Biology for AP® Courses Crosswalk

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Unit 1: Chemistry of Life

8-11% AP Exam Weighting, ~5-7 Class Periods

The Big Ideas covered in Unit 1 include the following:

BIG IDEA 2: *Energetics* ENE
- What is the role of energy in the making and breaking of polymers?

BIG IDEA 3: *Information Storage and Transmission* IST
- How do living systems transmit information in order to ensure their survival?

BIG IDEA 4: *Systems Interactions* SYI
- How would living systems function without the polarity of the water molecule?

Unit 1 Topics	Suggested OpenStax Sections/Pages
1.1 Structure of Water and Hydrogen Bonding **Enduring Understanding:** **SYI-1** *Living systems are organized in a hierarchy of structural levels that interact.* **LO:** SYI-1.A **EK:** SYI-1.A.1, SYI-1.A.2, SYI-1.A.3	The concepts covering the molecular structure of water and its properties based on hydrogen bonding are found in Chapter 2. Specific sections include Sections 2.1 and 2.2, with cohesion, adhesion, and surface tension mentioned specifically on pages 63–65 (PDF 72-74). ***Suggested Skill: Visual Representations*** Students should describe the differences among bond types and molecular shapes for water, methane, and carbon dioxide (page 57).
1.2 Elements of Life **Enduring Understanding:** **ENE-1** *The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.* **LO:** ENE-1.A **EK:** ENE-1.A.1, ENE-1.A.2	The concept that organisms exchange matter (especially the SPONCH elements) with the environment because atoms and small molecules are used to build macromolecules necessary for life functions is covered throughout the text in multiple sections and contexts, including the following: 2.1, 2.2, and 2.3 (atoms, isotopes, ions, water, carbon, and bonding); 4.2 and 4.6 (cell membrane structure); 6.1, 6.2, 6.3, and 6.4 (energy, metabolism, and ATP); 7.1, 7.2, 7.3, 7.4, 7.5, and 7.6 (cellular respiration); 8.2 (photosynthesis); and 37.2 and 37.3 (nutrient cycling, e.g., nitrogen cycle). ***Suggested Skill: Visual Representations*** *Visual Connection* on page 897 offers an explanation of the five stages of biofilm development.
1.3 Introduction to Biological Macromolecules **Enduring Understanding:** **SYI-1** *Living systems are organized in a hierarchy of structural levels that interact.* **LO:** SYI-1.B **EK:** SYI-1.B.1	Dehydration synthesis and hydrolysis are specifically introduced in Chapter 3, Section 3.1, pages 88–90. Sections 3.2–3.5 describe the properties of monomers and polymers. ***Suggested Skill: Visual Representations*** Click here to access a video representation of the processes of dehydration synthesis and hydrolysis.

Exclusion Statement: *The molecular structure of specific nucleotides and amino acids and of specific carbohydrate polymers is beyond the scope of the AP® exam.*	
1.4 Properties of Biological Macromolecules **Enduring Understanding:** **SYI-1** *Living systems are organized in a hierarchy of structural levels that interact.* **LO:** SYI-1.B **EK:** SYI-1.B.2 ***Exclusion Statement:*** *The molecular structure of specific lipids is beyond the scope of the AP® Exam.*	Chapter 3 is the primary resource that addresses the properties and functions of nucleic acids, proteins, complex carbohydrates, and lipids as they pertain to living systems. ***Suggested Skill: Concept Explanation*** Page 121 offers a visual representation of the four levels of protein structure, which students can then describe conceptually.
1.5 Structure and Function of Biological Macromolecules **Enduring Understanding:** **SYI-1** *Living systems are organized in a hierarchy of structural levels that interact.* **LO:** SYI-1.C **EK:** SYI-1.C.1 Illustrative Example from the CED ● *Cellulose versus starch versus glycogen*	In Chapter 3, the structure and function of biological macromolecules in living systems is presented along with the information required under Subtopic 1.4. ***Suggested Skill: Argumentation*** Knowing that a protein's shape informs its function, students should predict the effects of a change in the normal formation of a protein.
1.6 Nucleic Acids **Enduring Understanding:** **IST-1** *Heritable information provides for continuity of life.* **LO:** IST-1.A; **EK:** IST-1.A.1	In Chapter 3, Section 3.5 (pages 122–129) focuses entirely on nucleic acid types along with the structures and roles of DNA and RNA. ***Suggested Skill: Visual Representations*** Page 129 of the text offers a model-creating activity in which students can give an explanation from the *Think About It* prompt.

Unit 2: Cell Structure and Function

10-13% AP Exam Weighting, ~11-13 Class Periods

The Big Ideas covered in Unit 2 include the following:

BIG IDEA 1: *Evolution* EVO
- Defend the origin of eukaryotic cells.

BIG IDEA 2: *Energetics* ENE
- How do the mechanisms for transport across membranes support energy conservation?
- What are the advantages and disadvantages of cellular compartmentalization?

BIG IDEA 4: *Systems Interactions* SYI
- How are living systems affected by the presence or absence of subcellular components?

