Course Overview

My AP Biology course provides students with an opportunity to pursue the rigors of college curriculum while providing the flexibility and support required in a High School setting. Projects, essays, lab investigations, lectures and activities are integrated into each thematic unit. Students are asked to see and use science as its own epistemology and therefore place emphasis on long term conceptual knowledge and application. This course covers all of the curricular topics and provides the requisite student led hands on lab experiences as outlined by the College Board. Additional lab and hands on activities complement the curriculum and are part of each unit. Although challenging and complex, biology is also beautiful, interesting and fun. Students are encouraged to test their imaginations, required to problem solve on a very high level and hopefully challenged to view the world through a scientific lens.

Course Objectives

Clear Springs High School is a young school with a competitive spirit and commitment to excellence. Graduates will need skills for college and beyond.   It is imperative that students in AP Biology attain the note taking, study skills and problem solving abilities necessary for this course and for their future college and real world experiences. These skills are also critical in their approach to problems in life. Students are challenged to view Biology from a non-human centric perspective and begin to appreciate the delicate balances that exist within and between organisms and their environment. Most major Universities will accept AP exam scores ranging from 3 to 5. If a student hopes to attain a high score on the May exam, he or she should expect to engage, work and prepare for the entire length of the course.

Resources

Reece, Jane, et al., *Campbell Biology,* 9th Edition, 2011, Pearson Benjamin Cummings.

Giffen, Cynthia and Heitz, Jean. *Practicing Biology* (to accompany Campbell-Reece Biology), 3rd Edition, 2008, Pearson Benjamin Cummings.

<www.campbellbiology.com> (The website to accompany the main text provides animations, investigations, PowerPoint and other audio-visual sources to enhance instruction)

AP Biology Investigative Labs: an Inquiry Based Approach. The College Board, 2012.

Cecie Starr, Ralph Taggart. *Biology: The Unity and Diversity of Life,* Tenth Edition.   Thomson Brooks/Cole. (2005)

Raven and Johnson . *Student Study Guide*, New York, NY: McGraw-Hill.

Hopson and Wessells. *Essentials of Biology.* New York, NY: McGraw Hill

Test bank of exams from Texas A&M, The University of Texas, Sam Houston State University, Rice University, The University of Houston

Advanced Placement Biology Content

**Students must have completed both first year biology and chemistry prior to enrolling in AP Biology.*

This course is structured around the *four big ideas* and *enduring understandings* identified in the curriculum framework. The College Board has very specific learning objectives that are the focus of this course.

The ***big ideas*** are interrelated, and will act as threads that tie together content and concepts.

The four "Big ideas":

Big idea 1: The process of evolution drives the diversity and unity of life.

Big idea 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis.

Big idea 3: Living systems store, retrieve, transmit and respond to information essential to life processes.

Big idea 4: Biological systems interact, and these systems and their interactions possess complex properties.

Students will develop and embrace an academic culture that encourages the use of seven important science practices:

Science Practices (SP)

1. The student can use representations and models to communicate scientific phenomena and solve scientific problems.
2. The student can use mathematics appropriately.
3. The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.
4. The student can plan and implement data collection strategies appropriate to a particular scientific question.
5. The student can perform data analysis and evaluation of evidence.
6. The student can work with scientific explanations and theories.
7. The student is able to connect and relate knowledge across various scales, concepts and representations in and across domains.

Teaching Strategies

To support the goals of college readiness, love of science, AP credit and a positive fun experience for all it is imperative that effective and well researched teaching practices be implemented. CCISD encourages the use of very specific strategies termed the Common Learning Framework. They include:

Talking to Learn
Talking to learn creates the space for students to articulate their thinking and strengthen their voice. It can take place in pairs, in collaborative group work and as a whole class. As students become accustomed to talking in class, the teacher serves as a facilitator to engage students in higher levels of discourse. Classroom talk opens the space for questioning, effective scaffolding and successful collaborative group work and literacy groups.

Collaborative Group Work
Collaborative group work involves bringing students or staff members together in small groups for the common purpose of engaging in learning. Effective group work is well planned and strategic. Students or staff members are grouped intentionally with each individual held accountable for contributing to the group activity. Each activity is designed so that participants with diverse skill and knowledge levels are supported as well as challenged by their peers.

Scaffolding
Scaffolding helps student to connect prior knowledge and experience with new information. Teachers use this strategy to connect students with previous learning in a content area as well as with previous learning in an earlier grade. Scaffolding also helps facilitate thinking about a text by asking student to draw on their objective experience and prior learning to make connections to new materials and ideas.

Literacy Groups
Literacy groups provide students with a collaborative structure for understanding a variety of texts and engaging in a higher level of discourse. Group roles traditionally drive literacy groups by giving each student a role to play and a defined purpose within the group. The specific roles or discussion guidelines may vary for different content areas, lengths of texts, or student level of sophistication using this strategy, but the purpose of literacy groups is to raise student engagement with texts by creating a structure within which they may do so.

Writing to Learn
Writing to learn is a strategy through which students can develop their ideas, their critical thinking ability and their writing skills. Writing to learn enables students to experiment every day with written language and increase their fluency and mastery of written conventions. Writing to learn can also be used as formative assessment and as a way to scaffold mid- and high- stakes writing assignments and tests.

Effective Questioning
Questioning challenges students and teachers to use good questions as a way to open conversations and further intellectual inquiry. Effective questioning (by the teacher and by students) deepens classroom conversations and the level of discourse students apply to their work. Teachers use this strategy to create opportunities for students to investigate and analyze their thinking as well as the thinking of their peers and the authors that they read in each of their classes.

Class discussions may be based on animations from various sources (textbook, CDs, Internet, etc.) to help the students visualize what they have read. Quizzes and short writing assignments are interspersed throughout the units as formative assessments to redirect and focus.

The course is structured around active conversation and inquiry. Students will maintain a written record (lab notebook) of investigations conducted. Students will be given the opportunity to create various products.

- Lab reports that emphasize the development and testing of a hypothesis, the ability to organize collected data, and the ability to analyze and clearly discuss the results.
- Posters, Power point presentations, movies, songs, animations, and models

The Investigative Laboratory Component

Students are given the opportunity to engage in student-directed laboratory investigations throughout the course for a minimum of 25% of instructional time. Students will conduct a minimum of eight inquiry-based investigations (two per big idea throughout the course).

Additional labs and activities will be conducted to deepen students' conceptual understanding and to reinforce the application of science practices within a hands-on, discovery based environment.

Course Schedule

The Course Outline describes how the essential knowledge statements, learning objectives and seven science practices are the focus of each unit within the course. Due to the reduction in required content for AP Biology, all sections of each chapter will not be covered and/or may be used for reference as needed. The outlined timeline is approximate. Assignments include many ways to meet the objectives (worksheets, readings, dry labs, wet labs, Free Response writing, projects, etc.), and a few of these activities have been elaborated upon in order to fully demonstrate the incorporation of curricular requirements. These assignments connect biological content across big ideas.

Course Outline

UNIT #1 BIOCHEMISTRY / SCIENCE AS A PROCESS Big Ideas: 1,2,3 and 4	Learning Objective
<u>Science Practices (SP)</u> 1. The student can use representations and models to communicate scientific phenomena and solve scientific problems. 2. The student can use mathematics appropriately. 3. The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course. 4. The student can plan and implement data collection strategies appropriate to a particular scientific question. 5. The student can perform data analysis and evaluation of evidence. 6. The student can work with scientific explanations and theories. 7. The student is able to connect and relate knowledge across various scales, concepts and representations in and across domains.	Examine science as a process and an epistemology
Essential knowledge 2.A.3: Organisms must exchange matter with the environment to grow, reproduce and maintain organization. a. Molecules and atoms from the environment are necessary to build new molecules. 1. Carbon moves from the environment to organisms where it is used to build carbohydrates, proteins, lipids or nucleic acids. Carbon is used in storage compounds and cell formation in all organisms. 2. Nitrogen moves from the environment to organisms where it is used in building proteins and nucleic acids. Phosphorus moves from the environment to organisms where it is used in nucleic acids and certain lipids. 3. Living systems depend on properties of water that result from its polarity and hydrogen bonding. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Cohesion • Adhesion	Justify the selection of data regarding the types of molecules that an animal, plant, or bacterium will take up as necessary building blocks and excrete as waste products. [LO 2.8, SP 4.1]
Essential knowledge 4.A.1: The subcomponents of biological molecules and their sequence determine the properties of that molecule. a. Structure and function of polymers are derived from the way their monomers are assembled. 1. In nucleic acids, biological information is encoded in sequences of nucleotide monomers. Each nucleotide has structural components: a five-carbon sugar (deoxyribose or ribose), a phosphate and a nitrogen base (adenine, thymine, guanine, cytosine or uracil). DNA and RNA differ in function and differ slightly in structure, and these structural differences account for the differing functions. [See also **1.D.1, 2.A.3, 3.A.1**] 2. In proteins, the specific order of amino acids in a polypeptide (primary structure) interacts with the environment to determine the overall shape of the protein, which also involves secondary tertiary and quaternary structure and, thus, its function. The R group of an amino acid can be categorized by chemical properties (hydrophobic, hydrophilic and ionic), and the interactions of these R groups determine structure and function of that region of the protein. [See also **1.D.1, 2.A.3,2.B.1**] 3. In general, lipids are nonpolar; however, phospholipids exhibit structural properties, with polar regions that interact with other polar molecules such as water, and with nonpolar regions where differences in saturation determine the structure and function of lipids. [See also **1.D.1, 2.A.3, 2. B.1**]	Explain the connection between the sequence and the subcomponents of a biological polymer and its properties. [LO 4.1, SP 7.1] Construct explanations based on evidence of how variation in molecular units provides cells with a wider range of functions. [LO 4.22, SP 6.2] Represent graphically or model quantitatively the exchange of molecules between an organism and its environment, and the subsequent uses of these molecules to build new molecules that facilitate dynamic homeostasis, growth, and reproduction. [LO 2.9, SP 1.1, SP 1.4]

