Science
Learning Outcomes for Biology
Grades 9 - 12

Each of the unnumbered, broad outcomes will be addressed in all biology courses.
The numbered subtopics represent ways that the broad outcomes can be addressed.

Students will

Standard #

Demonstrate an understanding of how living things are made of atoms bonded together to form organic molecules.

1.1 Explain the significance of carbon in organic molecules.

1.2 Recognize the six most common elements in organic molecules (C, H, N, O, P, S).

1.3 Describe the composition and functions of carbohydrates lipids, proteins, and nucleic acids.

1.4 Describe how dehydration synthesis and hydrolysis relate to organic molecules.

1.5 Explain the role of enzymes in biochemical reactions.

Demonstrate an understanding that all living things are composed of cells and that life processes in a cell are based on molecular interactions.

2.1 Relate cell parts/organelles to their functions.

2.2 Differentiate between prokaryotic and eukaryotic cells in terms of their structures and degrees of complexity.

2.3 Distinguish between plant and animal cells.

2.4 Describe how cells function in a narrow range of physical conditions, such as temperature and pH, to perform life functions that maintain homeostasis.

2.5 Explain the role of cell membranes in diffusion, osmosis, and active transport.

2.6 Identify the reactants and products in the general reaction of photosynthesis.

2.7 Provide evidence that the organic compounds produced by plants are the primary source of energy and nutrients for most living things.

Learning Outcomes for Biology
Grades 9 - 12 *Continued*

Students will

Standard #

Demonstrate an understanding that all living things are composed of cells and that life processes in a cell are based on molecular interactions. *(Continued)*

2.8 Recognize that cellular respiration produces ATP.

2.9 Explain the interrelated nature of photosynthesis and respiration.

2.10 Describe the processes of mitosis, meiosis, and the cell cycle and their significance.

Demonstrate an understanding of how genes are a set of instructions encoded in the DNA sequence of each organism that specify the sequence of amino acids in proteins characteristic of that organism.

3.1 Describe the structure and function of DNA and distinguish among replication, transcription, and translation.

3.3 Describe the general pathway by which ribosomes produce proteins by using tRNA to translate genetic information encoded within mRNA.

3.4 Explain how mutations in the DNA sequence of a gene may result in phenotypic change in an organism and in its offspring.

3.5 Differentiate between dominant, recessive, codominant, polygenic, and sex-linked traits.

3.6 State and apply Mendel's laws of segregation and independent assortment.

3.7 Use a Punnet Square to determine the genotype and phenotype of monohybrid crosses.

3.8 Explain how zygotes are produced in the fertilization process.

3.9 Recognize that, while viruses lack cellular structure, they have the genetic material needed to influence living cells.

Learning Outcomes for Biology
Grades 9 - 12 *Continued*

Students will

Standard #

Demonstrate an understanding of how evolution and biodiversity are the result of genetic changes that occur in constantly changing environments.

5.1 Explain how the fossil record and other evidence support the theory of evolution.

5.2 Illustrate how genetic variation is preserved or eliminated from a population through Darwinian natural selection (organic evolution) resulting in biodiversity.

5.3 Describe how the taxonomic system classifies living things into domains and kingdoms.

Demonstrate an understanding of the interrelationship of structure and function in organ systems of all organisms.

4.1 Explain how major organ systems in humans have functional units with specific anatomy that perform the function of that organ system.

4.2 Describe how the functions of individual human systems are integrated to maintain an homeostatic balance.

4.3 Compare and contrast the relationship between structure and function of major organ systems in plants and animals.

Demonstrate an understanding that ecology is the study of the interaction between living systems and their environment.

6.1 Explain how biotic and abiotic factors cycle in an ecosystem.

6.2 Use a food web to identify and distinguish producers, consumers, and decomposers and to explain the transfer of energy through trophic levels.

6.3 Identify the factors in an ecosystem that influence fluctuations in population size.

6.4 Analyze changes in an ecosystem resulting from natural causes, changes in climate, human activity, or the introduction of non-native species.

