Correlation with the AP® Biology Course and Exam Description

Unit 1: Chemistry of Life

AP® Exam Weighting: 8–11%; 5–7 class periods

- **Big Idea 2 (ENE):** Biological systems use energy and molecular building blocks to grow, to reproduce, and to maintain dynamic homeostasis.
- **Big Idea 3 (IST):** Living systems store, retrieve, transmit, and respond to information essential to life processes.
- **Big Idea 4 (SYI):** Biological systems interact, and these systems and their interactions exhibit complex properties.

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
1.1: Structure of Water and Hydrogen Bonding **Big Idea 4**	**SYI-1:** Living systems are organized in a hierarchy of structural levels that interact. **SYI-1.A:** Explain how the properties of water that result from its polarity and hydrogen bonding affect its biological function.	**SYI-1.A.1:** The subcomponents of biological molecules and their sequence determine the properties of that molecule.	3.2–3.6, p. 39–49
		SYI-1.A.2: Living systems depend on properties of water that result from its polarity and hydrogen bonding.	2.5–2.6, p. 30–33 28.4, p. 472–474
		SYI-1.A.3: The hydrogen bonds between water molecules result in cohesion, adhesion, and surface tension.	2.5, p. 30–31 28.4, p. 472–474
1.2: Elements of Life **Big Idea 2**	**ENE-1:** The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules. **ENE-1.A:** Describe the composition of macromolecules required by living organisms.	**ENE-1.A.1:** Organisms must exchange matter with the environment to grow, reproduce, and maintain organization.	5.2, p. 78–79 6.2–6.5, p. 100-111 7.2–7.6, p. 116–127
		ENE-1.A.2: Atoms and molecules from the environment are necessary to build new molecules. a. Carbon is used to build biological molecules such as carbohydrates, proteins, lipids, and nucleic acids. Carbon is used in storage compounds and cell formation in all organisms. b. Nitrogen is used to build proteins and nucleic acids. Phosphorus is used to build nucleic acids and certain lipids	28.4, p. 472–475 3.2, 3.3–3.6, p. 38, 41–49 3.4–3.6, p. 44–49
1.3: Introduction to Biological Macromolecules **Big Idea 4**	**SYI-1:** Living systems are organized in a hierarchy of structural levels that interact. **SYI-1.B:** Describe the properties of the monomers and the type of bonds that connect the monomers in biological macromolecules.	**SYI-1.B.1:** Hydrolysis and dehydration synthesis are used to cleave and form covalent bonds between monomers.	3.2–3.6, p. 40–49
1.4: Properties of Biological Macromolecules **Big Idea 4**	**SYI-1:** Living systems are organized in a hierarchy of structural levels that interact. **SYI-1.B:** Describe the properties of the monomers and the type of bonds that connect the monomers in biological macromolecules.	**SYI-1.B.2:** Structure and function of polymers are derived from the way their monomers are assembled. a. 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 structure and function. b. In proteins, the specific order of amino acids in a polypeptide (primary structure) determines the overall shape of the protein. Amino acids have directionality, with an amino (NH_2) terminus and a carboxyl (COOH) terminus. The R group of an amino acid can be categorized by chemical properties (hydrophobic, hydrophilic, or ionic), and the interactions of these R groups determine structure and function of that region of the protein. c. Complex carbohydrates comprise sugar monomers whose structures determine the properties and functions of the molecules. d. Lipids are nonpolar macromolecules. i. Differences in saturation determine the structure and function of lipids. ii. Phospholipids contain polar regions that interact with other polar molecules, such as water, and with nonpolar regions that are often hydrophobic.	3.2–3.6, p. 40–49 3.3, p. 41–43 3.4, p. 43–45 3.6, p. 40 3.5, p. 46–48

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
1.5: Structure and Function of Biological Macromolecules **Big Idea 4**	**SYI-1:** Living systems are organized in a hierarchy of structural levels that interact. **SYI-1.C:** Explain how a change in the subunits of a polymer may lead to changes in structure or function of the macromolecule.	**SYI-1.C.1:** Directionality of the subcomponents influences structure and function of the polymer. a. Nucleic acids have a linear sequence of nucleotides that have ends, defined by the 3′ hydroxyl and 5′ phosphates of the sugar in the nucleotide. During DNA and RNA synthesis, nucleotides are added to the 3′ end of the growing strand, resulting in the formation of a covalent bond between nucleotides. b. DNA is structured as an antiparallel double helix, with each strand running in opposite 5′ to 3′ orientation. Adenosine nucleotides pair with thymine nucleotides via two hydrogen bonds. Cytosine nucleotides pair with guanine nucleotides by three hydrogen bonds. c. Proteins comprise linear chains of amino acids, connected by the formation of covalent bonds at the carboxyl terminus of the growing peptide chain.	3.3, p. 41–43 3.5, p. 46–48 3.6, p. 49 8.3, p. 134–136 8.5, p. 138–140, 9.2–9.3, p. 148–151
		d. Proteins have primary structure determined by the sequence order of their constituent amino acids, secondary structure that arises through local folding of the amino acid chain into elements such as alpha-helices and beta-sheets, tertiary structure that is the overall three-dimensional shape of the protein and often minimizes free energy, and quaternary structure that arises from interactions between multiple polypeptide units. The four elements of protein structure determine the function of a protein. e. Carbohydrates comprise linear chains of sugar monomers connected by covalent bonds. Carbohydrate polymers may be linear or branched.	
1.6: Nucleic Acids **Big Idea 3**	**IST-1:** Heritable information provides for continuity of life. **IST-1.A:** Describe the structural similarities and differences between DNA and RNA.	**IST-1.A.1:** DNA and RNA molecules have structural similarities and differences related to their function. a. Both DNA and RNA have three components — sugar, a phosphate group, and a nitrogenous base — that form nucleotide units that are connected by covalent bonds to form a linear molecule with 5′ and 3′ ends, with the nitrogenous bases perpendicular to the sugar-phosphate backbone. b. The basic structural differences between DNA and RNA include the following i. DNA contains deoxyribose and RNA contains ribose. ii. RNA contains uracil and DNA contains thymine. iii. DNA is usually double stranded; RNA is usually single stranded. iv. The two DNA strands in double-stranded DNA are antiparallel in directionality.	3.6, p. 49 8.3, p. 134–137 9.2, p. 148–149

Unit 2: Cell Structure and Function

AP® Exam Weighting: 10–13%; 11–13 class periods

- **Big Idea 1 (EVO):** The process of evolution drives the diversity and unity of life.
- **Big Idea 2 (ENE):** Biological systems use energy and molecular building blocks to grow, to reproduce, and to maintain dynamic homeostasis.
- **Big Idea 4 (SYI):** Biological systems interact, and these systems and their interactions exhibit complex properties.

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
2.1: Cell Structure: Sub-Cellular Components **Big Idea 4**	**SYI-1:** Living systems are organized in a hierarchy of structural levels that interact. **SYI-1.D:** Describe the structure and/or function of subcellular components and organelles.	**SYI-1.D.1:** Ribosomes comprise ribosomal RNA (rRNA) and protein. Ribosomes synthesize protein according to mRNA sequence.	4.3–4.4, p. 58–61 9.4–9.5, p. 153–155
		SYI-1.D.2: Ribosomes are found in all forms of life, reflecting the common ancestry of all known life.	4.3–4.4, p. 58–61 9.4–9.5, p. 153–155 20.5, p. 324
		SYI-1.D.3: Endoplasmic reticulum (ER) occurs in two forms: smooth and rough. Rough ER is associated with membrane-bound ribosomes. a. Rough ER compartmentalizes the cell. b. Smooth ER functions include detoxification and lipid synthesis.	4.5, p. 62–63

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
		SYI-1.D.4: The Golgi complex is a membrane-bound structure that consists of a series of flattened membrane sacs. a. Functions of the Golgi include the correct folding and chemical modification of newly synthesized proteins and packaging for protein trafficking. b. Mitochondria have a double membrane. The outer membrane is smooth, but the inner membrane is highly convoluted, forming folds. c. Lysosomes are membrane-enclosed sacs that contain hydrolytic enzymes. d. A vacuole is a membrane-bound sac that plays many and differing roles. In plants, a specialized large vacuole serves multiple functions. e. Chloroplasts are specialized organelles that are found in photosynthetic algae and plants. Chloroplasts have a double outer membrane.	4.5, p. 62–63 4.6, p. 64 4.7, p. 65 5.10, p. 95 6.2, p. 101 6.5, p. 108–110 7.2–7.4, p. 116–123 11.4, p. 180 19.7, p. 310–313 21.2, p. 338–339 37.6, p. 647
2.2: Cell Structure and Function **Big Idea 4**	**SYI-1:** Living systems are organized in a hierarchy of structural levels that interact. **SYI-1.E:** Explain how subcellular components and organelles contribute to the function of the cell.	**SYI-1.E.1:** Organelles and subcellular structures, and the interactions among them, support cellular function. a. Endoplasmic reticulum provides mechanical support, carries out protein synthesis on membrane-bound ribosomes, and plays a role in intracellular transport. b. Mitochondrial double membrane provides compartments for different metabolic reactions. c. Lysosomes contain hydrolytic enzymes, which are important in intracellular digestion, the recycling of a cell's organic materials, and programmed cell death (apoptosis). d. Vacuoles have many roles, including storage and release of macromolecules and cellular waste products. In plants, it aides in retention of water for turgor pressure.	4.5, p. 62–63 4.6, p. 64 5.10, p. 94–95 37.6, p. 646–647
	SYI-1: Living systems are organized in a hierarchy of structural levels that interact. **SYI-1.F:** Describe the structural features of a cell that allow organisms to capture, store, and use energy.	**SYI-1.F.1:** The folding of the inner membrane increases the surface area, which allows for more ATP to be synthesized.	4.6, p. 64 7.3–7.4, p. 119–122
		SYI-1.F.2: Within the chloroplast are thylakoids and the stroma.	4.7, p. 65 6.4, p. 104–107
		SYI-1.F.3: The thylakoids are organized in stacks, called grana.	4.7, p. 65 6.2, p. 100–101
		SYI-1.F.4: Membranes contain chlorophyll pigments and electron transport proteins that comprise the photosystems.	6.3–6.4, p. 102–107
		SYI-1.F.5: The light-dependent reactions of photosynthesis occur in the grana.	6.3–6.4, p. 102–107
		SYI-1.F.6: The stroma is the fluid within the inner chloroplast membrane and outside of the thylakoid.	6.2, p. 100–102 6.5, p. 108–109
		SYI-1.F.7: The carbon fixation (Calvin-Benson cycle) reactions of photosynthesis occur in the stroma.	6.5, p. 108–109
		SYI-1.F.8: The Krebs cycle reactions occur in the matrix of the mitochondria.	7.3, p. 119–121
		SYI-1.F.9: Electron transport and ATP synthesis occur on the inner mitochondrial membrane.	7.4, p. 121–122