4. Carbohydrates are composed of sugar monomers whose structures and bonding with each other by dehydration synthesis determine the properties and functions of the molecules. Illustrative examples include: cellulose versus starch. b. Directionality influences structure and function of the polymer. 1. Nucleic acids have ends, defined by the 3' and 5' carbons of the sugar in the nucleotide, that determine the direction in which complementary nucleotides are added during DNA synthesis and the direction in which transcription occurs (from 5' to 3'). [See also **3.A.1**] 2. Proteins have an amino (NH2) end and a carboxyl (COOH) end, and consist of a linear sequence of amino acids connected by the formation of peptide bonds by dehydration synthesis between the amino and carboxyl groups of adjacent monomers. 3. The nature of the bonding between carbohydrate subunits determines their relative orientation in the carbohydrate, which then determines the secondary structure of the carbohydrate. ***Essential knowledge 4.C.1: Variation in molecular units provides cells with a wider range of functions.*** a. Variations within molecular classes provide cells and organisms with a wider range of functions. [See also **2.B.1**, **3.A.1**, **4.A.1**, **4.A.2**] *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Different types of phospholipids in cell membranes • Different types of hemoglobin • MHC proteins • Chlorophylls • Molecular diversity of antibodies in response to an antigen	
Essential knowledge 4.B.1: Interactions between molecules affect their structure and function. a. Change in the structure of a molecular system may result in a change of the function of the system. [See also **3.D.3**] b. The shape of enzymes, active sites and interaction with specific molecules are essential for basic functioning of the enzyme. 1. For an enzyme-mediated chemical reaction to occur, the substrate must be complementary to the surface properties (shape and charge) of the active site. In other words, the substrate must fit into the enzyme's active site. 2. Cofactors and coenzymes affect enzyme function; this interaction relates to a structural change that alters the activity rate of the enzyme. The enzyme may only become active when all the appropriate cofactors or coenzymes are present and bind to the appropriate sites on the enzyme. c. Other molecules and the environment in which the enzyme acts can enhance or inhibit enzyme activity. Molecules can bind reversibly or irreversibly to the active or allosteric sites, changing the activity of the enzyme. d. The change in function of an enzyme can be interpreted from data regarding the concentrations of product or substrate as a function of time. These representations demonstrate the relationship between an enzyme's activity, the disappearance of substrate, and/ or presence of a competitive inhibitor.	Refine representations and models to explain how the subcomponents of a biological polymer and their sequence determine the properties of that polymer. [LO 4.2, SP 1.3] Use models to predict and justify that changes in the subcomponents of a biological polymer affect the functionality of the molecule. [LO 4.3, SP 6.1, SP 6.4] Analyze data to identify how molecular interactions affect structure and function. [LO 4.17, SP 5.1]
UNIT #2 CYTOLOGY Big Ideas 1,2, and 3	**Learning Objective**
Essential knowledge 2.A.3: Organisms must exchange matter with the environment to grow, reproduce and maintain organization. b. Surface area-to-volume ratios affect a biological system's ability to obtain necessary resources or eliminate waste products. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. As cells increase in volume, the relative surface area decreases and demand for material resources increases; more cellular structures are necessary to adequately exchange materials and energy with the environment. These limitations restrict cell size. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Root hairs • Cells of the alveoli • Cells of the villi • Microvilli 2. The surface area of the plasma membrane must be large enough to adequately exchange materials; smaller cells have a more favorable surface area-to-volume ratio for exchange of materials with the environment.	Use calculated surface area-to-volume ratios to predict which cell(s) might eliminate wastes or procure nutrients faster by diffusion. [LO 2.6, SP 2.2] Explain how cell size and shape affect the overall rate of nutrient intake and the rate of waste elimination. [LO 2.7, SP 6.2]

Essential knowledge 2.B.1: Cell membranes are selectively permeable due to their structure. a. Cell membranes separate the internal environment of the cell from the external environment. b. Selective permeability is a direct consequence of membrane structure, as described by the fluid mosaic model. [See also **4.A.1**] *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Cell membranes consist of a structural framework of phospholipid molecules, embedded proteins, cholesterol, glycoproteins and glycolipids. 2. Phospholipids give the membrane both hydrophilic and hydrophobic properties. The hydrophilic phosphate portions of the phospholipids are oriented toward the aqueous external or internal environments, while the hydrophobic fatty acid portions face each other within the interior of the membrane itself. 3. Embedded proteins can be hydrophilic, with charged and polar side groups, or hydrophobic, with nonpolar side groups. 4. Small, uncharged polar molecules and small nonpolar molecules, such as N2, freely pass across the membrane. Hydrophilic substances such as large polar molecules and ions move across the membrane through embedded channel and transport proteins. Water moves across membranes and through channel proteins called aquaporins. c. Cell walls provide a structural boundary, as well as a permeability barrier for some substances to the internal environments. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Plant cell walls are made of cellulose and are external to the cell membrane. 2. Other examples are cells walls of prokaryotes and fungi.	Explain how internal membranes and organelles contribute to cell functions. [LO 2.13, SP 6.2] Use representations and models to describe differences in prokaryotic and eukaryotic cells. [LO 2.14, SP 1.4] Make a prediction about the interactions of subcellular organelles. [LO 4.4, SP 6.4] Construct explanations based on scientific evidence as to how interactions of subcellular structures provide essential functions. [LO 4.5, SP 6.2] Use representations and models to analyze situations qualitatively to describe how interactions of subcellular structures, which possess specialized functions, provide essential functions. [LO 4.6, SP 1.4]
Essential knowledge 2.B.2: Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes. a. Passive transport does not require the input of metabolic energy; the net movement of molecules is from high concentration to low concentration. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Passive transport plays a primary role in the import of resources and the export of wastes. 2. Membrane proteins play a role in facilitated diffusion of charged and polar molecules through a membrane. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Glucose transport • Na+/K+ transport 3. External environments can be hypotonic, hypertonic or isotonic to internal environments of cells. b. Active transport requires free energy to move molecules from regions of low concentration to regions of high concentration. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Active transport is a process where free energy (often provided by ATP) is used by proteins embedded in the membrane to “move” molecules and/or ions across the membrane and to establish and maintain concentration gradients. 2. Membrane proteins are necessary for active transport. c. The processes of endocytosis and exocytosis move large molecules from the external environment to the internal environment and vice versa, respectively. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. In exocytosis, internal vesicles fuse with the plasma membrane to secrete large macromolecules out of the cell. 2. In endocytosis, the cell takes in macromolecules and particulate matter by forming new vesicles derived from the plasma membrane.	Use representations and models to pose scientific questions about the properties of cell membranes and selective permeability based on molecular structure. [LO 2.10, SP 1.4, SP 3.1] Construct models that connect the movement of molecules across membranes with membrane structure and function. [LO 2.11, SP 1.1, SP 7.1, SP 7.2] Use representations and models to analyze situations or solve problems qualitatively or quantitatively to investigate whether dynamic homeostasis is maintained by the active movement of molecules across membranes. [LO 2.12, SP 1.4]
Essential knowledge 2.B.3: Eukaryotic cells maintain internal membranes that partition the cell into specialized regions. a. Internal membranes facilitate cellular processes by minimizing competing interactions and by increasing surface area where reactions can occur. b. Membranes and membrane-bound organelles in eukaryotic cells localize (compartmentalize) intracellular metabolic processes and specific enzymatic reactions. [See also **4.A.2**] *To foster student understanding of this concept, instructors can choose an illustrative example, such as:* • Endoplasmic reticulum • Mitochondria • Chloroplasts	

• Golgi • Nuclear envelope c. Archaea and Bacteria generally lack internal membranes and organelles and have a cell wall.	
Essential knowledge 4.A.2: The structure and function of subcellular components, and their interactions, provide essential cellular processes. a. Ribosomes are small, universal structures comprised of two interacting parts: ribosomal RNA and protein. In a sequential manner, these cellular components interact to become the site of protein synthesis where the translation of the genetic instructions yields specific polypeptides. [See also **2.B.3**] b. Endoplasmic reticulum (ER) occurs in two forms: smooth and rough. [See also **2.B.3**] *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Rough endoplasmic reticulum functions to compartmentalize the cell, serves as mechanical support, provides site-specific protein synthesis with membrane-bound ribosomes and plays a role in intracellular transport. 2. In most cases, smooth ER synthesizes lipids. c. The Golgi complex is a membrane-bound structure that consists of a series of flattened membrane sacs (cisternae). [See also **2.B.3**] 1. Functions of the Golgi include synthesis and packaging of materials (small molecules) for transport (in vesicles), and production of lysosomes. d. Mitochondria specialize in energy capture and transformation. [See also **2.A.2**, **2.B.3**] 1. Mitochondria have a double membrane that allows compartmentalization within the mitochondria and is important to its function. 2. The outer membrane is smooth, but the inner membrane is highly convoluted, forming folds called cristae. 3. Cristae contain enzymes important to ATP production; cristae also increase the surface area for ATP production. e. Lysosomes are membrane-enclosed sacs that contain hydrolytic enzymes, which are important in intracellular digestion, the recycling of a cell's organic materials and programmed cell death (apoptosis). Lysosomes carry out intracellular digestion in a variety of ways. [See also **2.B.3**] f. A vacuole is a membrane-bound sac that plays roles in intracellular digestion and the release of cellular waste products. In plants, a large vacuole serves many functions, from storage of pigments or poisonous substances to a role in cell growth. In addition, a large central vacuole allows for a large surface area to volume ratio. [See also **2.A.3, 2.B.3**] g. Chloroplasts are specialized organelles found in algae and higher plants that capture energy through photosynthesis. [See also **2.A.2, 2 .3**] 1. The structure and function relationship in the chloroplast allows cells to capture the energy available in sunlight and convert it to chemical bond energy via photosynthesis. 2. Chloroplasts contain chlorophylls, which are responsible for the green color of a plant and are the key light-trapping molecules in photosynthesis. There are several types of chlorophyll, but the predominant form in plants is chlorophyll *a*. 3. Chloroplasts have a double outer membrane that creates a compartmentalized structure, which supports its function. Within the chloroplasts are membrane-bound structures called thylakoids. Energy-capturing reactions housed in the thylakoids are organized in *stacks*, called "grana," to produce ATP and $NADPH_2$, which fuel carbon-fixing reactions in the Calvin-Benson cycle. Carbon fixation occurs in the stroma, where molecules of CO_2 are converted to carbohydrates.	Justify the scientific claim that organisms share many conserved core processes and features that evolved and are widely distributed among organisms today. [LO 1.16, SP 6.1] Pose scientific questions that correctly identify essential properties of shared, core life processes that provide insights into the history of life on Earth. [LO 1.14, SP 3.1]
Essential knowledge 1.B.1: Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today. a. Structural and functional evidence supports the relatedness of all domains. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. DNA and RNA are carriers of genetic information through transcription, translation and replication. [See also **3.A.1**] 2. Major features of the genetic code are shared by all modern living systems. [See also **3.A.1**]	