6.5 Explain how symbiotic behavior produces interactions within ecosystems.

Learning Outcomes for Chemistry
Grades 9 - 12

Each of the unnumbered, broad outcomes will be addressed in all chemistry courses.
The numbered subtopics represent ways that the broad outcomes can be addressed.

Students will

Standard #

Demonstrate and understanding of how chemists solve problems and communicate their knowledge.

5.3, Utilize the mole concept when calculating mass, particle, and volume relationships.

4.6, 5.4 Create empirical and molecular formulas when provided the identities of the interacting elements/ions and interpret these formulas with respect to molar mass and percent composition.

4.7 Create correct formulas when provided names of compounds, and name compounds when provided formulas.

5.1 Create balanced equations that are consistent with observations of physical and chemical change.

5.5 Interpret chemical equations with respect to mass, mole, and volume relationships.

Use dimensional analysis as a tool for problem solving.

Use dimensional analysis as a tool for deriving concept interrelationships.

5.2 Recognize synthesis, decomposition, single replacement, double replacement, and neutralization reactions.

Demonstrate an understanding of the underlying structure of atoms and how this dictates the chemical and physical behavior of matter.

2.1 Describe the contributions of Dalton, Thompson, Rutherford, Chadwick, Bohr, Heisenberg, Planck, and Einstein with respect to the development of the modern atomic theory.

2.2 Interpret Dalton's atomic theory in terms of the laws of conservation of mass, constant composition, and multiple proportions.

2.3 Characterize atoms with respect to proton, neutron and electron composition.

Learning Outcomes for Chemistry
Grades 9 - 12 *Continued*

Students will

Standard #	
	Demonstrate an understanding of the underlying structure of atoms and how this dictates the chemical and physical behavior of matter. *(Continued)*
	Demonstrate an understanding of atomic number, mass number, atomic mass, and isotopes.
2.4	Understand that matter has properties of both particles and waves.
2.5	Interpret atomic emission/absorption spectra with respect to electron energy changes as electrons move among quantum levels.
2.6	Describe the electromagnetic spectrum in terms of wavelength, energy, and regions.
2.7	Write electron configurations for elements.
2.8	Differentiate among alpha, beta, and gamma radiation and create and interpret simple radiochemical equations.
2.9	Recognize and compare fission and fusion reactions.
2.10, 2.11	Explain the processes of half-life and radiochemical transmutation.
3.1, 3.3	Use atomic electron configurations to explain the organization of the periodic table.
3.2	Use the periodic table to identify metals, nonmetals, metalloids, families (groups), periods, valence electrons, and reactivity.
3.4	Use the periodic table to identify relative ionization energies, electronegativities, electron affinities, and sizes of atoms and ions.

Grades 9 - 12 *Continued*

Students will

Standard #

Demonstrate an understanding of (1) why molecules have the properties and shapes they do; (2) the nature of the forces that hold them together; and (3) how these characteristics dictate their behavior.

4.1 Explain how atoms combine to form compounds through both ionic and covalent bonding.

4.2 Draw Lewis dot structures for molecules and ions.

4.3 Use elecronegativity and ionization energy to predict bonding behavior.

4.4 Predict and account for the shapes and polarities of molecules.

4.5 Use geometry and polarity to predict and classify van der Waals interactions among molecules.

Demonstrate an understanding of the states of matter including (1) the factors that influence which state is assumed by a substance; (2) the behaviors of each state of matter; and (3) how the states of matter assist us in understanding bonding forces and in predicting chemical behavior.

1.1 Identify and explain some of the physical properties that are used to classify matter (e.g., density, melting point, and boiling point).

1.3 Describe the three states of matter in terms of energy, particle motion, and phase transitions.

1.4 Distinguish between chemical and physical changes.

6.1 Use the kinetic molecular theory to explain the relationship among pressure, volume, temperature, and number of particles within a sample.

6.2 Explain the relationship between temperature and kinetic energy.

Derive the gas laws from fundamental concepts.

