

1. BEHAVIOR
   1) Recognize that the immune system, endocrine system, and nervous system can affect the homeostasis of an organism.
   2) Describe how the functions of all the human body systems are interrelated at a chemical level and how they maintain homeostasis.

2. DISEASE
   1) Explain that disease in organisms can be caused by intrinsic failures of the system or infection by other organisms, and describe as well as provide examples of how some diseases are caused by: the breakdown in cellular function, congenital conditions, genetic disorders, malnutrition, and emotional health, including stress.
   2) Explain that vaccines were developed to reduce or eliminate diseases, and provide examples of how these medical advances have proven to be successful.
   3) Describe and provide examples of how new medical techniques, efficient health care delivery systems, improved sanitation, and a more complete understanding of the nature of disease provides today's humans a better chance of staying healthier than their forebears.
   4) Describe how some drugs mimic or block the molecules involved in transmitting nerve or hormone signals and explain how this disturbs the normal operations of the brain and body.

5) Explain that gene mutation in a cell can result in uncontrolled division, which is called cancer and describe how exposure of cells to certain chemicals and radiation increase mutation, and thus the chance for cancer.

*6) Use evidence to make and support conclusions about the ways that humans or other organisms are affected by environmental factors or heredity (e.g., pathogens, diseases, medical advances, pollution, mutations).*

3. HUMAN IDENTITY
   1) Describe how the length and quality of human life are influenced by many factors, including sanitation, diet, medical care, gender, genes, and environmental conditions and personal health behaviors.
   2) Explain how the immune system functions to prevent and fight disease.

*3) Explain how the immune system, endocrine system, or nervous system works and draw conclusions about how systems interact to maintain homeostasis in the human body.*

## LS5 – **The growth of scientific knowledge in Life Science has been advanced through the development of technology and is used (alone or in combination with other sciences) to identify, understand and solve local and global issues.**

1. DESIGN TECHNOLOGY
   1) Describe ways in which technology has increased our understanding of the life sciences.
   2) Understand that technology is designed with a particular function in mind, and principles of life science are useful in creating technology for the life sciences.

2. TOOLS
   1) Describe the use and benefits of equipment such as, light microscopes, transmission electron microscopes, scanning electron microscopes, spectrophotometers, probes, and robotics to the study of the life sciences.

### 3. SOCIAL ISSUES (LOCAL AND GLOBAL)

MEDICAL TECHNOLOGIES

1) Describe ways technology can support and improve our understanding of environmental issues.
2) Describe aspects of the medical system available to help people in New Hampshire, including: prevention programs, vaccines and pharmaceuticals, hospitals and rehabilitation facilities.

BIOTECHNOLOGIES

3) Recognize that biotechnology is used in many areas, such as agriculture, pharmaceuticals, the environment, and genetic engineering, and understand that it requires extensive knowledge of the systems being changed.
4) Explain how advances in agriculture made using biotechnology have directly affected the food production over the past 100 years, and that this change has profoundly affected societies all over the globe, making larger populations and urban centers a possibility.

4. CAREER AND TECHNICAL EDUCATION CONNECTIONS
   1) Explain the kinds of applications of knowledge and skills necessary for jobs/careers specific to the life sciences.

# Physical Science

## PS1 – All living and nonliving things are composed of matter having characteristic properties that distinguish one substance from another (independent of size/amount of substance).

1. COMPOSITION
   1) Recognize and describe the structure of an atom and explain how the major components interact with one another.
   2) Recognize how elements are arranged in the periodic table, and explain how this arrangement illustrates the repeating patterns among elements with similar properties, such as the relationship between atomic number and atomic mass.
   3) Explain that neutrons and protons are made up of even smaller constituents.
   4) Define isotopes, recognize that most elements have two or more isotopes, and explain that although the number of neutrons has little affect on how the atom interacts with others, they do affect the mass and stability of the nucleus.

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| *5)* | *Scientific thought about atoms has changed over time. Using information (narratives or models of atoms) provided, cite evidence that changed our understanding of the atom and the development of atomic theory.* |
| *6)* | *Model and explain the structure of an atom or explain how an atom's electron configuration, particularly the outermost electron(s), determines how that atom can interact with other atoms.* |

2. PROPERTIES
   1) Explain that the physical properties of a compound are determined by its molecular structure and the interactions among the molecules.
   2) Determine whether an atom is either electrically neutral or an ion by referring to the its number of electrons.
   3) Explain how the chemical properties of an element are governed by the electron configuration of atoms, and describe how atoms interact with one another by transferring or sharing the outermost electrons.
   4) Explain that radioactive materials are unstable and undergo spontaneous nuclear reactions, which emit particles and/or wavelike radiation.
   5) Explain that states of matter rely on the arrangement and motion of molecules, and differentiate between the structures of solids, liquids, and gases.

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| *6)* | *Use physical and chemical properties as determined through an investigation to identify a substance.* |
| 7) | *Explain how properties of elements and the location of elements on the periodic table are related.* |

## PS2 – Energy is necessary for change to occur in matter. Energy can be stored, transferred and transformed, but cannot be destroyed.