Correlation (continued)

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
2.3: Cell Size **Big Idea 2**	**ENE-1:** The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules. **ENE-1.B:** Explain the effect of surface area-to-volume ratios on the exchange of materials between cells or organisms and the environment.	**ENE-1.B.1:** Surface area-to-volume ratios affect the ability of a biological system to obtain necessary resources, eliminate waste products, acquire or dissipate thermal energy, and otherwise exchange chemicals and energy with the environment. **ENE-1.B.2:** The surface area of the plasma membrane must be large enough to adequately exchange materials. a. These limitations can restrict cell size and shape. Smaller cells typically have a higher surface area-to-volume ratio and more efficiently exchange of materials with the environment. b. As cells increase in volume, the relative surface area decreases and the demand for internal resources increases. c. More complex cellular structures (e.g., membrane folds) are necessary to adequately exchange materials with the environment. d. As organisms increase in size, their surface area-to-volume ratio decreases, affecting properties like rate of heat exchange with the environment.	4.2, p. 56–57 9.4–9.5, p. 153–155 4.2, p. 56–57 4.5, p. 62–63 5.8–5.10, p. 90–95 6.2–6.5, p. 100–110 7.2–7.5, p. 116–125 19.7, p. 311–313 20.7, p. 328
	ENE-1: The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules. **ENE-1.C:** Explain how specialized structures and strategies are used for the efficient exchange of molecules to the environment.	**ENE-1.C.1:** Organisms have evolved highly efficient strategies to obtain nutrients and eliminate wastes. Cells and organisms use specialized exchange surfaces to obtain and release molecules from or into the surrounding environment.	4.5, p. 62–63 4.8, p. 66–67 5.8–5.10, p. 90–95 6.2–6.5, p. 100–110 7.2–7.5, p. 116-125 20.6, p. 326–327
2.4: Plasma Membranes **Big Idea 2**	**ENE-2:** Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments. **ENE-2.A:** Describe the roles of each of the components of the cell membrane in maintaining the internal environment of the cell.	**ENE-2.A.1:** Phospholipids have both hydrophilic and hydrophobic regions. The hydrophilic phosphate regions of the phospholipids are oriented toward the aqueous external or internal environments, while the hydrophobic fatty acid regions face each other within the interior of the membrane.	3.4, p. 44–45 5.7, p. 88–89
		ENE-2.A.2: Embedded proteins can be hydrophilic, with charged and polar side groups, or hydrophobic, with nonpolar side groups.	5.7, p. 89
	ENE-2: Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments. **ENE-2.B:** Describe the Fluid Mosaic Model of cell membranes.	**ENE-2.B.1:** Cell membranes consist of a structural framework of phospholipid molecules that is embedded with proteins, steroids (such as cholesterol in eukaryotes), glycoproteins, and glycolipids that can flow around the surface of the cell within the membrane.	5.7, p. 88
2.5: Membrane Permeability **Big Idea 2**	**ENE-2:** Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments. **ENE-2.C:** Explain how the structure of biological membranes influences selective permeability.	**ENE-2.C.1:** The structure of cell membranes results in selective permeability.	5.9, p. 92–93
		ENE-2.C.2: Cell membranes separate the internal environment of the cell from the external environment.	5.7, p. 88–90
		ENE-2.C.3: Selective permeability is a direct consequence of membrane structure, as described by the fluid mosaic model.	5.7, p. 88–90 5.9, p. 92–93
		ENE-2.C.4: Small nonpolar molecules, including N_2, O_2, and CO_2 freely pass across the membrane. Hydrophilic substances, such as large polar molecules and ions, move across the membrane through embedded channel and transport proteins.	5.8, p. 90–93
		ENE-2.C.5: Polar uncharged molecules, including H_2O, pass through the membrane in small amounts.	5.8, p. 90

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
	ENE-2: Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments. **ENE-2.D:** Describe the role of the cell wall in maintaining cell structure and function.	**ENE-2.D.1:** Cell walls provide a structural boundary, as well as a permeability barrier for some substances to the internal environments.	3.3, p. 43 4.3, p. 58–59 4.9, p. 68
		ENE-2.D.2: Cell walls of plants, prokaryotes, and fungi are composed of complex carbohydrates.	3.3, p. 43 4.3, p. 58–59 4.9, p. 68
2.6: Membrane Transport **Big Idea 2**	**ENE-2:** Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments. **ENE-2.E:** Describe the mechanisms that organisms use to maintain solute and water balance.	**ENE-2.E.1:** Passive transport is the net movement of molecules from high concentration to low concentration without the direct input of metabolic energy.	5.9, p. 92
		ENE-2.E.2: Passive transport plays a primary role in the import of materials and the export of wastes.	5.9, p. 92
		ENE-2.E.3: Active transport requires the direct input of energy to move molecules from regions of low concentration to regions of high concentration.	5.9, p. 93
	ENE-2: Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments. **ENE-2.F:** Describe the mechanisms that organisms use to transport large molecules across the plasma membrane.	**ENE-2.F.1:** The selective permeability of membranes allows for the formation of concentration gradients of solutes across the membrane.	5.8–5.9, p. 90–93
		ENE-2.F.2: The processes of endocytosis and exocytosis require energy to move large molecules into and out of cells. i. In exocytosis, internal vesicles fuse with the plasma membrane and secrete large macromolecules out of the cell. ii. In endocytosis, the cell takes in macromolecules and particulate matter by forming new vesicles derived from the plasma membrane.	4.8, p. 66–67 5.10, p. 94–95
2.7: Facilitated Diffusion **Big Idea 2**	**ENE-2:** Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments. **ENE-2.G:** Explain how the structure of a molecule affects its ability to pass through the plasma membrane.	**ENE-2.G.1:** Membrane proteins are required for facilitated diffusion of charged and large polar molecules through a membrane. a. Large quantities of water pass through aquaporins. b. Charged ions, including Na^+ and K^+, require channel proteins to move through the membrane. c. Membranes may become polarized by movement of ions across the membrane.	5.8–5.9, p. 90–93 40.6, p. 706 5.8–5.9, p. 90–93 32.4–32.5, p. 539–543
		ENE-2.G.2: Membrane proteins are necessary for active transport.	5.9, p. 93
		ENE-2.G.3: Metabolic energy (such as from ATP) is required for active transport of molecules and/or ions across the membrane and to establish and maintain concentration gradients.	28.4–28.5, p. 474–477 40.2–40.5, p. 700–705
		ENE-2.G.4: The Na^+/K^+ ATPase contributes to the maintenance of the membrane potential.	5.9, p. 93 32.4, p. 539–541
2.8: Tonicity and Osmoregulation **Big Idea 2**	**ENE-2:** Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments. **ENE-2.H:** Explain how concentration gradients affect the movement of molecules across membranes.	**ENE-2.H.1:** External environments can be hypotonic, hypertonic or isotonic to internal environments of cells. a. Water moves by osmosis from areas of high water potential/low osmolarity/low solute concentration to areas of low water potential/high osmolarity/high solute concentration. Water Potential: $\Psi = \Psi_p + \Psi_s$ Ψ_p = pressure potential Ψ_s = solute potential	5.8, p. 90–91

Correlation (continued)

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
	ENE-2: Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments. **ENE-2.I:** Explain how osmoregulatory mechanisms contribute to the health and survival of organisms.	**ENE-2.I.1:** Growth and homeostasis are maintained by the constant movement of molecules across membranes.	28.3–28.5, p. 470–477 32.4–32.5, p. 539–542 36.7, p. 625 40.2–40.8, p. 700–708
		ENE-2.I.2: Osmoregulation maintains water balance and allows organisms to control their internal solute composition/water potential. Solute Potential of a Solution $\Psi_s = -iCRT$ where: i = ionizationconstant C = molar concentration R = pressure constant (R = 0.831 $\frac{L\ bars}{mol/N}$ T = temperature in Kelvin (°C + 273)	40.2–40.8, p. 700–708
2.9: Mechanisms of Transport **Big Idea 2**	**ENE-2:** Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments. **ENE-2.J:** Describe the processes that allow ions and other molecules to move across membranes.	**ENE-2.J.1:** A variety of processes allow for the movement of ions and other molecules across membranes, including passive and active transport, endocytosis and exocytosis.	4.8, p. 66–67 5.8–5.10, p. 90–95
2.10: Cell Compartment-alization **Big Idea 2**	**ENE-2:** Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments. **ENE-2.K:** Describe the membrane-bound structures of the eukaryotic cell.	**ENE-2.K.1:** Membranes and membrane-bound organelles in eukaryotic cells compartmentalize intracellular metabolic processes and specific enzymatic reactions.	4.4–4.7, p. 59–65
	ENE-2: Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments. **ENE-2.L:** Explain how internal membranes and membrane-bound organelles contribute to compartmentalization of eukaryotic cell functions.	**ENE-2.L.1:** Internal membranes facilitate cellular processes by minimizing competing interactions and by increasing surface areas where reactions can occur.	4.4–4.7, p. 59–65
2.11: Origins of Cell Compartment-alization **Big Idea 1**	**EVO-1:** Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence. **EVO-1.A:** Describe similarities and/or differences in compartmentalization between prokaryotic and eukaryotic cells.	**EVO-1.A.1:** Membrane-bound organelles evolved from once free-living prokaryotic cells via endosymbiosis.	19.7, p. 310–313 21.2, p. 339
		EVO-1.A.2: Prokaryotes generally lack internal membrane-bound organelles but have internal regions with specialized structures and functions.	4.3, p. 57 20.5, p. 324–326
		EVO-1.A.3: Eukaryotic cells maintain internal membranes that partition the cell into specialized regions.	4.4–4.7, p. 59–65
	EVO-1: Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence. **EVO-1.B:** Describe the relationship between the functions of endosymbiotic organelles and their free-living ancestral counterparts.	**EVO-1.B.1:** Membrane-bound organelles evolved from previously free-living prokaryotic cells via endosymbiosis.	19.7, p. 310–313

Unit 3: Cellular Energetics

AP® Exam Weighting: 12–16%; 14–17 class periods

- **Big Idea 2 (ENE):** Biological systems use energy and molecular building blocks to grow, reproduce, and maintain dynamic homeostasis.
- **Big Idea 4 (SYI):** Biological systems interact, and these systems and their interactions exhibit complex properties.