3. Metabolic pathways are conserved across all currently recognized domains. [See also **3.D.1**] b. Structural evidence supports the relatedness of all eukaryotes. [See also **2.B.3**, **4.A.2**] *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Cytoskeleton (a network of structural proteins that facilitate cell movement, morphological integrity and organelle transport) • Membrane-bound organelles (mitochondria and/or chloroplasts) • Linear chromosomes • Endomembrane systems, including the nuclear envelope	
UNIT #3 CELL PROCESSES AND ENERGY Big Ideas: 1, 2, 3 and 4	**Learning Objective**
Essential knowledge 2.A.1: All living systems require constant input of free energy. a. Life requires a highly ordered system. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Order is maintained by constant free energy input into the system. 2. Loss of order or free energy flow results in death. 3. Increased disorder and entropy are offset by biological processes that maintain or increase order. b. Living systems do not violate the second law of thermodynamics, which states that entropy increases over time. 1. Order is maintained by coupling cellular processes that increase entropy (and so have negative changes in free energy) with those that decrease entropy (and so have positive changes in free energy). 2. Energy input must exceed free energy lost to entropy to maintain order and power cellular processes. 3. Energetically favorable exergonic reactions, such as ATP→ADP, that have a negative change in free energy can be used to maintain or increase order in a system by being coupled with reactions that have a positive free energy change. c. Energy-related pathways in biological systems are sequential and may be entered at multiple points in the pathway. [See also **2.A.2**] • Krebs cycle • Glycolysis • Calvin cycle • Fermentation d. Organisms use free energy to maintain organization, grow and reproduce. 1. Organisms use various strategies to regulate body temperature and metabolism. **** revisit when you cover species diversity*** • Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) • Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) • Elevated floral temperatures in some plant species 2. Reproduction and rearing of offspring require free energy beyond that used for maintenance and growth. Different organisms use various reproductive strategies in response to energy availability. ***revisit during plants and organ systems** • Seasonal reproduction in animals and plants • Life-history strategy (biennial plants, reproductive diapause) 3. There is a relationship between metabolic rate per unit body mass and the size of multicellular organisms — generally, the smaller the organism, the higher the metabolic rate. 4. Excess acquired free energy versus required free energy expenditure results in energy storage or growth. 5. Insufficient acquired free energy versus required free energy expenditure results in loss of mass and, ultimately, the death of an organism. e. Changes in free energy availability can result in changes in population size. f. Changes in free energy availability can result in disruptions to an ecosystem. ***revisit in ecology** • Change in the producer level can affect the number and size of other trophic levels. • Change in energy resources levels such as sunlight can affect the number and size of the trophic levels. ***Essential knowledge 2.A.2: Organisms capture and store free energy for use in biological processes.***	**Energy** Explain how biological systems use free energy based on empirical data that all organisms require constant energy input to maintain organization, to grow, and to reproduce. [LO 2.1, SP 6.2] Justify a scientific claim that free energy is required for living systems to maintain organization, to grow, or to reproduce, but that multiple strategies exist in different living systems. [LO 2.2, SP 6.1] Predict how changes in free energy availability affect organisms, populations, and ecosystems. [LO 2.3, SP 6.4] Use representations and models to analyze how cooperative interactions within organisms promote efficiency in the use of energy and matter. [LO 4.18, SP 1.4] Use representations to pose scientific questions about what mechanisms and structural features allow organisms to capture, store, and use free energy. [LO 2.4, SP 1.4, SP 3.1] Construct explanations of the mechanisms and structural features of cells that allow organisms to capture, store, or use free energy. [LO 2.5, SP 6.2] Describe specific examples of conserved core biological processes and features shared by all domains or within one domain of life, and how these shared, conserved core processes and features support the concept of common ancestry for all organisms. [LO 1.15, SP 7.2]

a. Autotrophs capture free energy from physical sources in the environment. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Photosynthetic organisms capture free energy present in sunlight. 2. Chemosynthetic organisms capture free energy from small inorganic molecules present in their environment, and this process can occur in the absence of oxygen. b. Heterotrophs capture free energy present in carbon compounds produced by other organisms. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Heterotrophs may metabolize carbohydrates, lipids and proteins by hydrolysis as sources of free energy. 2. Fermentation produces organic molecules, including alcohol and lactic acid, and it occurs in the absence of oxygen. c. Different energy-capturing processes use different types of electron acceptors. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • NADP+ in photosynthesis • Oxygen in cellular respiration d. The light-dependent reactions of photosynthesis in eukaryotes involve a series of coordinated reaction pathways that capture free energy present in light to yield ATP and NADPH, which power the production of organic molecules. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. During photosynthesis, chlorophylls absorb free energy from light, boosting electrons to a higher energy level in Photosystems I and II. 2. Photosystems I and II are embedded in the internal membranes of chloroplasts (thylakoids) and are connected by the transfer of higher free energy electrons through an electron transport chain (ETC). [See also **4.A.2**] 3. When electrons are transferred between molecules in a sequence of reactions as they pass through the ETC, an electrochemical gradient of hydrogen ions (protons) across the thykaloid membrane is established. 4. The formation of the proton gradient is a separate process, but it is linked to the synthesis of ATP from ADP and inorganic phosphate via ATP synthase. 5. The energy captured in the light reactions as ATP and NADPH powers the production of carbohydrates from carbon dioxide in the Calvin cycle, which occurs in the stroma of the chloroplast. e. Photosynthesis first evolved in prokaryotic organisms; scientific evidence supports that prokaryotic (bacterial) photosynthesis was responsible for the production of an oxygenated atmosphere; prokaryotic photosynthetic pathways were the foundation of eukaryotic photosynthesis. f. Cellular respiration in eukaryotes involves a series of coordinated enzyme-catalyzed reactions that harvest free energy from simple carbohydrates. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Glycolysis rearranges the bonds in glucose molecules, releasing free energy to form ATP from ADP and inorganic phosphate, and resulting in the production of pyruvate. 2. Pyruvate is transported from the cytoplasm to the mitochondrion, where further oxidation occurs. [See also **4.A.2**] 3. In the Krebs cycle, carbon dioxide is released from organic intermediates ATP is synthesized from ADP and inorganic phosphate via substrate level phosphorylation and electrons are captured by coenzymes. 4. Electrons that are extracted in the series of Krebs cycle reactions are carried by NADH and FADH2 to the electron transport chain. g. The electron transport chain captures free energy from electrons in a series of coupled reactions that establish an electrochemical gradient across membranes. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Electron transport chain reactions occur in chloroplasts (photosynthesis), mitochondria (cellular respiration) and prokaryotic plasma membranes. 2. In cellular respiration, electrons delivered by NADH and FADH2 are passed to a series of electron acceptors as they move toward the terminal electron acceptor, oxygen. In photosynthesis, the terminal electron acceptor is NADP+.	

3. The passage of electrons is accompanied by the formation of a proton gradient across the inner mitochondrial membrane or the thylakoid membrane of chloroplasts, with the membrane(s) separating a region of high proton concentration from a region of low proton concentration. In prokaryotes, the passage of electrons is accompanied by the outward movement of protons across the plasma membrane. 4. The flow of protons back through membrane-bound ATP synthase by chemiosmosis generates ATP from ADP and inorganic phosphate. 5. In cellular respiration, decoupling oxidative phosphorylation from electron transport is involved in thermoregulation. h. Free energy becomes available for metabolism by the conversion of ATP→ADP, which is coupled to many steps in metabolic pathways. ***Essential knowledge 4.A.2: The structure and function of subcellular components, and their interactions, provide essential cellular processes.*** g. Chloroplasts are specialized organelles found in algae and higher plants that capture energy through photosynthesis. [See also **2.A.2, 2 .3**] *Evidence of student learning is a demonstrated understanding of each of the following:* 1. The structure and function relationship in the chloroplast allows cells to capture the energy available in sunlight and convert it to chemical bond energy via photosynthesis. 2. Chloroplasts contain chlorophylls, which are responsible for the green color of a plant and are the key light-trapping molecules in photosynthesis. There are several types of chlorophyll, but the predominant form in plants is chlorophyll *a*. 3. Chloroplasts have a double outer membrane that creates a compartmentalized structure, which supports its function. Within the chloroplasts are membrane-bound structures called thylakoids. Energy-capturing reactions housed in the thylakoids are organized in stacks, called "grana," to produce ATP and NADPH2, which fuel carbon-fixing reactions in the Calvin-Benson cycle. Carbon fixation occurs in the stroma, where molecules of CO2 are converted to carbohydrates.	
Essential knowledge 4.B.2: Cooperative interactions within organisms promote efficiency in the use of energy and matter. a. Organisms have areas or compartments that perform a subset of functions related to energy and matter, and these parts contribute to the whole. [See also **2.A.2**, **4.A.2**] *Evidence of student learning is a demonstrated understanding of each of the following:* 1. At the cellular level, the plasma membrane, cytoplasm and, for eukaryotes, the organelles contribute to the overall specialization and functioning of the cell.	
Essential knowledge 1.B.1: Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today. a. Structural and functional evidence supports the relatedness of all domains. 3. Metabolic pathways are conserved across all currently recognized domains. [See also **3.D.1**]	
UNIT #4 CELL TO CELL INTERACTIONS Big Ideas: 1, 2, 3 and 4	**Learning Objective**
Essential knowledge 3.D.1: Cell communication processes share common features that reflect a shared evolutionary history. a. Communication involves transduction of stimulatory or inhibitory signals from other cells, organisms or the environment. [See also **1.B.1**] b. Correct and appropriate signal transduction processes are generally under strong selective pressure. c. In single-celled organisms, signal transduction pathways influence how the cell responds to its environment. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Use of chemical messengers by microbes to communicate with other nearby cells and to regulate specific pathways in response to population density (quorum sensing) • Use of pheromones to trigger reproduction and developmental pathways • Response to external signals by bacteria that influences cell movement d. In multicellular organisms, signal transduction pathways coordinate the activities within individual cells that support the function of the organism as a whole. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Epinephrine stimulation of glycogen breakdown in mammals	**Cell Communication/Signaling** Describe basic chemical processes for cell communication shared across evolutionary lines of descent. [LO 3.31, SP 7.2] Generate scientific questions involving cell communication as it relates to the process of evolution. [LO 3.32, SP 3.1] Use representation(s) and appropriate models to describe features of a cell signaling pathway. [LO 3.33, SP 1.4] Construct explanations of cell communication through cell-to-cell direct contact or through chemical signaling. [LO 3.34, SP 6.2]

• Temperature determination of sex in some vertebrate organisms • DNA repair mechanisms ***Essential knowledge 3.D.2: Cells communicate with each other through direct contact with other cells or from a distance via chemical signaling.*** a. Cells communicate by cell-to-cell contact. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Immune cells interact by cell-cell contact, antigen-presenting cells (APCs), helper T-cells and killer T-cells. [See also **2.D.4**] • Plasmodesmata between plant cells that allow material to be transported from cell to cell. b. Cells communicate over short distances by using local regulators that target cells in the vicinity of the emitting cell. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Neurotransmitters • Plant immune response • Quorum sensing in bacteria • Morphogens in embryonic development c. Signals released by one cell type can travel long distances to target cells of another cell type. *Evidence of student learning is a demonstrated understanding of the following:* 1. Endocrine signals are produced by endocrine cells that release signaling molecules, which are specific and can travel long distances through the blood to reach all parts of the body. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Insulin • Human growth hormone • Thyroid hormones • Testosterone • Estrogen	Create representation(s) that depict how cell-to-cell communication occurs by direct contact or from a distance through chemical signaling. [LO 3.35, SP 1.1] Describe a model that expresses the key elements of signal transduction pathways by which a signal is converted to a cellular response. [LO 3.36, SP 1.5] Justify claims based on scientific evidence that changes in signal transduction pathways can alter cellular response. [LO 3.37, SP 6.1] Describe a model that expresses key elements to show how change in signal transduction can alter cellular response. [LO 3.38, SP 1.5] Construct an explanation of how certain drugs affect signal reception and, consequently, signal transduction pathways. [LO 3.39, SP 6.2]
Essential knowledge 3.D.3: Signal transduction pathways link signal reception with cellular response. a. Signaling begins with the recognition of a chemical messenger, a ligand, by a receptor protein. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Different receptors recognize different chemical messengers, which can be peptides, small chemicals or proteins, in a specific one-to-one relationship. 2. A receptor protein recognizes signal molecules, causing the receptor protein's shape to change, which initiates transduction of the signal. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • G-protein linked receptors • Ligand-gated ion channels • Receptor tyrosine kinases b. Signal transduction is the process by which a signal is converted to a cellular response. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Signaling cascades relay signals from receptors to cell targets, often amplifying the incoming signals, with the result of appropriate responses by the cell. 2. Second messengers are often essential to the function of the cascade. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Ligand-gated ion channels • Second messengers, such as cyclic GMP, cyclic AMP calcium ions (Ca2+), and inositol triphosphate (IP3) 3. Many signal transduction pathways include: i. Protein modifications (an illustrative example could be how methylation changes the signaling process) ii. Phosphorylation cascades in which a series of protein kinases add a phosphate group to the next protein in the cascade sequence	