Unit 2 Topics	Suggested OpenStax Sections/Pages
2.1 Cell Structure: Subcellular Components **Enduring Understanding:** **SYI-1** *Living systems are organized in a hierarchy of structural levels that interact.* **LO:** SYI-1.D **EK:** SYI-1.D.1, SYI-1.D.2, SYI-1.D.3, SYI-1.D.4 Illustrative Example from the CED • *Glycosylation and other chemical modifications of proteins that take place within the Golgi and determine protein function or targeting* ***Exclusion Statement:*** *Specific functions of smooth ER in specialized cells are beyond the scope of the course and the AP® Exam, as is the role of the Golgi in the synthesis of specific phospholipids and the packaging of specific enzymes for lysosomes, peroxisomes, and secretory vesicles.*	Ribosomes and protein synthesis are presented in Chapter 15, Section 15.5, specifically pages 618–619, with a visual representation on page 620. The rough and smooth ER structures are presented in Chapter 4 on page 169 while the Golgi apparatus is discussed on pages 170–171. Additional cell organelle structures are explored on pages 163–167. ***Suggested Skill: Concept Explanation*** The CED illustrative example of *glycosylation*, mentioned in the text on page 704, can be used to elaborate on the process of translation. Once students can explain translation, they can further understand that changes can happen *after* translation, such as glycosylation.
2.2 Cell Structure and Function **Enduring Understanding:** **SYI-1** *Living systems are organized in a hierarchy of structural levels that interact.* **LO:** SYI-1.E, SYI-1.F **EK:** SYI-1.E.1, SYI-1.F.1, SYI-1.F.2, SYI-1.F.3, SYI-1.F.4, SYI-1.F.5, SYI-1.F.6, SYI-1.F.7, SYI-1.F.8, SYI-1.F.9	While Topic 2.1 focused on the structure of the cell components, Topic 2.2 focuses on the components' functions. The function of each cellular component is discussed along with its structure on the pages that correspond with Topic 2.1, pages 41–59. The second component of this topic addresses how the cell captures, stores, and uses energy. The process of photosynthesis is covered in Chapter 8, starting on page 329. The Calvin cycle is covered here (page 350), and the Krebs cycle is presented on pages 293–295. There is also a link on page 295 to an interactive presentation covering the Krebs cycle.

	Suggested Skill: Argumentation Page 333 of the OpenStax text offers a *Think About It* prompt in which students can argue as to why scientists believe that photosynthesis evolved before aerobic cellular respiration.
2.3 Cell Size **Enduring Understanding: ENE-1** *The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.* **LO:** ENE-1.B, ENE-1.C **EK:** ENE-1.B.1, ENE-1.B.2, ENE-1.C.1 Illustrative Examples from the CED *Root hair cells, guard cells, gut epithelial cells, vacuoles, cilia, and stomata*	On page 151, Chapter 4, Section 4.2 begins with a *Connection for AP® Courses* in which the surface area-to-volume factor is introduced. Page 155 provides a *Visual Connection* to demonstrate how an increase in cell size reduces the surface area-to-volume ratio. Critical Thinking questions 46–49 on page 191 give students practice with these concepts. Several sections address the mechanisms through which organisms exchange materials and resources from and into the environment, such as the following: • Organisms must exchange matter with the environment to grow, reproduce, and maintain organization (2.1, 2.2, 3.3, 4.2, 4.6, 6.1, 6.8, 22.4, 22.5, 23.5, 25.8, 37.3). • Cell membranes are selectively permeable, due to their structure (3.2, 3.3, 5.1, 5.2, 5.3, 5.4, 8.3). • Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes (2.3, 3.3, 5.2, 5.3, 5.4). • Interactions among living systems and with their environment result in the movement of matter and energy (3.2, 3.3, 6.2, 6.3, 6.6, 7.5, 7.6, 8.2, 10.3, 18.1, 23.1, 22.4, 45.2, 45.6, 46.2, 47.3). ***Suggested Skill: Statistical Tests and Data Analysis*** Offer students the following prompt: *Which of the following cells would likely exchange nutrients and wastes with its environment more efficiently: a spherical cell with a diameter of 5 µm or a cubed-shaped cell with a side length of 7 µm? Provide a quantitative justification for your answer based on surface area-to-volume ratios.* ***Suggested Skill: Visual Representations*** Students can create an annotated diagram to explain how approximately 300 million alveoli in a human lung increase surface area for gas exchange to the size of a tennis court. Use the diagram to explain how the cellular structures of alveoli, capillaries, and red blood cells allow for rapid diffusion of O_2 and CO_2 among them.
2.4 Plasma Membranes **Enduring Understanding: ENE-2** *Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.* **LO:** ENE-2.A, ENE-2.B **EK:** ENE-2.A.1, ENE-2.A.2, ENE-2.B.1	Chapter 5 focuses on the structure and function of the plasma membranes, and Topic 2.4 is especially correlated with Section 5.1 in the OpenStax text. Each component is presented and discussed, and the fluid mosaic model receives coverage on pages 197–200. ***Suggested Skill: Visual Representations*** Page 220 features a *Science Practices Connection* in which students are asked to create a representation or diagram of a neutrophil destroying an invading pathogen.
2.5 Membrane Permeability	In Chapter 5, Section 5.2 introduces the concept of selective permeability on page 205 and builds on the information about structure and function presented in Section 5.1. Page 206 specifically highlights how nonpolar materials pass through

