Science Standards
Grades 9-12

In support of the recommendation by the State Board of Education that all students take at least three years of high school science, nine Core Content Standards are given for grades 9-11. Only three of these Core Content Standards need to be learned ***in depth*** each year. Local school district curriculum teams will decide which of the areas will be learned in grades 9, 10, and 11, depending on students' needs and interests.

Recognizing that many students will take a fourth year of science, standards for crosscutting concepts and abilities apply to all four years of science, grades 9-12. The skills and abilities found in the crosscutting concepts are essential for all students, whether attending college, technical schools, an apprenticeship program, or entering the world of work; hence their inclusion in grades 9-12. Specific content domain standards are not delineated in grade 12 to allow for flexibility in high school course offerings.

As illustrated by the grid below, the three crosscutting EALRs of Systems, Inquiry, and Application are not to be learned in isolation, but rather in conjunction with content in the science domains. Not every topic needs to address all three crosscutting EALRs. But in any given unit, content in Systems, Inquiry, and Application should be experienced in the context of several science lessons so that students can see the commonalities among the domains of science while continuing to learn the fundamental procedural underpinnings that cut across all of the sciences.

Grades 9-12 **EALR 4 Domains of Science**	**EALR 1** **Systems** **SYS**	**EALR 2** **Inquiry** **INQ**	**EALR 3** **Application** **APP**
Physical Science PS1 Newton's Laws PS2 Chemical Reactions PS3 Transformation and Conservation of Energy **Earth and Space Science** ES1 Evolution of the Universe ES2 Energy in Earth Systems ES3 Evolution of the Earth **Life Science** LS1 Processes Within Cells LS2 Maintenance and Stability of Populations LS3 Mechanisms of Evolution	Predictability and Feedback	Conducting Analyses and Thinking Logically	Science, Technology, and Society

Standards for Grades 9-12

EALR 1: Systems

Big Idea: Systems (SYS)

Core Content: *Predictability and Feedback*

In prior grades students learned how to simplify and analyze complex situations by thinking about them as systems. In grades 9-12 students learn to construct more sophisticated system models, including the concept of feedback. Students are expected to determine whether or not systems analysis will be helpful in a given situation and if so, to describe the system, including subsystems, boundaries, flows, and feedbacks. The next step is to use the system as a dynamic model to predict changes. Students are also expected to recognize that even the most sophisticated models may not accurately predict how the real world functions. This deep understanding of systems and ability to use systems analysis is an essential tool both for scientific inquiry and for technological design.

	Content Standards	**Performance Expectations**
	Students know that:	*Students are expected to:*
9-12 SYSA	*Feedback* is a process in which the *output* of a *system* provides information used to regulate the operation of the *system*. *Positive feedback* increases the disturbance to a *system*. *Negative feedback* reduces the disturbance to a *system*.	• Give examples of a positive *feedback system* and *explain* its regulatory mechanism (e.g., global warming causes Earth's ice caps to melt, reflecting less energy to space, increasing temperatures).*a • Give examples of a negative *feedback system* and *explain* its regulatory mechanism (e.g., when a human body overheats, it produces sweat that cools the body by evaporation).*a
9-12 SYSB	Systems thinking can be especially useful in *analyzing* complex situations. To be useful, a *system* needs to be specified as clearly as possible.	• Determine if a *systems* approach will be helpful in answering a *question* or solving a problem.*b • Represent the *system* with a diagram specifying components, boundaries, flows, and *feedbacks*.*a • *Describe* relevant *subsystems* and the larger *system* that contains the *system* being analyzed.*a • Determine how the *system functions* with respect to other *systems*.
9-12 SYSC	In complex *systems*, entirely new and unpredictable *properties* may emerge. Consequently, modeling a complex *system* in sufficient detail to make *reliable* predictions may not be possible.	• Create a simplified *model* of a complex *system*. Trace the possible consequences of a change in one part of the *system* and *explain how* the simplified *model* may not be adequate to reliably *predict* consequences.
9-12 SYSD	*Systems* can be changing or in *equilibrium*.	• *Analyze* whether or not a *system* (e.g., population) is changing or in *equilibrium*. *c • Determine whether a *state of equilibrium* is static or dynamic (e.g., inflows equal outflows). *c

Mathematics Connections

*a	A1.8.A	Analyze a problem situation and represent it mathematically.
	A1.1.A	Select and justify functions and equations to model and solve problems.
*b	A1.8.B	Select and apply strategies to solve problems.
	A1.8.D	Generalize a solution strategy for a single problem to a class of related problems, and apply a strategy for a class of related problems to solve a specific problem.
*c	A1.8.H	Use inductive reasoning about algebra and the properties of numbers to make conjectures, and use deductive reasoning to prove or disprove conjectures.
	A1.7.C	Express arithmetic and geometric sequences in explicit and recursive forms, translate between the two forms, explain how rate of change is represented in each form, and use the forms to find specific terms in the sequence.

EALR 2: Inquiry

Big Idea: Inquiry (INQ)

Core Content: *Conducting Analyses and Thinking Logically*

In prior grades students learned to revise questions so they can be answered scientifically. In grades 9-12 students extend and refine their understanding of the nature of inquiry and their ability to formulate questions, propose hypotheses, and design, conduct, and report on investigations. Refinement includes an increased understanding of the kinds of questions that scientists ask and how the results reflect the research methods and the criteria that scientific arguments are judged by. Increased abilities include competence in using mathematics, a closer connection between student-planned investigations and existing knowledge, improvements in communication and collaboration, and participation in a community of learners.

