Science: Grade 9 - 12

Key Scientific Concepts

In each DoDEA high school science course, students further the development of major concepts and processes including:

- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, equilibrium and measurement
- Theories of evolution such as biological, chemical and geological
- Form and function

Standards Included in Every Course

Included in every high school science course are the strands of scientific inquiry, the history and nature of science, science in personal and social perspectives, science and technology, and specific content standards. These standards provide all students with a facility in scientific investigations and an ability to make connections across the sciences, mathematics, and technology.

Each science course contributes to the student's content knowledge, the development of process skills, and the development of science literacy, to make the study of science a worthwhile lifetime endeavor. Specific courses engage students in deepening their knowledge, skills and understandings related to the standards.

DODEA High School Science Courses

Courses that directly address and support the DoDEA high school science standards and provide students with optional and expanded opportunities for learning in specific science areas are:

- Biology, Human Anatomy & Physiology, Marine Biology, Oceanography, AP Biology,
- Environmental Science
- Physics Applications in the Community; Physics; AP Physics B, AP Physics C
- Chemistry Applications in the Community; Chemistry, AP Chemistry
- Earth and Space Science, Astronomy
- Science Technology Society, Science Research

Strand:

S1 Scientific Inquiry

The student extends their understanding of scientific inquiry and their ability to conduct scientific investigations; that is, the student:

Standards:

S1a: constructs questions that initiate and guide scientific investigations.

S1b: designs and conducts scientific investigations using established procedures that are safe, humane, and ethical.

S1c: uses technology and mathematics to systematically gather, record, analyze, explain, and interpret data.

S1d: formulates and revises scientific conclusions, explanations and models (physical, conceptual, mathematical) based on scientific knowledge, logic, and evidence.

S1e: recognizes, analyzes and evaluates alternative explanations and models.

S1f: evaluates and defends scientific arguments, acknowledging references and contributions of others.

S1g: communicates the scientific inquiry process using appropriate scientific language and mathematics.

Strand:

S2 History and Nature of Science

The student demonstrates understanding of science as a human endeavor, examining the nature of scientific knowledge and historical perspectives; that is, the student:

Standards:

S2a: describes how the work of scientists is influenced by their ethical standards and by societal, cultural, and personal beliefs, and how scientists use the habits of mind (such as: reasoning, insight, creativity, intellectual honesty, tolerance for ambiguity and openness to new ideas) in their work.

S2b: compares and contrasts the difference between science and other ways of knowing through use of empirical standards, logical arguments, and skepticism.

S2c: assesses the work of scientists showing that all scientific ideas depend on experimental and observational confirmation and are subject to change as new evidence becomes available.

S2d: describes the contributions of diverse cultures to scientific knowledge and the changes to scientific thinking that evolve over time, building upon earlier knowledge.

Strand:

S3 Science in Personal and Social Perspectives

The student demonstrates an understanding of the impact each individual, community, and human enterprise has on natural conditions and resources from local, national, and global perspectives; that is, the student:

Standards:

S3a: employs the tenets of personal and community health, safety and resource conservation.

S3b: identifies, accesses and uses data to construct explanations about the characteristics, rates, and sources of changes in populations, natural resources, and environmental quality.

S3c: assesses potential danger and risk of natural and human-induced hazards.

S3d: analyzes the relationships among technological, social, political, and economic changes and the impact on humans and the environment.

Strand:

S4 Science and Technology

The student demonstrates abilities of technological design and understandings about science, engineering and technology; that is, the student:

Standards:

S4a: uses technology to perform scientific investigations to secure valid and reliable results.

S4b: identifies and/or constructs a problem or need in relation to technological designs; proposes new designs and chooses between alternative solutions.

S4c: constructs understandings about the fields of science and engineering, the interrelationships between science and technology, and explains their contribution to society.

S4d: analyzes innovations in science and technology with respect to alternatives, risks, costs and benefits to society and the environment.

Strand:

S5 Biology The student demonstrates a conceptual understanding of the organization of life on Earth; that is, the student:

Standards:

S5a: describes, analyzes and compares structure, function, and organization of various cells.