Essential knowledge 3.D.4: Changes in signal transduction pathways can alter cellular response. a. Conditions where signal transduction is blocked or defective can be deleterious, preventative or prophylactic. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Diabetes, heart disease, neurological disease, autoimmune disease, cancer, cholera • Effects of neurotoxins, poisons, pesticides • Drugs (Hypertensives, Anesthetics, Antihistamines and Birth Control Drugs)	
Unit #5 Cell Cycle, Big Ideas: 1 and 3	**Learning Objective**
Essential knowledge 3.A.2: In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis or meiosis plus fertilization. a. The cell cycle is a complex set of stages that is highly regulated with checkpoints, which determine the ultimate fate of the cell. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Interphase consists of three phases: growth, synthesis of DNA, preparation for mitosis. 2. The cell cycle is directed by internal controls or checkpoints. Internal and external signals provide stop-and-go signs at the checkpoints. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Mitosis-promoting factor (MPF) • Action of platelet-derived growth factor (PDGF) • Cancer results from disruptions in cell cycle control 3. Cyclins and cyclin-dependent kinases control the cell cycle. 4. Mitosis alternates with interphase in the cell cycle. 5. When a cell specializes, it often enters into a stage where it no longer divides, but it can reenter the cell cycle when given appropriate cues. Nondividing cells may exit the cell cycle; or hold at a particular stage in the cell cycle. b. Mitosis passes a complete genome from the parent cell to daughter cells. 1. Mitosis occurs after DNA replication. 2. Mitosis followed by cytokinesis produces two genetically identical daughter cells. 3. Mitosis plays a role in growth, repair, and asexual reproduction 4. Mitosis is a continuous process with observable structural features along the mitotic process. Evidence of student learning is demonstrated by knowing the order of the processes (replication, alignment, separation). c. Meiosis, a reduction division, followed by fertilization ensures genetic diversity in sexually reproducing organisms. 1. Meiosis ensures that each gamete receives one complete haploid (1n) set of chromosomes. 2. During meiosis, homologous chromosomes are paired, with one homologue originating from the maternal parent and the other from the paternal parent. Orientation of the chromosome pairs is random with respect to the cell poles. 3. Separation of the homologous chromosomes ensures that each gamete receives a haploid (1n) set of chromosomes composed of both maternal and paternal chromosomes. 4. During meiosis, homologous chromatids exchange genetic material via a process called "crossing over," which increases genetic variation in the resultant gametes. [See also **3.C.2**] 5. Fertilization involves the fusion of two gametes, increases genetic variation in populations by providing for new combinations of genetic information in the zygote, and restores the diploid number of chromosomes. ***Essential knowledge 3.C.1: Changes in genotype can result in changes in phenotype.*** c. Errors in mitosis or meiosis can result in changes in phenotype. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Changes in chromosome number often result in new phenotypes, including sterility caused by triploidy and increased vigor of other polyploids. [See also **3.A.2**] 2. Changes in chromosome number often result in human disorders with developmental limitations, including Trisomy 21	**The Cell Cycle, Mitosis, and Meiosis** Make predictions about natural phenomena occurring during the cell cycle. [LO 3.7, SP 6.4] Describe the events that occur in the cell cycle. [LO 3.8, SP 1.2] Construct an explanation, using visual representations or narratives, as to how DNA in chromosomes is transmitted to the next generation via mitosis, or meiosis followed by fertilization. [LO 3.9, SP 6.2] Represent the connection between meiosis and increased genetic diversity necessary for evolution. [LO 3.10, SP 7.1] Evaluate evidence provided by data sets to support the claim that heritable information is passed from one generation to another through mitosis, or meiosis followed by fertilization. [LO 3.11, SP 5.3]

(Down syndrome) and XO (Turner syndrome). [See also **3.A.2, 3.A.3**]	
Unit #6 Protein Synthesis Big Ideas: 1 and 3	**Learning Objective**
Essential knowledge 3.A.1: DNA, and in some cases RNA, is the primary source of heritable information. a. Genetic information is transmitted from one generation to the next through DNA or RNA. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Genetic information is stored in and passed to subsequent generations through DNA molecules and, in some cases, RNA molecules. 2. Noneukaryotic organisms have circular chromosomes, while eukaryotic organisms have multiple linear chromosomes, although in biology there are exceptions to this rule. 3. Prokaryotes, viruses and eukaryotes can contain plasmids, which are small extra-chromosomal, double-stranded circular DNA molecules. 4. The proof that DNA is the carrier of genetic information involved a number of important historical experiments. These include: i. Contributions of Watson, Crick, Wilkins, and Franklin on the structure of DNA ii. Avery-MacLeod-McCarty experiments iii. Hershey-Chase experiment 5. DNA replication ensures continuity of hereditary information. Replication is a semiconservative process; that is, one strand serves as the template for a new, complementary strand.ii. Replication requires DNA polymerase plus many other essential cellular enzymes, occurs bidirectionally, and differs in the production of the leading and lagging strands. 6. Genetic information in retroviruses is a special case and has an alternate flow of information: from RNA to DNA, made possible by reverse transcriptase, an enzyme that copies the viral RNA genome into DNA. This DNA integrates into the host genome and becomes transcribed and translated for the assembly of new viral progeny. [See also **3.C.3**] b. DNA and RNA molecules have structural similarities and differences that define function. [See also **4.A.1**] *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Both have three components — sugar, phosphate and a nitrogenous base — which form nucleotide units that are connected by covalent bonds to form a linear molecule with 3' and 5' ends, with the nitrogenous bases perpendicular to the sugar-phosphate backbone. 2. The basic structural differences include: i. DNA contains deoxyribose (RNA contains ribose). ii. RNA contains uracil in lieu of thymine in DNA. iii. DNA is usually double stranded, RNA is usually single stranded. iv. The two DNA strands in double-stranded DNA are antiparallel in directionality. 3. Both DNA and RNA exhibit specific nucleotide base pairing that is conserved through evolution: adenine pairs with thymine or uracil (A-T or A-U) and cytosine pairs with guanine (C-G). i. Purines (G and A) have a double ring structure. ii. Pyrimidines (C, T and U) have a single ring structure. 4. The sequence of the RNA bases, together with the structure of the RNA molecule, determines RNA function. i. mRNA carries information from the DNA to the ribosome. ii. tRNA molecules bind specific amino acids and allow information in the mRNA to be translated to a linear peptide sequence. iii. rRNA molecules are functional building blocks of ribosomes.	**Gene to Protein** Construct scientific explanations that use the structures and mechanisms of DNA and RNA to support the claim that DNA and, in some cases, that RNA are the primary sources of heritable information. [LO 3.1, SP 6.5] Justify the selection of data from historical investigations that support the claim that DNA is the source of heritable information. [LO 3.2, SP 4.1] Describe representations and models that illustrate how genetic information is copied for transmission between generations. [LO 3.3, SP 1.2] Describe representations and models illustrating how genetic information is translated into polypeptides. [LO 3.4, SP 1.2] Create a visual representation to illustrate how changes in a DNA nucleotide sequence can result in a change in the polypeptide produced. [LO 3.25, SP 1.1] Predict how a change in a specific DNA or RNA sequence can result in changes in gene expression. [LO 3.6, SP 6.4]

iv. The role of RNAi includes regulation of gene expression at the level of mRNA transcription. c. Genetic information flows from a sequence of nucleotides in a gene to a sequence of amino acids in a protein. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. The enzyme RNA-polymerase reads the DNA molecule in the 3' to 5' direction and synthesizes complementary mRNA molecules that determine the order of amino acids in the polypeptide. 2. In eukaryotic cells the mRNA transcript undergoes a series of enzyme-regulated modifications. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Addition of a poly-A tail • Addition of a GTP cap • Excision of introns 3. Translation of the mRNA occurs in the cytoplasm on the ribosome. 4. In prokaryotic organisms, transcription is coupled to translation of the message. Translation involves energy and many steps, including initiation, elongation and termination. The salient features include: i. The mRNA interacts with the rRNA of the ribosome to initiate translation at the (start) codon. ii. The sequence of nucleotides on the mRNA is read in triplets called codons. iii. Each codon encodes a specific amino acid, which can be deduced by using a genetic code chart. Many amino acids have more than one codon. iv. tRNA brings the correct amino acid to the correct place on the mRNA. v. The amino acid is transferred to the growing peptide chain. vi. The process continues along the mRNA until a “stop” codon is reached. vii. The process terminates by release of the newly synthesized peptide/protein. d. Phenotypes are determined through protein activities. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Enzymatic reactions • Transport by proteins • Synthesis • Degradation ***Essential knowledge 3.C.1: Changes in genotype can result in changes in phenotype.*** a. Alterations in a DNA sequence can lead to changes in the type or amount of the protein produced and the consequent phenotype. [See also **3.A.1**] 1. DNA mutations can be positive, negative or neutral based on the effect or the lack of effect they have on the resulting nucleic acid or protein and the phenotypes that are conferred by the protein. b. Errors in DNA replication or DNA repair mechanisms, and external factors, including radiation and reactive chemicals, can cause random changes, e.g., mutations in the DNA. 1. Whether or not a mutation is detrimental, beneficial or neutral depends on the environmental context. Mutations are the primary source of genetic variation.	

UNIT #7 GENETICS BIG IDEAS 1,2,3 and 4	**Learning Objective**
Essential knowledge 3.A.3: The chromosomal basis of inheritance provides an understanding of the pattern of passage (transmission) of genes from parent to offspring. a. Rules of probability can be applied to analyze passage of single gene traits from parent to offspring. b. Segregation and independent assortment of chromosomes result in genetic variation. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Segregation and independent assortment can be applied to genes that are on different chromosomes. 2. Genes that are adjacent and close to each other on the same chromosome tend to move as a unit; the probability that they will segregate as a unit is a function of the distance between them. 3. The pattern of inheritance (monohybrid, dihybrid, sex-linked, and genes linked on the same homologous chromosome) can often be predicted from data that gives the parent genotype/phenotype and/or the offspring phenotypes/genotypes. c. Certain human genetic disorders can be attributed to the inheritance of single gene traits or specific chromosomal changes, such as nondisjunction. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Sickle cell anemia • Tay-Sachs disease • Huntington's disease • X-linked color blindness • Trisomy 21/Down syndrome • Klinefelter's syndrome d. Many ethical, social and medical issues surround human genetic disorders. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Reproduction issues • Civic issues such as ownership of genetic information, privacy, historical contexts, etc. ***Essential knowledge 3.A.4: The inheritance pattern of many traits cannot be explained by simple Mendelian genetics.*** a. Many traits are the product of multiple genes and/or physiological processes. *Evidence of student learning is a demonstrated understanding of the following:* 1. Patterns of inheritance of many traits do not follow ratios predicted by Mendel's laws and can be identified by quantitative analysis, where observed phenotypic ratios statistically differ from the predicted ratios. b. Some traits are determined by genes on sex chromosomes. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Sex-linked genes reside on sex chromosomes (X in humans). • In mammals and flies, the Y chromosome is very small and carries few genes. • In mammals and flies, females are XX and males are XY; as such, X-linked recessive traits are always expressed in males. • Some traits are sex limited, and expression depends on the sex of the individual, such as milk production in female mammals and pattern baldness in males. c. Some traits result from nonnuclear inheritance. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Chloroplasts and mitochondria are randomly assorted to gametes and daughter cells; thus, traits determined by chloroplast and mitochondrial DNA do not follow simple Mendelian rules. 2. In animals, mitochondrial DNA is transmitted by the egg and not by sperm; as such, mitochondrial-determined traits are maternally inherited.	**Mendel's Model** Construct a representation that connects the process of meiosis to the passage of traits from parent to offspring. [LO 3.12, SP 1.1, SP 7.2] Pose questions about the ethical, social, or medical issues surrounding human genetic disorders. [LO 3.13, SP 3.1] Apply mathematical routines to determine Mendelian patterns of inheritance provided by data sets. [LO 3.14, SP 2.2] Explain deviations from Mendel's model of the inheritance of traits. [LO 3.15, SP 6.5] Explain how the inheritance patterns of many traits cannot be accounted for by Mendelian genetics. [LO 3.16, SP 6.3] Describe representations of an appropriate example of inheritance patterns that cannot be explained by Mendel's model of the inheritance of traits. [LO 3.17, SP 1.2] Construct explanations of the influence of environmental factors on the phenotype of an organism. [LO 4.23, SP 6.2] Use evidence to justify a claim that a variety of phenotypic responses to a single environmental factor can result from different genotypes within the population. [LO 4.25, SP 6.1]