Students will

Standard #

Demonstrate an understanding of the states of matter including (1) the factors that influence which state is assumed by a substance; (2) the behaviors of each state of matter; and (3) how the states of matter assist us in understanding bonding forces and in predicting chemical behavior. *(Continued)*

6.3, 6.5, 6.6 Use the gas laws to predict the behavior of gases.

6.4 Distinguish between ideal and nonideal gas behavior and describe the conditions that promote each.

6.5 Demonstrate an understanding of Dalton's law of partial pressures by calculating partial and total pressures.

Demonstrate an understanding of the roles of enthalpy and entropy as driving forces for change.

10.1 Interpret the Law of Conservation of Energy.

10.2 Recognize and explain the roles of enthalpy and entropy in the determination of change within the universe.

10.3 Analyze energy changes using calorimetry.

10.4 Determine heats of reaction using Hess' Law.

Explain the significance of Gibb's free energy expression and use this expression to predict spontaneity.

Demonstrate an understanding of solutions including types, preparation, and properties.

7.1 Describe the process by which solutes dissolve in solvents.

7.2 Identify and explain the factors that affect the rate of dissolving.

7.3 Distinguish among unsaturated, saturated, and supersaturated solutions and describe the particle interactions within each.

Learning Outcomes for Chemistry
Grades 9 - 12 *Continued*

Students will

Standard #

Demonstrate an understanding of solutions including types, preparation, and properties.

7.4 Calculate and use molarity, molality, and percent by mass units of concentration.

7.5 Interpret solubility curves.

7.6 Predict, explain, and calculate changes in colligative properties that occur within solutions.

Use changes in colligative properties to calculate molecular mass.

7.7 Create full and net ionic equations for precipitation reactions in solutions.

Demonstrate an understanding of (1) the dynamic nature of chemical systems; (2) the factors that influence the mechanism and rate of chemical change; and (3) how chemical reactions can be predicted and controlled.

Describe and explain the significance of dynamic equilibria.

9.1 Write an equilibrium expression when given the corresponding chemical equation.

9.1 Calculate and interpret equilibrium constants when provided concentration data.

9.2 Use LeChatelier's Principle to predict equilibrium shifts when the system is stressed.

9.3 Identify the factors that affect the rate of a chemical reaction and interpret equilibria behaviors in terms of these factors.

9.4 Explain reaction rates in terms of collision frequency, energy, and particle orientation.

9.5 Explain the influence of activation energy upon reaction rate.

Describe and explain catalytic behavior.

Learning Outcomes for Chemistry
Grades 9 - 12 *Continued*

Students will

Standard #

Demonstrate an understanding of (1) acid-base and oxidation–reduction/ electro-chemical systems; and (2) the role these systems assume in the world around us.

8.1	Recognize acids and bases in terms of the presence of hydronium and hydroxide ions.
8.2	Explain, compare, and contrast the behavior of acids and bases with respect to strength.
8.3	Identify buffer systems and explain their ability to control pH.
8.4	Explain the selection and utilization of acid-base indicators.
8.5	Describe, explain, and perform acid-base titrations.
	Interpret titration curves for all combinations of strong and weak acid-base systems.
8.6	Calculate pH and pOH values for acid-base systems.
11.1	Describe oxidation and reduction and identify redox systems.
11.2	Assign oxidation numbers.
11.3	Balance redox reactions by the half-reaction method.
	Balance redox reactions by the oxidation number method and in acid-base solution.
11.4, 11.5, 11.6	Explain the structure and function of electrochemical and voltaic cells.
11.7	Use standard reduction potentials to calculate cell voltage.

Science
Learning Outcomes for Earth Science
Grades 9 - 12

Each of the unnumbered, broad outcomes will be addressed in all earth science courses. The numbered subtopics represent ways that the broad outcomes can be addressed.

Students will

Standard #

Develop an understanding of the creation, history, and composition of the earth.