	Content Standards	**Performance Expectations**
	Students know that:	*Students are expected to:*
9-12 INQA Question	Scientists *generate* and *evaluate* *questions* to *investigate* the *natural world*.	• *Generate* and *evaluate* a *question* that can be answered through a scientific *investigation*. Critique *questions generated* by others and *explain* whether or not the *questions* are scientific.*a
9-12 INQB Investigate	Scientific progress requires the use of various methods appropriate for answering different kinds of research *questions*, a thoughtful plan for gathering data needed to answer the *question*, and care in collecting, *analyzing*, and displaying the data.	• Plan and conduct a scientific *investigation*, choosing a method appropriate to the *question* being asked. • Collect, *analyze*, and display data using calculators, computers, or other technical devices when available.*b
9-12 INQC Explain	*Conclusions* must be logical, based on *evidence*, and consistent with prior *established* knowledge.	• Draw *conclusions* supported by *evidence* from the *investigation* and consistent with established scientific knowledge.*c • Analyze alternative explanations and decide which best fits the data and *evidence*.*d
9-12 INQD Communicate Clearly	The methods and procedures that scientists use to obtain *evidence* must be clearly reported to enhance opportunities for further *investigation*.	• Write a detailed laboratory report that includes: the *question* that motivated the study, a justification for the kind of *investigation* chosen, *hypotheses* (if any), a description of what was done, a summary of data in tables and graphs, and a *conclusion*, based on the *evidence*, that responds to the *question*.
9-12 INQE Model	The essence of scientific *investigation* involves the development of a *theory* or conceptual *model* that can *generate* testable predictions.	• Formulate one or more *hypotheses* based on a *model* or *theory* of a causal *relationship*. Demonstrate creativity and critical thinking to formulate and *evaluate* the *hypotheses*.
9-12 INQF Communicate	*Science* is a human endeavor that involves logical reasoning and creativity and entails the testing, revision, and occasional discarding of theories as new *evidence* comes to light.	• *Evaluate* an *investigation* to determine if it was a *valid* means of answering the *question*, and whether or not the results were *reliable*. *e • *Describe* the development of a scientific *theory* that illustrates logical reasoning, creativity, testing, revision, and replacement of prior *ideas* in light of new *evidence*.

	Content Standards	Performance Expectations
9-12 INQG Intellectual Honesty	Public *communication* among scientists is an essential aspect of research. Scientists *evaluate* the *validity* of one another's *investigation*s, check the *reliability* of results, and *explain* inconsistencies in findings.	• Participate in a scientific discussion about one's own *investigation*s and those performed by others. • Respond to *questions* and criticisms, and if appropriate, revise explanations based on these discussions.
9-12 INQH Intellectual Honesty	Scientists carefully *evaluate* sources of information for *reliability* before using that information. When referring to the *ideas* or findings of others, they cite their sources of information.	• Provide appropriate citations for all *ideas*, findings, and information used in any and all written reports. • *Explain* the consequences for failure to provide appropriate citations.

Mathematics Connections

*a	8.5.H	Make and test conjectures based on data or information collected from explorations and experiments.
*b	8.5.D	Represent a problem situation, describe the process used to solve the problem, and verify the reasonableness of the solution.
	A1.8.A	Analyze a problem situation and represent it mathematically.
	A2.1.A	Select and justify functions and equations to model and solve problems.
	A2.6.F	Calculate and interpret measures of variability and standard deviation, and use these measures to describe and *compare* data sets.
	A1.8.F	Summarize mathematical ideas with precision and efficiency for a given audience and purpose.
	A1.6.E	Describe the correlation of data in scatter plots in terms of strong or weak and positive or negative.
*c	A1.6.B	Make valid inferences and draw conclusions based on data.
	A1.8.G	Synthesize information to draw conclusions and evaluate the arguments and conclusions of others.
*e	A1.8.C	Evaluate a solution for reasonableness, verify its accuracy, and interpret the solution in the context of the original problem.
*d	A1.6.D	Find the equation of a linear function that best fits bivariate data that are linearly related, interpret the slope and the y-intercept of the line, and use the equation to make predictions.
	A1.8.H	Use inductive reasoning about algebra and the properties of numbers to make conjectures, and use deductive reasoning to prove or disprove conjectures.
*e	G.7.C	Evaluate a solution for reasonableness, verify its accuracy, and interpret it in the context of the original problem.

Note: This standard is closely aligned to Mathematics Core Processes A1.8 and G.7.

EALR 3: Application

Big Idea: Application (APP)

Core Content: *Science, Technology, and Society*

In prior grades students learn to work with other members of a team to apply the full process of technological design and relevant science concepts to solve problems. In grades 9-12 students apply what they have learned to address societal issues and cultural differences. Students learn that science and technology are interdependent, that science and technology influence society, and that society influences science and technology. Students continue to increase their abilities to work with other students and to use mathematics and information technologies (when available) to solve problems. They transfer insights from those increased abilities when considering local, regional, and global issues. These insights and capabilities will help prepare students to solve societal and personal problems in future years.

	Content Standards	**Performance Expectations**
	Students know that:	*Students are expected to:*
9-12 APPA	*Science* affects society and cultures by influencing the way many people think about themselves, others, and the *environment*. Society also affects *science* by its prevailing views about what is important to study and by deciding what research will be funded.	• *Describe* ways that scientific *ideas* have influenced society or the development of differing cultures. • List *questions* that scientists *investigate* that are stimulated by the needs of society (e.g., medical research, *global climate* change).
9-12 APPB	The *technological design process* begins by defining a problem in terms of *criteria* and *constraints*, conducting research, and generating several different *solutions*.	• Work collaboratively with other students to *generate ideas* for solving a problem. Identify *criteria* and *constraints*, research the problem, and *generate* several possible *solutions*.
9-12 APPC	Choosing the best *solution* involves comparing alternatives with respect to *criteria* and *constraints*, then building and testing a *model* or other representation of the final design.	• Choose the best *solution* for a problem, create a model or drawing of the final design, and devise a way to test it. Redesign the *solution*, if necessary, then present it to peers.*b
9-12 APPD	The ability to solve problems is greatly enhanced by use of mathematics and information technologies.	• Use proportional reasoning, functions, graphing, and estimation to solve problems.*a*b*c • Use computers, probes, and software when available to collect, display, and analyze data.
9-12 APPE	Perfect *solutions* do not exist. All technological *solutions* involve *trade-offs* in which decisions to include more of one quality means less of another. All *solutions* involve consequences, some intended, others not.	• *Analyze* a societal issue that may be addressed through *science* and/or *technology*. *Compare* alternative *solutions* by *considering trade-offs* and unintended consequences (e.g., removing dams to increase salmon spawning).
9-12 APPF	It is important for all citizens to *apply science* and *technology* to critical issues that influence society.	• Critically *analyze* scientific information in current events to make personal choices or to understand public-policy decisions.*d