Enduring Understanding: ENE-2 *Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.* **LO:** ENE-2.C, ENE-2.D **EK:** ENE-2.C.1, ENE-2.C.2, ENE-2.C.3, ENE-2.C.4, ENE-2.C.5, ENE-2.D.1, ENE-2.D.2	more easily than polar materials in the *Factors That Affect Diffusion* section. Page 164 (Section 4.3) presents the cell wall, including its polysaccharide (carbohydrate) composition. Fungal cell walls are discussed in Chapter 22, Section 22.1, on page 900. ***Suggested Skill: Questions and Methods*** Page 210 of the OpenStax text (PDF page 214) presents students with a link to a dispersion image where they can observe and explain what is occurring within the beakers in the lab setup. ***Suggested Skill: Statistical Tests and Data Analysis*** On page 234 of the text, *Science Practice Challenge* question 39 provides students with a data table and instructions to analyze and graph the data and form a conclusion based on the data represented.
2.6 Membrane Transport **Enduring Understanding:** ENE-2 *Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.* **LO:** ENE-2.E, ENE-2.F **EK:** ENE-2.E.1, ENE-2.E.2, ENE-2.E.3, ENE-2.F.1, ENE-2.F.2	The essential knowledge concepts of passive transport and active transport are covered in Chapter 5, specifically Sections 5.2 and 5.3, pages 204–218. Endocytosis and exocytosis are presented in Section 5.4, pages 219–224. ***Suggested Skill: Questions and Methods*** On page 235 of the text, *Science Practice Challenge* question 41 presents the results of an investigation of rice-plant growth in high-salt environments. Part C of this question asks students to pose an additional question that researchers could investigate as an extension of the initial experiment. ***Suggested Skill: Statistical Tests and Data Analysis*** The concepts related to water potential, osmosis, and diffusion are covered in *Investigation 4: Diffusion and Osmosis* from the AP® lab manual, available from the College Board website or by clicking here. Specifically, students investigate what causes plants to wilt if they are not watered.
2.7 Facilitated Diffusion **Enduring Understanding:** ENE-2 *Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.* **LO:** ENE-2.G **EK:** ENE-2.G.1, ENE-2.G.2, ENE-2.G.3, ENE-2.G.4	Facilitated diffusion is presented on pages 207–208 (PDF 216–217). The active transport phenomenon and the energy it requires are explored beginning on page 213 (PDF page 221). *Na^+-K^+ ATPase* is explained on pages 215–216 (PDF 224–225). See pages S52–S53 of the AP® lab manual, where water potential is described as a predictor of the direction of water diffusion through plant tissues, along with its equation. ***Suggested Skill: Argumentation*** The *Science Practices Connection* on page 217 (PDF 226) asks students to create a representation or diagram and then elaborate on their thinking by changing an environmental factor and explaining how the material transport would be affected.
2.8 Tonicity and Osmoregulation **Enduring Understanding:** ENE-2 *Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.*	Tonicity is introduced on page 209 (PDF 218), and osmoregulation is covered in Chapter 32, beginning on page 1394 (PDF 1402). A water potential *Visual Connection* is presented on pages 973–974 (PDF 982–983). ***Suggested Skill: Representing and Describing Data*** *Science Practice Challenge* question 39 on page 234 requests in part B that students complete a graph within the context of a plasma membrane analysis.

LO: ENE-2.H, ENE-2.I **EK:** ENE-2.H.1, ENE-2.I.1, ENE-2.I.2 Illustrative Examples from the CED • *Contractile vacuoles in protists* • *Central vacuoles in plant cells*	
2.9 Mechanisms of Transport **Enduring Understanding:** **ENE-2** *Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.* **LO:** ENE-2.J **EK:** ENE-2.J.1	The concepts of passive (page 204, PDF 213) and active (page 212, PDF 221) transport, endocytosis (page 219, PDF 228), and exocytosis (page 223, PDF 232) are covered throughout the content connected with CED Topics 2.1 through 2.8. ***Suggested Skill: Concept Explanation*** Diagrams are presented on pages 220 and 223 for endocytosis and exocytosis, respectively, and students can be given the opportunity to use these and the information presented in the text to explain both processes.
2.10 Cell Compartmentalization **Enduring Understanding:** **ENE-2** *Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.* **LO:** ENE-2.K, ENE-2.L **EK:** ENE-2.K.1, ENE-2.L.1	The concept of compartmentalization is presented throughout the text, beginning with Section 4.3 on eukaryotic cells, in Section 14.2 (page 558, PDF 567), and in Section 16.1 (page 639, PDF 648). ***Suggested Skill: Argumentation*** Page 166 of the textbook (PDF 175) includes, in the first bullet of the *Think About It* section, a prompt for students to predict how other organelles might be affected if the nucleolus were unable to carry out its function.
2.11 Origins of Cell Compartmentalization **Enduring Understanding:** **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.* **LO:** EVO-1.A, EVO-1.B **EK:** EVO-1.A.1, EVO-1.A.2, EVO-1.A.3, EVO-1.B.1	The concept of endosymbiosis is introduced on page 165 (PDF 174), and although eukaryotic cell structures and functions have been presented throughout Unit 2, the structures of prokaryotic cells are more specifically called out here and are presented in detail starting on page 147 (PDF 156). The *Connection for AP® Courses* section on page 157 presents examples as to how eukaryotic cells are thought to have evolved from prokaryotic cells. ***Suggested Skill: Argumentation*** Page 166 (PDF 175) includes, in the third bullet of the *Activity* section, a *Ten-Minute Debate* option in which students work in small teams to create a visual representation supporting the claim that eukaryotes evolved from prokaryotes.

Unit 3: Cellular Energetics

10-13% AP Exam Weighting, ~11-13 Class Periods

The Big Ideas covered in Unit 3 include the following:

BIG IDEA 2: *Energetics* ENE
- How is energy captured and then used by a living system?

BIG IDEA 4: *Systems Interactions* SYI
- How do organisms use energy or conserve energy to respond to environmental stimuli?