- All living organisms are made of cells. Cells are composed of a small number of chemical elements mainly carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulfur. Carbon atoms can easily bond to several other carbon atoms in chains and rings to form the large complex molecules of life.
- Every cell is covered by a selectively permeable membrane that controls what can enter and leave the cell. In all but quite primitive cells, a complex network of proteins provides organization and shape and, for animal cells, movement.
- Within every cell are specialized parts for the containment of hereditary material, energy transfer, protein building, waste disposal, information feedback, and even movement. In addition, most cells both individually and in groups in multicellular organisms perform some specialized function that others do not.
- Communication between cells is required to coordinate their diverse activities. Some cells secrete substances that spread only to nearby cells. Others secrete hormones, special molecules that are carried in the bloodstream to widely distributed cells that have specific receptor sites to which they attach. Along nerve cells, electrical impulses carry information much more rapidly than is possible by diffusion or blood flow.

S5b: communicates an understanding of the biochemistry of life including organic compounds, enzymes, cellular respiration and photosynthesis.

- Chemical bonds between atoms of carbon-containing (organic) molecules can be used to assemble larger macromolecules with biological activity (including proteins, DNA, carbohydrates, and lipids).
- The work of the cell is carried out by the many different types of molecules it assembles, mostly proteins. Protein molecules are long, usually folded chains made from 20 different kinds of amino-acid molecules. The function of each protein molecule depends on its specific sequence of amino acids and the shape the chain takes is a consequence of attractions between the chain's parts.
- Complex interactions among the different kinds of molecules in the cell cause distinct cycles of activities, such as growth and division. Cell behavior can also be affected by molecules from other parts of the organism or even other organisms.
- Cell functions are regulated. Regulation occurs both through changes in the activity of the functions performed by proteins and through the selective expression of individual genes. This regulation allows cells to respond to their environment and to control and coordinate cell products, growth and division.
- For the body to use food for energy and building materials, the food must be broken down through a series of biochemical processes into molecules that are absorbed and transported to cells.

- In some animals and humans to release energy from food, oxygen must be supplied to cells, and carbon dioxide removed. Lungs take in oxygen for the combustion of food and eliminate the carbon dioxide produced. The exchange of the two gases takes place in the alveoli of the lungs. However, metabolic processes can change when there is limited oxygen or hostile environments.
- The processes of photosynthesis and respiration in plants transfer energy from the Sun to living systems (e.g., chloroplasts in plant cells use energy from sunlight to combine molecules of carbon dioxide and water into complex, energy rich organic compounds, and release oxygen into the environment).

S5c: describes the behavior of organisms and hypothesizes the relationship to nervous and endocrine systems and various external stimuli.

- Characteristics can be observed at molecular, cellular, and whole-organism levels—in structure, chemistry, or behavior. These characteristics strongly influence what capabilities an organism will have and how it will react.
- Multicellular organisms have nervous systems that help an organism adjust to changes in both its internal and external environments. Nervous systems are formed from specialized cells that carry impulses rapidly through their long cell extensions called axons. The nerve cells communicate with each other by secreting specific excitatory and inhibitory molecules. In sense organs, specialized cells detect light, sound, and specific chemicals that enable organisms to monitor what is going on in their environment.
- The nervous system works by electrochemical signal transport from one nerve to the next. The hormonal system exerts its influences through chemicals that circulate in the blood. These two systems also affect each other by coordinating body functions.
- Organisms have behavioral responses to internal changes and to external stimuli. Responses to external stimuli can result from interactions with the organism's own species and others, as well as environmental changes. These responses either can be innate or learned.
- Drugs, structural injuries, and chemical imbalances may mimic and/or block the molecules involved in transmitting nerve or hormone signals and therefore disturb normal operations of the brain and body.

S5d: elaborates on the principles of genetics and explains the role of DNA, genes, chromosomes, and mutation in reproduction and heredity.

