Life Science Prior Essential Knowledge (to take AP Biology or college level courses).

From <http://professionals.collegeboard.com/profdownload/cbscs-science-standards-2009.pdf>

**Standard LS.1 (9-12)**

**Evolution**

The diversity and unity of life can be explained by the process of evolution.

**Objective LS.1.1 Evidence of Common Ancestry and Divergence**

**LSH-PE (Life Science High School- Performance Expectations)**

**LSH-PE.1.1.1** Provide evidence — reported in print and electronic resources, and regarding similarities and differences between organisms from the fossil record and preserved DNA — that supports the idea of descent with modification. Explain how similarities and differences among organisms support the idea of descent with modification.

**LSH-PE.1.1.2** Construct a simple model (e.g., phylogenetic tree), based on anatomical evidence (physical traits), of the degree of relatedness among various organisms. If necessary, revise the model based on the inclusion of new molecular (i.e., DNA and/or amino acid) evidence.

**LSH-PE.1.1.3** Explain, in terms of preserved DNA sequences, why specific extinct or extant organisms within a line of descent are considered

to be either closely or more distantly related (i.e., share a common ancestor)

Essential Knowledge.

• Organisms resemble their ancestors because genetic information (DNA) is transferred from ancestor to offspring during reproduction.

• The branching that characterizes lines of descent can be inferred from the DNA composition of organisms over time.

• The similarities and differences in DNA sequences, amino acid sequences, anatomical evidence and fossil evidence provide information about the branching sequence of lines of evolutionary descent.

**Objective LS.1.2 Natural Selection**

**LSH-PE.1.2.1** Construct a model or run a simulation that represents natural selection in terms of how changes in environmental conditions

can result in selective pressure on a population of organisms.

**LSH-PE.1.2.1a** Gather and record data from the model or simulation on the composition (e.g., distribution of traits, number of organisms, change in environmental conditions) of a population under varying environmental conditions. Complete multiple trials or use class data.

**LSH-PE.1.2.1b** Represent the data in a way that demonstrates the relationship, if any, between the environmental changes and the population.

**LSH-PE.1.2.1c** Calculate measures of central tendencies (i.e., mean, median, mode), represent spread of data (e.g., range), and determine error (e.g., number of **outliers**) of each variable in order to analyze the data and make a claim about the patterns observed.

**LSH-PE.1.2.1d** Explain how each part of the model or simulation is similar to, or different from, the process of natural selection.

**LSH-PE.1.2.2** Predict and justify, based on ideas about natural selection, what might happen to a population of organisms after many generations if the population becomes geographically isolated from another population of the same species, and if the two groups experience different **biotic** and/or environmental conditions.

**LSH-PE.1.2.3** Give examples, using information gathered from print and electronic resources, of observations made by Charles Darwin of variation within species and of changes in environmental conditions that he used in the development of his theory of natural selection. For each example, explain how the observations support the theory of natural selection.

**ESSENTIAL KNOWLEDGE (9–12)**

• Natural selection leads to a diversity of organisms that are anatomically, behaviorally and physiologically well suited to survive and reproduce in a specific environment.

• Over time, the differential survival and reproduction of organisms within a population that have an advantageous heritable trait lead to an increase in the proportion of individuals in future generations that have the trait and a decrease in the proportion of individuals that do not.

• Changes in the **abiotic** environment, including climatic and geological processes, have contributed to the decline of some species and the expansion of other species.

• When environmental change — naturally occurring or human induced — happens, extinction can occur. Species become extinct because they cannot survive and reproduce in their environments. If members cannot adjust — because change in the environment is too fast or too drastic — they die or become unable to reproduce, thus negating opportunity for evolution.

• Charles Darwin’s theory of evolution had a dramatic effect on biology because of his use of clear and understandable argument and the inclusion of a massive array of evidence to support the argument.

**Objective LS.1.3 Genetic Variation Within Populations**

**LSH-PE.1.3.1** Give examples of how, following a change in environmental conditions, variation in traits within a specific population of organisms might affect the survival and reproductive ability of some of the organisms in that population, but not other organisms in the same population. Give examples of other environmental changes that may not affect the survival and reproduction of any of these organisms. Describe the type of data needed to determine whether the survival or reproductive success of individual organisms was due to the genetic variation within the population.

**LSH-PE.1.3.2** Compare the effects of a significant environmental change on a population with great genetic diversity and the effects of such a change on a population with little genetic diversity. In each instance, indicate the environmental change, the organisms within the species that were affected, and the organisms that were not affected. Explain why genetic variation among organisms within the species affected the survival of the species.

**LSH-PE.1.3.3** Explain similarities and differences between populations (e.g., dogs, horses, crops) undergoing artificial selection and populations undergoing natural selection. Describe the roles that humans play in artificial selection and how these roles are similar to the natural processes that take place in natural selection.

**LSH-PE.1.3.4** Give examples, using information gathered from print and electronic resources, of different organisms whose classification as members of different “species” is questionable. After evaluating the two different proposed definitions of the term “species” that led to the controversial classification of the organisms, make and justify a claim about whether or not the organisms provided as examples should be considered members of different species or of the same species.

**ESSENTIAL KNOWLEDGE (9–12)**

• Natural selection can occur only if there is variation in the genetic information between organisms of the same species in a population and variation in the expression of that genetic information as a trait. Genetic variation within a population influences the likelihood that a population will survive and produce offspring.7

• Sexual reproduction not only allows the continuation of traits (phenotype) in a population but also provides a source of genetic variation among the individuals of a population.

• The expression of new anatomical, physiological and behavioral traits (phenotype) in organisms within a population can result from recombining existing genes and random sorting during sex cell production and fertilization. Variation within a population of organisms can also result from genetic mutations that create variation in the expression of traits (phenotype) between organisms of the same species.

• In artificial selection, humans have the capacity to influence certain characteristics of organisms by manipulating the transfer of genetic information from generation to generation.

**Standard LS.2 Cells as a System**

**Objective LS.2.1 Cell Function**

**LSH-PE.2.1.1** Describe the structure and function of at least one organ located in a plant and the analogous organ located in an animal (e.g., organs used for food storage, movement, reproduction, etc.). Description includes the types of cells, the structure of these cells, and the processes they perform to support the function of both the organ and the organism as a whole.

**LSH-PE.2.1.2** Describe the function of at least one type of organ located in two different plants or in two different animals. Description includes the similarities and differences in the cells that make up the organ, and the similarities and differences in the processes that the cells perform to support the function of the organ in the two organisms.