Unit 3 Topics	Suggested OpenStax Sections/Pages
3.1 Enzyme Structure **Enduring Understanding:** ENE-1 *The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.* **LO:** ENE-1.D **EK:** ENE-1.D.1, ENE-1.D.2	The *Connection for AP® Courses* section on page 259 (PDF 268) introduces enzymes as the macromolecules that speed up chemical reactions. The active site and substrate specificity are explained in Chapter 6, Section 6.5 (page 261, PDF 270), and the induced-fit model and function are presented on pages 261–262 (PDF 270–271). ***Suggested Skill: Concept Explanation*** Figure 6.16 on page 262 (PDF 271) provides a visual explanation of the induced-fit model, which students can put into their own words from before the substrate enters the active site through the release of products.
3.2 Enzyme Catalysis **Enduring Understanding:** ENE-1 *The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.* **LO:** ENE-1.E **EK:** ENE-1.E.1	Catalysts are described in Chapter 6, Section 6.5, at the bottom of page 260 (PDF 268), and a graph on the following page offers a visual representation of the action of enzymes. This is explained in the section cited above, which also covers enzyme structure. ***Suggested Skill: Questions and Methods*** On page 279 of the text (PDF 288) there is a guided investigation (question 62) for students to complete. While doing so, students can modify the investigation with respect to the variables and controls being used.
3.3 Environmental Impacts on Enzyme Function **Enduring Understanding:** ENE-1 *The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.* **LO:** ENE-1.F, ENE-1.G **EK:** ENE-1.F.1, ENE-1.F.2, ENE-1.G.1, ENE-1.G.2, ENE-1.G.3, ENE-1.G.4 ***Exclusion Statement:*** *Students must understand the underlying concepts and applications of this equation, but performing calculations using this equation are beyond the scope of the course and the AP® Exam.*	On page 260 (PDF 269), in Section 6.5 of Chapter 6, the second paragraph that begins with "Enzyme activity . . ." presents how environmental conditions (including pH) can impact the structure and functioning of an enzyme. Though denaturation is mentioned here, it is covered more deeply in Chapter 3, Section 3.4: *Proteins*, where the concept of reversible denaturation is also presented. ***Suggested Skill: Argumentation, Statistical Tests, and Data Analysis*** This standard is covered in *Investigation 13: Enzyme Activity* from the AP® lab manual, available from the College Board website or by clicking here. Students investigate how abiotic or biotic factors influence the rates of enzymatic reactions.

3.4 Cellular Energy **Enduring Understanding:** ENE-1 *The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.* **LO:** ENE-1.H **EK:** ENE-1.H.1, ENE-1.H.2, ENE-1.H.3 ***Exclusion Statement:*** *Students will need to understand the concept of energy, but the equation for Gibbs free energy is beyond the scope of the course and the AP® Exam.*	The bulk of this topic's content is covered in Chapter 6: *Metabolism*. However, the concept that all organisms require a constant input of free energy is covered throughout the text in sections 6.1, 6.2, 6.3, 6.4, 6.7, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 8.2, 23.1, 23.5, 36.3, and 37.2. Chapter 6 provides coverage of energy and metabolism, with the laws of thermodynamics discussed starting on page 254 (PDF 263). ***Suggested Skill: Argumentation*** Page 255 of the OpenStax text (PDF 264) asks students to connect the second law of thermodynamics with the energy pathways that happen with inanimate objects. Students can argue regarding the connection between the energy transfer in living organisms with that of everyday objects.
3.5 Photosynthesis **Enduring Understanding:** ENE-1 *The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.* **LO:** ENE-1.I, ENE-1.J **EK:** ENE-1.I.1, ENE-1.I.2, ENE-1.J.1, ENE-1.J.2, ENE-1.J.3, ENE-1.J.4, ENE-1.J.5 ***Exclusion Statement:*** *Memorization of the steps in the Calvin cycle, the structure of the molecules, and the names of enzymes* ***(with the exception of ATP synthase)*** *are beyond the scope of the course and the AP® Exam.*	Chapter 8 is devoted to the process of photosynthesis. The main summary of the process on page 333 shows that photosynthesis uses light from the sun plus other inputs to yield energy-storing sugar molecules. The *Connection for AP® Courses* section on page 330 highlights that the process of photosynthesis is responsible for an oxygenated atmosphere, but special focus should be given to **ENE-1.I.1**, the concept that the process began with prokaryotic organisms, giving rise eventually to photosynthetic eukaryotic organisms. The light-dependent reaction of photosynthesis is given its own section (8.2) starting on page 336 (PDF 345), with specific coverage starting on page 343 (PDF 352). The Calvin cycle is presented on page 348 with a diagram on page 350 (PDF 357 and 359, respectively). ***Suggested Skill: Argumentation*** The *Everyday Connection for AP® Courses* callout on page 353 poses a question about the presence of CO_2 in the earth's atmosphere even after life began, and students are to infer what this means for the evolution of photosynthetic organisms. ***Suggested Skill: Statistical Analysis and Data Analysis*** This standard is covered in Investigation 5: *Photosynthesis* from the AP® lab manual, available from the College Board website or by clicking here. Students investigate environmental factors that affect the rate of photosynthesis in living leaves.
3.6 Cellular Respiration **Enduring Understanding:** ENE-1 *The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.* **LO:** ENE-1.K, ENE-1.L **EK:** ENE-1.K.1, ENE-1.K.2, ENE-1.K.3, ENE-1.L.1, ENE-1.L.2, ENE-1.L.3, ENE-1.L.4, ENE-1.L.5, ENE-1.L.6, ENE-1.L.7	The concept of cellular respiration is fully explored in Chapter 7, pages 281–318 (PDF 290–327). Special focus should be given to the *Connection for AP® Courses* introduction at the beginning of each chapter section. ***Suggested Skill: Representing and Describing Data*** Question 57 in the *Science Practice Challenge* questions section (page 326, PDF 335) provides an opportunity for students to sketch a graph predicting the distribution of *E. coli* bacteria throughout the intestinal tract.