1. CHANGE

1) Recognize and explain that atoms may be bonded together into molecules or formula units (crystalline solids).
2) Recognize that atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus and explain that the outer electrons govern the chemical properties of an element.
3) Explain that compounds are formed through both ionic and covalent bonding.
4) Recognize that the rates of chemical reactions can vary greatly, and identify the factors that influence these reaction rates, such as how often the reacting atoms and molecules encounter one another, the temperature, and the properties of the reacting species, including shape.

*5) Explain relationships between and among electric charges, magnetic fields, electromagnetic forces, and atomic particles.*

2. CONSERVATION
   1) Explain that chemical reactions either release or consume energy.
   2) Explain that chemical reactions can be accelerated by catalysts, such as enzymes.
   3) Recognize that a large number of important reactions involve the transfer of either electrons or hydrogen ions between reacting ions, molecules, or atoms.
   4) Identify the variety of structures that may be formed from the bonding of carbon atoms, and describe their roles in various chemical reactions, including those required for life processes.

   *5) Demonstrate how transformations of energy produce some energy in the form of heat and therefore the efficiency of the system is reduced (chemical, biological, and physical systems).*

3. ENERGY
   1) Explain that all energy can be considered to be either kinetic energy, potential energy, or energy contained by a field.
   2) Provide examples of how kinetic and potential energy can be transformed from one to the other.
   3) Describe how the energy associated with individual atoms and molecules can be used to identify the substances they comprise; and explain that each kind of atom or molecule can gain or lose energy only in particular discrete amounts, absorbing and emitting light only at wavelengths corresponding to these amounts.
   4) Explain the range of the electromagnetic spectrum as it relates to both wavelength and energy, and provide examples of practical applications of the different wavelengths in the spectrum.
   5) Recognize that the human eye can only see a narrow range of wavelengths within the electromagnetic spectrum; and explain how the variations of wavelength within that range of visible light are perceived as differences in color.
   6) Describe the relationship between heat and temperature, explaining that heat energy consists of the random motion and vibrations of atoms, molecules, and ions and that the higher the temperature, the greater the atomic or molecular motion.
   7) Explain that waves, such as light, seismic, sound waves, have energy and can transfer energy when they interact with matter.
   8) Explain that nuclear reactions convert a fraction of the mass of interacting particles into energy and release much greater amounts of energy than atomic interactions.
   9) Describe how electrons flow easily in some materials, such as metals, whereas in insulating materials, such as glass, they can hardly flow at all.

   *10) Using information provided about chemical changes, draw conclusions about the energy flow in a given chemical reaction (e.g., exothermic reactions, endothermic reactions).*

## PS3 - The motion of an object is affected by force.

1. FORCES
   1) Explain that magnetic forces are related to the action of electrons and can be thought of as different aspects of a single electromagnetic force; and describe how the interplay of these forces is the basis for electric motors, generators, radio, television, and many other modern technologies.
   2) Recognize that the strength of the electric force between two charged objects is proportional to the charges and, as with gravitation, is inversely proportional to the square of the distance between them.
   3) Recognize that the strength of the gravitational force between two masses is proportional to the masses and inversely proportional to the square of the distance between them.
   4) Compare the strength of nuclear, electromagnetic and gravitational forces; and explain that the strength of nuclear forces account for the great amounts of energy released from the nuclear reactions in atomic or hydrogen bombs, and in the Sun and other stars.
   5) Recognize that electromagnetic forces exist within and between atoms.
   6) Recognize that different kinds of materials respond to electric forces in various ways, and differentiate between insulators, semiconductors, conductors and superconductors.
   7) Describe the difference between materials that contain equal proportions of positive and negative charges and those that have a very small excess or deficit of negative charges.

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   | *8) Given information (e.g., graphs, data, diagrams), use the relationships between or among force, mass, velocity, momentum, acceleration to predict and explain the motion of objects.* |

2. MOTION
   1. Interpret and apply the laws of motion to determine the effects of forces on the motion of objects.
   2. Recognize that apparent changes in wavelength can provide information about changes in motion, explain that the observed wavelength of a wave depends upon the relative motion of the source and the observer, and relates these to the differences between shorter and longer wavelengths.

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   | *3. Apply the concepts of inertia, motion, and momentum to predict and explain situations involving forces and motion, including stationary objects and collisions.* |
   | *4. Explain the effects on wavelength and frequency as electromagnetic waves interact with matter (e.g., light diffraction, blue sky).* |

## PS4 - The growth of scientific knowledge in Physical Science has been advanced through the development of technology and is used (alone or in combination with other sciences) to identify, understand and solve local and global issues.

1. DESIGN TECHNOLOGY
   1) Recognize the basic principles of energy, work and power are related to design technology.

2. TOOLS
   1) Identify tools, such as thermostats and thermal sensors, and explain their use in environmental control systems.

3. SOCIAL ISSUES (LOCAL & GLOBAL)

ENERGY, POWER AND TRANSPORTATION

1) Explain that power systems have a source of energy, a process, loads, and some have a feedback system.
2) Demonstrate and explain how an engine converts chemical energy in the form of fuel, into mechanical energy in the form of motion.
3) Calculate the efficiency of an engine, and explain why a perfectly efficient engine is impossible.
4) Explain the relationship between energy and power.

MANUFACTURING

5) Explain the benefits of standardization of parts.

4. CAREER TECHNICAL EDUCATION CONNECTIONS
   1) Explain the kinds of applications of knowledge and skills necessary for jobs/careers specific to the physical sciences.