**LSH-PE.2.1.3** Describe, using information gathered from print and electronic resources, the structure and function of at least two organs that are part of a human body system (e.g., circulatory, digestive, gas exchange). Description includes how the two organs differ regarding the types of cells that make up each organ. Explain, using knowledge of systems of cells, how the cells and organs

coordinate and contribute to the overall essential functions of the organism.

**ESSENTIAL KNOWLEDGE (9–12)**

• In multicellular organisms, groups of one or more kinds of cells make up different systems of cells (i.e., tissues and organs) that are connected and that cooperate with each other in order to perform the essential functions of life within an organism.

• Different multicellular organisms use different systems of specialized cells to carry out the same basic life functions.

• The human body is made up of cells that are organized into tissues and organs. These tissues and organs make up complex systems that have specialized functions (e.g., circulatory, endocrine, etc.) that support essential life functions of the organism.

**Objective LS.2.2 Cell Structure**

**LSH-PE.2.2.1** Observe the internal structures of at least three different types of cells (e.g., amoeba, fungi, plant root, plant leaf, animal muscle, and animal skin). Describe, using information gathered from print and electronic resources, the functions of these structures. Construct a representation of each cell type, and compare — using gathered information and knowledge of cell structures and functions — the structures and functions across cell types. Explain why the representation is limited and simplified.

**LSH-PE.2.2.2** Investigate the movement of molecules across a membrane.

**LSH-PE.2.2.2a** Formulate a **scientific question** about the movement of molecules across a membrane under differing conditions of temperature, starting concentration, pH, etc.

**LSH-PE.2.2.2b** Plan an investigation to address the variables that might affect the movement of molecules across a membrane.

**LSH-PE.2.2.2c** Gather and record data on the movement of molecules across a membrane via passive transport under varying conditions of temperature, starting concentration, pH, etc., by completing multiple trials or by using class data. (Movement across the membrane can be measured as the percent change in the mass or volume of liquids on either side of the membrane, or by the degree of color change of liquids on either side of the membrane.)

**LSH-PE.2.2.2d** Calculate measures of central tendency (i.e., mean), spread of data (i.e., range) and error (i.e., number of outliers) of the concentration of the different molecules on either side of the membrane at different times.

**LSH-PE.2.2.2e** Make claims about the movement of the different molecules across the membrane and the factors that affect that movement.

**LSH-PE.2.2.3** Explain why cells of organisms swell when placed in water and why they shrink when placed in a solution of salt water. Evaluate other student explanations of the same phenomenon. Construct a representation that generalizes the phenomenon to all organisms.

**LSH-PE.2.2.4** Construct a representation of a cell membrane undergoing passive and active transport, in terms of difference in concentration, required energy and direction of molecule movement. Explain how the movement of molecules impacts the cell, and, as a result, impacts the organism as well.

**LSH-PE.2.2.5** Collect data on the rates of reactions (synthesis and breakdown) via different enzymes and the rates of reactions that occur without each enzyme. Construct tables and graphs to represent the data for each enzyme. Compare the rates of reactions for the different enzymes.

**LSH-PE.2.2.6** Give examples of several enzyme-catalyzed reactions that occur in living systems, and describe the importance of each reaction for the organism. Explain why an organism that has a deficiency of one of the enzymes is unable to perform a particular life function.

**ESSENTIAL KNOWLEDGE (9–12)**

• The essential functions of a cell involve chemical reactions that take place between many different types of molecules (e.g., water, carbohydrates, lipids, nucleic acids and proteins) and that are facilitated by enzymes. Water plays an important role both in reactions and as a major environmental component for all cells.

• Enzymes are proteins that enable chemical reactions to proceed at rates that support life functions. Environmental factors and modulators (inhibitors and activators) influence an enzyme’s activity and its ability to regulate chemical reactions (i.e., life’s essential functions).

*[****BOUNDARY:*** *The targets of understanding are (1) changes in reaction rates due to enzymes, and (2) the factors that affect enzymes. Quantitative treatment of reaction rates is out of the scope of this objective. The molecular orientation of molecules (i.e., tertiary structure) and the specific enzyme mechanism (i.e., induced fit) are also not appropriate.]*

• Due to differences in concentration of molecules, molecules move in and out of a cell and among cells through specialized mechanisms called passive transport and active transport. The concentration of molecules and energy are factors in type and direction of transport.

**Objective LS.2.3 Cell Growth and Repair**

**LSH-PE.2.3.1** Make a claim about and justify, using ideas about conservation of matter, why new atoms and molecules must be added to cells in order for them to grow.

**LSH-PE.2.3.2** Construct a representation of the changes that occur in a cell in terms of its size and internal components, and of the number of cells produced as a cell goes through a single cycle of cell growth and division. Predict, based on the representation, what might happen to a cell (e.g., increase in size, change in internal structure) that does not go through the entire cell cycle but still goes through division.

**LSH-PE.2.3.3** Describe, using information gathered from print and electronic resources, examples of the following cell types from any multicellular organism: a cell type that divides, a cell type that does not divide at all, or a cell type that divides only under very unusual circumstances. Description includes information about the consequences and significance to an organism of having some cells that divide and some that do not.

**LSH-PE.2.3.4** Identify, using information gathered from print and electronic resources, several specific parts of the cell cycle that are monitored by check point systems, and describe some of the problems that might occur if abnormal cells were allowed to continue cycling.

**ESSENTIAL KNOWLEDGE (9–12)**

• Cells typically undergo a continuous cycle of cell growth and division. Although most cells share the same cell cycle phases (e.g., cell growth, DNA replication, preparation for division, separation of chromosomes, cell membrane pinching off two daughters), the length of each cell cycle phase, and therefore the frequency of cell division, varies among different cell types.

*[****BOUNDARY:*** *Detailed descriptions of the actions taking place during the different phases are not as important as the overall impact of these actions on the cell (changes that take place to the cell and its internal components) throughout the cycle.]*

• Normal progression through the cell cycle and readiness to initiate reproduction are constantly evaluated at check points throughout the cell cycle; abnormal or damaged cells are targeted for repair or for intentional destruction (apoptosis). Malfunctions in the check point feedback system

**Objective LS.2.4 Cell Differentiation**

**LSH-PE.2.4.1** Construct a representation to demonstrate how gene activation and gene inactivation lead to cell differentiation. Representation includes the transmission of genetic information from DNA to protein to cell traits.