1.1	Identify the sources of internal and external energy of the earth (radioactive decay, gravity, solar energy).
1.3	Describe the characteristics of waves (wavelength, frequency, velocity, amplitude).
2.1	Recognize, describe, and differentiate between renewable and nonrenewable sources of energy.
2.2	Explain the advantage and limitations of renewable sources of energy.
2.3	Explain the advantage and limitations of nonrenewable sources of energy.
2.4	Describe ways in which people have tried to control the use of renewable and nonrenewable sources of energy.
3.8	Describe the rock cycle and the processes which are responsible for the formation of igneous, sedimentary, and metamorphic rocks. Compare the physical properties of these rock types.
3.9	Compare the physical properties and the mineral combinations found in rocks.
3.11	Describe the absolute and relative dating methods used to measure geologic time, e.g., index fossils, radioactive dating, law of superposition, and cross-cutting relationships.
3.12	Describe the evolution of the solid earth in terms of the major geologic eras.
1.14	Explain how scientists study the earth system through the use of a combination of ground-based observations, satellite observations, and computer models of the earth system, and why it is necessary to use all of these tools together.
3.10	Explain how the composition and arrangement of atoms determine a mineral's physical and chemical characteristics.

Learning Outcomes for Earth Science
Grades 9 - 12 *Continued*

Students will

Standard #

Recognize the major forces in the development of the earth's geomorphology, including plate tectonics, earthquakes, volcanoes, glaciers, mountain building, weathering, and erosion.

3.1 Explain both physical and chemical weathering and how these processes lead to the formation of sediments, soils, soil texture and structure, and soil horizons.

3.2 Describe how glaciers, gravity, wind, waves, and rivers cause weathering and erosion. Give examples of how the effects of these processes can be seen in our local environment.

3.6 Explain how water flows into and through a watershed, e.g., aquifers, wells, porosity, permeability, water table, capillary water, runoff.

3.13 Explain how seismic data is used to reveal the interior structure of the layered earth.

3.14 Explain how seismic data is used to locate an earthquake epicenter.

3.15 Recognize the magnitude values of earthquakes as measured by the Richter scale and give examples of relative damage that would be incurred at each magnitude.

3.16 Explain how the magnetic field of the earth is produced.

3.18 Explain how paleomagnetic patterns, preserved in rocks, provide evidence of the earth's magnetic field over geologic time.

3.19 Trace the development of a lithospheric plate from its growing margin at a divergent boundary (mid-ocean ridge) to its destructive margin at a convergent boundary (subduction zone). Explain the relationship between convection currents and the motion of the lithospheric plates.

3.20 Relate earthquakes, volcanic activity, mountain building, and tectonic uplift to plate movements.

3.21 Relate the effects of sudden seafloor movements to the generation of tsunamis.

Learning Outcomes for Earth Science
Grades 9 - 12 *Continued*

Students will

Standard #

Recognize the major forces in the development of the earth's geomorphology, including plate tectonics, earthquakes, volcanoes, glaciers, mountain building, weathering, and erosion. *(Continued)*

3.22 Provide examples of how societies have been affected by tectonic activity (e.g., hazards from eruptions and earthquakes, bedrock type and soil conditions, building designs).

2.5 Describe the effects on the environment of using both renewable and nonrenewable sources of energy.

2.6 Describe ways in which scientists are addressing these effects on the environment.

Demonstrate an understanding of the creation of the ocean and the role it plays in the environment.

1.13 Explain what causes the tides and describe how they affect the coastal environment.

3.21 Relate the effects of sudden seafloor movements to the generation of tsunamis.

1.11 Explain the dynamics of oceanic currents, including upwelling, density and deep water currents, the local Labrador Current and Gulf Stream, and their relationship to the global circulation within the marine environment and climate.

1.12 Describe the effects of longshore currents, storms, and artificial structures (jetties, sea walls) on coastal erosion in Massachusetts.

3.5 Describe how the oceans store carbon dioxide.

Demonstrate an understanding of the structure and dynamics of the atmosphere as they apply to weather prediction, weather patterns, severe storms, global climate, and human impact**.**

1.6 Explain how the layers of the atmosphere affect the dispersal of incoming radiation through reflection, absorption, and re-radiation.