Mathematics Connections

*a	A1.8.A	Analyze a problem situation and represent it mathematically.
*b	A1.8.C	Evaluate a solution for reasonableness, verify its accuracy, and interpret it in the context of the original problem.
*c	A1.3B.	Represent a function with a symbolic expression, as a graph, in a table, and using words, and make connections among these representations.
*d	A1.8.G	Synthesize information to draw conclusions and evaluate the arguments and conclusions of others.

EALR 4: Physical Science

Big Idea: Force and Motion (PS1)

Core Content: *Newton's Laws*

In prior grades students learned to measure, record, and calculate the average speed of objects, and to tabulate and graph the results. In grades 9-11 students learn to apply Newton's Laws of Motion and Gravity both conceptually and quantitatively. Students are able to calculate average speed, I, and acceleration. Students also develop an understanding of forces due to gravitational and electrical attraction. These fundamental concepts enable students to understand the forces that govern the observable world and provide a foundation for a full course in physics.

	Content Standards	**Performance Expectations**
	Students know that:	*Students are expected to:*
9-11 PS1A	*Average velocity* is defined as a change in position with respect to time. *Velocity* includes both *speed* and direction.	• Calculate the *average velocity* of a moving object, given the object's change in position and time. ($v = x_2-x_1/ t_2-t_1$) *a • *Explain how* two objects moving at the same *speed* can have different velocities.
9-11 PS1B	*Average acceleration* is defined as a change in *velocity* with respect to time. *Acceleration* indicates a change in *speed* and/or a change in direction.	• Calculate the *average acceleration* of an object, given the object's change in *velocity* with respect to time. ($a = v_2-v_1/ t_2-t_1$) *a • *Explain how* an object moving at constant *speed* can be *accelerating.**b
9-11 PS1C	An object at rest will remain at rest unless acted on by an unbalanced *force*. An object in *motion* at constant *velocity* will continue at the same *velocity* unless acted on by an unbalanced *force*. (Newton's *First Law of Motion*, the *Law of Inertia*)	• Given specific scenarios, *compare* the *motion* of an object acted on by balanced *forces* with the *motion* of an object acted on by unbalanced *forces*.
9-11 PS1D	A net *force* will cause an object to accelerate or change direction. A less massive object will *speed* up more quickly than a more massive object subjected to the same *force*. (Newton's *Second Law* of *Motion*, F=ma)	• *Predict* how objects of different *masses* will *accelerate* when subjected to the same *force*. • Calculate the *acceleration* of an object, given the object's *mass* and the net *force* on the object, using Newton's *Second law* of *Motion* (F=ma).*c
9-11 PS1E	Whenever one object exerts a *force* on another object, a *force* of equal magnitude is exerted on the first object in the opposite direction. (Newton's *Third Law* of *Motion*)	• Illustrate with everyday examples that for every action there is an equal and opposite reaction (e.g., a person exerts the same *force* on the Earth as the Earth exerts on the person).
9-11 PS1F	*Gravitation* is a universal attractive *force* by which objects with *mass* attract one another. The gravitational *force* between two objects is proportional to their *masses* and inversely proportional to the square of the distance between the objects. (Newton's *Law* of *Universal Gravitation*)	• *Predict* how the gravitational *force* between two bodies would differ for bodies of different *masses* or different distances apart.*d • *Explain how* the *weight* of an object can change while its *mass* remains constant.

	Content Standards	Performance Expectations
9-11 PS1G	Electrical *force* is a *force* of nature independent of *gravity* that exists between charged objects. Opposite charges attract while like charges repel.	• *Predict* whether two charged objects will attract or repel each other, and *explain* why.
9-11 PS1H	Electricity and magnetism are two aspects of a single *electromagnetic force*. Moving electric charges produce magnetic *forces*, and moving magnets produce electric *forces*.	• Demonstrate and *explain that* an electric current flowing in a wire will create a magnetic field around the wire (*electromagnetic effect*). • Demonstrate and *explain that* moving a magnet near a wire will cause an electric current to flow in the wire (the generator effect).

Mathematics Connections

*a	7.2.E	Represent proportional relationships using graphs, tables, and equations, and make connections among the representations.
	7.2.F	Determine the slope of a line corresponding to the graph of a proportional relationship, and relate slope to similar triangles.
	A1.3.B	Represent a function with a symbolic expression, as a graph, in a table, and using words, and make connections among these representations.
	A1.4.C	Identify and interpret the slopes and intercepts of a linear function, including equations for parallel and perpendicular lines.
	A1.2.B	Recognize the multiple uses of variables, determine all possible values of variables that satisfy prescribed conditions, and evaluate algebraic expressions that involve variables.
	A1.8.A	Analyze a problem situation and represent it mathematically.
*b	A1.4.C	Identify and interpret the slopes and intercepts of a linear function, including equations for parallel and perpendicular lines.
	A1.2.B	Recognize the multiple uses of variables, determine all possible values of variables that satisfy prescribed conditions, and evaluate algebraic expressions that involve variables.
*c	7.2.E	Represent proportional relationships, using graphs, tables, and equations, and make connections among the representations.
	A1.6.B	Make valid inferences and draw conclusions based on data.
	A1.2.B	Recognize the multiple uses of variables, determine all possible values of variables that satisfy prescribed conditions, and evaluate algebraic expressions that involve variables.
	A1.7.D	Solve an equation involving several variables by expressing one variable in terms of the others.
*d	A1.3.B	Represent a function with a symbolic expression, as a graph, in a table, and using words, and make connections among these representations.
	A1.6.B	Make valid inferences and draw conclusions based on data.
	A1.7.D	Solve an equation involving several variables by expressing one variable in terms of the others.