**LSH-PE.2.4.2** Give examples, using information gathered from print and electronic resources, of situations in which errors that occur during gene activation or gene inactivation lead to errors in cell differentiation.

**LSH-PE.2.4.3** Gather, from print and electronic resources, data that can be used as evidence to support or refute the claim that some kinds of stem cells have a greater potential than other kinds of stem cells to develop into a variety of different tissue types. Include comparisons between embryonic stem cells and adult or body stem cells, and comparisons among different types of adult stem cells.

**LSH-PE.2.4.4** Identify current applications of plant and animal stem cells, and describe problems surrounding the use of these cells.

**ESSENTIAL KNOWLEDGE (9–12)**

• During the successive division of an embryo’s cells, activation or inactivation of different genes in these cells causes the cells to develop in different ways.

• The stem cells of plants and animals divide through mitosis. After the cells divide, at least one of the daughter cells remains undifferentiated. At specific times, some daughter cells will differentiate to become a specific type of cell with a specialized function, while others will continue as non-specialized cells. There are stem cells at all stages of development (e.g., in embryos as well as in adults). Adult stem cells continue to divide, generating both a differentiated daughter cell of a specific tissue type and an undifferentiated daughter cell.

**Standard LS.3 Interdependent Relationships**

**Objective LS.3.1 Living Systems and the Physical Environment (abiotic)**

**(none for 9-12)**

**Objective LS.3.2 Interactions of Living Systems (limited resources)**

**(none for 9-12)**

**Objective LS.3.3 Ecosystem Stability**

**LSH-PE.3.3.1** Describe the abiotic characteristics of an ecosystem: its boundaries, its components, its inputs and outputs, and its interactions, as well as the boundaries and other characteristics of overlapping ecosystems.

**LSH-PE.3.3.2** Analyze data (e.g., mean, mode, spread of data, sampling error) that show the number of different species and the number of organisms within a species in two or more ecosystems over time (one of the ecosystems has more fluctuations than the other). Make a claim about the relative stability of each ecosystem. Devise a measure of relative stability, taking into account whether the stability is simply a lack of fluctuation of organism numbers, or if the stability should be measured based on a regular recurrence of a cyclical pattern of variation in an ecosystem.

*[****BOUNDARY:*** *There is no standard measure of relative stability for biodiversity. The measure of relative stability is generated by the student to give him or her an appreciation of the complexity of the factors involved.]*

**LSH-PE.3.3.3** Gather information — and, when appropriate, numerical data — from print and electronic resources about the stability of various ecosystems, in terms of changes in the biotic and abiotic components of those ecosystems over time. Make a claim, based on this information and/or data, about whether the ecosystem is stable or unstable, and describe which conditions/factors indicate stability or instability.

**LSH-PE.3.3.4** Analyze data that depict changes in the abiotic components of an ecosystem and changes in the biotic components of an ecosystem over time (e.g., percent change, average change, correlation and proportionality). Evaluate claims of possible relationships between the changes in the abiotic components and the biotic components of the environment.

**LSH-PE.3.3.5** Predict what will happen to the number of organisms of a given species in an ecosystem following a temporary biotic or abiotic change in that ecosystem (e.g., a very cold winter or a disease that kills large numbers of one of the species in the ecosystem) and what will happen after conditions return to what they were before the disruption. Justification for the prediction is based on knowledge of how ecosystems typically respond to temporary changes in environmental conditions, how this particular ecosystem has responded to such changes in the past, and the scale of these particular changes.

**ESSENTIAL KNOWLEDGE (9–12)**

• The number of organisms in ecosystems fluctuates over time as a result of mechanisms such as migration, birth and death. These fluctuations are essential for ecosystem stability and characterize the dynamic nature of ecosystems. Extreme fluctuations in the size of populations offset the stability of ecosystems in terms of habitat and resource availability.

• Ecosystems can be reasonably stable over hundreds or thousands of years.9 If a disturbance to the biotic or abiotic components of an ecosystem occurs, the affected ecosystem may return to a system similar to the original one, or it may take a new direction and become a very different type of ecosystem.

• Ecosystems are not always stable over short periods of time. Changes in climate, migration by an invading species into an ecosystem, and human activity can impact the stability of an ecosystem.

**Objective LS.4.1 Matter Cycling (**Students understand that matter is continuously recycled within the biological system and between the biological (biotic) and physical (abiotic) components of an ecosystem.) none for 9-12th grade.

**Objective LS.4.2 Energy Transfer**

Students understand that all of the processes that take place within organisms require energy. In most ecosystems, the energy is derived from the Sun and transferred into chemical energy in photosynthetic organisms of that ecosystem.

**LSH-PE.4.2.1** Construct a graphical representation of the number of sugar molecules that are broken down into carbon dioxide and the amount of ATP (adenosine triphosphate) that is produced during fermentation (when oxygen is limited) and during cellular respiration (when oxygen is available). Explain, using the representation, common exercise phenomena (e.g., lactic acid buildup,

changes in breathing during and after exercise, cool down after exercise).

**LSH-PE.4.2.2** Investigate variables that affect the processes of fermentation and/or cellular respiration in living organisms. *[****BOUNDARY:*** *The context of this investigation is purposely open so that experiences that best fit students’ interest and level* *of understanding can be selected.]*

**LSH-PE.4.2.2a** Formulate a scientific question about the relationship between variables (e.g., type of food, temperature, process input, process output) that impact fermentation and/or cellular respiration.

**LSH-PE.4.2.2b** Gather and record data (e.g., color indicator change, pulse rate, amount and type of product or reactant), using tools to improve accuracy and precision of measurements, and complete multiple trials or use class data.

**LSH-PE.4.2.2c** Construct graphs and tables of data for changes in the different variable conditions.

**LSH-PE.4.2.2d** Calculate changes in rate, percent change, averages and measurement error in order to analyze data and discover patterns. Evaluate the data as it relates to the formulated scientific question.

**LSH-PE.4.2.2e** Coordinate the results of different investigations that have analyzed different variables that impact either fermentation or cellular respiration. Construct a representation of all of the evidence collected from the various studies.

**LSH-PE.4.2.2f** Make a claim, based on evidence collected from all investigations, about real-world phenomena (e.g., ethanol production, wine or bread making, exercise).