Learning Outcomes for Earth Science
Grades 9 - 12 *Continued*

Students will

Standard #

Demonstrate an understanding of the structure and dynamics of the atmosphere as they apply to weather prediction, weather patterns, severe storms, global climate, and human impact**.** *(Continued)*

1.7 Provide examples of how the unequal heating of the earth and the Coriolis Effect influence global circulation patterns and explain their impact on Massachusetts weather and climate (convection cells, trade winds, westerlies, polar easterlies, land/sea breezes, mountain/ valley breezes).

1.8 Explain how the revolution of the earth and the inclination of the axis of the earth cause the earth's seasonal variations (equinox and solstices).

3.4 Describe the evolution of the atmosphere.

3.7 Compare and contrast the processes of the hydrologic cycle including evaporation, condensation, precipitation, runoff, infiltration, and transpiration.

1.5 Explain how the transfer of energy through radiation, conduction, and convection contributes to global atmospheric processes (storms, winds).

1.9 Describe how the inclination of the incoming solar radiation can impact the amount of energy received by a given surface area.

1.10 Describe the various conditions associated with frontal boundaries and cyclonic storms, e.g., thunderstorms, winter storms (nor'easters), hurricanes, tornadoes and their impact on human affairs, including storm preparations.

Comprehend the earth's place in the solar system and universe, including the evolution of the universe, stars, and planets.

4.1 Explain the Big Bang Theory and discuss the evidence that supports it (background radiation and Doppler effect ~ red shift).

4.2 Explain the unit of distance called a light year.

4.5 Compare and contrast the motions of rotation and revolution of orbiting bodies (day, year, solar and lunar eclipses) and describe the influence of gravity and inertia on these motions.

Learning Outcomes for Earth Science
Grades 9 - 12 *Continued*

Students will

Standard #	
	Comprehend the earth's place in the solar system and universe, including the evolution of the universe, stars, and planets. *(Continued)*
4.7	Compare and contrast the various instrumentation used to study deep space and the solar system, (e.g., refracting telescope, reflecting telescope, radio telescope, spectrophotometer).
4.8	Explain how the sun, earth, and solar system formed from a nebula cloud of dust and gas in a spiral arm of the Milky Way Galaxy about 4.6 billion years ago.
1.4	Describe the nature of the continuous emission and absorption spectrum that indicates the composition of stars.
4.3	Use the Hertzsprung-Russell Diagram to explain the life histories of stars.
4.4	Compare and contrast the final three outcomes of stellar evolution based on mass (black hole, neutron star, white dwarf).
4.6	Explain Kepler's Laws of Motion.

Science
Learning Outcomes for Physics
Grades 9 - 12

Each of the unnumbered, broad outcomes will be addressed in all physics courses.
The numbered subtopics represent ways that the broad outcomes can be addressed.

Students will

Standard #

Use the language of physics, and report and manipulate physical quantities.

1.12 Identify appropriate standard international units of measurement for force, mass, distance, speed, acceleration, and time, and explain how they are measured.

2.6 Identify appropriate SI units for energy, work, power, and momentum, and explain how they are measured.

5.5 Identify appropriate SI units for current, voltage, and resistance, and explain how they are measured.

Demonstrate the ability to describe the motion of objects through mathematical and graphical methods.

1.1, 1.2 Distinguish between vector and scalar quantities, and illustrate how to represent and manipulate vectors algebraically and graphically.

1.3, 1.4 Solve problems involving velocity, speed, and constant acceleration.

Describe the causes of motion and make predictions about the motion based on the classical Newtonian model.

1.5 Explain the relationship between mass and inertia.

1.6, **1.7**, **1.10** Interpret and apply Newton's three laws of motion.

1.8 Use a free body diagram to show forces acting on an object and determine the net force.

1.9 Qualitatively distinguish between static and kinetic friction, their dependencies, and their effects on motion of objects.

Learning Outcomes for Physics
Grades 9 - 12 *Continued*

Students will

Standard #

Demonstrate the ability to use the laws of conservation of energy and momentum as an alternative approach to predict and describe the movement of objects.