EALR 4: Physical Science

Big Idea: Matter: Properties and Change (PS2)

Core Content: *Chemical Reactions*

In prior years, students learned the basic concepts behind the atomic nature of matter. In grades 9-11 students learn about chemical reactions, starting with the structure of an atom. They learn that the Periodic Table groups elements with similar physical and chemical properties. With grounding in atomic structure, students learn about the formation of molecules and ions, compounds and solutions, and the details of a few common chemical reactions. They also learn about nuclear reactions and the distinction between fusion and fission. These concepts about the fundamental properties of matter will help students understand chemical and nuclear reactions that are important in modern society and lay the groundwork for both chemistry and life science.

	Content Standards	**Performance Expectations**
	Students know that:	*Students are expected to:*
9-11 PS2A	*Atoms* are composed of *proton*s, *neutrons*, and *electrons*. The *nucleus* of an *atom* takes up very little of the *atom*'s volume but makes up almost all of the *mass*. The *nucleus* contains *protons* and *neutrons*, which are much more massive than the *electrons* surrounding the *nucleus*. *Protons* have a positive charge, *electrons* are negative in charge, and *neutrons* have no net charge.	• *Describe* the relative charges, *masses*, and locations of the *protons*, *neutrons*, and *electrons* in an *atom* of an *element*.
9-11 PS2B	*Atoms* of the same *element* have the same number of *protons*. The number and arrangement of *electrons* determines how the *atom* interacts with other *atoms* to *form molecules* and *ionic arrays*.	• Given the number and arrangement of *electrons* in the outermost shell of an *atom*, *predict* the *chemical properties* of the *element*.
9-11 PS2C	When *elements* are listed in order according to the number of *protons*, 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*.	• Given the number of *protons*, identify the *element* using a Periodic Table. • *Explain* the arrangement of the *elements* on the Periodic Table, including the significant *relationships* among *elements* in a given column or row.
9-11 PS2D	*Ions* are produced when *atoms* or *molecules* lose or gain *electrons*, thereby gaining a positive or negative electrical charge. *Ions* of opposite charge are attracted to each other, forming *ionic bonds*. Chemical formulas for *ionic compounds* represent the proportion of *ion* of each *element* in the *ionic array*.	• *Explain how ions* and *ionic bonds* are formed (e.g., sodium *atoms* lose an *electron* and chlorine *atoms* gain an *electron*, then the charged *ions* are attracted to each other and *form* bonds). • *Explain* the meaning of a chemical formula for an *ionic array* (e.g., NaCl).
9-11 PS2E	*Molecular compounds* are composed of two or more *elements* bonded together in a fixed proportion by sharing *electrons* between *atoms*, forming *covalent bond*s. Such *compounds* consist of well-defined *molecules*. Formulas of *covalent compounds* represent the types and number of *atoms* of each *element* in each *molecule*.	• Give examples to illustrate that *molecules* are groups of two or more *atoms* bonded together (e.g., a *molecule* of water is formed when one oxygen *atom* shares *electrons* with two hydrogen *atoms*). • *Explain* the meaning of a chemical formula for a *molecule* (e.g., CH_4 or H_2O).*a

	Content Standards	Performance Expectations
9-11 PS2F	All forms of life are composed of large *molecules* that contain carbon. Carbon *atoms* bond to one another and other *elements* by sharing electrons, forming *covalent bond*s. Stable *molecules* of carbon have four *covalent bond*s per carbon *atom*.	• Demonstrate how carbon *atoms form* four *covalent bond*s to make large *molecules*. Identify the *functions* of these *molecules* (e.g., plant and animal tissue, polymers, sources of food and nutrition, *fossil fuels*).
9-11 PS2G	*Chemical reactions* change the arrangement of *atoms* in the *molecules* of substances. *Chemical reactions* release or acquire energy from their surroundings and result in the formation of new substances.	• *Describe* at least three *chemical reactions* of particular importance to humans (e.g., burning of *fossil fuels*, *photosynthesis*, rusting of metals). • Use a chemical equation to illustrate how the *atoms* in *molecules* are arranged before and after a reaction. • Give examples of *chemical reactions* that either release or acquire energy and result in the formation of new substances (e.g., burning of *fossil fuels* releases large amounts of energy in the form of heat).
9-11 PS2H	*Solutions* are *mixtures* in which particles of one substance are evenly distributed through another substance. *Liquids* are limited in the amount of dissolved *solid* or *gas* that they can contain. *Aqueous solutions* can be *described* by relative quantities of the dissolved substances and acidity or alkalinity (pH).	• Give examples of *common solutions*. *Explain* the differences among the processes of dissolving, melting, and reacting. • *Predict* the result of adding increased amounts of a substance to an *aqueous solution*, in concentration and pH.*b
9-11 PS2I	The rate of a physical or *chemical change* may be affected by *factors* such as temperature, surface area, and pressure.	• *Predict* the *effect* of a change in temperature, surface area, or pressure on the rate of a given physical or *chemical change*.*b
9-11 PS2J	The number of *neutrons* in the *nucleus* of an *atom* determines the *isotope* of the *element*. Radioactive *isotopes* are unstable and emit particles and/or *radiation*. Though the timing of a single nuclear decay is unpredictable, a large group of nuclei decay at a predictable rate, making it possible to estimate the age of materials that contain radioactive *isotopes*.	• Given the *atomic number* and *atomic mass number* of an *isotope*, students draw and label a *model* of the *isotope's* atomic structure (number of *protons*, *neutrons,* and *electrons*). • Given data from a sample, use a decay curve for a radioactive *isotope* to find the age of the sample. *Explain how* the decay curve is derived. *c
9-11 PS2K	Nuclear reactions convert *matter* into energy, releasing large amounts of energy *compare*d with *chemical reactions*. *Fission* is the splitting of a large *nucleus* into smaller pieces. *Fusion* is the joining of nuclei and is the process that *generates* energy in the Sun and other stars.	• Distinguish between nuclear *fusion* and nuclear *fission* by describing how each process transforms *elements* present before the reaction into *elements* present after the reaction.