**LSH-PE.4.2.3** Give examples of functions (e.g., removal of wastes, muscular activity, cell division) that are carried out by organisms and that

involve the conversion of ATP to ADP (adenosine diphosphate) and an inorganic phosphate.

**LSH-PE.4.2.4** Give examples of chemical reactions (e.g., synthesis of glycogen, oxidation of glucose) involved in basic functions of organisms in which the reactants and products of the reaction are paired with reactions involving ATP and ADP and an inorganic phosphate. Construct an illustration, in terms of reactants and products, of the chemical reactions of basic functions and ATP and ADP with an inorganic phosphate. *[****BOUNDARY:*** *The molecular structure of molecules is not appropriate for this PE.]*

**LSH-PE.4.2.5** Construct a representation of the transfer of energy through an ecosystem, starting with the Sun and ending with increased motion of molecules in the environment. Representation should reflect the idea that energy is conserved. Explain, based on the transformation of chemical energy to thermal energy at various trophic levels and on the nature of reactions, the need for constant input of energy into an ecosystem.

**LSH-PE.4.2.6** Construct a representation that links the movement of matter (i.e., carbon atom, water molecule) and the transfer of energy through the processes of photosynthesis and cellular respiration. Predict and justify, based on knowledge of energy transfer and matter cycling, what might happen to the mass of a biosystem if the source of energy were limited.

**LSH-PE.4.2.7** Construct a model of a food chain that includes a quantification of the distribution and buildup of a potentially damaging chemical that is introduced into an ecosystem. Predict, using the model, consequences at each trophic level as the relative concentration of the chemical increases. Justification includes changes in the number of organisms at each trophic level, matter cycling, and energy transfer from one level to another.

**ESSENTIAL KNOWLEDGE (9–12)**

• Life processes involve a complex sequence of chemical reactions in which chemical energy is transferred from one system of interacting molecules to another. Some of the energy in these reactions is transferred to the environment as thermal energy (heat).

• All living systems require an input of energy to drive the reactions in essential life functions and to compensate for the inefficient transfer of energy. The chemical reactions in living systems involve the transfer of thermal energy (heat) to the environment. The thermal energy is no longer available to drive chemical reactions; therefore, a continuous source of energy is needed. In many organisms, the energy that keeps the chemical reactions in organisms going comes from food that reacts with oxygen. The energy stored in that food ultimately comes from the Sun. *[****BOUNDARY:*** *Students are not expected to know that chemosynthesis is a process that supplies energy for the synthesis of* *food in an ecosystem.]*

• The transfer of chemical energy within living systems involves chemical reactions among ATP, ADP and an inorganic phosphate. The conversion of ATP to ADP and an inorganic phosphate drives other essential reactions in living systems. *[****BOUNDARY:*** *Students are not required to know the chemical names or the molecular structures of ATP and ADP.]*

• During cellular respiration, molecules from food — mainly sugars and fats — are converted in the presence of oxygen into carbon dioxide and water, and the chemical energy of that reaction is used to combine ADP and an inorganic phosphate to make ATP.

• During fermentation, molecules from food are partially broken down in cells in the absence of oxygen into smaller molecules (but not completely into carbon dioxide and water). Compared to the chemical reactions that take place during cellular respiration, these reactions result in less ADP being combined with an inorganic phosphate to produce ATP; therefore, less energy is made available during fermentation than during cellular respiration for the chemical reactions that maintain an organism’s body functions.

**Standard LS.5 Information Transmission, Storage and Retrieval**

Living systems have multiple mechanisms that are used to store, retrieve and transmit information.

**Objective LS.5.1 Changing Model of Inheritance** (none for 9-12th grade)

**Objective LS.5.2 Genetic Information Transmission**

**LSH-PE.5.2.1** Estimate and justify how many variations are possible in the set of chromosomes (DNA molecules) that the sex cells of a particular organism (e.g., mosquito, fruit fly or other organism with a low number of chromosomes) receive during sex cell formation. Construct a model that includes a label for each chromosome and that illustrates some of the possible combinations of chromosomes that will be present in the sex cells that are produced.

**LSH-PE.5.2.2** Explain, based on knowledge of how sex cells form in sexually reproducing organisms, why there is variation among offspring, even within the same family.

**LSH-PE.5.2.3** Observe the variation of traits among the individual organisms within a population. Explain, based on the transmission of genetic information, why there is so much variation within the population.

**LSH-PE.5.2.4** Construct a representation — or several representations — of sex cell formation, demonstrating that the DNA of the daughter cells is different from the DNA of the parent cell. Representation includes the process of replication, the separation of homologous chromosomes (first stage of meiosis), and the separation of the replicated chromosomes to create cells with just a single version of each chromosome (second stage of meiosis).

**LSH-PE.5.2.5** Construct a model of a particular gene on a pair of DNA molecules. Construct a new model that incorporates the DNA molecule model into a model of homologous chromosomes in a cell nucleus.

**ESSENTIAL KNOWLEDGE (9–12)**

• Sex cells are formed by a process of division (meiosis) in which the number of chromosomes, and thus the amount of DNA, per cell is halved after replication.

• With the exception of sex chromosomes, for each DNA molecule (chromosome) in the body cells of a multicellular organism, there is a similar, but not identical, chromosome (homologous pair). Although these pairs of similar chromosomes can carry the same genes, they may have slightly different versions of the genes (alleles). During the formation of sex cells (meiosis), one chromosome from each pair is randomly passed on (independent assortment) to form sex cells, resulting in a multitude of possible genetic combinations.

• The cell produced during fertilization has one “set” of DNA molecules from each parent. The cell (zygote) then divides asexually as the organism grows and develops so that the body cells of the organism have two “sets” of DNA molecules.

**Objective LS.5.3 DNA to Trait**

**LSH-PE.5.3.1** Analyze the primary structure (amino acid sequence) of specific proteins (e.g., insulin and hemoglobin). Create a table showing which amino acids make up each protein molecule, and the numbers of each amino acid that make up these proteins.

*[****BOUNDARY:*** *Emphasis should be placed on the differences among protein composition, NOT on the memorization of amino acid structure, types or sequence.]*

**LSH-PE.5.3.2** Evaluate and, if necessary, revise representations that illustrate the processes of transcription and translation to show how the sequence of nucleotide bases produces a complementary strand of bases in RNA (ribonucleic acid), and how each sequence of three bases in RNA codes for specific amino acids that are linked together to make proteins.