- The many body cells in an individual can be very different from one another, even though they are all descended from a single stem cell and thus have essentially identical genetic instructions. Different genetic instructions are used in different types of cells, influenced by the cell's environment and past history.
- The genetic information encoded in DNA molecules provides instructions for assembling protein molecules. The individual units that make up the genetic code are virtually the same for all life forms. Before a cell divides, the instructions are duplicated so that each of the

two new cells gets all the necessary information to perform life processes.
- The information passed from parents to offspring is coded in DNA molecules through a series of units called genes.
- Genes are segments of DNA molecules. Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it. The resulting features may help, harm, or have little or no effect on the offspring's success in its environment.
- The sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations in the offspring of any two parents.
- Changes in DNA (mutations) occur spontaneously at low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Only mutations in germ cells can create the variation that changes an organism's offspring.

S5e: relates theories of biological evolution to geologic time and addresses speciation, biodiversity, natural selection, and biological classification.
- Heritable characteristics influence what capabilities an organism will have and how it will react, and therefore influence how likely it is to survive and reproduce.
- Offspring of advantaged individuals, in turn, are more likely than others to survive and reproduce in that environment. The proportion of individuals that have advantageous characteristics will increase.
- New heritable characteristics can result from new combinations of existing genes or from mutations of genes in reproductive cells.
- Natural selection leads to organisms that are well suited for survival in particular environments. When an environment changes, the survival value of some inherited characteristics may change.
- Natural selection and its long-term consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the molecular similarities observed among the diverse species of living organisms.
- Biological changes over time appear to be like the growth of a bush: Some branches survive from the beginning with little or no change, many die out altogether, and others branch repeatedly, sometimes giving rise to more complex organisms. Thus, the theory of evolution builds on what already exists, so the more variety there is, the more there can be in the future. However, long-term progress is not necessarily in some set direction.
- The basic idea of biological evolution is that the Earth's present-day species developed from earlier, distinctly different species.

S5f: examines ecology as interrelationships of biotic and abiotic factors and explains the transfer of matter and energy within ecosystems.
- The interrelationships and interdependencies of organisms and environments establish a variety of ecosystems.
- Understanding any one part of an ecosystem requires knowledge of how the parts interact with each other.

- The amount of life any environment can support is limited by the available energy, water, oxygen, and minerals, and by the ability of ecosystems to recycle the residue of dead organic materials.
- Human activities can deliberately or inadvertently change the equilibrium in ecosystems. An ecosystem in equilibrium may return to the same state of equilibrium if the disturbances it experiences are small. However, large disturbances may also cause a shift in the equilibrium so that ecosystems eventually settle into a different new state of equilibrium.
- In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution. Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium.
- The complexity and organization of organisms accommodate the need for obtaining, transforming, transporting, releasing, and eliminating the matter and energy used to sustain the organism. Plants alter the Earth's atmosphere by removing carbon dioxide from it, using the carbon to make sugars and releasing oxygen.
- As matter and energy flows through different levels of organization of living systems – cells, tissues, organs, organisms, communities – and between living systems and the physical environment, chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy into the environment as heat. Matter and energy are conserved in each change.

Strand:

S6 Physics

The student demonstrates a conceptual understanding of the organization and interaction of matter and energy, and motion and forces; that is, the student:

Standards:

S6a: communicates an understanding of atomic and subatomic structure, addressing parts and properties of the atom, electron configuration, nuclear forces, radioactivity, and nuclear reactions.

- Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and electrons holds the atom together.
- The atom's nucleus is composed of protons and neutrons, which are much more massive than electrons. When an element has atoms that differ in the number of neutrons, these atoms are called different isotopes of the element.
- Neutrons have a mass that is nearly identical to that of protons, but neutrons have no electric charge. Although neutrons have little effect on how an atom interacts with others, they do affect the mass and stability of the nucleus. Isotopes of the same element have the same number of protons (and therefore of electrons) but differ in the number of neutrons.
- Atoms often join with one another in various combinations in distinct molecules or in repeating three-dimensional crystal patterns. An enormous variety of biological, chemical, and physical phenomena can

be explained by changes in the arrangement and motion of atoms and molecules.