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
3.1: Enzyme Structure **Big Idea 2**	**ENE-1:** The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules. **ENE-1.D:** Describe the properties of enzymes.	**ENE-1.D.1:** The structure of enzymes includes the active site that specifically interacts with substrate molecules.	5.4, p. 82
		ENE-1D.2: For an enzyme-mediated chemical reaction to occur, the shape and charge of the substrate must be compatible with the active site of the enzyme.	5.4, p. 82–83
3.2: Enzyme Catalysis **Big Idea 2**	**ENE-1:** The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules. **ENE-1.E:** Explain how enzymes affect the rate of biological reactions.	**ENE-1.E.1:** The structure and function of enzymes contributes to the regulation of biological processes. a. Enzymes are biological catalysts that facilitate chemical reactions in cells by lowering the activation energy.	5.4, p. 82–83
3.3: Environmental Impacts on Enzyme Function **Big Idea 2**	**ENE-1:** The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules. **ENE-1.F:** Explain how changes to the structure of an enzyme may affect its function.	**ENE-1.F.1:** Change to the molecular structure of a component in an enzymatic system may result in a change of the function or efficiency of the system. a. Denaturation of an enzyme occurs when the protein structure is disrupted, eliminating the ability to catalyze reactions. b. Environmental temperatures and pH outside the optimal range for a given enzyme will cause changes to its structure, altering the efficiency with which it catalyzes reactions.	5.4, p. 83
		ENE-1.F.2: In some cases, enzyme denaturation is reversible, allowing the enzyme to regain activity.	No reference
	ENE-1: The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules. **ENE-1.G:** Explain how the cellular environment affects enzyme activity.	**ENE-1.G.1:** Environmental pH can alter the efficiency of enzyme activity, including through disruption of hydrogen bonds that provide enzyme structure. $pH = -\log[H^+]$ For the purposes of the AP® Exam, students will not be required to perform calculations using this equation; however, they must understand the underlying concepts and applications.	5.4, p. 83
		ENE-1.G.2: The relative concentrations of substrates and products determine how efficiently an enzymatic reaction proceeds.	5.5, p. 84
		ENE-1.G.3: Higher environmental temperatures increase the speed of movement of molecules in a solution, increasing the frequency of collisions between enzymes and substrates and therefore increasing the rate of reaction.	5.4, p. 83
		ENE-1G.4: Competitive inhibitor molecules can bind reversibly or irreversibly to the active site of the enzyme. Noncompetitive inhibitors can bind allosteric sites, changing the activity of the enzyme.	5.5, p. 84–85

Correlation (continued)

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
3.4: Cellular Energy **Big Idea 2**	**ENE-1:** The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules. **ENE-1.H:** Describe the role of energy in living organisms.	**ENE-1.H.1:** All living systems require constant input of energy.	6.2, p. 100–101 7.2, p. 116–119
		ENE-1.H.2: Life requires a highly ordered system and does not violate the second law of thermodynamics. a. Energy input must exceed energy loss to maintain order and to power cellular processes. b. Cellular processes that release energy may be coupled with cellular processes that require energy. c. Loss of order or energy flow results in death.	5.2, p. 78–79 5.3, p. 80–81 5.6, p. 87–88
		ENE-1.H.3: Energy-related pathways in biological systems are sequential to allow for a more controlled and efficient transfer of energy. A product of a reaction in a metabolic pathway is generally the reactant for the subsequent step in the pathway.	5.5, p. 84–86 6.4–6.5, p. 104–110 7.2–7.4, p. 116–122
3.5: Photosynthesis **Big Idea 2**	**ENE-1:** The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules. **ENE-1.I:** Describe the photosynthetic processes that allow organisms to capture and store energy.	**ENE-1.I.1:** Organisms capture and store energy for use in biological processes. i. Photosynthesis captures energy from the sun and produces sugars. a. Photosynthesis first evolved in prokaryotic organisms. b. Scientific evidence supports the claim that prokaryotic (cyanobacterial) photosynthesis was responsible for the production of an oxygenated atmosphere. c. Prokaryotic photosynthetic pathways were the foundation of eukaryotic photosynthesis.	6.3–6.4, p. 102–107 16.4, p. 255–256 19.2, p. 304–305 19.6, p. 310 19.7, p. 310–313
		ENE-1.I.2: The light-dependent reactions of photosynthesis in eukaryotes involve a series of coordinated reaction pathways that capture energy present in light to yield ATP and NADPH, which power the production of organic molecules.	6.2, p. 100–102 6.4, p. 104–107
	ENE-1: The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules. **ENE-1.J:** Explain how cells capture energy from light and transfer it to biological molecules for storage and use.	**ENE-1.J.1:** During photosynthesis, chlorophylls absorb energy from light, boosting electrons to a higher energy level in photosystems I and II.	6.3-6.4, p. 102–107
		ENE-1.J.2: Photosystems I and II are embedded in the internal membranes of chloroplasts and are connected by the transfer of higher energy electrons through an electron transport chain (ETC).	6.4, p. 104–107
		ENE-1.J.3: When electrons are transferred between molecules in a sequence of reactions as they pass through the ETC, an electrochemical gradient of protons (hydrogen ions) is established across the internal membrane.	6.4, p. 104–107
		ENE-1.J.4: The formation of the proton gradient is linked to the synthesis of ATP from ADP and inorganic phosphate via ATP synthase.	6.4, p. 104–107
		ENE-1.J.5: The energy captured in the light reactions and transferred to ATP and NADPH powers the production of carbohydrates from carbon dioxide in the Calvin cycle, which occurs in the stroma of the chloroplast.	6.5, p. 108–110

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
3.6: Cellular Respiration **Big Idea 2**	**ENE-1:** The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules. **ENE-1.K:** Describe the processes that allow organisms to use energy stored in biological macromolecules.	**ENE-1.K.1:** Fermentation and cellular respiration use energy from biological macromolecules to produce ATP. Respiration and fermentation are characteristic of all forms of life.	7.2–7.5, p. 116–125
		ENE-1.K.2: Cellular respiration in eukaryotes involves a series of coordinated enzyme-catalyzed reactions that capture energy from biological macromolecules.	7.3–7.4, p. 119–123
		ENE-1.K.3: The electron transport chain transfers energy from electrons in a series of coupled reactions that establish an electrochemical gradient across membranes. a. Electron transport chain reactions occur in chloroplasts, mitochondria, and prokaryotic plasma membranes. b. In cellular respiration, electrons delivered by NADH and $FADH_2$ are passed to a series of electron acceptors as they move toward the terminal electron acceptor, oxygen. In photosynthesis, the terminal electron acceptor is $NADP^+$. Aerobic prokaryotes use oxygen as a terminal electron acceptor, while anaerobic prokaryotes use other molecules. In photosynthesis, the terminal electron acceptor is $NADP^+$. Aerobic prokaryotes use oxygen as a terminal electron acceptor, while anaerobic prokaryotes use other molecules. c. The transfer of electrons is accompanied by the formation of a proton gradient across the inner mitochondrial membrane or the internal 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 movement of protons across the plasma membrane. d. The flow of protons back through membrane-bound ATP synthase by chemiosmosis drives the formation of ATP from ADP and inorganic phosphate. This is known as oxidative phosphorylation in cellular respiration, and photophosphorylation in photosynthesis. e. In cellular respiration, decoupling oxidative phosphorylation from electron transport generates heat. This heat can be used be endothermic organisms to regulate body temperature.	6.4, p. 104–107 7.4, p. 121–123 19.6–19.7, p. 310–313 20.6, p. 326–327
	ENE-1: The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules. **ENE-1.L:** Explain how cells obtain energy from biological macromolecules in order to power cellular functions.	**ENE-1.L.1:** Glycolysis is a biochemical pathway that releases energy in glucose to form ATP from ADP and inorganic phosphate, NADH from NAD^+, and pyruvate.	7.2, p. 118–119
		ENE-1.L.2: Pyruvate is transported from the cytosol to the mitochondrion, where further oxidation occurs.	7.3, p. 119–121
		ENE-1.L.3: In the Krebs cycle, carbon dioxide is released from organic intermediates, ATP is synthesized from ADP and inorganic phosphate, and electrons are transferred to the coenzymes NADH and $FADH_2$.	7.3, p. 119–121
		ENE-1.L.4: Electrons extracted in glycolysis and Krebs cycle reactions are transferred by NADH and $FADH_2$ to the electron transport chain in the inner mitochondrial membrane.	7.4, p. 122
		ENE-1.L.5: When electrons are transferred between molecules in a sequence of reactions as they pass through the ETC, an electrochemical gradient of protons (hydrogen ions) across the inner mitochondrial membrane is established.	7.4, p. 122
		ENE-1.L.6: Fermentation allows glycolysis to proceed in the absence of oxygen and produces organic molecules, including alcohol and lactic acid, as waste products.	7.5, p. 123–125
		ENE-1.L.7: The conversion of ATP to ADP releases energy, which is used to power many metabolic processes.	4.8, p. 66–67 5.6, p. 87–88 5.9, p. 93 6.5, p. 108–109

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
3.7: Fitness **Big Idea 4**	**SYI-3:** Naturally occurring diversity among and between components within biological systems affects interactions with the environment. **SYI-3.A:** Explain the connection between variation in the number and types of molecules within cells to the ability of the organism to survive and/or reproduce in different environments.	**SYI-3.A.1:** Variation at the molecular level provides organisms with the ability to respond to a variety of environmental stimuli.	38.2, p. 662
		SYI-3.A.2: Variation in the number and types of molecules within cells provides organisms a greater ability to survive and/or reproduce in different environments.	4.7, p. 65

Unit 4: Cell Communication and Cell Cycle

AP® Exam Weighting: 12–16%; 14–17 class periods

- **Big Idea 2 (ENE):** Biological systems use energy and molecular building blocks to grow, reproduce, and maintain dynamic homeostasis.
- **Big Idea 3 (IST):** Living systems store, retrieve, transmit, and respond to information essential to life processes.