*[****BOUNDARY:*** *Emphasis should be placed on the bigger ideas of form and function and following the transmission of information, not on the details (e.g., components of a ribosome, structure of tRNA, directionality) of the mechanism.]*

**LSH-PE.5.3.3** Construct a representation that illustrates the process of the production of the amino acid sequence of a section of a given protein molecule from an organism. Representation should first show the relationship between these amino acids and a sequence of nucleotide bases in RNA, and then show the relationship between that sequence of nucleotide bases in RNA and the sequence of bases in DNA.

**LSH-PE.5.3.4** Give examples, using information gathered from print and electronic resources, of traits that result from specific proteins. Include examples of the following types of proteins: structural, regulatory and enzymatic. Examples should span structural, behavioral and physiological traits.

*[****BOUNDARY:*** *This performance expectation is intended to focus on the fact that proteins in the form of enzymes determine traits, not on the details of the cascade of reactions or the chemical structures involved.]*

**LSH-PE.5.3.5** Describe how traits in organisms are the result of DNA structure. Include ideas about the connection between traits and proteins, the connection between protein structure and the sequence of bases in RNA, and the connection between RNA sequence and DNA sequence.

**LSH-PE.5.3.6** Give examples, using information gathered from print and electronic resources, of traits that depend on the quantity of protein produced, which, in turn, is dependent on the number of copies of a particular version of a gene. Predict and justify how zero, one or two copies of a particular version of a gene might affect the expression of a particular trait.

*[****BOUNDARY:*** *Emphasis should not be placed on the mechanisms of gene expression, the cascade of reactions, or any specific details of mechanisms. The amount of protein produced also depends on the type of promoter and the rate of synthesis, but these concepts are not within the scope of the 9–12 grade band.]*

**LSH-PE.5.3.7** Identify functions performed by DNA segments that do not code for proteins.

**ESSENTIAL KNOWLEDGE (9–12)**

• Genes are segments of DNA that are in locatable regions on the DNA molecules that specify protein sequence and, in turn, an organism’s traits.

• Not all DNA segments specify proteins; some segments of DNA are involved in regulation or structural functions. Some segments of DNA have no known function.

• The protein information contained in the sequence of nucleotide bases that makes up a strand of DNA is transmitted to a messenger RNA molecule (transcription). The messenger RNA molecule, with the help of other RNA molecules (ribosomal and transfer), then guides the production of a specific amino acid sequence of a particular protein (translation). These messenger RNA molecules degrade into nucleotide bases, which are then recycled into new RNA.

*[****BOUNDARY:*** *In order for this statement to be accurate, the following concepts must be understood: Not all DNA is transcribed, and not all RNA is translated. However, this is not essential knowledge for the student.]*

• Proteins are long, folded chains (polymers) composed of 20 different amino acids (monomers). Amino acid sequence determines the shape and function of the protein molecule that is produced.

• Protein molecules are responsible for the observable traits of an organism and for most of the life functions that take place within an organism. The enzymes that catalyze chemical reactions in organisms are proteins.

• Traits (phenotype) can be structural, physiological or behavioral; they can include readily observable features at the organism level as well as less observable features at the cellular and molecular levels.

• Sexually reproducing organisms contain two similar, but not identical, versions of each chromosome (i.e., the chromosomes have some genes [alleles] that are the same on both versions of the chromosome and some that are not). Each trait that results from these different gene combinations depends on the nature and amount of the protein that each gene produces, as well as on the interactions among those proteins.

**Objective LS.5.4 Imperfect Transmission of Genetic Information**

Students understand that there are various ways in which the transmission of genetic information can be imperfect, and that these imperfections may have positive, negative or no consequences to the organism.

**LSH-PE.5.4.1** Explain why an insertion, deletion or substitution of an individual nucleotide base affects not only the amino acid sequence of the proteins that are produced but also the protein structure that results from the altered amino acid sequence.

**LSH-PE.5.4.2** Explain, using information on a particular error in copying DNA during replication for a specific trait (e.g., insertion, deletion or substitution), why there could be an alteration in that trait. Justification is based on knowledge of the relationship among DNA, proteins and traits.

**LSH-PE.5.4.3** Give examples, using evidence gathered from print and electronic resources, of genetic diseases (e.g., cystic fibrosis, sicklecell anemia, Tay-Sachs disease or phenylketonuria) that result from mutations to a single gene. Identify, for each example, the specific type of mutation that causes the change in amino acid sequence and ultimately the change in the protein that is produced.

**LSH-PE.5.4.4** Give examples, using evidence gathered from print and electronic resources, of instances when viruses are linked to cancer. Explain, based on knowledge of viral gene insertions and of the relationship among DNA, proteins and traits, how a viral insertion into DNA can cause cancer.

**LSH-PE.5.4.5** Give examples, using evidence gathered from print and electronic resources, of the potential of using viruses for curing genetic diseases via gene therapy. Make a claim about, and justify, based on knowledge of viral DNA and viral insertions, why some viruses are appropriate for this application.

**ESSENTIAL KNOWLEDGE (9–12)**

• Mutations involve changes to an organism’s DNA and may be caused by internal factors (i.e., errors that occur during DNA replication or the division process) or by external factors (i.e., radiation or chemicals). Mutations may occur at the individual gene level or at the chromosomal level, but all mutations involve changes to DNA.

• Mutations may cause no change in an organism’s traits (phenotype), cause a detrimental change or cause a beneficial change.

• Mutations that alter the sequence of DNA may lead to a change in the protein produced. Changes to any of the proteins responsible for traits may result in an alternative trait (phenotype).

• Not everything that carries genetic information is a cell. A virus, which is not a cell, contains either DNA or RNA as its genetic information. To reproduce, a virus uses its own DNA or RNA but also uses the cellular machinery of the host cell. Often, the viral genes are incorporated into the host DNA or RNA, disrupting the DNA sequence within the host cell.

**Objective LS.5.5 Nongenetic Information Transmission**

Students understand that nongenetic transmission of information within and among organisms involves specialized molecules, cell structures and cell systems. *[****BOUNDARY:*** *Only very basic models (e.g., single receptor and single transmitter) and a very basic distinction between direct communication and distance communication via molecules are necessary. Focus should be on the basic input/output regulation of a system; model of communication or feedback should be very simple (e.g., few steps and a small number of molecules involved in the mechanism).]*

**LSH-PE.5.5.1** Construct a model that represents the molecular communication that takes place between cells that are in direct cell-to-cell contact, and a model that represents the molecular communication among cells in which molecules are released from one cell and target other cells in the vicinity of the emitting cell (e.g., neurotransmitters, local hormones, growth factors).