a. Environmental factors influence many traits both directly and indirectly. [See also **3.B.2**, **3.C.1**] *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Height and weight in humans • Flower color based on soil pH • Seasonal fur color in arctic animals • Sex determination in reptiles • Density of plant hairs as a function of herbivory • Effect of adding lactose to a Lac + bacterial culture • Effect of increased UV on melanin production in animals • Presence of the opposite mating type on pheromones production in yeast and other fungi b. An organism's adaptation to the local environment reflects a flexible response of its genome. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Darker fur in cooler regions of the body in certain mammal species • Alterations in timing of flowering due to climate changes ***Essential knowledge 4.C.3: The level of variation in a population affects population dynamics.*** a. Population ability to respond to changes in the environment is affected by genetic diversity. Species and populations with little genetic diversity are at risk for extinction. [See also **1.A.1**, **1.A.2**, **1.C.1**] *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • California condors • Black-footed ferrets • Prairie chickens • Potato blight causing the potato famine • Corn rust affects on agricultural crops • Tasmanian devils and infectious cancer b. Genetic diversity allows individuals in a population to respond differently to the same changes in environmental conditions. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Not all animals in a population stampede. • Not all individuals in a population in a disease outbreak are equally affected; some may not show symptoms, some may have mild symptoms, or some may be naturally immune and resistant to the disease. c. Allelic variation within a population can be modeled by the Hardy- Weinberg equation(s). [See also **1.A.1**] ***Essential knowledge 4.C.1: Variation in molecular units provides cells with a wider range of functions.*** b. Multiple copies of alleles or genes (gene duplication) may provide new phenotypes. [See also **3.A.4**, **3.C.1**] *Evidence of student learning is a demonstrated understanding of each of the following:* 1. A heterozygote may be a more advantageous genotype than a homozygote under particular conditions, since with two different alleles, the organism has two forms of proteins that may provide functional resilience in response to environmental stresses. 2. Gene duplication creates a situation in which one copy of the gene maintains its original function, while the duplicate may evolve a new function. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • The antifreeze gene in fish	
UNIT #8 GENE REGULATION AND ENGINERING	**Learning Objective**

Essential knowledge 3.B.1: Gene regulation results in differential gene expression, leading to cell specialization.

a. Both DNA regulatory sequences, regulatory genes, and small regulatory RNAs are involved in gene expression.

1. Regulatory sequences are stretches of DNA that interact with regulatory proteins to control transcription.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Promoters
- Terminators
- Enhancers

2. A regulatory gene is a sequence of DNA encoding a regulatory protein or RNA.

b. Both positive and negative control mechanisms regulate gene expression in bacteria and viruses.

Evidence of student learning is a demonstrated understanding of each of the following:

1. The expression of specific genes can be turned on by the presence of an inducer.
2. The expression of specific genes can be inhibited by the presence of a repressor.
3. Inducers and repressors are small molecules that interact with regulatory proteins and/or regulatory sequences.
4. Regulatory proteins inhibit gene expression by binding to DNA and blocking transcription (negative control).
5. Regulatory proteins stimulate gene expression by binding to DNA and stimulating transcription (positive control) or binding to repressors to inactivate repressor function.
6. Certain genes are continuously expressed; that is, they are always turned "on," e.g., the ribosomal genes.

c. In eukaryotes, gene expression is complex and control involves regulatory genes, regulatory elements and transcription factors that act in concert.

Evidence of student learning is a demonstrated understanding of each of the following:

1. Transcription factors bind to specific DNA sequences and/or other regulatory proteins.
2. Some of these transcription factors are activators (increase expression), while others are repressors (decrease expression).
3. The combination of transcription factors binding to the regulatory regions at any one time determines how much, if any, of the gene product will be produced.

d. Gene regulation accounts for some of the phenotypic differences between organisms with similar genes.

Essential knowledge 4.A.3: Interactions between external stimuli and regulated gene expression result in specialization of cells, tissues and organs.

a. Differentiation in development is due to external and internal cues that trigger gene regulation by proteins that bind to DNA. [See also **3.B.1, 3. B.2**]

b. Structural and functional divergence of cells in development is due to expression of genes specific to a particular tissue or organ type. [See also **3.B.1, 3.B.2**]

c. Environmental stimuli can affect gene expression in a mature cell. [See also **3.B.1, 3.B.2**]

Essential knowledge 2.C.1: Organisms use feedback mechanisms to maintain their internal environments and respond to external environmental changes.

a. Negative feedback mechanisms maintain dynamic homeostasis for a particular condition (variable) by regulating physiological processes, returning the changing condition back to its target set point.

- Operons in gene regulation
- Temperature regulation in animals
- Plant responses to water limitations

Essential knowledge 3.B.2: A variety of intercellular and intracellular signal transmissions mediate gene expression.

a. Signal transmission within and between cells mediates gene expression.

- Cytokines regulate gene expression to allow for cell replication and division.
- Mating pheromones in yeast trigger mating gene expression
- Levels of cAMP regulate metabolic gene expression in bacteria.
- Expression of the SRY gene triggers the male sexual development pathway in animals.
- Ethylene levels cause changes in the production of different enzymes, allowing fruits to ripen.

Gene Expression

Describe the connection between the regulation of gene expression and observed differences between different kinds of organisms. [LO 3.18, SP 7.1]

Describe the connection between the regulation of gene expression and observed differences between individuals in a population. [LO 3.19, SP 7.1]

Explain how the regulation of gene expression is essential for the processes and structures that support efficient cell function. [LO 3.20, SP 6.2]

Use representations to describe how gene regulation influences cell products and function. [LO 3.21, SP 1.4]

Refine representations to illustrate how interactions between external stimuli and gene expression result in specialization of cells, tissues, and organs. [LO 4.7, SP 1.3]

Justify a claim made about the effect(s) on a biological system at the molecular, physiological, or organismal level when given a scenario in which one or more components within a negative regulatory system is altered. [LO 2.15, SP 6.1]

Explain how signal pathways mediate gene expression, including how this process can affect protein production. [LO 3.22, SP 6.2]

Use representations to describe mechanisms of the regulation of gene expression. [LO 3.23, SP 1.4]

Connect concepts in and across domains to show that the timing and coordination of specific events are necessary for normal development in an organism and that these events are regulated by multiple mechanisms. [LO 2.31, SP 7.2]

Use a graph or diagram to analyze situations or solve problems (quantitativelyor qualitatively) that involve timing and coordination of events necessary for normal development in an organism. [LO 2.32, SP 1.4]

Justify scientific claims with scientific evidence to show that timing and coordination of several events are necessary for normal development in an organism and that these events are regulated by multiple mechanisms. [LO 2.33, SP 6.1]

Describe the role of programmed cell death in development and differentiation, the reuse of molecules, and the maintenance of dynamic homeostasis. [LO 2.34, SP 7.1]

• Seed germination and gibberellin. b. Signal transmission within and between cells mediates cell function. • Mating pheromones in yeast trigger mating genes expression and sexual reproduction. • Morphogens stimulate cell differentiation and development. • Changes in p53 activity can result in cancer. • HOX genes and their role in development. ***Essential knowledge 2.E.1: Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms.*** a. Observable cell differentiation results from the expression of genes for tissue-specific proteins. b. Induction of transcription factors during development results in sequential gene expression. 1. Homeotic genes are involved in developmental patterns and sequences. 2. Embryonic induction in development results in the correct timing of events. 3. Temperature and the availability of water determine seed germination in most plants. 4. Genetic mutations can result in abnormal development. 5. Genetic transplantation experiments support the link between gene expression and normal development. 6. Genetic regulation by microRNAs plays an important role in the development of organisms and the control of cellular functions. c. Programmed cell death (apoptosis) plays a role in the normal development and differentiation. • Morphogenesis of fingers and toes • Immune function • *C. elegans* development • Flower development	
Essential knowledge 3.A.1: DNA, and in some cases RNA, is the primary source of heritable information. e. Genetic engineering techniques can manipulate the heritable information of DNA and, in special cases, RNA. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Electrophoresis • Plasmid-based transformation • Restriction enzyme analysis of DNA • Polymerase Chain Reaction (PCR) f. *Illustrative examples of products of genetic engineering include:* • Genetically modified foods • Transgenic animals • Cloned animals • Pharmaceuticals, such as human insulin or factor X ***Essential knowledge 3.C.2: Biological systems have multiple processes that increase genetic variation.*** a. The imperfect nature of DNA replication and repair increases variation. b. The horizontal acquisitions of genetic information primarily in prokaryotes via transformation (uptake of naked DNA), transduction (viral transmission of genetic information), conjugation (cell-to-cell transfer) and transposition (movement of DNA segments within and between DNA molecules) increase variation. [See also **1.B.3**] c. Sexual reproduction in eukaryotes involving gamete formation, including crossing-over during meiosis and the random assortment of chromosomes during meiosis, and fertilization serve to increase variation. Reproduction processes that increase genetic variation are evolutionarily conserved and are shared by various organisms. [See also **1.B.1, 3.A.2, 4.C.2, 4. C3**]	**Genetic Engineering/Research** Justify the claim that humans can manipulate heritable information by identifying *at least two* commonly used technologies. [LO 3.5, SP 6.4] Predict how a change in genotype, when expressed as a phenotype, provides a variation that can be subject to natural selection. [LO 3.24, SP 6.4, SP 7.2] Explain the connection between genetic variations in organisms and phenotypic variations in populations. [LO 3.26, SP 7.2] Predict the effects of a change in an environmental factor on the genotypic expression of the phenotype. [LO 4.24, SP 6.4]