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
4.1: Cell Communication **Big Idea 3**	**IST-3:** Cells communicate by generating, transmitting, receiving, and responding to chemical signals. **IST-3.A:** Describe the ways that cells can communicate with one another.	**IST-3.A.1:** Cells communicate with one another through direct contact with other cells or from a distance via chemical signaling. a. Cells communicate by cell-to-cell contact.	29.4, p. 488 30.2, p. 500 32.2, p. 536–537 34.2–34.3, p. 580–582
	IST-3: Cells communicate by generating, transmitting, receiving, and responding to chemical signals. **IST-3.B:** Explain how cells communicate with one another over short and long distances.	**IST-3.B.1:** Cells communicate over short distances by using local regulators that target cells in the vicinity of the signal-emitting cell. a. Signals released by one cell type can travel long distances to target cells of another cell type.	29.4, p. 488 30.2, p. 500 32.2, p. 536–537 34.3, p. 582–583 34.7, p. 588–590
4.2: Introduction to Signal Transduction **Big Idea 3**	**IST-3:** Cells communicate by generating, transmitting, receiving, and responding to chemical signals. **IST-3.C:** Describe the components of a signal transduction pathway.	**IST-3.C.1:** Signal transduction pathways link signal reception with cellular responses.	32.2, p. 536 34.2, p. 580–582
		IST-3.C.2: Many signal transduction pathways include protein modification and phosphorylation cascades.	32.2, p. 536–537 34.3, p. 582–583
	IST-3: Cells communicate by generating, transmitting, receiving, and responding to chemical signals. **IST-3.D:** Describe the role of components of a signal transduction pathway in producing a cellular response.	**IST-3.D.1:** Signaling begins with the recognition of a chemical messenger—a ligand—by a receptor protein in a target cell. a. The ligand-binding domain of a receptor recognizes a specific chemical messenger, which can be a peptide, a small chemical, or protein, in a specific one-to-one relationship. b. G protein–coupled receptors are an example of a receptor protein in eukaryotes.	34.2–34.3, p. 580–583
		IST-3.D.2: Signaling cascades relay signals from receptors to cell targets, often amplifying the incoming signals, resulting in the appropriate responses by the cell, which could include cell growth, secretion of molecules, or gene expression. a. After the ligand binds, the intracellular domain of a receptor protein changes shape, initiating transduction of the signal. b. Second messengers (such as cyclic AMP) are molecules that relay and amplify the intracellular signal. c. Binding of ligand to ligand-gated channels can cause the channel to open or close.	32.5, p. 536–537 34.3, p. 582–583

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
4.3: Signal Transduction **Big Idea 3**	**IST-3:** Cells communicate by generating, transmitting, receiving, and responding to chemical signals. **IST-3.E:** Describe the role of the environment in eliciting a cellular response.	**IST-3.E.1:** Signal transduction pathways influence how the cell responds to its environment.	32.2, p. 536–537 34.2, p. 580–582 37.4–37.8, p. 640–652
	IST-3: Cells communicate by generating, transmitting, receiving, and responding to chemical signals. **IST-3.F:** Describe the different types of cellular responses elicited by a signal transduction pathway.	**IST-3.F.1:** Signal transduction may result in changes in gene expression and cell function, which may alter phenotype or result in programmed cell death (apoptosis).	30.2, p. 500 34.2–34.3, p. 580–583 37.4–37.8, p. 640–652 42.3–42.4, p. 738–741
4.4: Changes in Signal Transduction Pathways **Big Idea 3**	**IST-3:** Cells communicate by generating, transmitting, receiving, and responding to chemical signals. **IST-3.G:** Explain how a change in the structure of any signaling molecule affects the activity of the signaling pathway.	**IST-3.G.1:** Changes in signal transduction pathways can alter cellular response. a. Mutations in any domain of the receptor protein or in any component of the signaling pathway may affect the downstream components by altering the subsequent transduction of the signal.	34.3, p. 582–583
		IST-3.G.2: Chemicals that interfere with any component of the signaling pathway may activate or inhibit the pathway.	32.6, p. 544–545
4.5: Feedback **Big Idea 2**	**ENE-3:** Timing and coordination of biological mechanisms involved in growth, reproduction, and homeostasis depend on organisms responding to environmental cues. **ENE-3.A:** Describe positive and/or negative feedback mechanisms.	**ENE-3.A.1:** Organisms use feedback mechanisms to maintain their internal environments and respond to internal and external environmental changes.	31.9, p. 530–531 32.4, p. 540 41.5, p. 721–723
	ENE-3: Timing and coordination of biological mechanisms involved in growth, reproduction, and homeostasis depend on organisms responding to environmental cues. **ENE-3.B:** Explain how negative feedback helps to maintain homeostasis.	**ENE-3.B.1:** Negative feedback mechanisms maintain homeostasis for a particular condition by regulating physiological processes. If a system is perturbed, negative feedback mechanisms return the system back to its target set point. These processes operate at the molecular and cellular levels.	30.2, p. 500 30.5, p. 506 31.9, p. 530–531 34.6, p. 586–587 40.6, p. 705–707 41.5, p. 721–723
	ENE-3: Timing and coordination of biological mechanisms involved in growth, reproduction, and homeostasis depend on organisms responding to environmental cues. **ENE-3.C:** Explain how positive feedback affects homeostasis.	**ENE-3.C.1:** 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.	30.5, p. 506 41.5, p. 721–723 42.10, p. 749–750
4.6: Cell Cycle **Big Idea 3**	**IST-1:** Heritable information provides for continuity of life. **IST-1.B:** Describe the events that occur in the cell cycle.	**IST-1.B.1:** In eukaryotes, cells divide and transmit genetic information via two highly regulated processes.	11.2–11.3, p. 176–179
		IST-1.B.2: The cell cycle is a highly regulated series of events for the growth and reproduction of cells. a. The cell cycle consists of sequential stages of interphase (G1, S, G2), mitosis or meiosis, and cytokinesis. b. A cell can enter a stage (G0) where it no longer divides, but it can reenter the cell cycle in response to appropriate cues. Nondividing cells may exit the cell cycle or be held at a particular stage in the cell cycle.	11.2, p. 176–177 11.5, p. 181

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
	IST-1: Heritable information provides for continuity of life. **IST-1.C:** Explain how mitosis results in the transmission of chromosomes from one generation to the next.	**IST-1.C.1:** Mitosis is a process that ensures the transfer of a complete genome from a parent cell to two genetically identical daughter cells. a. Mitosis plays a role in growth, tissue repair, and asexual reproduction. b. Mitosis alternates with interphase in the cell cycle. c. Mitosis occurs in a sequential series of steps (prophase, metaphase, anaphase, telophase).	11.2–11.3, p. 176–179
4.7: Regulation of Cell Cycle **Big Idea 3**	**IST-1:** Heritable information provides for continuity of life. **IST-1.D:** Describe the role of checkpoints in regulating the cell cycle.	**IST-1.D.1:** A number of internal controls or checkpoints regulate progression through the cycle.	11.2, p. 177
		IST-1.D.2: Interactions between cyclins and cyclin-dependent kinases control the cell cycle.	No reference
	IST-1: Heritable information provides for continuity of life. **IST-1.E:** Describe the effects of disruptions to the cell cycle on the cell or organism.	**IST-1.E.1:** Disruptions to the cell cycle may result in cancer and/or programmed cell death (apoptosis).	11.2, p. 177 11.6, p. 182–183

Unit 5: Heredity

AP® Exam Weighting: 8–11%; 9–11 class periods

- **Big Idea 1 (EVO)**: The process of evolution drives the diversity and unity of life.
- **Big Idea 3 (IST):** Living systems store, retrieve, transmit, and respond to information essential to life processes.
- **Big Idea 4 (SYI):** Biological systems interact, and these systems and their interactions exhibit complex properties.