Mathematics Connections

*a	G.3.J	Describe prisms, pyramids, parallelepipeds, tetrahedra, and regular polyhedra in terms of their faces, edges, vertices, and properties.
*b	7.2.E	Represent proportional relationships, using graphs, tables, and equations, and make connections among the representations.
*c	A1.1.A	Select and justify functions and equations to model and solve problems.
	A1.7.A	Sketch the graph for an exponential function of the form $y = ab^n$ where n is an integer, describe the effects that changes in the parameters a and b have on the graph, and answer questions that arise in situations modeled by exponential functions.
	A1.7.B	Find the approximate solutions to exponential equations.

EALR 4: Physical Science

Big Idea: Energy: Transfer, Transformation, and Conservation (PS3)

Core Content: *Transformation and Conservation of Energy*

In prior grades students learned to apply the concept of "energy" in various settings. In grades 9-11 students learn fundamental concepts of energy, including the Law of Conservation of Energy—that the total amount of energy in a closed system is constant. Other key concepts include gravitational potential and kinetic energy, how waves transfer energy, the nature of sound, and the electromagnetic spectrum. Energy concepts are essential for understanding all of the domains of science (EALR 4), from the ways that organisms get energy from their environment, to the energy that drives weather systems and volcanoes.

	Content Standards	**Performance Expectations**
	Students know that:	*Students are expected to:*
9-11 PS3A	Although energy can be *transferred* from one object to another and can be *transformed* from one form of energy to another *form*, the total energy in a *closed system* is constant and can neither be created nor destroyed. (*Conservation of Energy*)	• *Describe* a situation in which energy is *transferred* from one place to another and *explain how* energy is conserved.*a • *Describe* a situation in which energy is *transformed* from one *form* to another and *explain how* energy is conserved.*a
9-11 PS3B	*Kinetic energy* is the energy of *motion*. The kinetic energy of an object is defined by the equation: $E_k = ½ mv^2$	• Calculate the *kinetic energy* of an object, given the object's *mass* and *velocity*. *b
9-11 PS3C	*Gravitational potential energy* is due to the separation of mutually attracting *masses*. *Transformations* can occur between *gravitational potential energy* and *kinetic energy*, but the total amount of energy remains constant.	• Give an example in which *gravitational potential energy* and *kinetic energy* are changed from one to the other (e.g., a child on a swing illustrates the alternating *transformation* of *kinetic* and *gravitational potential energy*).
9-11 PS3D	*Waves* (including sound, seismic, light, and water *waves*) *transfer* energy when they interact with *matter*. *Waves* can have different *wavelengths, frequencies*, and *amplitudes*, and travel at different *speeds*.	• Demonstrate how energy can be transmitted by sending *waves* along a spring or rope. Characterize physical *waves* by *frequency, wavelength, amplitude*, and *speed*. • *Apply* these *properties* to the pitch and volume of sound *waves* and to the *wavelength* and magnitude of water *waves*.*b
9-11 PS3E	*Electromagnetic waves* differ from physical *waves* because they do not require a medium and they all travel at the same *speed* in a vacuum. This is the maximum *speed* that any object or *wave* can travel. Forms of *electromagnetic waves* include X-rays, ultraviolet, visible light, infrared, and radio.	• Illustrate the *electromagnetic spectrum* with a labeled diagram, showing how regions of the spectrum differ regarding *wavelength*, *frequency*, and energy, and how they are used (e.g., infrared in *heat* lamps, microwaves for heating foods, X-rays for medical imaging).

Mathematics Connections

*a	G.6.F	Solve problems involving measurement conversions within and between systems, including those involving derived units, and analyze solutions in terms of reasonableness of solutions and appropriate units.
*b	A1.2.B	Recognize the multiple uses of variables, determine all possible values of variables that satisfy prescribed conditions, and evaluate algebraic expressions that involve variables.
	A1.7.D	Solve an equation involving several variables by expressing one variable in terms of the others.

EALR 4: Earth and Space Science

Big Idea: Earth in Space (ES1)

Core Content: *Evolution of the Universe*

In prior grades students learned about other objects in the Solar System and how they are held together by a force called "gravity." In grades 9-11 students learn the current scientific theory about the origin of the universe and subsequent formation of our Solar System. These discoveries are based on the important concept that the physical principles that apply today on Earth apply everywhere in the universe, now and in the distant past. These fundamental concepts help students make coherent sense of the universe and engage in further wondering and learning.

	Content Standards	**Performance Expectations**
	Students know that:	*Students are expected to:*
9-11 ES1A	Stars have "*life cycles*." During their active periods, stars produce heavier *elements*, starting with the *fusion* of hydrogen to *form* helium. The heaviest *elements* are formed when massive stars "die" in massive explosions.	• Connect the *life cycles* of stars to the production of *elements* through the process of nuclear *fusion*.
9-11 ES1B	The *Big Bang theory* of the origin of the universe is based on *evidence* (e.g., red shift) that all galaxies are rushing apart from one another. As space expanded and *matter* began to cool, gravitational attraction pulled clumps of *matter* together, forming the stars and galaxies, clouds of *gas* and dust, and planetary *systems* that we see today. If we were to run time backwards, we would find that all of the galaxies were in the same place 13.7 billion years ago.	• Cite *evidence* that supports the "*Big Bang theory*" (e.g., red shift of galaxies or 3K background radiation).

EALR 4: Earth and Space Science

Big Idea: Earth Systems, Structures, and Processes (ES2)

Core Content: *Energy in Earth Systems*

In prior grades students learned about planet Earth as an interacting system of solids, liquids, and gases, and about the water cycle, the rock cycle, and the movement of crustal plates. In grades 9-11 students learn how the uneven heating of Earth's surface causes differences in climate in different parts of the world, and how the tilt of Earth's axis with respect to the plane of its orbit around the Sun causes seasonal variations. Students also learn about the essential biogeochemical cycles that continuously move elements such as carbon and nitrogen through Earth systems. These major ideas about energy inputs and outputs in and around the Earth help students understand Earth as a dynamic system.