2.1 Interpret and provide examples that illustrate the law of conservation of energy.

2.2 Provide examples of how energy can be transformed from kinetic to potential and vice versa.

2.3 Quantitatively apply the law of conservation of energy to basic systems.

2.4 Describe the relationship between energy, work, and power both conceptually and quantitatively.

2.5 Interpret the law of conservation of momentum, provide examples that illustrate it, and calculate the momentum of an object.

Quantitatively apply the law of conservation of momentum to simple systems.

Demonstrate the ability to explain why objects follow curvilinear paths, and relate this information to celestial motion.

Define centripetal force and centripetal acceleration, and use these concepts to explain circular motion.

Identify direction of centripetal force and centripetal acceleration.

1.11 Demonstrate a conceptual understanding of Newton's law of universal gravitation.

Combine Newton's universal law of gravitation with laws describing circular motion to develop Kepler's three laws of planetary motion.

Apply Kepler's three laws to simple celestial systems.

Learning Outcomes for Physics
Grades 9 - 12 *Continued*

Students will

Standard #

Describe different forms of periodic motion qualitatively and quantitatively.

Interpret Hooke's Law and use it to determine unknown spring constants.

Combine Hooke's Law with the law of conservation of energy to predict the behavior of an oscillating system.

Recognize the factors that affect the period of simple oscillating systems.

Describe the characteristics and behaviors of waves.

4.1 Differentiate between wave motion and the motion of objects.

4.2 Recognize the measurable properties of waves and explain their interrelationships.

4.4 Distinguish between mechanical and electromagnetic waves.

4.3 Distinguish between transverse and longitudinal waves.

4.5 Interpret and qualitatively apply the laws of reflection and refraction.

4.6 Recognize the effects of polarization, wave interaction, and Doppler effect.

4.8 Explain the relationship between the speed of a wave and the medium through which it travels.

4.7 Construct, explain, and interpret graphs of constructive and destructive interference.

4.9 Recognize the characteristics of standing waves and explain the conditions under which two waves can interfere to produce a standing wave.

Learning Outcomes for Physics
Grades 9 - 12 *Continued*

Students will

Standard #

Demonstrate an understanding (1) of the dual nature of light, and (2) of how the wave-particle duality affects its characteristics and behavior; and (3) develop a working knowledge of how light interacts with optical devices such as lenses and mirrors.

6.1 Describe the electromagnetic spectrum in terms of wavelength and energy, and be able to identify specific regions.

6.2 Explain how various wavelengths in the electromagnetic spectrum have many useful applications.

6.3 Calculate the frequency and energy of an electromagnetic wave from the wavelength.

4.5 Interpret and qualitatively apply the laws of reflection and refraction.

Analyze interference and diffraction for single- and double-slit patterns.

Explain polarization and recognize its effects.

Describe virtual image formation by plane mirrors using the ray model and the laws of reflection.

Analyze real and virtual images formed by concave and convex mirrors and provide examples of their use.

Apply the mirror equation in relation to object/image distances and focal length.

Analyze real and virtual images formed by concave and convex thin lenses and provide examples of their uses.

Apply the lens-makers equation in relation to object/image distances and focal length.

Develop an understanding (1) of the nature of the electric field and how it influences charges with the field; (2) how these moving charges can be manipulated in a circuit; (3) how to analyze and design basic direct current circuits.

5.1 Recognize the characteristics of static charge and explain how a static charge is generated and transferred.

Learning Outcomes for Physics
Grades 9 - 12 *Continued*

Students will

Standard #

5.2 Demonstrate an understanding of electric force by interpreting and applying Coulomb's law.

5.3 Demonstrate an understanding of electric fields.

Develop an understanding (1) of the nature of the electric field and how it influences charges with the field; (2) how these moving charges can be manipulated in a circuit; (3) how to analyze and design basic direct current circuits. *(Continued)*

Demonstrate an understanding of electric potential.

5.4 Develop a qualitative and quantitative understanding of current, voltage, and resistance and of the interrelationships among them (Ohm's Law).

Qualitatively analyze simple household circuits.

5.6 Qualitatively analyze circuits using Kirchoff's and Ohm's laws**.**