Exclusion Statement: *The names of the specific electron carriers in the electron transport chain; the specific steps, names of enzymes, and intermediates of the pathways for these processes; and memorization of the steps in glycolysis and the Krebs cycle and of the structures of the molecules and the names of the enzymes involved are all beyond the scope of the course and the AP® Exam.*	***Suggested Skill: Argumentation and Data Analysis*** This standard is covered in *Investigation 6: Cellular Respiration* from the AP® lab manual, available from the College Board website or by clicking here. Students investigate factors that affect the rate of cellular respiration in multicellular organisms.
3.7 Fitness **Enduring Understanding: SYI-3** *Naturally occurring diversity among and between components within biological systems affects interactions with the environment.* **LO:** SYI-3.A **EK:** SYI-3.A.1, SYI-3.A.2 Illustrative Examples from the CED • *Different types of phospholipids in cell membranes allow the organism flexibility to adapt to different environmental temperatures.* • *Different types of hemoglobin maximize oxygen absorption in organisms at different developmental stages.* • *Different chlorophylls give the plant greater flexibility to exploit or absorb incoming wavelengths of light for photosynthesis.*	The concept of fitness is addressed throughout the OpenStax text in many different sections. In Chapter 9, covering cell communication, it is noted in Section 9.4 that bacteria living in biofilms have a higher fitness than bacteria living on their own. ***Suggested Skill: Argumentation and Data Analysis*** The BLAST lab (page T67) recommended in the CED for topic 3.7 (Investigation 6: *Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST*, from the AP lab manual) poses a question in its explanation of a cladogram: *Humans and fruit flies share approximately 60% of their DNA, which would place them farther apart on a cladogram. Can you draw a cladogram that depicts the evolutionary relationship among humans, chimpanzees, fruit flies, and mosses?* Beyond drawing a cladogram, students could debate the connections among these organisms, connecting their fitness at the cellular level with how their environment helped select their most advantageous traits for evolution.

Unit 4: Cell Communication and Cell Cycle

10-15% AP Exam Weighting, ~9-11 Class Periods

The Big Ideas covered in Unit 4 include the following:

BIG IDEA 2: *Energetics* ENE
- How is energy captured and then used by a living system?

BIG IDEA 4: *Systems Interactions* SYI
- How do organisms use energy or conserve energy to respond to environmental stimuli?

Unit 4 Topics	Suggested OpenStax Sections/Pages
4.1 Cell Communication **Enduring Understanding:** IST-3 *Cells communicate by generating, transmitting, receiving, and responding to chemical signals.* **LO:** IST-3.A, IST-3.B **EK:** IST-3.A.1, IST-3.B.1 <u>Illustrative Examples from the CED</u> (see CED page 84 for the full list) • *Immune cells interact by cell-to-cell contact, antigen-presenting cells (APCs), helper T cells, and killer T cells.* • *Neurotransmitters and quorum-sensing bacteria* • *Insulin, testosterone, and estrogen*	In Chapter 9, Sections 9.1 and 9.3 (starting on pages 366 and 382, respectively) provide coverage for the essential knowledge standards presented here. Forms of signaling covered include paracrine, endocrine, autocrine, and direct. ***<u>Suggested Skill: Concept Explanation</u>*** Students can select or be assigned one of the illustrative examples provided in the left column (or from page 84 of the CED) and can explain the concept in a peer-tutoring or class review session.
4.2 Introduction to Signal Transduction **Enduring Understanding:** IST-3 *Cells communicate by generating, transmitting, receiving, and responding to chemical signals.* **LO:** IST-3.C, IST-3.D **EK:** IST-3.C.1, IST-3.C.2, IST-3.D.1, IST-3.D.2	The main-focus sections for this concept in Chapter 9 are 9.1 and 9.2, with the process of signal transduction defined in Section 9.2, on page 377 (PDF 386). The concept is covered in various passages throughout the beginning of Chapter 9, including identifying the role of ligand binding as the pathway initiator. ***<u>Suggested Skill: Concept Application</u>*** The *Special Focus Material* titled *Cell-to-Cell Communication—Cell Signaling* (available <u>here</u> on the AP® website) includes an introductory lab where students can see the concept of cell-to-cell communication in action and describe how it led to the resulting outcome.
4.3 Signal Transduction **Enduring Understanding:** IST-3 *Cells communicate by generating, transmitting, receiving, and responding to chemical signals.* **LO:** IST-3.E, IST-3.F **EK:** IST-3.E.1, IST-3.F.1	The main focus sections 9.3 (page 382, PDF 391) and 9.4 (page 386, PDF 395) provide material for the essential knowledge standards included here. Section 9.3 specifically covers apoptosis, while 9.4 describes how cell signaling allows bacteria to respond to environmental cues, including quorum sensing. ***<u>Suggested Skill: Argumentation</u>*** The *Think About It* prompt in the *Science Practices Connection for AP® Courses* section on page 390 (PDF 399) offers a prompt for students to argue their point of view using evidence from the content in Chapter 9.