	Content Standards	**Performance Expectations**
	Students know that:	*Students are expected to:*
9-11 ES2A	*Global climate* differences result from the uneven heating of Earth's surface by the Sun. Seasonal climate *variations* are due to the tilt of Earth's axis with respect to the plane of Earth's nearly circular *orbit* around the Sun.	• *Explain that* Earth is warmer near the equator and cooler near the poles due to the uneven heating of Earth by the Sun. • *Explain that* it's warmer in summer and colder in winter for people in Washington State because the intensity of sunlight is greater and the days are longer in summer than in winter. Connect these seasonal changes in sunlight to the tilt of Earth's axis with respect to the plane of its *orbit* around the Sun.
9-11 ES2B	*Climate* is determined by *energy transfer* from the sun at and near Earth's surface. This *energy transfer* is influenced by dynamic processes such as cloud cover and Earth's rotation, as well as static conditions such as proximity to mountain ranges and the ocean. Human activities, such as burning of *fossil fuels*, also affect the *global climate*.	• *Explain how* the *climate* in the Pacific Northwest region is affected by seasonal weather *patterns*, as well as other *factors* such as the addition of greenhouse *gases* to the *atmosphere* and proximity to mountain ranges and to the ocean.
9-11 ES2C	Earth is a *system* that contains a fixed amount of each stable chemical *element* existing in different chemical forms. Each *element* on Earth moves among reservoirs in the solid Earth, oceans, *atmosphere*, and *organisms* as part of *biogeochemical cycle*s driven by energy from Earth's interior and from the Sun.	• *Describe* the different forms taken by carbon and nitrogen, and the reservoirs where they are found. • *Give examples* of carbon found on Earth (e.g., carbonate rocks such as limestone, in coal and oil, in the atmosphere as carbon dioxide *gas*, and in the tissues of all living *organisms*).
9-11 ES2D	The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources and it depletes those resources that cannot be renewed.	• *Identify* renewable and nonrenewable resources in the Pacific Northwest region. • *Explain* how human use of natural resources stress natural processes and link that use to a possible long term consequence.

EALR 4: Earth and Space Science

Big Idea: Earth History (ES3)

Core Content: *Evolution of the Earth*

In prior grades students learned about a few of the methods that have made it possible to uncover the history of our planet. In grades 9-11 students learn about the major changes in Earth systems over geologic time and some of the methods used to gather evidence of those changes. Methods include observation and measurement of sediment layers, using cores drilled from the sea bottom and from ancient glaciers, and the use of radioactive isotopes. Findings of Earth history include the existence of life as early as 3.5 billion years ago and major changes in the composition of Earth's atmosphere.

	Content Standards	**Performance Expectations**
	Students know that:	*Students are expected to:*
9-11 ES3A	Interactions among the solid Earth, the oceans, the atmosphere, and *organisms* have resulted in the ongoing *evolution* of the Earth *system*. We can observe changes such as earthquakes and volcanic eruptions on a human time scale, but many processes such as mountain building and plate movements take place over hundreds of millions of years.	• *Interpret* current rock formations of the Pacific Northwest as *evidence* of past geologic events. *Consider* which Earth processes that may have caused these rock formations (e.g., *erosion*, *deposition*, and scraping of terrain by glaciers, floods, volcanic eruptions, and *tsunami*). • Construct a possible timeline showing the development of these rock formations given the cause of the formations.
9-11 ES3B	Geologic time can be estimated by several methods (e.g., counting tree rings, observing rock sequences, using *fossils* to correlate sequences at various locations, and using the known decay rates of radioactive *isotopes* present in rocks to measure the time since the rock was formed).	• *Explain how* decay rates of radioactive materials in rock layers are used to establish the timing of geologic events. *a • Given a geologic event, *explain* multiple methods that could be used to establish the timing of that event.
9-11 ES3C	*Evidence* for one-celled forms of life—the bacteria—extends back billions of years. The appearance of life on Earth caused dramatic changes in the composition of Earth's *atmosphere*, which did not originally contain oxygen.	• *Compare* the chemical composition of the Earth's *atmosphere* before bacteria and plants evolved and after they became widespread.
9-11 ES3D	Data gathered from a variety of methods have shown that Earth has gone through a number of periods when Earth was much warmer and much colder than today.	• *Describe factors* that change climates over long periods of time and cite methods that scientists have found to gather information on ancient climates.

Mathematics Connections

*a	A1.1.A	Select and justify functions and equations to model and solve problems.
	A1.7.A	Sketch the graph for an exponential function of the form $y = ab^n$ where n is an integer, describe the effects that changes in the parameters a and b have on the graph, and answer questions that arise in situations modeled by exponential functions.
	A1.7.B	Find the approximate solutions to exponential equations.

EALR 4: Life Science

Big Idea: Structures and Functions of Living Organisms (LS1)

Core Content: *Processes Within Cells*

In prior grades students learned that all living systems are composed of cells which make up tissues, organs, and organ systems. In grades 9-11 students learn that cells have complex molecules and structures that enable them to carry out life functions such as photosynthesis and respiration and pass on their characteristics to future generations. Information for producing proteins and reproduction is coded in DNA and organized into genes in chromosomes. This elegant yet complex set of processes explains how life forms replicate themselves with slight changes that make adaptations to changing conditions possible over long periods of time. These processes that occur within living cells help students understand the commonalities among the diverse living forms that populate Earth today.