**LSH-PE.5.5.2** Construct a model to describe the communication between distant cells (e.g., hormones, pheromones, chemotaxis) and the process by which molecular communication between distant cells leads to particular outcomes.

**LSH-PE.5.5.3** Evaluate and, if necessary, revise representations of how drugs such as alcohol, nicotine, morphine, tetrahydrocannabinol (THC) and methamphetamines affect neurotransmitters and the communication that normally takes place between and/or among cells.

**LSH-PE.5.5.4** Construct a simple representation of a feedback mechanism that maintains the internal conditions of a living system within certain limits as the external conditions change. Describe, using the representation, the response of the system to some particular system imbalance (e.g., lack of water causing stomata to contract).

**LSH-PE.5.5.5** Construct a representation of the interaction of the endocrine and nervous systems (e.g., hormones and electrochemical impulses) as they interact with other body systems to respond to a change in the environment (e.g., touching a hot stove). Explain how the representation is like and unlike the phenomenon it is representing.

**ESSENTIAL KNOWLEDGE (9–12)**

• Communication takes place at the molecular level by means of specialized molecules that send and receive information.

• Molecular communication takes place when molecules from one cell interact with molecules from other cells; these interactions often take place with the help of proteins in the cell membrane.

• There are systems (e.g., endocrine and nervous [sensory]) within and between organisms that send, receive and process information over short and long distances by using specialized molecules.

• The output of one system can be the input to another system. Molecules produced in one system can encourage or discourage what is going on in another system.

• Feedback communication maintains a living system’s internal conditions within certain limits (e.g., temperature, molecular concentration, pH), allowing it to remain alive and functional even as external conditions are changing.

• Feedback systems may involve enzymes, membrane proteins and/or gene regulators, and their communication can be affected by environmental conditions.

• Many drugs affect the normal communication among cells by interacting with or altering the proteins in the cell’s membranes, or by altering the molecule that is transmitting information.

**Standard SP.1 Scientific Questions and Predictions**

Asking scientific questions that can be tested empirically and structuring these questions in the form of testable predictions

Students ask scientific questions about phenomena, problems or issues that can be addressed through scientific investigations or with evidence from existing models. All science knowledge is eligible for such questioning. Keeping in mind that each phenomenon or problem occurs under specific conditions, students make predictions based on their science knowledge, observations and measurements of objects and events in the natural world, or data. Their predictions serve as a lens to focus data collection back to the scientific question. Students develop and refine both scientific questions and predictions so that they can be addressed through scientific investigations.

**ESSENTIAL KNOWLEDGE**

• A scientific question is one that is testable and can be supported or refuted with empirical evidence.

• A scientific question has its origins in observations and measurements of objects and events in the natural world, and in what is already known about the world.

• When posing a scientific question or solving a problem, it is important to identify what is known or assumed about the situation or condition being observed or measured.

• Scientific questions are often revised during the process of planning an investigation (see Objective SP.2.1). There is a dynamic relationship among the plan to gather evidence about the phenomenon, problem or issue; the evidence itself; and the development and refinement of a scientific question.

• Information compiled from similar studies, problems and investigations is gathered to provide insight into the formulation or revision of a scientific question, a potential plan to gather evidence, and plausible data to address the phenomenon or problem.

• Scientific questions should be asked of peers, instructors and other resources as a part of science discourse and the evaluation of evidence and explanations. Scientific questions are asked and researched to clarify personal understanding of the natural world.

• Scientific questions are foundational to the construction of an explanation.

**Objective SP.1.2 Predictions**

Students make and justify predictions concerning natural phenomena. Predictions and justifications are based on observations of the world, on knowledge of the discipline and on empirical evidence.

**ESSENTIAL KNOWLEDGE**

• A prediction about a natural phenomenon can be based on direct observations and measurements of patterns and regularities in the natural world and on the conditions of the natural phenomenon; data collected by others; knowledge of the discipline; or physical, mental or mathematical models of phenomena.

• Predictions are claims with justification about what might happen under certain conditions. The justification could be based on **principles** and concepts or on previous empirical evidence.

• Predictions should take into account existing scientific theories or models, scientific laws and new data.

• A prediction is further refined as new knowledge develops or as empirical evidence is collected.

• Predictions may place boundaries around the experimental parameters (e.g., type and amount of data; frequency and length of data collection).

**Standard SP.2**

**Generation of Evidence**

Collecting data to address scientific questions and to support predictions

Students use controlled experiments, naturalistic observations, historic reconstruction, archived data and/or the findings of other scientists as

resources to address scientific questions or test predictions. While considering the scientific question or the prediction, students decide what

to measure (or which existing measurements to use) and observe, decide what unit of measure to use, develop data or archival data collection

methods, and systematically collect and record data. Students recognize that data and evidence are different, and that the determination of

which data can be used as evidence to address a particular scientific question or prediction depends on the question being asked, the prediction

being made or the explanation.

Students use a variety of strategies (e.g., categorical, descriptive and quantitative) for collecting and recording **valid** and **reliable** data.

Students recognize the reasons for multiple measures of the same phenomenon (i.e., repeated measures of the same dependent variable or

multiple investigations that measure the same phenomenon in different ways) and, when appropriate, use multiple measures to estimate

the validity and reliability of the data. Students use technology and science tools to extend the senses and to enable more sophisticated

measurements to be made, and they use technology and mathematics to organize scientific data.

**Objective SP.2.1 Data Collection**

Students select and use appropriate measurement methods and techniques for gathering data, and systematically record and organize observations and measurements.

**ESSENTIAL KNOWLEDGE**

• The nature of the scientific question being asked or the prediction being made determines the data (categorical or numerical) that must be gathered, the methods of gathering the data, and the **accuracy** and **precision** that are required to answer the question or test the prediction.

• Some methods of gathering data require the manipulation of variables (independent and dependent) and the control or monitoring of variables. The selection of the variables to be observed or measured, and of appropriate methods of observation and measurement, is determined by the data intended to be used as evidence to address the scientific question or the prediction.

• Data should be recorded in an orderly and systematic way to facilitate later analysis of the selected data and the use of this data as evidence to support an explanation. In all instances, observations and measurements are recorded objectively, avoiding bias.