Illustrative Examples from the CED (see CED page 87 for the full list) ● *Use of chemical messengers by microbes to communicate with other nearby cells and to regulate specific pathways in response to population density (quorum sensing)* ● *Cytokines regulating gene expression to allow for cell replication and division*	
4.4 Changes in Signal Transduction Pathways **Enduring Understanding:** **IST-3** *Cells communicate by generating, transmitting, receiving, and responding to chemical signals.* **LO:** IST-3.G **EK:** IST-3.G.1, IST-3.G.2	Sections 9.2, 9.3, and 9.4 in Chapter 9 are the primary-focus areas for this topic. Changes in signal transduction pathways and their associated effects on the cell are presented directly at the beginning of Section 9.3 and throughout the remainder of the chapter. ***Suggested Skill: Argumentation*** A great example to discern how disruption in cell signaling can cause effects or changes in an organism is unregulated cell growth that leads to cancer, included in the *Connection for AP® Courses* text at the beginning of Section 9.3. Students can consider the impact of a cell signaling disruption in an organism and make a case for how that can lead to cancer.
4.5 Feedback **Enduring Understanding:** **ENE-3** *Timing and coordination of biological mechanisms involved in growth, reproduction, and homeostasis depend on organisms responding to environmental cues.* **LO:** ENE-3.A, ENE-3.B, ENE-3.C **EK:** ENE-3.A.1, ENE-3.B.1, ENE-3.C.1 Illustrative Examples from the CED ● *Blood sugar regulation by insulin and glucagon* ● *Lactation in mammals* ● *Onset of labor in childbirth* ● *Ripening of fruit*	The concept of feedback, both positive and negative, is presented throughout various chapters and sections in the text, including 5.2, 5.3, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 8.2, 10.1, 11.1, 21.1, 23.5, 23.6, 24.3, and 28.3. Section 24.3: *Homeostasis*, on page 1037 (PDF 1046), defines the terms and provides examples of the different types. Illustrative examples from the CED include blood sugar regulation by insulin and glucagon (negative) as well as lactation, the onset of labor in childbirth, and the ripening of fruit (positive). ***Suggested Skill: Argumentation*** Textbook pages 1039 and 1040 (PDF 1048 and 1049) include diagrams of negative and positive feedback, respectively, and an exercise on page 1040 (PDF 1049) gives students an opportunity to select (argue for) whether a given scenario exemplifies positive or negative feedback.
4.6 Cell Cycle **Enduring Understanding:** **IST-1** *Heritable information provides for continuity of life.* **LO:** IST-1.B, IST-1.C **EK:** IST-1.B.1, IST-1.B.2, IST-1.C.1	The cell cycle is largely covered in Chapter 10, which includes cellular reproduction, and specifically in Sections 10.2, 10.3, and 10.4. For Topic 4.6, Section 10.2 is the most salient for learning about the cell cycle, and the cycle of mitosis is covered here as well. ***Suggested Skill: Representing and Describing Data*** The end-of-chapter questions 39, 40, 44, and 47 all require students to interpret a graph or data table to answer the questions. In a class setting, students can put the conclusions derived from the data in their own words. ***Suggested Skill: Statistical Tests and Data Analysis*** The *Investigation 7: Cell Division: Mitosis and Meiosis* lab in the lab manual (page T121) offers students the opportunity to perform mathematical calculations as they investigate how eukaryotic cells divide to produce

	genetically identical cells or to produce gametes with half the normal amount of DNA.
4.7 Regulation of Cell Cycle **Enduring Understanding:** IST-1 *Heritable information provides for continuity of life.* **LO:** IST-1.D, IST-1.E **EK:** IST-1.D.1, IST-1.D.2, IST-1.E.1 ***Exclusion Statement:*** *Knowledge of specific cyclin-Cdk pairs or growth factors is beyond the scope of the course and the AP® Exam.*	Regulation of the cell cycle is covered in Chapter 10, Sections 10.3 and 10.4. Section 10.3 focuses primarily on the internal and external mechanisms that control the cell cycle, while Section 10.4 focuses solely on how unchecked cell division can give rise to cancer. ***Suggested Skill: Argumentation*** The *Link to Learning* on page 430 (PDF 439) asks students to consider how the cellular behavior leads to the formation of tumors. Students can select an option and defend their choice based on evidence learned from the chapter.

Unit 5: Heredity

8-11% AP Exam Weighting, ~9-11 Class Periods

The Big Ideas covered in Unit 5 include the following:

BIG IDEA 1: *Evolution* EVO
- How is our understanding of evolution influenced by our knowledge of genetics?

BIG IDEA 3: *Information Storage and Transmission* IST
- Why is it important that not all inherited characteristics get expressed in the next generation?
- How would Mendel's laws have been affected if he had studied a different type of plant?

BIG IDEA 4: *Systems Interactions* SYI
- How does the diversity of a species affect inheritance?

Unit 5 Topics	Suggested OpenStax Sections/Pages
5.1 Meiosis **Enduring Understanding:** **IST-1** *Heritable information provides for continuity of life.* **LO:** IST-1.F, IST-1.G **EK:** IST-1.F.1, IST-1.G.1	Sections 11.1 and 11.2 of Chapter 11 focus on meiosis. Toward the end of Section 11.1, on page 453 (PDF 462), there is a special focus on comparing meiosis and mitosis with a concise visual representation on page 454 (PDF 463). The *Link to Learning* on page 456 (PDF 465) connects students with an interactive animation that also compares the two processes. ***Suggested Skill: Concept Exploration*** The *Link to Learning* on page 451 (PDF 460) connects students with an animation that can be viewed all at once and then broken down into individual parts. It helps bring the process to life. Students can then practice describing the process and steps in their own words. ***Suggested Skill: Statistical Tests and Data Analysis*** The *Investigation 7: Cell Division: Mitosis and Meiosis* lab in the AP® lab manual offers students the opportunity to perform mathematical calculations as they investigate how eukaryotic cells divide to produce genetically identical cells or to produce gametes with half the normal amount of DNA.
5.2 Meiosis and Genetic Diversity **Enduring Understanding:** **IST-1** *Heritable information provides for continuity of life.* **LO:** IST-1.H **EK:** IST-1.H.1, IST-1.H.2, IST-1.H.3 ***Exclusion Statement:*** *The details of sexual reproduction cycles in various plants and animals are beyond the scope of the course and the AP® Exam.*	The meiosis components of this topic are covered in Chapter 11, Section 11.1, while 11.2 focuses on sexual reproduction and the associated concepts in Essential Knowledge standard IST-1.H.3. ***Suggested Skill: Questions and Methods*** The *Evolution Connection* on page 458 (PDF 467) presents the Red Queen hypothesis to students, where they have to identify a scenario that could support the proposed hypothesis.