	Content Standards	**Performance Expectations**
	Students know that:	*Students are expected to:*
9-11 LS1A	Carbon-containing *compounds* are the building blocks of life. *Photosynthesis* is the process that plant cells use to combine the energy of sunlight with *molecules* of carbon dioxide and water to produce energy-rich *compounds* that contain carbon (*food*) and release oxygen.	• *Explain how* plant cells use *photosynthesis* to produce their own food. Use the following equation to illustrate how plants rearrange *atoms* during *photosynthesis*: $6CO_2+6H_2O+$light energy —> $C_6H_{12}O_6+6O_2$ *a • *Explain* the importance of *photosynthesis* for both plants and animals, including humans.
9-11 LS1B	The gradual combustion of carbon-containing *compounds* within cells, called *cellular respiration*, provides the primary energy source of living *organisms*; the combustion of carbon by burning of *fossil fuels* provides the primary energy source for most of modern society.	• *Explain how* the process of *cellular respiration* is similar to the burning of *fossil fuels* (e.g., both processes involve combustion of carbon-containing *compounds* to transform chemical energy to a different *form* of energy). *a
9-11 LS1C	Cells contain specialized parts for determining essential *functions* such as regulation of cellular activities, energy capture and release, formation of proteins, waste disposal, the *transfer* of information, and movement.	• Draw, label, and *describe* the *functions* of components of essential structures within cells (e.g., *cellular membrane*, *nucleus*, *chromosome*, *chloroplast*, *mitochondrion*, *ribosome*)
9-11 LS1D	The cell is surrounded by a membrane that separates the interior of the cell from the outside world and determines which substances may enter and which may leave the cell.	• *Describe* the structure of the ` and how the membrane regulates the flow of materials into and out of the cell.
9-11 LS1E	The *genetic information* responsible for inherited *characteristics* is encoded in the DNA *molecules* in *chromosomes*. DNA is composed of four subunits (A,T,C,G). The sequence of subunits in a *gene* specifies the amino acids needed to make a protein. *Proteins* express inherited traits (e.g., eye color, hair texture) and carry out most cell *function*.	• *Describe* how DNA *molecules* are long chains linking four subunits (smaller *molecules*) whose sequence encodes *genetic information*. • Illustrate the process by which *gene* sequences are copied to produce proteins.

	Content Standards	Performance Expectations
9-11 LS1F	All of the *functions* of the cell are based on *chemical reactions*. Food *molecules* are broken down to provide the energy and the chemical constituents needed to synthesize other *molecules*. Breakdown and synthesis are made possible by proteins called *enzyme*s. Some of these *enzymes* enable the cell to store energy in special chemicals, such as ATP, that are needed to drive the many other *chemical reactions* in a cell.	• *Explain how* cells break down food *molecules* and use the constituents to synthesize proteins, sugars, fats, DNA and many other *molecules* that cells require. • *Describe* the role that *enzymes* play in the breakdown of food *molecules* and synthesis of the many different *molecules* needed for cell structure and *function*. • *Explain how* cells extract and store energy from food *molecules*.
9-11 LS1G	Cells use the DNA that forms their *genes* to encode *enzymes* and other proteins that allow a cell to grow and divide to produce more cells, and to respond to the *environment*.	• *Explain that* regulation of cell *functions* can occur by changing the activity of proteins within cells and/or by changing whether and how often particular *genes* are expressed.
9-11 LS1H	*Genes* are carried on *chromosomes*. Animal cells contain two copies of each *chromosome* with *genetic information* that regulate body structure and *functions*. Cells divide by a process called *mitosis,* in which the *genetic information* is copied so that each new cell contains exact copies of the original *chromosomes*.	• *Describe* and *model* the process of *mitosis*, in which one cell divides, producing two cells, each with copies of both *chromosomes* from each pair in the original cell.
9-11 LS1I	Egg and sperm cells are formed by a process called *meiosis* in which each resulting cell contains only one representative *chromosome* from each pair found in the original cell. *Recombination* of *genetic information* during *meiosis* scrambles the *genetic information*, allowing for new *genetic* combinations and *characteristics* in the offspring. Fertilization restores the original number of *chromosome* pairs and reshuffles the *genetic information*, allowing for *variation* among offspring.	• *Describe* and *model* the process of *meiosis* in which egg and sperm cells are formed with only one set of *chromosomes* from each parent. • *Model* and *explain* the process of *genetic recombination* that may occur during *meiosis* and how this then results in differing *characteristics* in offspring. • *Describe* the process of *fertilization* that restores the original *chromosome* number while reshuffling the *genetic information*, allowing for *variation* among offspring. • *Predict* the outcome of specific *genetic* crosses involving two *characteristics* *a,*b

Mathematics Connections

*a	A1.3.B	Represent a function with a symbolic expression, as a graph, in a table, and using words, and make connections among these representations.
*b	A1.6.B	Make valid inferences and draw conclusions based on data.

EALR 4: **Life Science**

Big Idea: **Ecosystems (LS2)**

Core Content: ***Maintenance and Stability of Populations***

In prior grades students learned to apply key concepts about ecosystems to understand the interactions among organisms and the nonliving environment. In grades 9-11 students learn about the factors that foster or limit growth of populations within ecosystems and that help to maintain the health of the ecosystem overall. Organisms participate in the cycles of matter and flow of energy to survive and reproduce. Given abundant resources, populations can increase at rapid rates. But living and nonliving factors limit growth, resulting in ecosystems that can remain stable for long periods of time. Understanding the factors that affect populations is important for many societal issues, from decisions about protecting endangered species to questions about how to meet the resource needs of civilization while maintaining the health and sustainability of Earth's ecosystems.