• Multiple measures (i.e., repeated measures of the same dependent variable, measures of potential intervening variables, or multiple investigations that measure the same phenomenon in different ways) of the same phenomenon should be used to ensure validity and reliability of data.

**Objective SP.2.2 Evaluating Data for Evidence**

Students determine which data from a specific investigation can be used as evidence to address a scientific question or to support a prediction or an explanation, and distinguish credible data from noncredible data in terms of quality.

**ESSENTIAL KNOWLEDGE**

• Data are recorded observations or measurements.

• Data that address or are relevant to a specific scientific question or a prediction, and that can be used in relation to a specific explanation, can be used as evidence.

• Before data can be used as evidence, the data must be deemed credible. Criteria for determining credibility include, but are not limited to the following:

◆◆ Data are reproducible, or collected in a manner that ensures validity or reliability (e.g., precision of instrument is considered; measurement procedure is carefully followed; sample size is large; bias is avoided; a control sample of data is included when appropriate; other conditions or variables are constant; completeness of data set is considered; source of data is considered).

◆◆ Replication of an investigation confirms accuracy and precision of observations and measurements.

• Inconsistent data help determine which data are good to use as evidence relative to a particular scientific question or a particular prediction. Inconsistent data may be credible (i.e., collected using appropriate methods, instruments, etc.), while still not relevant to the question being asked or the prediction being made.

• Collected data that are not consistent with a scientific question, a prediction or an explanation are also considered valuable for the possible revision of collection methods or scientific questions, and for the evaluation of the precision of the explanation, the prediction, or the conditions of the phenomenon or situation. These data are not considered evidence because they do not address the scientific question or prediction of focus.

• Peer review is an important part of determining credibility of data in that peers need to evaluate the methods used to identify patterns or collect data and the statistics used to interpret data.

**Standard SP.3**

**Data Analysis**

Searching for regularities and patterns in observations and measurements (i.e., data analysis)

Students identify patterns or relationships through examination and analysis of data, guided by the scientific question or prediction under

consideration. Analysis of data may involve a variety of tasks that overlap and are interdependent, such as the determination of the quality

of data used as evidence, the identification of patterns and the statistical analysis of patterns. Students need to determine which data may

be either **outliers** or products of inaccurate or inappropriate data collection, as well as the impact of an outlier on the measured variables,

correlation or trend. Data analysis requires identification of any uncertainty of a reported value, of sources of error (sampling or measurement)

in data collection, of **anomalies** or of the central tendencies or variability of data. The scientific question or prediction assists in the selection

of appropriate units or range of data as well as the representation of variables in a graph or chart. Students should use technology and

mathematics as often as possible as tools to analyze scientific data or to extend the senses. For detailed knowledge of the mathematical and

statistical applications involved in data analysis, see Objectives SP.5.1 and SP.5.2.

**Objective SP.3.1 Analyzing Data for Patterns** Students analyze data to discover patterns.

**ESSENTIAL KNOWLEDGE**

• Mathematical and statistical processes are applied, based on the scientific question and on the data generated, as part of the data analysis. These processes may include calculation of mean, median, mode, range and variance; qualitative representations or patterns involving exponential changes; analysis of linear functions; and treatment and/or expression of experimental error where appropriate.

• Appropriate representation (e.g., line graph instead of histogram, error bars on graphs for best estimate of slopes) is selected and created for organizing data. Appropriate symbols, notation and terminology are used in the representation. (Constructing representations [e.g., maps, tables, graphs] for the purpose of organizing data to find patterns is different from constructing a representation for the purpose of explaining — see Objective SP.4.2.)

• When appropriate, data are re-expressed in a different format to make patterns evident, to address a scientific question or a prediction, and to better understand the data. Re-expression may involve verbal summaries, discipline-specific drawings and diagrams, maps, summary charts and tables, frequency plots, bar graphs (histograms) or scatter plots. All forms of re-expressed data should account for the selected variables, the units of measure and the scale.

**Standard SP.4 Evidence-Based Explanations and Models**

Using evidence and science knowledge to construct scientific explanations, models and representations

Students use evidence to draw conclusions about the scientific questions asked and the predictions made. Based on patterns in evidence, students develop logical explanations of the phenomena that are under investigation. Students use their knowledge of the relevant science discipline to explain how or why an object or system has its observed properties, or how or why an observed natural or designed phenomenon occurs in different problems. Their explanations should consist of a claim, the evidence, and the reasoning that links the claim with the evidence. Students are expected to ensure that the explanation is based on accurate information and sound reasoning. In addition to being able to make explicit justifications for their own claims, students should also be able to recognize and refute claims that do not reflect the use of scientific evidence and reasoning. In communicating an explanation, students need to distinguish between their description and their overall explanation. Representations and models are tools that help communicate evidence, explanations, theories or predictions. Constructing a representation or model for the purpose of explaining is different from constructing a table, graph or diagram for the purpose of analyzing patterns in data.

**Objective SP.4.1 Constructing Explanations**

Students construct explanations that are based on observations and measurements of the world, on empirical evidence and on reasoning grounded in the theories, principles and concepts of the discipline.

**ESSENTIAL KNOWLEDGE**

• A scientific explanation includes (1) a claim about natural or designed objects, systems or phenomena; (2) the evidence, which can consist of empirical evidence or observations; and (3) the reasoning that links the claim with the evidence. A scientific explanation can specify causal relationships, generalizations (inductive and analogical), contrasting relationships or proposed models. An explanation also specifies, based on science knowledge, how or why a natural or designed system has its observed properties, or how an observed phenomenon occurs.

• A claim itself is not a complete explanation because it lacks evidence and reasoning. All claims should be justified by evidence or knowledge of principles or concepts of a discipline. Evidence used in the explanation consists of data (from investigations, scientific observations and measurements, the findings of other scientists, historic reconstruction, and/or archived data) that have been represented, analyzed and interpreted in the context of a specific scientific question or prediction.

• Both the evidence that supports the claim and the evidence that refutes the claim should be accounted for in the explanation. Alternative explanations should also be taken into consideration.

• Science knowledge used in the reasoning of an explanation can include data/information from previous investigations, as well as historical or current models and/or representations, concepts, principles or theories.