UNIT #9 EVOLUTION Big Ideas: 1 and 3	**Learning Objective**
Essential knowledge 1.A.1: Natural selection is a major mechanism of evolution. a. According to Darwin's theory of natural selection, competition for limited resources results in differential survival. Individuals with more favorable phenotypes are more likely to survive and produce more offspring, thus passing traits to subsequent generations. b. Evolutionary fitness is measured by reproductive success. c. Genetic variation and mutation play roles in natural selection. A diverse gene pool is important for the survival of a species in a changing environment. d. Environments can be more or less stable or fluctuating, and this affects evolutionary rate and direction; different genetic variations can be selected in each generation. e. An adaptation is a genetic variation that is favored by selection and is manifested as a trait that provides an advantage to an organism in a particular environment. f. In addition to natural selection, chance and random events can influence the evolutionary process, especially for small populations. g. Conditions for a population or an allele to be in Hardy-Weinberg equilibrium are: (1) a large population size, (2) absence of migration, (3) no net mutations, (4) random mating and (5) absence of selection. These conditions are seldom met. h. Mathematical approaches are used to calculate changes in allele frequency, providing evidence for the occurrence of evolution in a population. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Graphical analysis of allele frequencies in a population • Application of the Hardy-Weinberg equilibrium equation ***Essential knowledge 1.A.2: Natural selection acts on phenotypic variations in populations.*** a. Environments change and act as selective mechanism on populations. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Flowering time in relation to global climate change • Peppered moth b. Phenotypic variations are not directed by the environment but occur through random changes in the DNA and through new gene combinations. c. Some phenotypic variations significantly increase or decrease fitness of the organism and the population. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Sickle cell anemia • Peppered moth • DDT resistance in insects d. Humans impact variation in other species. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Artificial selection • Loss of genetic diversity within a crop species • Overuse of antibiotics ***Essential knowledge 1.A.3: Evolutionary change is also driven by random processes.*** a. Genetic drift is a nonselective process occurring in small populations. b. Reduction of genetic variation within a given population can increase the differences between populations of the same species. ***Essential knowledge 3.C.1: Changes in genotype can result in changes in phenotype.*** d. Changes in genotype may affect phenotypes that are subject to natural selection. Genetic changes that enhance survival and reproduction can be selected by environmental conditions. [See also **1.A.2, 1.C.3**] *To foster student understanding of this concept, instructors can choose an illustrative example such as:*	**Population Genetics** Convert a data set from a table of numbers that reflect a change in the genetic makeup of a population over time and apply mathematical methods and conceptual understandings to investigate the cause(s) and effect(s) of this change. [LO 1.1, SP 1.5, SP 2.2] Evaluate evidence provided by data to qualitatively and quantitatively investigate the role of natural selection in evolution. [LO 1.2, SP 2.2, SP 5.3] Analyze data to support the claim that responses to information and communication of information affect natural selection. [LO 2.38, SP 5.1] Apply mathematical methods to data from a real or simulated population to predict what will happen to the population in the future. [LO 1.3, SP 2.2] Evaluate data-based evidence that describes evolutionary changes in the genetic makeup of a population over time. [LO 1.4, SP 5.3] Connect evolutionary changes in a population over time to a change in the environment. [LO 1.5, SP 7.1] Use data from mathematical models based on the Hardy-Weinberg equilibrium to analyze genetic drift and effects of selection in the evolution of specific populations. [LO 1.6, SP 1.4, SP 2.1] Justify data from mathematical models based on the Hardy-Weinberg equilibrium to analyze genetic drift and the effects of selection in the evolution of specific populations. [LO 1.7, SP 2.1] Use theories and models to make scientific claims and/or predictions about the effects of variation within populations on survival and fitness. [LO 4.26, SP 6.4] Make predictions about the effects of genetic drift, migration, and artificial selection on the

• Antibiotic resistance mutations • Pesticide resistance mutations • Sickle cell disorder and heterozygote advantage *Evidence of student learning is a demonstrated understanding of the following:* 1. Selection results in evolutionary change.	genetic makeup of a population. [LO 1.8, SP 6.4]
Essential knowledge 1.A.4: Biological evolution is supported by scientific evidence from many disciplines, including mathematics. a. Scientific evidence of biological evolution uses information from geographical, geological, physical, chemical and mathematical applications. b. Molecular, morphological and genetic information of existing and extinct organisms add to our understanding of evolution. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Fossils can be dated by a variety of methods that provide evidence for evolution. These include the age of the rocks where a fossil is found, the rate of decay of isotopes including carbon-14, the relationships within phylogenetic trees, and the mathematical calculations that take into account information from chemical properties and/or geographical data. 2. Morphological homologies represent features shared by common ancestry. Vestigial structures are remnants of functional structures, which can be compared to fossils and provide evidence for evolution. 3. Biochemical and genetic similarities, in particular DNA nucleotide and protein sequences, provide evidence for evolution and ancestry. 4. Mathematical models and simulations can be used to illustrate and support evolutionary concepts. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Graphical analyses of allele frequencies in a population • Analysis of sequence data sets • Analysis of phylogenetic trees • Construction of phylogenetic trees based on sequence data ***Essential knowledge 1.B.2: Phylogenetic trees and cladograms are graphical representations (models) of evolutionary history that can be tested.*** a. Phylogenetic trees and cladograms can represent traits that are either derived or lost due to evolution. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Number of heart chambers in animals • Opposable thumbs • Absence of legs in some sea mammals b. Phylogenetic trees and cladograms illustrate speciation that has occurred, in that relatedness of any two groups on the tree is shown by how recently two groups had a common ancestor. c. Phylogenetic trees and cladograms can be constructed from morphological similarities of living or fossil species, and from DNA and protein sequence similarities, by employing computer programs that have sophisticated ways of measuring and representing relatedness among organisms. d. Phylogenetic trees and cladograms are dynamic (i.e., phylogenetic trees and cladograms are constantly being revised), based on the biological data used, new mathematical and computational ideas, and current and emerging knowledge. ***Essential knowledge 2.E.3: Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection.*** 4. Cooperative behavior within or between populations contributes to the survival of the populations. *Students should be able to demonstrate understanding of the above concept by using an illustrative example such as:* • Availability of resources leading to fruiting body formation in fungi and certain types of bacteria • Niche and resource partitioning • Mutualistic relationships (lichens; bacteria in digestive tracts of animals; mycorrhizae) • Biology of pollination ***Essential knowledge 4.C.3: The level of variation in a population affects population dynamics.*** b. Genetic diversity allows individuals in a population to respond differently to the same changes in environmental conditions.	**Evidence for Evolution** Evaluate evidence provided by data from many scientific disciplines to support biological evolution. [LO 1.9, SP 5.3] Refine evidence based on data from many scientific disciplines that support biological evolution. [LO 1.10, SP 5.2] Design a plan to answer scientific questions regarding how organisms have changed over time using information from morphology, biochemistry, and geology. [LO 1.11, SP 4.2] Connect scientific evidence from many scientific disciplines to support the modern concept of evolution. [LO 1.12, SP 7. Construct and/or justify mathematical models, diagrams, or simulations that represent processes of biological evolution. [LO 1.13, SP 1.1, SP 2.1] Pose scientific questions about a group of organisms whose relatedness is described by a phylogenetic tree or cladogram in order to (1) identify shared characteristics, (2) make inferences about the evolutionary history of the group, and (3) identify character data that could extend or improve the phylogenetic tree. [LO 1.17, SP 3.1] **LO 1.18** The student is able to evaluate evidence provided by a data set in conjunction with a phylogenetic tree or a simple cladogram to determine evolutionary history and speciation. [See **SP 5.3**] **LO 1.19** The student is able create a hylogenetic tree or simple cladogram that correctly represents evolutionary history and speciation from a provided data set. [See **SP 1.1**] Construct explanations based on scientific evidence that homeostatic mechanisms reflect continuity due to common ancestry and/or divergence due to adaptation in different environments. [LO 2.25, SP 6.2]

To foster student understanding of this concept, instructors can choose an illustrative example such as: • Not all animals in a population stampede. • Not all individuals in a population in a disease outbreak are equally affected; some may not show symptoms, some may have mild symptoms, or some may be naturally immune and resistant to the disease. c. Allelic variation within a population can be modeled by the Hardy- Weinberg equation(s). [See also **1.A.1**]	
Essential knowledge 1.C.1: Speciation and extinction have occurred throughout the Earth's history. a. Speciation rates can vary, especially when adaptive radiation occurs when new habitats become available. b. Species extinction rates are rapid at times of ecological stress. [See also **4.C.3**] *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Five major extinctions • Human impact on ecosystems and species extinction rates ***Essential knowledge 1.C.2: Speciation may occur when two populations become reproductively isolated from each other.*** a. Speciation results in diversity of life forms. Species can be physically separated by a geographic barrier such as an ocean or a mountain range, or various pre-and post-zygotic mechanisms can maintain reproductive isolation and prevent gene flow. b. New species arise from reproductive isolation over time, which can involve scales of hundreds of thousands or even millions of years, or speciation can occur rapidly through mechanisms such as polyploidy in plants. ***Essential knowledge 1.C.3: Populations of organisms continue to evolve.*** a. Scientific evidence supports the idea that evolution has occurred in all species. b. Scientific evidence supports the idea that evolution continues to occur. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Chemical resistance (mutations for resistance to antibiotics, pesticides, herbicides or chemotherapy drugs occur in the absence of the chemical) • Emergent diseases • Observed directional phenotypic change in a population (Grants' observations of Darwin's finches in the Galapagos) • A eukaryotic example that describes evolution of a structure or process such as heart chambers, limbs, the brain and the immune system	**Origin of Species** Analyze data related to questions of speciation and extinction throughout the Earth's history. [LO 1.20, SP 5.1] Design a plan for collecting data to investigate the scientific claim that speciation and extinction have occurred throughout the Earth's history. [LO 1.21, SP 4.2] Use data from a real or simulated population(s), based on graphs or models of types of selection, to predict what will happen to the population in the future. [LO 1.22, SP 6.4] Justify the selection of data that addresses questions related to reproductive isolation and speciation. [LO 1.23, SP 4.1] Describe speciation in an isolated population and connect it to change in gene frequency, change in environment, natural selection, and/or genetic drift. [LO 1.24, SP 7.2] Describe a model that represents evolution within a population. [LO 1.25, SP 1.2] Evaluate given data sets that illustrate evolution as an ongoing process. [LO 1.26, SP 5.3]
UNIT #10 BIODIVERSITY and ECOLOGY Big Ideas: 1, 3, and 4	**Learning Objectives**
Essential knowledge 1.D.1: There are several hypotheses about the natural origin of life on Earth, each with supporting scientific evidence. a. Scientific evidence supports the various models. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Primitive Earth provided inorganic precursors from which organic molecules could have been synthesized due to the presence of available free energy and the absence of a significant quantity of oxygen. 2. In turn, these molecules served as monomers or building blocks for the formation of more complex molecules, including amino acids and nucleotides. [See also **4.A.1**] 3. The joining of these monomers produced polymers with the ability to replicate, store and transfer information. 4. These complex reaction sets could have occurred in solution (organic soup model) or as reactions on solid reactive surfaces. [See also **2.B.1**]	**Origin of Life** Describe a scientific hypothesis about the origin of life on Earth. [LO 1.27, SP 1.2] Evaluate scientific questions based on hypotheses about the origin of life on Earth. [LO 1.28, SP 3.3] Describe the reasons for revisions of scientific hypotheses about the origin of life on Earth. [LO 1.29, SP 6.3]