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
5.1: Meiosis **Big Idea 3**	**IST-1:** Heritable information provides for continuity of life. **IST-1.F:** Explain how meiosis results in the transmission of chromosomes from one generation to the next.	**IST-1.F.1:** Meiosis is a process that ensures the formation of haploid gamete cells in sexually reproducing diploid organisms. a. Meiosis results in daughter cells with half the number of chromosomes of the parent cell. b. Meiosis involves two rounds of a sequential series of steps (meiosis I and meiosis II).	12.2–12.3, p. 188–191
	IST-1: Heritable information provides for continuity of life. **IST-1.G:** Describe similarities and/or differences between the phases and outcomes of mitosis and meiosis.	**IST-1.G.1:** Mitosis and meiosis are similar in the way chromosomes segregate, but differ in the number of cells produced and the genetic content of the daughter cells.	12.2, p. 188–189 11.2–11.3, p. 176–179
5.2: Meiosis and Genetic Diversity **Big Idea 3**	**IST-1:** Heritable information provides for continuity of life. **IST-1.H:** Explain how the process of meiosis generates genetic diversity.	**IST-1.H.1:** Separation of the homologous chromosomes in meiosis I ensures that each gamete receives a haploid (1n) set of chromosomes that comprises both maternal and paternal chromosomes.	12.4, p. 192
		IST-1.H.2: During meiosis I, homologous chromatids exchange genetic material via a process called crossing over (recombination), which increases genetic diversity among the resultant gametes.	12.4, p. 192
		IST-1.H.3: Sexual reproduction in eukaryotes involving gamete formation—including crossing over, the random assortment of chromosomes during meiosis, and subsequent fertilization of gametes—serves to increase variation.	12.4, p. 192–194

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
5.3: Mendelian Genetics **Big Idea 3**	**EVO-2:** Organisms are linked by lines of descent from common ancestry. **EVO-2.A:** Explain how shared, conserved, fundamental processes and features support the concept of common ancestry for all organisms.	**EVO-2.A.1:** DNA and RNA are carriers of genetic information.	3.6, p. 49
		EVO-2.A.2: Ribosomes are found in all forms of life.	4.3, p. 58 4.5, p. 62–63
		EVO-2.A.3: Major features of the genetic code are shared by all modern living systems.	9.4, p. 152–153
		EVO-2.A.4: Core metabolic pathways are conserved across all currently recognized domains.	No reference
	IST-1: Heritable information provides for continuity of life. **IST-1.I:** Explain the inheritance of genes and traits as described by Mendel's laws.	**IST-1.I.1:** Mendel's laws of segregation and independent assortment can be applied to genes that are on different chromosomes.	13.3–13.4, p. 202–205
		IST-1.I.2: Fertilization involves the fusion of two haploid gametes, restoring the diploid number of chromosomes and increasing genetic variation in populations by creating new combinations of alleles in the zygote. a. Rules of probability can be applied to analyze passage of single gene traits from parent to offspring. b. The pattern of inheritance (monohybrid, dihybrid, sex-linked, and genetically linked genes) can often be predicted from data, including pedigree, that give the parent genotype/phenotype and the offspring genotypes/phenotypes.	12.2, p. 189 13.3–13.4, p. 202–205 14.4, p. 220–222 14.6, p. 224–226
5.4: Non-Mendelian Genetics **Big Idea 3**	**IST-1:** Heritable information provides for continuity of life. **IST-1.J:** Explain deviations from Mendel's model of the inheritance of traits.	**IST-1.J.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. a. Genes that are adjacent and close to one another on the same chromosome may appear to be genetically linked; the probability that genetically linked genes will segregate as a unit can be used to calculate the map distance between them.	13.5, p. 204–205 14.4, p. 220–222
		IST-1.J.2: Some traits are determined by genes on sex chromosomes, and are known as sex-linked traits. The pattern of inheritance of sex-linked traits can often be predicted from data, including pedigree, indicating the parent genotype/phenotype and the offspring genotypes/phenotypes.	14.4, p. 220–222
		IST-1.J.3: Many traits are the product of multiple genes and/or physiological processes actin in combination; these traits therefore do not segregate in Mendelian patterns.	13.5–13.7, p. 206–211
		IST-1.J.4: Some traits result from non-nuclear inheritance— a. 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. b. In animals, mitochondria are transmitted by the egg and not by sperm; as such, traits determined by the mitochondrial DNA are maternally inherited. c. In plants, mitochondria and chloroplasts are transmitted in the ovule and not in the pollen; as such, mitochondria-determined and chloroplast-determined traits are maternally inherited.	18.4, p. 295–296 41.7, p. 727

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
5.5: Environmental Effects on Phenotype **Big Idea 4**	**SYI-3:** Naturally occurring diversity among and between components within biological systems affects interactions with the environment. **SYI-3.B:** Explain how the same genotype can result in multiple phenotypes under different environmental conditions.	**SYI-3.B.1:** Environmental factors influence gene expression and can lead to phenotypic plasticity. Phenotypic plasticity occurs when individuals with the same genotype exhibit different phenotypes in different environments.	13.6, p. 208–209
5.6: Chromosomal Inheritance **Big Idea 4**	**SYI-3:** Naturally occurring diversity among and between components within biological systems affects interactions with the environment. **SYI-3.C:** Explain how chromosomal inheritance generates genetic variation in sexual reproduction.	**SYI-3.C.1:** Segregation, independent assortment of chromosomes, and fertilization result in genetic variation in populations.	12.2–12.4, p. 188–194
		SYI-3.C.2: The chromosomal basis of inheritance provides an understanding of the pattern of transmission of genes from parent to offspring.	12.2, p. 188–189
		SYI-3.C.3: Certain human genetic disorders can be attributed to the inheritance of a single affected or mutated allele, or specific chromosomal changes, such as nondisjunction.	14.2–14.6, p. 216–226

Unit 6: Gene Expression and Regulation

AP® Exam Weighting: 12–16%; 18–21 class periods

- **Big Idea 3 (IST):** Living systems store, retrieve, transmit, and respond to information essential to life processes.

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
6.1: DNA and RNA Structure **Big Idea 3**	**IST-1:** Heritable information provides for continuity of life. **IST-1.K:** Describe the structures involved in passing hereditary information from one generation to the next.	**IST-1.K.1:** DNA, and in some cases RNA, is the primary source of heritable information.	3.6, p. 49
		IST-1.K.2: Genetic information is transmitted from one generation to the next through DNA or RNA. a. Genetic information is stored in and passed to subsequent generations through DNA molecules and, in some cases, RNA molecules. b. Prokaryotic organisms typically have circular chromosomes, while eukaryotic organisms typically have multiple linear chromosomes.	3.6, p. 49 8.4, p. 137–138 20.2, p. 318–319 20.5, p. 324
		IST-1.K.3: Prokaryotes and eukaryotes can contain plasmids, which are small extra-chromosomal, double-stranded, circular DNA molecules.	4.3, p. 58 15.2, p. 232–233 20.5, p. 324–325
	IST-1: Heritable information provides for continuity of life. **IST-1.L:** Describe the characteristics of DNA that allow it to be used as the hereditary material.	**IST-1.L.1:** DNA, and sometimes RNA, exhibits 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). a. Purines (G and A) have a double ring structure. b. Pyrimidines (C, T and U) have a single ring structure.	8.3, p. 135

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
6.2: Replication **Big Idea 3**	**IST-1:** Heritable information provides for continuity of life. **IST-1.M:** Describe the mechanisms by which genetic information is copied for transmission between generations.	**IST-1.M.1:** DNA replication ensures continuity of hereditary information. a. DNA is synthesized in the 5′ to 3′ direction. b. Replication is a semiconservative process; that is, one strand of DNA serves as the template for a new strand of complementary DNA. c. Helicase unwinds the DNA strands. d. Topoisomerase relaxes supercoiling in front of the replication fork. e. DNA polymerase requires RNA primers to initiate DNA synthesis. f. DNA polymerase synthesizes new strands of DNA continuously on the leading strand and discontinuously on the lagging strand. g. Ligase joins the fragments on the lagging strand.	8.5, p. 139–140
6.3: Transcription and RNA Processing **Big Idea 3**	**IST-1:** Heritable information provides for continuity of life. **IST-1.N:** Describe the mechanisms by which genetic information flows from DNA to RNA to protein.	**IST-1.N.1:** The sequence of the RNA bases, together with the structure of the RNA molecule, determines RNA function. a. mRNA molecules carry information from DNA to the ribosome. b. Distinct tRNA molecules bind specific amino acids and have anti-codon sequences that base pair with the mRNA. tRNA is recruited to the ribosome during translation to generate the primary peptide sequence based on the mRNA sequence. c. rRNA molecules are functional building blocks of ribosomes.	9.2–9.5, p. 152–155 9.2, p. 149 9.4, p. 153
		IST-1.N.2: Genetic information flows from a sequence of nucleotides in DNA to a sequence of bases in an mRNA molecule to a sequence of amino acids in a protein.	9.2–9.4, p. 148–153
		IST-1.N.3: RNA polymerases use a single template strand of DNA to direct the inclusion of bases in the newly formed RNA molecule to a sequence of amino acids in a protein.	9.3, p. 150–151
		IST-1.N.4: The DNA strand acting as the template strand is also referred to as the noncoding stand, minus strand, or antisense strand. Selection of which DNA strand serves as the template strand depends on the gene being transcribed.	9.3, p. 150–151
		IST-1.N.5: The enzyme RNA polymerase synthesizes mRNA molecules in the 5′ to 3′ direction by reading the template DNA strand in the 3′ to 5′ direction.	9.3, p. 150–151
		IST-1.N.6: In eukaryotic cells the mRNA transcript undergoes a series of enzyme-regulated modifications— a. Addition of a poly-A tail. b. Addition of a GTP cap. c. Excision of introns and splicing and retention of exons. d. Excision of introns and splicing and retention of exons can generate different versions of the resulting mRNA molecules; this is known as alternative splicing.	9.3, p. 150–151

Correlation (continued)