- Energy levels are associated with configurations of atoms and molecules. Some changes of configuration require an input of energy whereas others release energy.
- The nuclear forces that hold the nucleus of an atom together, at nuclear distances, are usually stronger than the electric forces that would make it fly apart.
- Nuclear reactions convert a fraction of the mass of interacting particles into energy, and they can release much greater amounts of energy that atomic interactions. Fission is the splitting of a large nucleus into smaller pieces. Fusion is the joining of two nuclei at extremely high temperature and pressure.
- Radioactive isotopes are unstable and undergo spontaneous nuclear reactions, emitting particles and/or wavelike radiation.

S6b: analyzes and explains the relationship between structure and properties of matter (ions, molecules, compounds, elements) and uses those relationships to predict chemical properties of elements and placement on the Periodic Table.

- The configuration of atoms in a molecule determines the molecule's properties. Shapes are particularly important in how large molecules interact with others.
- When elements are listed in order by the masses of their atoms, the same sequence of properties appears over and over again in the list. The list is known as the Periodic Table.
- Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus. These outer electrons govern the chemical properties of the element.
- An element is composed of a single type of atom. When elements are listed in order according to the number of protons, repeated patterns of physical and chemical properties identify families of elements with similar properties.

S6c: articulates and demonstrates the principles of motions and forces and applies them to examples of impact on objects.

- An object's motion may be described by measurements of position, velocity, and acceleration from a specific point.
- Objects change their motion only when a net force is applied. The magnitude of the change in motion can be calculated using the relationship $F = ma$, which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object.
- Frictional force occurs between two objects in contact with each other, opposes the direction of motions and complicates the description of motion.
- The strength of the gravitational attractive force between two objects is proportional to their masses and inversely proportional to the square of the distance between them.
- The electrostatic force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel.

The strength of the force is proportional to the charges, and, as with gravitation, inversely proportional to the square of the distance between them.

- Electricity and magnetism are two aspects of a single phenomenon. Moving electric charges produce magnetic fields, and moving magnets can be used to produce electrical current. The current can flow through a complete circuit and is proportional to voltage and inversely proportional to the total resistance.
- Electrostatic forces acting within and between atoms are vastly stronger than the gravitational forces acting between the atoms. At the atomic level, electric forces between oppositely charged electrons and protons hold atoms and molecules together and thus are involved in all chemical reactions. On a larger scale, these forces hold solid and liquid materials together and act between objects when they are in contact—as in sticking or sliding friction.

S6d: analyzes the distinctions among thermal, potential, and kinetic energy and explains conservation of energy and its associated increase in disorder.

- Thermal energy consists of random motion and the vibration of atoms, molecules, and ions. The higher the temperature, the greater the atomic or molecular motion.
- All energy can be considered to be either kinetic energy, which is the energy of motion; potential energy, which is the stored energy dependent on relative position; or energy contained by a field, such as electromagnetic waves.
- The total energy of the universe is constant; it cannot be created or destroyed (conservation of energy). Energy can be transferred by collisions, as in chemical and nuclear reactions, or by waves, as in sound, light, and other types of radiation.
- In a closed system, everything tends to become less organized over time. Thus, in all energy transfers, the overall effect is that the energy is dispersed. Examples are the transfer of energy from hotter to cooler objects by conduction, radiation, or convection, and the warming of our surroundings when we burn fuels.

S6e: differentiates the interactions between matter and energy and uses waves and wave properties (including light, sound, transverse, longitudinal and electromagnetic waves) to identify matter.

- Each kind of atom or molecule can gain or lose energy only in discrete packets whose magnitudes are inversely proportional to their wavelengths. These atoms and molecules can absorb and emit light only at wavelengths corresponding to these packets and those wavelengths can be used to identify a specific substance.
- Waves, including sound, seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter.
- A wave's speed is the product of its frequency and wavelength. The speed of any wave varies with the substance that it travels through; however, only electromagnetic waves can travel through space and they all travel at the speed of light.