	Content Standards	**Performance Expectations**
	Students know that:	*Students are expected to:*
9-11 LS2A	*Matter* cycles and *energy* flows through living and nonliving components in *ecosystems*. The transfer of *matter* and *energy* is important for maintaining the health and sustainability of an *ecosystem*.	• *Explain how* plants and animals cycle carbon and nitrogen within an *ecosystem.* • *Explain how* matter cycles and energy flows in ecosystems, resulting in the formation of differing chemical compounds and heat.
9-11 LS2B	Living *organisms* have the capacity to produce very large *populations*. *Population density* is the number of individuals of a particular *population* living in a given amount of space.	• *Evaluate* the conditions necessary for rapid *population growth* (e.g., given adequate living and nonliving resources and no disease or predators, *populations* of an *organism* increase at rapid rates). • Given *ecosystem* data, calculate the *population density* of an *organism*.*a
9-11 LS2C	*Population growth* is limited by the availability of matter and energy found in resources, the size of the *environment*, and the presence of competing and/or predatory *organisms*.	• *Explain factors,* including matter and energy, in the *environment* that limit the growth of plant and animal *populations* in natural *ecosystems*.*a
9-11 LS2D	Scientists represent *ecosystems* in the *natural world* using mathematical *models*.	• Draw a *systems* diagram to illustrate and *explain* why introduced (nonnative) *species* often do poorly and have a tendency to die out, as well as why they sometimes do very well and force out native *species*. *a, *b
9-11 LS2E	Interrelationships of *organisms* may *generate ecosystems* that are stable for hundreds or thousands of years. *Biodiversity* refers to the different kinds of *organisms* in specific *ecosystems* or on the planet as a whole.	• *Compare* the *biodiversity* of *organisms* in different types of *ecosystems* (e.g., rain forest, grassland, desert) noting the interdependencies and interrelationships among the *organisms* in these different *ecosystems*.

	Content Standards	Performance Expectations
9-11 LS2F	The *concept* of *sustainable development* supports adoption of policies that enable people to obtain the resources they need today without limiting the ability of future *generations* to meet their own needs. Sustainable processes include substituting renewable for nonrenewable resources, recycling, and using fewer resources.	• *Explain how* scientific *concepts* and findings relate to a resource issue currently under discussion in the state of Washington (e.g., removal of dams to facilitate salmon spawning in rivers; construction of *wind* farms).* a,*b,*c. • *Explain how* the *concept* of *sustainable development* may be applied to a current resource issue in the state of Washington.*a,*b,*c.

Mathematics Connections

*a	A1.8.A	Analyze a problem situation and represent it mathematically.
	7.2.E	Represent proportional relationships using graphs, tables, and equations, and make connections among the representations.
	A1.3.B	Represent a function with a symbolic expression, as a graph, in a table, and using words, and make connections among these representations.
	A1.2.B	Recognize the multiple uses of variables, determine all possible values of variables that satisfy prescribed conditions, and evaluate algebraic expressions that involve variables.
*b	A1.6.B	Make valid inferences and draw conclusions based on data.
	A1.7.D	Solve an equation involving several variables by expressing one variable in terms of the others.
*c	A1.3.B	Represent a function with a symbolic expression, as a graph, in a table, and using words, and make connections among these representations.
	A1.6.B	Make valid inferences and draw conclusions based on data.

EALR 4: Life Science

Big Idea: Biological Evolution (LS3)

Core Content: *Mechanisms of Evolution*

In prior grades students learned how the traits of organisms are passed on through the transfer of genetic information during reproduction. In grades 9-11 students learn about the factors that underlie biological evolution: variability of offspring, population growth, a finite supply of resources, and natural selection. Both the fossil record and analyses of DNA have made it possible to better understand the causes of variability and to determine how the many species alive today are related. Evolution is the major framework that explains the amazing diversity of life on our planet and guides the work of the life sciences.

	Content Standards	**Performance Expectations**
	Students know that:	*Students are expected to:*
9-11 LS3A	Biological *evolution* is due to: (1) *genetic variability* of offspring due to *mutations* and *genetic recombination*, (2) the potential for a *species* to increase its numbers, (3) a finite supply of resources, and (4) *natural selection* by the *environment* for those offspring better able to survive and produce offspring.	• *Explain* biological *evolution* as the consequence of the *interactions* of four *factors*: *population growth*, inherited variability of offspring, a finite supply of resources, and *natural selection* by the *environment* of offspring better able to survive and reproduce. • *Predict* the *effect* on a *species* if one of these *factors* should change.*a
9-11 LS3B	Random changes in the *genetic* makeup of cells and *organisms* (*mutations*) can cause changes in their physical *characteristics* or behaviors. If the *genetic mutations* occur in eggs or sperm cells, the changes will be inherited by offspring. While many of these changes will be harmful, a small minority may allow the offspring to better survive and reproduce.	• *Describe* the molecular process by which *organisms* pass on physical and behavioral traits to offspring, as well as the *environmental* and *genetic factors* that cause minor differences (*variations*) in offspring or occasional "mistakes" in the copying of *genetic* material that can be inherited by future *generations* (*mutations*). • *Explain how* a *genetic mutation* may or may not allow a *species* to survive and reproduce in a given *environment*.
9-11 LS3C	The great *diversity* of *organisms* is the result of more than 3.5 billion years of *evolution* that has filled available *ecosystem niches* on Earth with life *forms*.	• *Explain how* the millions of different *species* alive today are related by descent from a *common ancestor*. • *Explain that genes* in *organisms* that are very different (e.g., yeast, flies, and mammals) can be very similar because these *organisms* all share a *common ancestor*.
9-11 LS3D	The *fossil* record and anatomical and molecular similarities observed among diverse *species* of living *organisms* provide *evidence* of biological *evolution*.	• Using the *fossil* record and anatomical and/or molecular (DNA) similarities as *evidence*, formulate a *logical argument* for biological *evolution* as an explanation for the development of a representative *species* (e.g., birds, horses, elephants, whales).

	Content Standards	Performance Expectations
9-11 LS3E	*Biological classifications* are based on how *organisms* are related, reflecting their evolutionary history. Scientists *infer relationships* from physiological traits, *genetic information*, and the ability of two *organisms* to produce fertile offspring.	• Classify *organisms*, using similarities and differences in physical and functional *characteristics*. • *Explain* similarities and differences among closely related *organisms* in terms of biological *evolution* (e.g., "Darwin's finches" had different beaks due to food sources on the islands where they evolved).

Mathematics Connections

*a	8.3.F	Determine probabilities for mutually exclusive, dependent, and independent events for small sample sizes.

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