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
6.4: Translation **Big Idea 3**	**IST-1:** Heritable information provides for continuity of life. **IST-1.O:** Describe how the phenotype of an organism is determined by its genotype.	**IST-1.O.1:** Translation of the mRNA to generate a polypeptide occurs on ribosomes that are present in the cytoplasm of both prokaryotic and eukaryotic cells, and on the rough endoplasmic reticulum of eukaryotic cells.	4.3, p. 58 4.5, p. 62-63
		IST-1.O.2: In prokaryotic organisms, translation of the mRNA molecule occurs while it is being transcribed.	9.5, p. 155
		IST-1.O.3: Translation involves energy and many sequential steps, including initiation, elongation, and termination.	9.5, p. 154–155
		IST-1.O.4: The salient features of translation include: a. Translation is initiated when the rRNA in the ribosome interacts with the mRNA at the start codon. b. The sequence of nucleotides on the mRNA is read in triplets called codons. c. Each codon encodes a specific amino acid, which can be deduced by using a genetic code chart. Many amino acids are encoded by more than one codon. d. Nearly all living organisms use the same genetic code, which is evidence for the common ancestry of all living organisms. e. tRNA brings the correct amino acid to the correct place specified by the codon on the mRNA. f. The amino acid is transferred to the growing polypeptide chain. g. The process continues along the mRNA until a stop codon is reached. h. The process terminates by release of the newly synthesized polypeptide/protein.	9.4–9.5, p. 152–155
		IST-1.O.5: Genetic information in retroviruses is a special case and has an alternative 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.	20.3, p. 320–321
6.5: Regulation of Gene Expression **Big Idea 3**	**IST-2:** Differences in the expression of genes accounts for some of the phenotypic differences between organisms. **IST-2.A:** Describe the types of interactions that regulate gene expression.	**IST-2.A.1:** Regulatory sequences are stretches of DNA that interact with regulatory proteins to control transcription.	10.3–10.4, p. 164–169
		IST-2.A.2: Epigenetic changes can affect gene expression through reversible modifications of DNA or histones.	10.5, p. 170–171 13.6, p. 208
		IST-2.A.3: The phenotype of a cell or organism is determined by the combination of genes that are expressed and the levels at which they are expressed. 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.	10.3, p. 164–168
	IST-2: Differences in the expression of genes accounts for some of the phenotypic differences between organisms. **IST-2.B:** Explain how the location of regulatory sequences relates to their function.	**IST-2.B.1:** Both prokaryotes and eukaryotes have groups of genes that are coordinately regulated. a. In prokaryotes, groups of genes called operons are transcribed in a single mRNA molecule. The *lac* operon is an example of an inducible system. b. In eukaryotes, groups of genes may be influenced by the same transcription factors to coordinately regulate expression.	10.3, p. 164–168 10.4, p. 168–169

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
6.6: Gene Expression and Cell Specialization **Big Idea 3**	**IST-2:** Differences in the expression of genes accounts for some of the phenotypic differences between organisms. **IST-2.C:** Explain how the binding of transcription factors to promoter regions affects gene expression and/or the phenotype of the organism.	**IST-2.C.1:** Promoters are DNA sequences upstream of the transcription start site where RNA polymerase and transcription factors bind to initiate transcription.	9.2–9.3, p. 148–150
		IST-2.C.2: Negative regulatory molecules inhibit gene expression by binding to DNA and blocking transcription.	10.4, p. 168–169
	IST-2: Differences in the expression of genes accounts for some of the phenotypic differences between organisms. **IST-2.D:** Explain the connection between the regulation of gene expression and phenotypic differences in cells and organisms.	**IST-2.D.1:** Gene regulation results in differential gene expression and influences cell products and function.	10.2–10.3, p. 162–168
		IST-2.D.2: Certain small RNA molecules have roles in regulating gene expression.	9.2, p. 149 10.2, p. 163
6.7: Mutations **Big Idea 3**	**IST-2:** Differences in the expression of genes accounts for some of the phenotypic differences between organisms. **IST-2.E:** Describe the various types of mutation.	**IST-2.E.1:** Changes in genotype can result in changes in phenotype. a. The function and amount of gene products determines the phenotype of organisms. i. The normal function of the genes and gene products collectively comprises the normal function of organisms. Disruptions in genes and gene products cause new phenotypes.	9.2, p. 148–149 9.6, p. 155–157 10.3, p. 164–168 13.1, p. 199–200 14.2–14.4, p. 216–222 17.1, p. 267–268 20.8, p. 331
		IST-2.E.2: Alterations in a DNA sequence can lead to changes in the type or amount of the protein produced and the consequent phenotype. 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.	17.2, p. 268–269
	IST-4: The processing of genetic information is imperfect and is a source of genetic variation. **IST-4.A:** Explain how changes in genotype may result in changes in phenotype.	**IST-4.A.1:** Errors in DNA replication or DNA repair mechanisms, and external factors, including radiation and reactive chemicals, can cause random mutations in the DNA. a. Whether a mutation is detrimental, beneficial, or neutral depends on the environmental context. b. Mutations are the primary source of genetic variation.	8.6, p. 140–142 14.5, p. 222–224 17.2, p. 268–269
		IST-4.A.2: Errors in mitosis or meiosis can result in changes in phenotype. a. Changes in chromosome number often result in new phenotypes, including sterility caused by triploidy, and increased vigor of other polyploids. b. Changes in chromosome number often result in human disorders with developmental limitations, including Down syndrome/Trisomy 21 and Turner syndrome.	11.6, p. 182–183 14.6, p. 224–226 17.8, p. 283–284
	IST-4: The processing of genetic information is imperfect and is a source of genetic variation. **IST-4.B:** Explain how alterations in DNA sequences contribute to variation that can be subject to natural selection.	**IST-4.B.1:** Changes in genotype may affect phenotypes that are subject to natural selection. Genetic changes that enhance survival and reproduction can be selected for by environmental conditions. a. 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 of DNA), and transposition (movement of DNA segments within and between DNA molecules) increase variation. b. Related viruses can combine/recombine genetic information if they infect the same host cell. c. Reproduction processes that increase genetic variation are evolutionarily conserved and are shared by various organisms.	12.1–12.2, p. 187–189 12.5, p. 194–195 14.5, p. 222 17.2, p. 269 20.4–20.5, p. 322–325

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
6.8: Biotechnology **Big Idea 3**	**IST-1:** Heritable information provides for continuity of life. **IST-1.P:** Explain the use of genetic engineering techniques in analyzing or manipulating DNA.	**IST-1.P.1:** Genetic engineering techniques can be used to analyze and manipulate DNA and RNA. a. Electrophoresis separates molecules according to size and charge. b. During polymerase chain reaction (PCR) DNA fragments are amplified. c. Bacterial transformation introduces DNA into bacterial cells. d. DNA sequencing determines the order of nucleotides in a DNA molecule.	15.3–15.4, p. 235–238 20.5, p. 325

Unit 7: Natural Selection

AP® Exam Weighting: 13–20%; 20–23 class periods

- **Big Idea 1 (EVO):** The process of evolution drives the diversity and unity of life.
- **Big Idea 4 (SYI):** Biological systems interact, and these systems and their interactions exhibit complex properties.

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
7.1: Introduction to Natural Selection **Big Idea 1**	**EVO-1:** Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence. **EVO-1.C:** Describe the causes of natural selection.	**EVO-1.C.1:** Natural selection is a major mechanism of evolution.	16.3, p. 252–254
		EVO-1.C.2: 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.	16.3, p. 252–254
	EVO-1: Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence. **EVO-1.D:** Explain how natural selection affects populations.	**EVO-1.D.1:** Evolutionary fitness is measured by reproductive success.	16.3, p. 253
		EVO-1.D.2: Biotic and abiotic environments can be more or less stable/fluctuating, and this affects the rate and direction of evolution; different genetic variations can be selected in each generation.	17.4, p. 272–276
7.2: Natural Selection **Big Idea 1**	**EVO-1:** Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence. **EVO-1.E:** Describe the importance of phenotypic variation in a population.	**EVO-1.E.1:** Natural selection acts on phenotypic variations in populations.	17.4, p. 272–276
		EVO-1.E.2: Environments change and apply selective pressures to populations.	17.4, p. 272–276
		EVO-1.E.3: Some phenotypic variations significantly increase or decrease fitness of the organism in particular environments.	17.2, p. 268–270 17.4–17.5, p. 272–278
7.3: Artificial Selection **Big Idea 1**	**EVO-1:** Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence. **EVO-1.F:** Explain how humans can affect diversity within a population.	**EVO-1.F.1:** Through artificial selection, humans affect variation in other species.	44.6, p. 781
	EVO-1: Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence. **EVO-1.G:** Explain the relationship between changes in the environment and evolutionary changes in the population.	**EVO-1.G.1:** Convergent evolution occurs when similar selective pressures result in similar phenotypic adaptations in different populations or species.	18.3, p. 294–295

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
7.4: Population Genetics **Big Idea 1**	**EVO-1:** Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence. **EVO-1.H:** Explain how random occurrences affect the genetic makeup of a population.	**EVO-1.H.1:** Evolution is also driven by random occurrences. a. Mutation is a random process that contributes to evolution b. Genetic drift is a nonselective process occurring in small populations. i. Bottlenecks ii. Founder effect Migration/gene flow can drive evolution.	9.6, p. 155–157 17.2, p. 268–269 17.6, p. 278–280
	EVO-1: Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence. **EVO-1.I:** Describe the role of random processes in the evolution of specific populations.	**EVO-1.I.1:** Reduction of genetic variation within a given population can increase the differences between populations of the same species.	17.6, p. 278–280
	EVO-1: Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence. **EVO-1.J:** Describe the change in the genetic makeup of a population over time.	**EVO-1.J.1:** Mutation results in genetic variation, which provides phenotypes on which natural selection acts.	17.2, p. 268–270
7.5: Hardy-Weinberg Equilibrium **Big Idea 1**	**EVO-1:** Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence. **EVO-1.K:** Describe the conditions under which allele and genotype frequencies will change in populations.	**EVO-1.K.1:** Hardy-Weinberg is a model for describing and predicting allele frequencies in a non-evolving population. 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, but they provide a valuable null hypothesis.	17.3, p. 270
		EVO-1.K.2: Allele frequencies in a population can be calculated from genotype frequencies. Hardy-Weinberg Equation: $p^2 + 2pq + q^2 = 1$ $P + q = 1$ where: p = frequency of allele 1 in the population	17.3, p. 270–272
	EVO-1: Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence. **EVO-1.L:** Explain the impacts on the population if any of the conditions of Hardy-Weinberg are not met.	**EVO-1.L.1:** Changes in allele frequencies provide evidence for the occurrence of evolution in a population.	17.3, p. 271
		EVO-1.L.2: Small populations are more susceptible to random environmental impact than large populations.	17.6, p. 278–280

Correlation (continued)