- Waves can superimpose on one another, bend around corners, reflect off surfaces, be absorbed by materials they encounter, and change direction when entering a new material. All these effects vary with wavelength. The observed wavelength of a wave depends upon the relative motion of the source and the observer.
- Electromagnetic waves include radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, x-rays, and gamma rays. Electromagnetic waves result when a charged object is accelerated or decelerated.
- Optics is the study of electromagnetic waves with wavelengths greater than x-rays and shorter than microwaves.

Strand:

S7 Chemistry The student demonstrates a conceptual understanding of the organization and behavior of matter; that is, the student:

Standards:

S7a: communicates an understanding of atomic structure, addressing parts and properties of the atom, electron configuration and nuclear forces.

- Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and electrons holds the atom together.
- The atom's nucleus is composed of protons and neutrons, which are much more massive than electrons. When an element has atoms that differ in the number of neutrons, these atoms are called different isotopes of the element.
- Neutrons have a mass that is nearly identical to that of protons, but neutrons have no electric charge. Although neutrons have little effect on how an atom interacts with others, they do affect the mass and stability of the nucleus. Isotopes of the same element have the same number of protons (and therefore of electrons) but differ in the number of neutrons.
- The nuclear forces that hold the nucleus of an atom together, at nuclear distances, are usually stronger than the electric forces that would make it fly apart. Nuclear reactions convert a fraction of the mass of interacting particles into energy, and they can release much greater amounts of energy than atomic interactions. Fission is the splitting of a large nucleus into smaller pieces. Fusion is the joining of two nuclei at extremely high temperature and pressure, and is the process responsible for the energy of the sun and other stars.
- Radioactive isotopes are unstable and undergo spontaneous nuclear reactions, emitting particles and/or wavelike radiation. The decay of any one nucleus cannot be predicted, but a large group of identical nuclei decay at a predictable rate. This predictability can be used to estimate the age of materials that contain radioactive isotopes.
- Scientists continue to investigate atoms and have discovered even smaller constituents of which neutrons and protons are made.

S7b: analyzes and demonstrates the relationship between structure and properties of matter (ions, molecules, compounds, elements) and uses those relationships to predict chemical properties of elements and their placement on the Periodic Table.

- An element is composed of a single type of atom. When elements are listed in order according to the number of protons (i.e., atomic number), repeating patterns of physical and chemical properties identify families of elements with similar properties. This “Periodic Table” is a consequence of the repeating pattern of outermost electrons and their permitted energies.
- Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus. These outer electrons govern the chemical properties of the element.
- The configuration of atoms in a molecule determines the molecule’s properties. Shapes are particularly important in how large molecules interact with others.
- The physical properties of compounds reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them.
- Solids, liquids, and gases differ in the distances and angles between molecules or atoms and therefore the energy that binds them together. In solids, the structure is nearly rigid; in liquids, molecules or atoms move around each other but do not move apart; and in gases, molecules or atoms move almost independently of each other and are mostly far apart.

S7c: assesses interactions of matter focusing on chemical reactions and bonds and applies the concept of conservation of matter to those interactions.

- Bonds between atoms are created when electrons are paired up by being transferred or shared. A substance composed of a single kind of atom is called an element. The atoms may be bonded together into molecules or crystalline solids. A compound is formed when two or more kinds of atoms bind together chemically.
- The rate of reactions among atoms and molecules depends on how often they encounter one another, which is affected by the concentration, pressure, and temperature of the reacting materials. Some atoms and molecules are highly effective in encouraging the interaction of others.
- Whenever the amount of energy in one place or form diminishes, the amount in other places or forms increases by the same amount.
- Chemical reactions occur all around us – in health care, cooking, cosmetics, and automobiles. Complex chemical reactions involving carbon-based molecules take place constantly in every cell in our bodies.
- Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light. Light can initiate many chemical reactions such as photosynthesis.