5.3 Mendelian Genetics **Enduring Understanding:** IST-1 *Heritable information provides for continuity of life.* **Enduring Understanding:** EVO-2 *Organisms are linked by lines of descent from common ancestry.* **LO:** EVO-2.A, IST-1.I **EK:** EVO-2.A.1, EVO-2.A.2, EVO-2.A.3, EVO-2.A.4, IST-1.I.1	Chapter 12 focuses completely on Mendel's experiments and heredity. That DNA and RNA are carriers of genetic information is a concept covered extensively throughout the text, including in the following sections: 3.5 (nucleic acids), 10.3 (control of the cell cycle), 13.1 (inheritance), 13.2, 14.1, 14.2, 14.3, 14.5, 15.1 (genetic code), 15.2, 15.3, 15.4, 15.5, 16.1 (gene regulation), 16.2, 16.3, 17.1, 17.3, 21.1, 21.2, and 22.4. The relevant equations and content for probability are covered on pages 475–476 (PDF 484–485). ***Suggested Skill: Argumentation*** The concept of heredity provides many opportunities to "predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on data." The *Think About It* section on page 475 (PDF 484) provides an opportunity for students to practice making such a prediction. ***Suggested Skill: Statistical Tests and Data Analysis*** Question 39 in the *Science Practice Challenge Questions* section (starting at the bottom of page 512, PDF 521) asks students to respond to a question using a chi-square statistic table.
5.4 Non-Mendelian Genetics **Enduring Understanding:** IST-1 *Heritable information provides for continuity of life.* **LO:** IST-1.J **EK:** IST-1.J.1, IST-1.J.2, IST-1.J.3, IST-1.J.4 Illustrative Examples from the CED ● *Sex-linked genes reside on sex chromosomes.* ● *In mammals and flies, females are XX and males are XY; as such, X-linked recessive traits are always expressed in males.* ● *In certain species, the chromosomal basis of sex determination is not based on X and Y chromosomes (such as ZW in birds, haplodiploidy in bees).*	Chapter 13 continues the genetics discussion by proposing findings that deviate from those of Mendel. That "the inheritance pattern of many traits cannot be explained by simple Mendelian genetics" is covered in Sections 4.3, 12.2, and 13.1. Specifically, genetic linkage and distances are introduced on page 519 (PDF 528), although this information is not required knowledge. ***Suggested Skill: Statistical Tests and Data Analysis*** The end-of-chapter questions included with Chapter 13 provide many opportunities for students to conduct statistical analyses, specifically the *Science Practice Challenge Questions* on page 540 (PDF 549).
5.5 Environmental Effects on Phenotype **Enduring Understanding:** SYI-3 *Naturally occurring diversity among and between components within biological systems affects interactions with the environment.* **LO:** SYI-3.B **EK:** SYI-3.B.1 Illustrative Examples from the CED ● *Height and weight in humans* ● *Flower color based on soil pH* ● *Seasonal fur color in arctic animals* ● *Sex determination in reptiles*	The influence of environmental factors on the expression of the genotype in an organism is covered in multiple chapters and sections, including 5.3, 11.2, 13.1, 13.2, 14.2, 14.6, 15.1, 17.1, 18.1, 19.1, 19.3, 22.3, 30.4, and 43.1. ***Suggested Skill: Concept Explanation*** The concept of seasonal camouflage can be explained further using the examples of the arctic fox and ptarmigan, highlighted on page 727 (PDF 736).

Effect of increased UV on melanin production in animals *Presence of the opposite mating type on pheromone production in yeast and other fungi*	
5.6 Chromosomal Inheritance **Enduring Understanding:** **SYI-3** *Naturally occurring diversity among and between components within biological systems affects interactions with the environment.* **LO:** SYI-3.C **EK:** SYI-3.C.1, SYI-3.C.2, SYI-3.C.3 <u>Illustrative Examples from the CED</u> *Sickle cell anemia* *Tay-Sachs disease* *Huntington's disease* *X-linked color blindness* *Trisomy 21 (Down syndrome)*	The chromosomal basis of inheritance is covered in multiple chapters and sections, including 11.2, 12.1, 12.2, 13.1, 14.2, 17.1, and 17.4, with the concepts of segregation and independent assortment covered on page 496 (PDF 505). Nondisjunction is covered throughout the text, but it is defined on page 527 (PDF 536) in the section *Disorders in Chromosome Number*. ***<u>Suggested Skill: Argumentation</u>*** The *Science Practices Connection for AP® Courses* on page 534 provides students with two opportunities to highlight through visual media the phenomena of chromosomal abnormality, nondisjunction, or both.

Unit 6: Gene Expression and Regulation

12-16% AP Exam Weighting, ~18-21 Class Periods

The Big Idea covered in Unit 6 is the following:

BIG IDEA 3: *Information Storage and Transmission* IST

- How does gene regulation relate to the continuity of life?
- How is a species' genetic information diversified from generation to generation?