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
7.6: Evidence for Evolution **Big Idea 1**	**EVO-1:** Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence. **EVO-1.M:** Describe the types of data that provide evidence for evolution.	**EVO-1.M.1:** Evolution is supported by scientific evidence from many disciplines *(geographical, geological, physical, biochemical, and mathematical data).*	16.1–16.5, p. 249–263
	EVO-1: Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence. **EVO-1.N:** Explain how morphological, biochemical, and geologic data provide evidence that organisms have changed over time.	**EVO-1.N.1:** Molecular, morphological, and genetic evidence from extant and extinct organisms adds to our understanding of evolution. a. Fossils can be dated by a variety of methods. These include: i. The age of the rocks where a fossil is found. ii. The rate of decay of isotopes including carbon-14. iii. Geographical data. b. Morphological homologies, including vestigial structures, represent features shared by common ancestry.	16.2, 250–252 16.4, p. 255–257 16.5, p. 262–263
		EVO-1.N.2: A comparison of DNA nucleotide sequences and/or protein amino acid sequences provides evidence for evolution and common ancestry.	18.4, p. 295–297
	EVO-2: Organisms are linked by lines of descent from common ancestry. **EVO-2.B:** Describe the fundamental molecular and cellular features shared across all domains of life, which provide evidence of common ancestry.	**EVO-2.B.1:** Many fundamental molecular and cellular features and processes are conserved across organisms.	1.3, p. 6–7 4.2, p. 54–55 4.10, p. 70–71 7.2, p. 118–119 10.3, p. 164–168 11.2, p. 176–177 19.4, p. 306–308 20.5, p. 324–326
		EVO-2.B.2: Structural and functional evidence supports the relatedness of organisms in all domains.	1.3, p. 6–7
7.7: Common Ancestry **Big Idea 1**	**EVO-2:** Organisms are linked by lines of descent from common ancestry. **EVO-2.C:** Describe structural and functional evidence on cellular and molecular levels that provides evidence for the common ancestry of all eukaryotes.	**EVO-2.C.1:** Structural evidence indicates common ancestry of all eukaryotes. a. Membrane-bound organelles. b. Linear chromosomes. c. Genes that contain introns.	8.4, p. 138 9.3, p. 151 19.7, p. 310–311
7.8: Continuing Evolution **Big Idea 1**	**EVO-3:** Life continues to evolve within a changing environment. **EVO-3.A:** Explain how evolution is an ongoing process in all living organisms.	**EVO-3.A.1:** Populations of organisms continue to evolve.	17.2–17.4, p. 268–276 17.8–17.9, p. 282–287
		EVO-3.A.2: All species have evolved and continue to evolve. a. Genomic changes over time. b. Continuous change in the fossil record. c. Evolution of resistance to antibiotics, pesticides, herbicides, or chemotherapy drugs. d. Pathogens evolve and cause emergent diseases.	15.5, p. 238-239 16.4, p. 255-256 17.1, p. 267-268 17.9, p. 287 20.4, p. 320-323 20.8, p. 330-331

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
7.9: Phylogeny **Big Idea 1**	**EVO-3:** Life continues to evolve within a changing environment**.** **EVO-3.B:** Describe the types of evidence that can be used to infer an evolutionary relationship.	**EVO-3.B.1:** Phylogenetic trees and cladograms show evolutionary relationships among lineages. a. Phylogenetic trees and cladograms both show relationships between lineages, but phylogenetic trees show the amount of change over time calibrated by fossils or a molecular clock. b. Traits that are either gained or lost during evolution can be used to construct phylogenetic trees and cladograms. i. Shared characters are present in more than one lineage. ii. Shared, derived characters indicate common ancestry and are informative for the construction of phylogenetic trees and cladograms. iii. The outgroup represents the lineage that is least closely related to the remainder of the organisms in the phylogenetic tree or cladogram. c. Molecular data typically provide more accurate and reliable evidence than morphological traits in the construction of phylogenetic trees or cladograms.	16.4–16.5, p. 255–263 18.2, p. 292–293 18.3–18.4, p. 293–296
	EVO-3: Life continues to evolve within a changing environment**.** **EVO-3.C:** Explain how a phylogenetic tree and/or cladogram can be used to infer evolutionary relatedness.	**EVO-3.C.1:** Phylogenetic trees and cladograms can be used to illustrate speciation that has occurred. The nodes on a tree represent the most recent common ancestor of any two groups or lineages.	18.2, p. 292–293
		EVO-3.C.2: Phylogenetic trees and cladograms can be constructed from morphological similarities of living or fossil species, and from DNA and protein sequence similarities.	18.2, p. 292–293
		EVO-3.C.3: Phylogenetic trees and cladograms represent hypotheses and are constantly being revised, based on evidence.	18.2, p. 292–293
7.10: Speciation **Big Idea 1**	**EVO-3:** Life continues to evolve within a changing environment. **EVO-3.D:** Describe the conditions under which new species may arise.	**EVO-3.D.1:** Speciation may occur when two populations become reproductively isolated from each other.	17.7, p. 280–282
		EVO-3.D.2: The Biological Species Concept provides a commonly used definition of species for sexually reproducing organisms. It states that species can be defined as a group capable of interbreeding and exchanging genetic information to produce viable, fertile offspring.	1.5, p. 11
	EVO-3: Life continues to evolve within a changing environment. **EVO-3.E:** Describe the rate of evolution and speciation under different ecological conditions.	**EVO-3.E.1:** Punctuated equilibrium is when evolution occurs rapidly after a long period of stasis. Gradualism is when evolution occurs slowly over hundreds of thousands or millions of years.	17.9, p. 285–287
		EVO-3.E.2: Divergent evolution occurs when adaptation to new habitats results in phenotypic diversification. Speciation rates can be especially rapid during times of adaptive radiation as new habitats become available.	17.9, p. 285–287 18.3, p. 293–295
	EVO-3: Life continues to evolve within a changing environment. **EVO-3.F:** Explain the processes and mechanisms that drive speciation.	**EVO-3.F.1:** Speciation results in diversity of life forms.	17.7, p. 280–282
		EVO-3.F.2: Speciation may be sympatric or allopatric.	17.8, p. 282–285
		EVO-3.F.3: Various prezygotic and postzygotic mechanisms can maintain reproductive isolation and prevent gene flow between populations.	17.7, p. 280–282

Correlation (continued)

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
7.11: Extinction **Big Idea 1**	**EVO-3:** Life continues to evolve within a changing environment. **EVO-3.G:** Describe factors that lead to the extinction of a population.	**EVO-3.G.1:** Extinctions have occurred throughout the Earth's history.	16.5, p. 260
		EVO-3.G.2: Extinction rates can be rapid during times of ecological stress.	48.2, p. 852–854
	EVO-3: Life continues to evolve within a changing environment. **EVO-3.H:** Explain how the risk of extinction is affected by changes in the environment.	**EVO-3.H.1:** Human activity can drive changes in ecosystems that cause extinctions.	48.3–48.6, p. 854–860
	EVO-3: Life continues to evolve within a changing environment. **EVO-3.I:** Explain species diversity in an ecosystem as a function of speciation and extinction rates.	**EVO-3.I.1:** The amount of diversity in an ecosystem can be determined by the rate of speciation and the rate of extinction.	No reference
	EVO-3: Life continues to evolve within a changing environment. **EVO-3.J:** Explain how extinction can make new environments available for adaptive radiation.	**EVO-3.J.1:** Extinction provides newly available niches that can then be exploited by different species.	45.4, p. 792–793 48.2, p. 852
7.12: Variations in Populations **Big Idea 4**	**SYI-3:** Naturally occurring diversity among and between components within biological systems affects interactions with the environment. **SYI-3.D:** Explain how the genetic diversity of a species or population affects its ability to withstand environmental pressures.	**SYI-3.D.1:** The level of variation in a population affects population dynamics. a. Population ability to respond to changes in the environment is influenced by genetic diversity. Species and populations with little genetic diversity are at risk of decline or extinction. b. Genetically diverse populations are more resilient to environmental perturbation because they are more likely to contain individuals that can withstand the environmental pressure. Alleles that are adaptive in one environmental condition may be deleterious in another because of different selective pressures.	17.2, p. 268–270 18.6, p. 298–299 48.7, p. 860–862
7.13: Origins of Life on Earth **Big Idea 4**	**SYI-3:** Naturally occurring diversity among and between components within biological systems affects interactions with the environment. **SYI-3.E:** Describe the scientific evidence that provides support for models of the origin of life on Earth.	**SYI-3.E.1:** Several hypotheses about the origin of life on Earth are supported with scientific evidence. a. Geological evidence provides support for models of the origin of life on Earth. i. The Earth formed approximately 4.6 billion years ago (bya). The environment was too hostile for life until 3.9 bya and 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. b. There are several models about the origin of life on Earth. i. Primitive Earth provided inorganic precursors from which organic molecules could have been synthesized because of the presence of available free energy and the absence of a significant quantity of atmospheric oxygen (O_2). ii. Organic molecules could have been transported to Earth by a meteorite or other celestial event. c. Chemical experiments have shown that it is possible to form complex organic molecules from inorganic molecules in the absence of life. i. Organic molecules/monomers served as building blocks for the formation of more complex molecules, including amino acids and nucleotides. ii. The joining of these monomers produced polymers with the ability to replicate, store, and transfer information.	19.2, p. 304–305 19.3–19.5, p. 305–309
		SYI-3.E.2: The RNA World Hypothesis proposes that RNA could have been the earliest genetic material.	19.4, p. 307

Unit 8: Ecology

AP® Exam Weighting: 10–15%; 18–21 class periods

- **Big Idea 1 (EVO):** The process of evolution drives the diversity and unity of life.
- **Big Idea 2 (ENE):** Biological systems use energy and molecular building blocks to grow, reproduce, and maintain dynamic homeostasis.
- **Big Idea 3 (IST):** Living systems store, retrieve, transmit, and respond to information essential to life processes.
- **Big Idea 4 (SYI):** Biological systems interact, and these systems and their interactions exhibit complex properties.