5. The RNA World hypothesis proposes that RNA could have been the earliest genetic material. ***Essential knowledge 1.D.2: Scientific evidence from many different disciplines supports models of the origin of life.*** a. Geological evidence provides support for models of the origin of life on Earth. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. The Earth formed approximately 4.6 billion years ago (bya), and the environment was too hostile for life until 3.9 bya, while the earliest fossil evidence for life dates to 3.5 bya. Taken together, this evidence provides a plausible range of dates when the origin of life could have occurred. 2. Chemical experiments have shown that it is possible to form complex organic molecules from inorganic molecules in the absence of life. b. Molecular and genetic evidence from extant and extinct organisms indicates that all organisms on Earth share a common ancestral origin of life. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Scientific evidence includes molecular building blocks that are common to all life forms. 2. Scientific evidence includes a common genetic code.	Evaluate scientific hypotheses about the origin of life on Earth. [LO 1.30, SP 6.5] Evaluate the accuracy and legitimacy of data to answer scientific questions about the origin of life on Earth. [LO 1.31, SP 4.4] Justify the selection of geological, physical, and chemical data that reveal early Earth conditions. [LO 1.32, SP 4.1]
Essential knowledge 3.C.3: Viral replication results in genetic variation, and viral infection can introduce genetic variation into the hosts. a. Viral replication differs from other reproductive strategies and generates genetic variation via various mechanisms. [See also **1.B.3**] *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Viruses have highly efficient replicative capabilities that allow for rapid evolution and acquisition of new phenotypes. 2. Viruses replicate via a component assembly model allowing one virus to produce many progeny simultaneously via the lyticcycle. 3. Virus replication allows for mutations to occur through usual host pathways. 4. RNA viruses lack replication error-checking mechanisms, and thus have higher rates of mutation. 5. Related viruses can combine/recombine information if they infect the same host cell. 6. HIV is a well-studied system where the rapid evolution of a virus within the host contributes to the pathogenicity of viral infection. b. The reproductive cycles of viruses facilitate transfer of genetic information. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Viruses transmit DNA or RNA when they infect a host cell. [See also **1.B.3**] *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Transduction in bacteria • Transposons present in incoming DNA 2. Some viruses are able to integrate into the host DNA and establish a latent (lysogenic) infection. These latent viral genomes can result in new properties for the host such as increased pathogenicity in bacteria.	**Viruses *versus* Cells** Construct an explanation of how viruses introduce genetic variation in host organisms. [LO 3.29, SP 6.2] Use representations and appropriate models to describe how viral replication introduces genetic variation in the viral population. [LO 3.30, SP 1.4]
Essential knowledge 2.C.1: Organisms use feedback mechanisms to maintain their internal environments and respond to external environmental changes. a. Negative feedback mechanisms maintain dynamic homeostasis for a particular condition (variable) by regulating physiological processes, returning the changing condition back to its target set point. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Operons in gene regulation • Temperature regulation in animals • Plant responses to water limitations b. Positive feedback mechanisms amplify responses and processes in biological organisms. The variable initiating the response is moved farther away from the initial set-point. Amplification occurs when the stimulus is further activated which, in turn, initiates an additional response that produces system change. *Students should be able to demonstrate understanding of the above concept by using an illustrative example such as:* • Lactation in mammals • Onset of labor in childbirth • Ripening of fruit b. Alteration in the mechanisms of feedback often results in deleterious consequences.	**Maintaining Homeostasis** Connect how organisms use negative feedback to maintain their internal environments. [LO 2.16, SP 7.2] Evaluate data that show the effect(s) of changes in concentrations of key molecules on negative feedback mechanisms. [LO 2.17, SP 5.3] Make predictions about how organisms use negative feedback mechanisms to maintain their internal environments. [LO 2.18, SP 6.4] Make predictions about how positive feedback mechanisms amplify activities and processes in organisms based on scientific theories and models. [LO 2.19, SP 6.4] Justify that positive feedback mechanisms

To foster student understanding of this concept, instructors can choose an illustrative example such as: • Diabetes mellitus in response to decreased insulin • Dehydration in response to decreased antidiuretic hormone (ADH) • Graves' disease (hyperthyroidism) • Blood clotting ***Essential knowledge 2.C.2: Organisms respond to changes in their external environments.*** a. Organisms respond to changes in their environment through behavioral and physiological mechanisms. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Photoperiodism and phototropism in plants • Hibernation and migration in animals • Taxis and kinesis in animals • Chemotaxis in bacteria, sexual reproduction in fungi • Nocturnal and diurnal activity: circadian rhythms • Shivering and sweating in humans ***Essential knowledge 2.E.2: Timing and coordination of physiological events are regulated by multiple mechanisms.*** a. In plants, physiological events involve interactions between environmental stimuli and internal molecular signals. [See also **2.C.2**] *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Phototropism, or the response to the presence of light 2. Photoperiodism, or the response to change in length of the night, that results in flowering in long-day and short-day plants b. In animals, internal and external signals regulate a variety of physiological responses that synchronize with environmental cycles and cues. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Circadian rhythms, or the physiological cycle of about 24 hours that is present in all eukaryotes and persists even in the absence of external cues • Diurnal/nocturnal and sleep/awake cycles • Jet lag in humans • Seasonal responses, such as hibernation, estivation and migration • Release and reaction to pheromones • Visual displays in the reproductive cycle c. In fungi, protists and bacteria, internal and external signals regulate a variety of physiological responses that synchronize with environmental cycles and cues. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Fruiting body formation in fungi, slime molds and certain types of bacteria • Quorum sensing in bacteria ***Essential knowledge 2.D.2: Homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments.*** a. Continuity of homeostatic mechanisms reflects common ancestry, while changes may occur in response to different environmental conditions. [See also **1.B.1**] b. Organisms have various mechanisms for obtaining nutrients and eliminating wastes. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Gas exchange in aquatic and terrestrial plants • Digestive mechanisms in animals such as food vacuoles, gastrovascular cavities, one-way digestive systems • Respiratory systems of aquatic and terrestrial animals • Nitrogenous waste production and elimination in aquatic and terrestrial animals c. Homeostatic control systems in species of microbes, plants and animals support common ancestry. [See also **1.B.1**] *To foster student understanding of this concept, instructors can choose an illustrative example such as the comparison of:* • Excretory systems in flatworms, earthworms and vertebrates • Osmoregulation in bacteria, fish and protists	amplify responses in organisms. [LO 2.20, SP 6.1] Justify the selection of the kind of data needed to answer scientific questions about the relevant mechanism that organisms use to respond to changes in their external environment. [LO 2.21, SP 4.1] Design a plan for collecting data to support the scientific claim that the timing and coordination of physiological events involve regulation. [LO 2.35, SP 4.2] Justify scientific claims with evidence to show how timing and coordination of physiological events involve regulation. [LO 2.36, SP 6.1] Use representations or models to analyze quantitatively and qualitatively the effects of disruptions to dynamic homeostasis in biological systems. [LO 2.28, SP 1.4] Explain how the distribution of ecosystems changes over time by identifying large-scale events that have resulted in these changes in the past. [LO 4.20, SP 6.3] Analyze data to identify phylogenetic patterns or relationships, showing that homeostatic mechanisms reflect both continuity due to common ancestry and change due to evolution in different environments. [LO 2.26, SP 5.1] Connect differences in the environment with the evolution of homeostatic mechanisms. [LO 2.27, SP 7.1]

• Osmoregulation in aquatic and terrestrial plants • Circulatory systems in fish, amphibians and mammals • Thermoregulation in aquatic and terrestrial animals (countercurrent exchange mechanisms) ***Essential knowledge 2.D.3: Biological systems are affected by disruptions to their dynamic homeostasis.*** a. Disruptions at the molecular and cellular levels affect the health of the organism. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Physiological responses to toxic substances • Dehydration • Immunological responses to pathogens, toxins and allergens b. Disruptions to ecosystems impact the dynamic homeostasis or balance of the ecosystem. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Invasive and/or eruptive species • Human impact • Hurricanes, floods, earthquakes, volcanoes, fires • Water limitation • Salination ***Essential knowledge 4.B.4: Distribution of local and global ecosystems changes over time.*** b. Geological and meteorological events impact ecosystem distribution. *Evidence of student learning is a demonstrated understanding of the following:* 1. Biogeographical studies illustrate these changes. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • El Nino • Continental drift • Meteor impact on dinosaurs	
Essential knowledge 2.D.1: All biological systems from cells and organisms to populations, communities and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy. a. Cell activities are affected by interactions with biotic and abiotic factors. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Cell density • Biofilms • Temperature • Water availability • Sunlight b. Organism activities are affected by interactions with biotic and abiotic factors. [See also **4.A.6**] *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Symbiosis (mutualism, commensalism, parasitism) • Predator–prey relationships • Water and nutrient availability, temperature, salinity, pH c. The stability of populations, communities and ecosystems is affected by interactions with biotic and abiotic factors. [See also **4.A.5, 4.A.6**] *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Water and nutrient availability • Availability of nesting materials and sites • Food chains and food webs • Species diversity • Population density • Algal blooms	**Interactions with Environment** Refine scientific models and questions about the effect of complex biotic and abiotic interactions on all biological systems, from cells and organisms to populations, communities, and ecosystems. [LO 2.22, SP 1.3, SP 3.2] Design a plan for collecting data to show that all biological systems (cells, organisms, populations, communities, and ecosystems) are affected by complex biotic and abiotic interactions. [LO 2.23, SP 4.2, SP 7.2] Analyze data to identify possible patterns and relationships between a biotic or abiotic factor and a biological system (cells, organisms, populations, communities, or ecosystems). [LO 2.24, SP 5.1]

Essential knowledge 2.E.3: Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection. a. Individuals can act on information and communicate it to others. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Innate behaviors are behaviors that are inherited. 2. Learning occurs through interactions with the environment and other organisms. b. Responses to information and communication of information are vital to natural selection. [See also **2.C.2**] *Evidence of student learning is a demonstrated understanding of each of the following:* 1. In phototropism in plants, changes in the light source lead to differential growth, resulting in maximum exposure of leaves to light for photosynthesis. 2. In photoperiodism in plants, changes in the length of night regulate flowering and preparation for winter. 3. Behaviors in animals are triggered by environmental cues and are vital to reproduction, natural selection and survival. *Students should be able to demonstrate understanding of the above concept by using an illustrative example such as:* • Hibernation • Estivation • Migration • Courtship 4. Cooperative behavior within or between populations contributes to the survival of the populations. *Students should be able to demonstrate understanding of the above concept by using an illustrative example such as:* • Availability of resources leading to fruiting body formation in fungi and certain types of bacteria • Niche and resource partitioning • Mutualistic relationships (lichens; bacteria in digestive tracts of animals; mycorrhizae) • Biology of pollination ***Essential knowledge 3.E.1: Individuals can act on information and communicate it to others.*** a. Organisms exchange information with each other in response to internal changes and external cues, which can change behavior. *Students should be able to demonstrate understanding of the above concept by using an illustrative example such as:* • Fight or flight response • Predator warnings • Protection of young • Plant-plant interactions due to herbivory • Avoidance responses b. Communication occurs through various mechanisms. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Living systems have a variety of signal behaviors or cues that produce changes in the behavior of other organisms and can result in differential reproductive success. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Herbivory responses • Territorial marking in mammals • Coloration in flowers 2. Animals use visual, audible, tactile, electrical and chemical signals to indicate dominance, find food, establish territory and ensure reproductive success. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Bee dances • Birds songs • Territorial marking in mammals • Pack behavior in animals	**Behavior** Justify scientific claims, using evidence, to describe how timing and coordination of behavioral events in organisms are regulated by several mechanisms. [LO 2.39, SP 6.1] Connect concepts in and across domain(s) to predict how environmental factors affect responses to information and change behavior. [LO 2.40, SP 7.2] Analyze data that indicate how organisms exchange information in response to internal changes and external cues, and which can change behavior. [LO 3.40, SP 5.1] Create a representation that describes how organisms exchange information in response to internal changes and external cues, and which can result in changes in behavior. [LO 3.41, SP 1.1] Describe how organisms exchange information in response to internal changes or environmental cues. [LO 3.42, SP 7.1]