- Different energy levels are associated with different configurations of atoms and molecules. Some changes of configuration require an input of energy whereas others release energy.
- When energy of an isolated atom or molecule changes, it does so in a definite jump from one value to another, with no possible values in between. The change in energy occurs when radiation is absorbed or emitted, so the radiation also has distinct energy values. As a result, the light emitted or absorbed by separate atoms or molecules (as in a gas) can be used to identify what the substance is.
- Energy is released whenever the nuclei of very heavy atoms, such as uranium or plutonium, split into middleweight ones, or when very light nuclei, such as those of hydrogen and helium, combine into heavier ones. The energy released in each nuclear reaction is very much greater than the energy given off in each chemical reaction.
- A large number of important reactions involve the transfer of either electrons (oxidation/reduction reactions) or hydrogen ions (acid/base reactions) between reacting ions, molecules, or atoms. In other reactions, chemical bonds are broken by heat or light to form very reactive radicals with electrons ready to form new bonds. Radical reactions control many processes such as the presence of ozone and greenhouse gases in the atmosphere, burning and processing of fossil fuels, the formation of polymers, and explosions.
- Chemical reactions can take place in a wide range of time periods. Reaction rates depend on how often the reacting atoms and molecules encounter one another, on temperature, and on the properties – including shape – of the reacting species.
- Catalysts accelerate chemical reactions. Chemical reactions in living systems are catalyzed by protein molecules called enzymes.

S7d: distinguishes the interactions of matter and energy and demonstrates the impact of variables (temperature, time, etc.) on those interactions.

- The rate of reactions among atoms and molecules depends on how often they encounter one another over time, which is affected by the concentration, pressure, and temperature of the reacting materials. Some atoms and molecules are highly effective in encouraging the interaction of others.
- Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter.
- Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength.
- In metals, electrons flow easily whereas in insulating materials such as glass, they can hardly flow at all. Semiconducting materials have intermediate behavior. At low temperatures some materials become superconductors and offer no resistance to the flow of electrons.

S7e: summarizes and illustrates the conservation of energy, the increase in disorder, and the different types of energy.

- Heat energy in a material consists of the disordered motions of its atoms or molecules. In any interactions of atoms or molecules, the statistical odds are that they will end up with less order than they began—that is, with the heat energy spread out more evenly. With huge numbers of atoms and molecules, the greater disorder is almost certain.
- Transformations of energy usually produce some energy in the form of heat, which spreads around by radiation or conduction into cooler places. Although just as much total energy remains, the energy that is spread out more evenly means less can be done with it.
- Energy can be transferred by collisions in chemical and nuclear reactions, by light waves and other radiations, and in many other ways. As these transfers occur, the matter involved becomes steadily less ordered.
- Everything tends to become less organized and less orderly over time. Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly. The quantity of energy distributed in its own way over time is called entropy.
- All energy can be considered to be kinetic energy, potential energy, or energy contained in a field.

Strand:

S8 Earth and Space Sciences

The student demonstrates a conceptual understanding of the organization of Earth and other celestial bodies; that is, the student:

Standards:

S8a: categorizes the sources and types of energy in the Earth system, identifies the geologic activity (such as volcanoes, plate tectonics, and earthquakes) resulting from or causing that energy, and illustrates the impact of such activity on the inhabitants and the environment.

- Earth systems have internal and external sources of energy, both of which create heat. The sun is the major external source of energy. Two primary sources of internal energy are the decay of radioactive isotopes and the gravitational energy from the Earth's original formation.
- The outward transfer of Earth's internal head drives convection circulation in the mantle that propels the plates across the face of the planet.
- Heating of the Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.
- Global climate is determined by energy transfer from the sun at and near the Earth's surface. This energy transfer is influenced by such factors as cloud cover, the Earth's rotation, and position of mountain ranges.
- The solid crust of the Earth—including both the continents and the ocean basins—consists of separate plates that ride on a denser, hot, gradually deformable layer of the Earth. The crust sections move very slowly, pressing against one another in some places, pulling apart in other places. Ocean-floor plates may slide under continental plates,

sinking deep into the Earth. The surface layers of these plates may fold forming mountain ranges.