• The reasoning that supports an explanation should include a series of logical statements. These interconnected statements should allude to supporting evidence and counterevidence, include an interpretation of data as it relates to the claim, and consider multiple alternative explanations. The explanation might also include an examination of other explanations for which

the data might be used and an identification of any anomalous data that was rejected.

**Objective SP.4.2 Models and Representations**

Students construct, use, re-express and revise models and representations of natural and designed objects, systems, phenomena and scientific ideas in the appropriate context and in formulating their explanation.

**ESSENTIAL KNOWLEDGE**

• A model or representation may be physical (e.g., diagrams, flow charts, maps, scale models), mathematical (e.g., equations, graphs) or conceptual (e.g., imagery, metaphor, analogy), and it can be specific to a discipline. There are symbols, notations and terminology that are appropriate for specific types of representations within a discipline.

• Models or representations can be used to predict or explain natural phenomena and to raise scientific questions about how particular systems work.

• Both models and representations are limited in their ability to accurately depict all aspects of phenomena. There are key elements of the model or representation that are similar to the actual phenomenon, and there are aspects of the model or representation that make it inaccurate.

• When translating between representations (e.g., translating a chemical formula into a representation of electron configuration), there are key components of a representation that must be re-expressed in the new representation. The purpose of the re-expression, as well as the natural phenomenon itself, affects the determination of the key components and how they must be re-expressed for the new purpose.

• Depending on the purpose of constructing the model or representation (e.g., predicting the size of an atom versus predicting the reactivity of an atom), a model or representation is revised if it is too simple or too complicated. In other instances, based on the purpose and phenomenon, multiple models or representations are constructed for clarity.

**Objective SP.4.3 Evaluating Explanations**

Students evaluate, compare and contrast explanations that are based on observations of the world, on empirical evidence and on reasoning grounded in the theories, principles and concepts of the discipline.

**ESSENTIAL KNOWLEDGE**

• Evaluation of scientific explanations includes comparing and contrasting, based on whether the two explanations are a result of different evidence but the same claim, the same evidence but different claims, the same claim and the same evidence, or different claims and different evidence.

*[****BOUNDARY:*** *At higher grade bands, the comparison between two explanations that are based on completely different claims and evidence can be included.]*

• Criteria for the evaluation of a scientific explanation include, but are not limited to, the following:

◆◆ Explanation is robust and useful for making predictions about new events or about outcomes not yet observed. It is likely that an explanation could be supported or reproduced by others.

◆◆ Integration of **fact** and opinion is avoided.

◆◆ Making conclusions that do not follow logically from the evidence is avoided.

◆◆ Explanation includes an explicit statement about the critical assumptions of the explanation.

◆◆ The claim is appropriately aligned to the scientific question or the prediction it is intended to address.

◆◆ The quality and quantity of the evidence used to support the explanation is appropriate.

◆◆ Data used as evidence are reproduced or reconfirmed with new or contrasting data from other scientific investigations. Adequate and sufficient data are used as evidence to test an explanation. Appropriate numbers are used when reporting evidence.

◆◆ All of the evidence is used, not just selected portions of the evidence.

◆◆ The reasoning linking the claim to the evidence is strong. The reasoning is considered strong if it includes well established, accurate scientific principles and if the steps of reasoning form a logical progression.

**Standard SP.5 Quantitative Applications**

Using mathematical reasoning and quantitative applications to interpret and analyze data to solve problems

Students understand that in science, the use of quantitative applications is a process that is integral to all disciplines and at all levels. The study of science relies heavily on observations of the natural world. Quantitative applications are tools and, at times, language that scientists use to understand and explain these observations in a measurable way, to interpret numerical data and to logically evaluate other scientists’ observations. Quantitative applications do not require students to come to some numerical conclusion by making complex calculations and crunching numbers. Rather, the purpose of using these quantitative applications is to focus on reasoning among scientific questions, data, evidence and explanations; analyzing data; conceptualizing algorithms; interpreting graphical representations; and finding relationships. These quantitative applications, along with the previous science practices objectives and essential knowledge statements, will aid students in enhancing the tools they need to think more scientifically while learning to examine the world through a more analytical lens.

All of the science standards are based on the assumption that students are enrolled in mathematics courses that meet the goals described in the *Mathematics and Statistics College Board Standards for College Success*. It is not assumed that students can apply these quantitative application skills in science at the same time they are mastering the mathematics performance expectations; however, it is expected that students in grades 9–12 can apply what they learned in grades 6–8 and that students in grades 6–8 can apply what they learned in grades 1–5.

As a result, many elementary math concepts (e.g., the four basic mathematical functions, fractions, decimals) are not addressed in the science practices standards.

**Objective SP.5.1 Proportionality Between Variables**

Students reason about relationships between variables (e.g., data, representations, uncertainty, samples) through the lens of ratios, rates, percentages, probability or proportional relationships when approaching or solving problems or when interpreting results or situations.

**ESSENTIAL KNOWLEDGE**

• Ratios, rates, percentages, measures of central tendencies (e.g., mean, median, mode), variability (e.g., variance, range, scatter, outliers) or correlation can be used to make comparisons, to interpret results, to solve — or estimate solutions to — problems,and to address scientific questions.

• Representations that are based on geometric figures (e.g., cubed or spherical cell) and characterized by using mathematical techniques (e.g., sketches, figures on grids, models) can help in characterizing the properties, interpreting changes or determining **interactions** of real systems involved in a problem or situation (e.g., cross section of a stream channel to determine discharge).

• Representations (e.g., actual, archived or simulated data) can help in estimating probabilities for events in which theoretical values are difficult or impossible to compute.

• The construction of mathematical formulas and the derivation of units often require dimensional analyses in two and three dimensions (e.g., length x width = area [units squared]).

**Objective SP.5.2 Patterns of Bivariate Relationships**

Students apply, analyze and create algebraic representations, relationships and patterns of linear functions, systems of linear inequalities, and one- or two-dimensional changes to solve problems, interpret situations and address scientific questions.

**ESSENTIAL KNOWLEDGE**

• One- and two-step linear equations are interpreted by using data tables, coordinate graphs and symbolic manipulation.

• Formulas are developed using arithmetic as well as geometric sequences of data.

• The concept of vectors in two dimensions is applied to represent, analyze and solve problems.

*[****BOUNDARY:*** *Students will only be expected to resolve vectors into their components and apply vector addition and subtraction both graphically and mathematically.]*

• Linear relationships among variables can be represented by graphs and functions.

• Linear patterns in data can be expressed as simple linear equations.