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
8.1: Responses to the Environment **Big Idea 2** **Big Idea 3**	**ENE-3:** Timing and coordination of biological mechanisms involved in growth, reproduction, and homeostasis depend on organisms responding to environmental cues. **ENE-3.D:** Explain how the behavioral and/or physiological response of an organism is related to changes in internal or external environment.	**ENE-3.D.1:** Organisms respond to changes in their environment through behavioral and physiological mechanisms.	31.9, p. 530–531 43.2, p. 756–757
		ENE-3.D.2: Organisms exchange information with one another in response to internal changes and external cues, which can change behavior.	43.2–43.3, p. 756–759 43.5–43.8, p. 761–767
	IST-5: Transmission of information results in changes within and between biological systems. **IST-5.A:** Explain how the behavioral responses of organisms affect their overall fitness and may contribute to the success of the population.	**IST-5.A.1:** Individuals can act on information and communicate it to others.	43.5, p. 761–762
		IST-5.A.2: Communication occurs through various mechanisms. a. Organisms have a variety of signaling behaviors that produce changes in the behavior of other organisms and can result in differential reproductive success. b. Animals use visual, audible, tactile, electrical, and chemical signals to indicate dominance, find food, establish territory, and ensure reproductive success.	43.2, p. 756–757 43.5–43.7, p. 761–766
		IST-5.A.3: Responses to information and communication of information are vital to natural selection and evolution. Natural selection favors innate and learned behaviors that increase survival and reproductive fitness.	43.3, p. 758–759 43.7–43.8, p. 764–767
8.2: Energy Flow through Ecosystems **Big Idea 2**	**ENE-1:** The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules. **ENE-1.M:** Describe the strategies organisms use to acquire and use energy.	**ENE-1.M.1:** Organisms use energy to maintain organization, grow and reproduce. a. Organisms use different strategies to regulate body temperature and metabolism. i. Endotherms use thermal energy generated by metabolism to maintain homeostatic body temperatures. ii. Ectotherms lack efficient internal mechanisms for maintaining body temperature, though they may regulate their temperature behaviorally by moving into the sun or shade or by aggregating with other individuals. b. Different organisms use various reproductive strategies in response to energy availability. c. 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. d. A net gain in energy results in energy storage or the growth of an organism. e. A net loss of energy results in loss of mass and, ultimately, the death of an organism.	5.2, p. 78–79 39.9, p. 694–695 40.9–40.10, p. 709–711 41.2, p. 716–717 44.5, p. 778–779

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
	ENE-1: The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules. **ENE-1.N:** Explain how changes in energy availability affect populations and ecosystems.	**ENE-1.N.1:** Changes in energy availability can result in changes in population size.	44.2–44.4, p. 772–777
		ENE.1.N.2: Changes in energy availability can result in disruptions to an ecosystem. a. A change in energy resources such as sunlight can affect the number and size of the trophic levels. b. A change in the producer level can affect the number and size of other trophic levels.	46.4, p. 811–813
	ENE-1: The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules. **ENE-1.O:** Explain how the activities of autotrophs and heterotrophs enable the flow of energy within an ecosystem.	**ENE-1.O.1:** Autotrophs capture energy from physical or chemical sources in the environment. a. Photosynthetic organisms capture energy present in sunlight. b. Chemosynthetic organisms capture energy from small inorganic molecules present in their environment, and this process can occur in the absence of oxygen.	6.2, p. 100–102 20.6, p. 326–327 46.2, p. 808–809
		ENE-1.O.2: Heterotrophs capture energy present in carbon compounds produced by other organisms. a. Heterotrophs may metabolize carbohydrates, lipids, and proteins as sources of energy by hydrolysis.	6.2, p. 100–101 46.2, p. 808–809
8.3: Population Ecology **Big Idea 4**	**SYI-1:** Living systems are organized in a hierarchy of structural levels that interact. **SYI-1.G:** Describe factors that influence growth dynamics of populations.	**SYI-1.G.1:** Populations comprise individual organisms that interact with one another and with the environment in complex ways.	44.2, p. 772–774
		SYI-1.G.2: Many adaptations in organisms are related to obtaining and using energy and matter in a particular environment. a. Population growth dynamics depend on a number of factors. Population Growth: $\frac{dN}{dT} = B - D$ where: dt = change in time B = birth rate D = death rate N = population size b. Reproduction without constraints results in the exponential growth of a population. Exponential Growth: $\frac{dN}{dT} = r_{max}$ where: dt = change in time N = population size r_{max} = maximum per capita growth rate of population	44.2–44.6, p. 772–781 44.3–44.4, p. 774–777
8.4: Effect of Density on Populations **Big Idea 4**	**SYI-1:** Living systems are organized in a hierarchy of structural levels that interact. **SYI-1.H:** Explain how the density of a population affects and is determined by resource availability in the environment.	**SYI-1.H.1:** A population can produce a density of individuals that exceeds the system's resource availability.	44.2–44.4, p. 772–777
		SYI-1.H.2: As limits to growth due to density-dependent and density-independent factors are imposed, a logistic growth model generally ensues. $\frac{dN}{dT} = \left(r\frac{K-N}{N}\right)_{max}$ where: dt = change in time N = population size r_{max} = maximum per capita growth rate of population K = carrying capacity	44.4, p. 776–777

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
8.5: Community Ecology **Big Idea 2**	**ENE-4:** Communities and ecosystems change on the basis of interactions among populations and disruptions to the environment. **ENE-4.A:** Describe the structure of a community according to its species composition and diversity.	**ENE-4.A.1:** The structure of a community is measured and described in terms of species composition and species diversity. Simpson's Diversity index: $\text{Diversity index} = 1 - \Sigma\left(\frac{n}{N}\right)^2$ n = total number of organisms of a particular species N = total number of organisms of all species	45.2, p. 790 45.8–45.9, p. 798–803
	ENE-4: Communities and ecosystems change on the basis of interactions among populations and disruptions to the environment. **ENE-4.B:** Explain how interactions within and among populations influence community structure.	**ENE-4.B.1:** Communities change over time depending on interactions between populations.	45.2–45.8, p. 790–801 46.2–46.3, p. 808–811
		ENE-4.B.2: Interactions among populations determine how they access energy and matter within a community.	44.2, p. 772–774 46.2–46.4, p. 808–813
		ENE-4.B.3: Relationships among interacting populations can be characterized by positive and negative effects, and can be modeled. Examples include predator/prey interactions, trophic cascades, and niche partitioning.	45.4–45.5, p. 792–794 46.4, p. 811–813
		ENE-4.B.4: Competition, predation, and symbioses, including parasitism, mutualism, and commensalism, can drive population dynamics.	45.2–45.7, p. 790–798
	ENE-4: Communities and ecosystems change on the basis of interactions among populations and disruptions to the environment. **ENE-4.C:** Explain how community structure is related to energy availability in the environment.	**ENE-4.C.1:** Cooperation or coordination between organisms, populations, and species can result in enhanced movement of, or access to, matter and energy.	45.2–45.3, p. 790–791 45.8, p. 798–801
8.6: Biodiversity **Big Idea 4**	**SYI-3:** Naturally occurring diversity among and between components within biological systems affects interactions with the environment. **SYI-3.F:** Describe the relationship between ecosystem diversity and its resilience to changes in the environment.	**SYI-3.F.1:** Natural and artificial ecosystems with fewer component parts and with little diversity among the parts are often less resilient to changes in the environment.	45.8, p. 798–801
		SYI-3.F.2: Keystone species, producers, and essential abiotic and biotic factors contribute to maintaining the diversity of an ecosystem.	45.8, p. 800 46.2–46.4, p. 808–813
	SYI-3: Naturally occurring diversity among and between components within biological systems affects interactions with the environment. **SYI-3.G:** Explain how the addition or removal of any component of an ecosystem will affect its overall short-term and long-term structure.	**SYI-3.G.1:** The diversity of species within an ecosystem may influence the organization of the ecosystem.	46.3, p. 810–811
		SYI-3.G.2: 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.	45.8, p. 800

Topic	Enduring Understanding and LO	Essential Knowledge	Text Section(s)
8.7: Disruptions to Ecosystems **Big Idea 1** **Big Idea 4**	**EVO-1:** Evolution is characterized by change in the genetic make-up of a population over time and is supported by multiple lines of evidence. **EVO-1.O:** Explain the interaction between the environment and random or preexisting variations in populations.	**EVO-1.O.1:** 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.	16.3, p. 252–254
		EVO-1.O.2: Mutations are random and are not directed by specific environmental pressures.	17.2, p. 268–270
	SYI-2: Competition and Cooperation are important aspects of biological systems. **SYI-2.A:** Explain how invasive species affect ecosystem dynamics.	**SYI-2.A.1:** The intentional or unintentional introduction of an invasive species can allow the species to exploit a new niche free of predators or competitors, or to outcompete other organisms for resources.	18.1, p. 291 45.1, p. 789 48.2, p. 853–854
		SYI-2.A.2: The availability of resources can result in uncontrolled population growth and ecological changes.	46.1, p. 807, 823
	SYI-2: Competition and Cooperation are important aspects of biological systems. **SYI-2.B:** Describe human activities that lead to changes in ecosystem structure and/or dynamics.	**SYI-2.B.1:** The distribution of local and global ecosystems changes over time.	47.11–47.13, p. 842–846 48.3, p. 854–856 48.7, p. 860–862
		SYI-2.B.2: Human impact accelerates change at local and global levels. a. The introduction of new diseases can devastate native species. b. Habitat change can occur because of human activity.	45.1, p. 789 45.8, p. 798–801 46.1, p. 807 46.8, p. 817–820, 823 48.2–48.8, p. 852–863
	SYI-2: Competition and Cooperation are important aspects of biological systems. **SYI-2.C:** Explain how geological and meteorological activity leads to changes in ecosystem structure and/or dynamics.	**SYI-2.C.1:** Geological and meteorological events affect habitat change and ecosystem distribution. a. Biogeographical studies illustrate these changes.	16.1–16.2, p. 249, 250–252 16.5, p. 258–263 45.9, p. 802–803