- Earthquakes often occur along the boundaries between colliding plates, and molten rock from below creates pressure that is released by volcanic eruptions, helping to build up mountains. Under the ocean basins, molten rock may well up between separating plates to create new ocean floor. Volcanic activity along the ocean floor may form undersea mountains, which can thrust above the ocean's surface to become islands.

S8b: compares and contrasts the composition of Earth materials and the processes within the geochemical cycle that govern their formation (including rocks, minerals, fossils, and other natural resources).

- The formation, weathering, sedimentation, and reformation of rock constitute a continuing "rock cycle" in which the total amount of material stays the same as its forms change. Old rocks at the surface gradually weather and form sediments that are buried, then compacted, heated, and often recrystallized into new rock.
- The slow movement of material within the Earth results from heat flowing out from the deep interior and the action of gravitational forces on regions of different density.
- The Earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on Earth moves among reservoirs in the solid Earth, oceans, atmosphere, and organisms as part of the geochemical cycles.
- Movement of matter between reservoirs is driven by the Earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of the matter. For example, carbon occurs in rocks as limestone, in the atmosphere as carbon dioxide, in water as dissolved carbon dioxide, and in all organisms as complex molecules that control the chemistry of life.
- Every mineral is a product of the redistribution or recombination of its component chemical elements to form a stable substance. The process of mineral formation is known as crystallization. The process is dependent upon the concentration of the chemical elements present and the temperature/pressure conditions.
- Some minerals are very rare and some exist in great quantities, but—for practical purposes—the ability to recover them is just as important as their abundance. As minerals are depleted, obtaining them becomes more difficult. Recycling and the development of substitutes can reduce the rate of depletion.

S8c: investigates and displays the relationships among weather, cloud cover, land features, atmosphere and oceans.

- Weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere. Solar radiation heats the land masses, oceans, and air. Transfer of heat energy at the boundaries between the atmosphere, the land masses, and the oceans results in layers of different temperatures and densities in both

the ocean and atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall—and such circulation, influenced by the rotation of the Earth, produces winds and ocean currents.
- Global climate is determined by energy transfer from the sun at and near the Earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover, and the Earth's rotation, and static conditions such as the position of mountain ranges and oceans.

S8d: presents and critiques theories on origin and evolution of the Earth's systems and other celestial bodies.
- Early in the history of the universe, matter, primarily light hydrogen and helium atoms, clumped together by gravitational attraction to form trillions of stars. Billions of galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of the visible mass in the universe.
- Stars produce energy from nuclear reactions. These and other processes in stars have led to the formation of all the other elements.
- The stars differ from each other in size, temperature, and age, but they appear to be made up of the same elements that are found on the Earth and to behave according to the same physical principles. Unlike our sun, most stars are in systems of two or more stars orbiting around one another.
- The "big bang" theory places the origin of the universe between 10 and 20 billion years ago, when the universe began in a hot dense state. The current theory is that its entire contents expanded explosively from a hot, dense, chaotic mass. Stars condensed by gravity out of clouds of molecules of the lightest elements until nuclear fusion of the light elements into heavier ones began to occur. Fusion released great amounts of energy over millions of years. Eventually, some stars exploded, producing clouds of heavy elements from which other stars and planets could later condense. The process of star formation and destruction continues.
- Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Current methods include use of radioactive isotopes present in rocks.
- Interactions among the solid Earth, oceans, atmosphere, and organisms have resulted in ongoing change of the Earth system. Some changes (e.g., earthquakes, volcanic eruptions) can be observed during one's lifetime while others (e.g., mountain building, plate movements) take place over hundreds of millions of years.

S8e: accesses information about significant space explorations and assesses the value of such explorations.
- The US Space Program has played a significant role in the collection of information about our solar system.
- NASA is a federal agency that leads and directs the US Space Program. It conducts manned (Apollo, Shuttle, International Space Station) and unmanned missions (SETI, Voyager, Mars Project, Hubble Space Telescope,) to explore space.

- The space program contributes to society through the development of commercial products such as a hybrid electric transit bus, portable blood collection products, and a hand-held e-mail device.
- There are cost-benefits and risks associated with sending people into space (e.g., Apollo, Challenger incident).