• Herd, flock, and schooling behavior in animals • Predator warning • Colony and swarming behavior in insects • Coloration c. Responses to information and communication of information are vital to natural selection and evolution. [See also **1.A.2**] *Evidence of student learning is a demonstrated understanding of the following:* 1. Natural selection favors innate and learned behaviors that increase survival and reproductive fitness. *Students should be able to demonstrate understanding of the above concept by using an illustrative example such as:* • Parent and offspring interactions • Migration patterns • Courtship and mating behaviors • Foraging in bees and other animals • Avoidance behavior to electric fences, poisons, or traps 2. Cooperative behavior tends to increase the fitness of the individual and the survival of the population. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Pack behavior in animals • Herd, flock and schooling behavior in animals • Predator warning • Colony and swarming behavior in insects .	
Essential knowledge 2.D.4: Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis. a. Plants, invertebrates and vertebrates have multiple, nonspecific immune responses. *Students should be able to demonstrate understanding of the above concept by using an illustrative example such as:* • Invertebrate immune systems have nonspecific response mechanisms, but they lack pathogen-specific defense responses. • Plant defenses against pathogens include molecular recognition systems with systemic responses; infection triggers chemical responses that destroy infected and adjacent cells, thus localizing the effects. • Vertebrate immune systems have nonspecific and nonheritable defense mechanisms against pathogens. b. Mammals use specific immune responses triggered by natural or artificial agents that disrupt dynamic homeostasis. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. The mammalian immune system includes two types of specific responses: cell mediated and humoral. 2. In the cell-mediated response, cytotoxic T cells, a type of lymphocytic white blood cell, "target" intracellular pathogens when antigens are displayed on the outside of the cells. 3. In the humoral response, B cells, a type of lymphocytic white blood cell, produce antibodies against specific antigens. 4. Antigens are recognized by antibodies to the antigen. 5. Antibodies are proteins produced by B cells, and each antibody is specific to a particular antigen. 6. A second exposure to an antigen results in a more rapid and enhanced immune response. ***Essential knowledge 3.E.2: Animals have nervous systems that detect external and internal signals, transmit and integrate information, and produce responses.*** a. The neuron is the basic structure of the nervous system that reflects function. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. A typical neuron has a cell body, axon and dendrites. Many axons have a myelin sheath that acts as an electrical insulator. 2. The structure of the neuron allows for the detection, generation, transmission and integration of signal information. 3. Schwann cells, which form the myelin sheath, are separated by gaps of unsheathed axon over which the impulse travels as the signal propagates along the neuron. b. Action potentials propagate impulses along neurons. *Evidence of student learning is a demonstrated understanding of each of the following:*	**Responses and Defenses** Create representations and models to describe immune responses. [LO 2.29, SP 1.1, SP 1.2] Create representations or models to describe nonspecific immune defenses in plants and animals. [LO 2.30, SP 1.1, SP 1.2] Construct an explanation, based on scientific theories and models, about how nervous systems detect external and internal signals, transmit and integrate information, and produce responses. [LO 3.43, SP 6.2, SP 7.1] Describe how nervous systems detect external and internal signals. [LO 3.44, SP 1.2] Describe how nervous systems transmit information. [LO 3.45, SP 1.2] Describe how the vertebrate brain integrates information to produce a response. [LO 3.46, SP 1.2] Create a visual representation of complex nervous systems to describe/explain how these systems detect external and internal signals, transmit and integrate information, and produce responses. [LO 3.47, SP 1.1] Create a visual representation to describe how nervous systems detect external and

1. Membranes of neurons are polarized by the establishment of electrical potentials across the membranes. 2. In response to a stimulus, Na+ and K+ gated channels sequentially open and cause the membrane to become locally depolarized. 3. Na+/K+ pumps, powered by ATP, work to maintain membrane potential. c. Transmission of information between neurons occurs across synapses. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. In most animals, transmission across synapses involves chemical messengers called neurotransmitters. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Acetylcholine • Epinephrine • Norepinephrine • Dopamine • Serotonin • GABA 2. Transmission of information along neurons and synapses results in a response. 3. The response can be stimulatory or inhibitory. d. Different regions of the vertebrate brain have different functions. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Vision • Hearing • Muscle movement • Abstract thought and emotions • Neuro-hormone production • Forebrain (cerebrum), midbrain (brainstem) and hindbrain (cerebellum) • Right and left cerebral hemispheres in humans	internal signals. [LO 3.48, SP 1.1] Create a visual representation to describe how nervous systems transmit information. [LO 3.49, SP 1.1] Create a visual representation to describe how the vertebrate brain integrates information to produce a response. [LO 3.50, SP 1.1]
Essential knowledge 4.A.4: Organisms exhibit complex properties due to interactions between their constituent parts. a. Interactions and coordination between organs provide essential biological activities. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Stomach and small intestines • Kidney and bladder • Root, stem and leaf b. Interactions and coordination between systems provide essential biological activities. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Respiratory and circulatory • Nervous and muscular • Plant vascular and leaf ***Essential knowledge 4.A.5: Communities are composed of populations of organisms that interact in complex ways.*** a. The structure of a community is measured and described in terms of species composition and species diversity. b. Mathematical or computer models are used to illustrate and investigate population interactions within and environmental impacts on a community. [See also **3.E.1**] *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Predator/prey relationships spreadsheet model • Symbiotic relationship • Graphical representation of field data • Introduction of species • Global climate change models	**Living Together** Evaluate scientific questions concerning organisms that exhibit complex properties due to the interaction of their constituent parts. [LO 4.8, SP 3.3] Predict the effects of a change in a component(s) of a biological system on the functionality of an organism(s). [LO 4.9, SP 6.4] Refine representations and models to illustrate biocomplexity due to interactions of the constituent parts. [LO 4.10, SP 1.3] Justify the selection of the kind of data needed to answer scientific questions about the interaction of populations within communities. [LO 4.11, SP 1.4, SP 4.1] Apply mathematical routines to quantities that describe communities composed of populations of organisms that interact in complex ways. [LO 4.12, SP 2.2] Predict the effects of a change in the community’s populations on the community.

c. Mathematical models and graphical representations are used to illustrate population growth patterns and interactions. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Reproduction without constraints results in the exponential growth of a population. 2. A population can produce a density of individuals that exceeds the system's resource availability. 3. As limits to growth due to density-dependent and density independent factors are imposed, a logistic growth model generally ensues. 4. Demographics data with respect to age distributions and fecundity can be used to study human populations. ***Essential knowledge 4.A.6: Interactions among living systems and with their environment result in the movement of matter and energy.*** a. Energy flows, but matter is recycled. [See also **2.A.1**] b. Changes in regional and global climates and in atmospheric composition influence patterns of primary productivity. c. Organisms within food webs and food chains interact. [See also **2.D.1**] d. Food webs and food chains are dependent on primary productivity. e. Models allow the prediction of the impact of change in biotic and abiotic factors. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Competition for resources and other factors limits growth and can be described by the logistic model. 2. Competition for resources, territoriality, health, predation, accumulation of wastes and other factors contribute to density dependent population regulation. f. Human activities impact ecosystems on local, regional and global scales. [See also **2.D.3**] *Evidence of student learning is a demonstrated understanding of each of the following:* 1. As human populations have increased in numbers, their impact on habitats for other species have been magnified. 2. In turn, this has often reduced the population size of the affected species and resulted in habitat destruction and, in some cases, the extinction of species. g. Many adaptations of organisms are related to obtaining and using energy and matter in a particular environment. [See also **2.A.1**, **2.A.2**] ***Essential knowledge 4.B.2: Cooperative interactions within organisms promote efficiency in the use of energy and matter.*** a. Organisms have areas or compartments that perform a subset of functions related to energy and matter, and these parts contribute to the whole. [See also **2.A.2**, **4.A.2**] *Evidence of student learning is a demonstrated understanding of each of the following:* 2. Within multicellular organisms, specialization of organs contributes to the overall functioning of the organism. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Exchange of gases • Circulation of fluids • Digestion of food • Excretion of wastes 3. Interactions among cells of a population of unicellular organisms can be similar to those of multicellular organisms, and these interactions lead to increased efficiency and utilization of energy and matter. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Bacterial community in the rumen of animals • Bacterial community in and around deep sea vents ***Essential knowledge 4.B.3: Interactions between and within populations influence patterns of species distribution and abundance.*** a. Interactions between populations affect the distributions and abundance of populations. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Competition, parasitism, predation, mutualism and commensalism can affect population dynamics. 2. Relationships among interacting populations can be characterized by positive and negative effects, and can be modeled mathematically (predator/prey, epidemiological models, and invasive species). 3. Many complex symbiotic relationships exist in an ecosystem, and feedback control systems play a role in the functioning of these ecosystems.	[LO 4.13, SP 6.4] Predict the effects of a change of matter or energy availability on communities. [LO 4.16, SP 6.4] Use data analysis to refine observations and measurements regarding the effect of population interactions on patterns of species distribution and abundance. [LO 4.19, SP 5.2] Predict consequences of human actions on both local and global ecosystems. [LO 4.21, SP 6.4] Make scientific claims and predictions about how species diversity within an ecosystem influences ecosystem stability. [LO 4.27, SP 6.4]

b. A population of organisms has properties that are different from those of the individuals that make up the population. The cooperation and competition between individuals contributes to these different properties. c. Species-specific and environmental catastrophes, geological events, the sudden influx/depletion of abiotic resources or increased human activities affect species distribution and abundance. [See also **1.A.1**, **1.A.2**] *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Loss of keystone species • Kudzu • Dutch elm disease ***Essential knowledge 4.B.4: Distribution of local and global ecosystems changes over time.*** a. Human impact accelerates change at local and global levels. [See also **1.A.2**] *To foster student understanding of this concept, instructors can choose an illustrative example such as:* • Logging, slash and burn agriculture, urbanization, monocropping, infrastructure development (dams, transmission lines, roads), and global climate change threaten ecosystems and life on Earth. • An introduced species can exploit a new niche free of predators or competitors, thus exploiting new resources. • Introduction of new diseases can devastate native species. *Illustrative examples include*: • Dutch elm disease • Potato blight • Small pox [historic example for Native Americans] ***Essential knowledge 4.C.4: The diversity of species within an ecosystem may influence the stability of the ecosystem.*** a. Natural and artificial ecosystems with fewer component parts and with little diversity among the parts are often less resilient to changes in the environment. [See also **1.C.1**] b. Keystone species, producers, and essential abiotic and biotic factors contribute to maintaining the diversity of an ecosystem. The effects of keystone species on the ecosystem are disproportionate relative to their abundance in the ecosystem, and when they are removed from the ecosystem, the ecosystem often collapses.	