Unit 6 Topics	Suggested OpenStax Sections/Pages
6.1 DNA and RNA Structure **Enduring Understanding:** IST-1 *Heritable information provides for continuity of life.* **LO:** IST-1.K, IST-1.L **EK:** IST-1.K.1, IST-1.K.2, IST-1.K.3, IST-1.L..1	Concepts revolving around the structures of DNA and RNA are referenced in multiple chapters and sections, including 3.5, 10.3, 13.1, 13.2, 14.1, 14.2, 14.3, 14.5, 15.1, 15.2, 15.3, 15.4, 15.5, 16.1, 16.2, 16.3, 17.1, 17.3, 21.1, 21.2, and 22.4 DNA structure in prokaryotes vs. eukaryotes is lightly covered in Chapter 4: *Cell Structure*, and plasmids are defined in Section 15.2, page 600 (PDF 609). Chapter 14: *DNA Structure and Function* covers the nucleotide base pairing found in DNA and RNA along with purines and pyrimidines. ***Suggested Skill: Concept Exploration*** Students read Watson and Crick's original *Nature* article, "Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid," They answer the following questions: How did Watson and Crick's model build on the findings of Rosalind Franklin? How did their model of DNA build on the findings of Hershey and Chase as well as others, showing that DNA can encode and pass information on to the next generation?
6.2 Replication **Enduring Understanding:** IST-1 *Heritable information provides for continuity of life.* **LO:** IST-1.M **EK:** IST-1.M.1 ***Exclusion Statement:*** *The names of the steps and particular enzymes involved (beyond DNA polymerase, ligase, RNA polymerase, helicase, and topoisomerase) are beyond the scope of the course and the AP® Exam.*	DNA replication is covered extensively in Chapter 14, specifically Sections 14.3, 14.4, and 14.5. ***Suggested Skill: Visual Representations*** The *Visual Connection* on page 564 (PDF 573) challenges students to think about enzyme mutation due to an impairment in the joining together of Okazaki fragments.
6.3 Transcription and RNA Processing **Enduring Understanding:** IST-1 *Heritable information provides for continuity of life.*	Prokaryotic and eukaryotic transcription are covered in Chapter 15 in Sections 15.2 and 15.3, respectively. RNA processing in eukaryotes is presented in Section 15.4. ***Suggested Skill: Visual Representations*** Working in small groups, students use a model of DNA to demonstrate synthesis transcription of mRNA to other groups in their class. In their demonstration, they must be sure to

LO: IST-1.N **EK:** IST-1.N.1, IST-1.N.2, IST-1.N.3, IST-1.N.4, IST-1.N.5, IST-1.N.6	distinguish the differences between DNA and RNA, the template and nontemplate strands of the DNA, the directionality of transcription, and the significance of promoters.
6.4 Translation **Enduring Understanding:** IST-1 *Heritable information provides for continuity of life.* **LO:** IST-1.O **EK:** IST-1.O.1, IST-1.O.2, IST-1.O.3, IST-1.O.4, IST-1.O.5 ***Exclusion Statement:*** *The details and names of the enzymes and factors involved in each of these steps; memorization of the genetic code; and the names of the steps and particular enzymes involved—beyond DNA polymerase, ligase, RNA polymerase, helicase, and topoisomerase—are beyond the scope of the course and the AP® Exam.*	Translation is covered in Section 3.4 of Chapter 3, which covers protein synthesis, starting on page 112 (PDF 121). Translation is also explored in Chapter 15. ***Suggested Skill: Visual Representations*** Using construction paper, markers, and scissors, students construct a model of DNA with at least eight nucleotides. Then, they use the model to distinguish between DNA and RNA and hypothesize how the DNA molecule is replicated during cell division. (Students should keep their molecules to model the processes of transcription and translation that they will explore in Chapter 15.) ***Suggested Skill: Argumentation*** After constructing a model of DNA (above), students use the model to predict the causes or effects of a change in, or disruption to, one or more components (e.g., mutation on the processes of DNA replication, transcription, or translation). Students should be able to relate these changes to the relationship between structure and function.
6.5 Regulation of Gene Expression **Enduring Understanding:** IST-2 *Differences in the expression of genes account for some of the phenotypic differences between organisms.* **LO:** IST-2.A, IST-2.B **EK:** IST-2.A.1, IST-2.A.2, IST-2.A.3, IST-2.B.1	Section 16.1 in Chapter 16 (page 636, PDF 645) provides an overview of the regulation of gene expression. ***Suggested Skill: Argumentation*** The *Evolution Connection* on page 639 (PDF 648) asks students to use their knowledge of evolutionary relationships to make a claim related to gene expression in prokaryotic cells.
6.6 Gene Expression and Cell Specialization **Enduring Understanding:** IST-2 *Differences in the expression of genes account for some of the phenotypic differences between organisms.* **LO:** IST-2.C. IST-2.D **EK:** IST-2.C.1, IST-2.C.2, IST-2.D.1, IST-2.D.2	Promoters are presented in Chapter 15: *Genes and Proteins*, on page 601 (PDF 610), while regulator molecules are covered in Chapter 10, related to cell reproduction (page 422, PDF 431). The connections between the regulation of gene expression and phenotypic differences are explored throughout Chapter 16. ***Suggested Skill: Argumentation*** Students can respond to the following prompt by making a claim and supporting it with evidence: *How can cells in a multicellular eukaryotic organism be of different types, given that they all share the same genome?*
6.7 Mutations **Enduring Understanding:** IST-2 *Differences in the expression of genes account for some of the phenotypic differences between organisms.* **Enduring Understanding:** IST-4	Mutations are covered extensively throughout the text. The concept that changes in genotype can result in changes in phenotype is covered throughout Sections 5.3, 11.2, 13.1, 13.2, 14.6, 15.1, 17.1, 18.1, 19.1, and 19.3. ***Suggested Skill: Visual Representations*** Using information from a book or online resource, such as Jonathan Weiner's *The Beak of the Finch*, students explain how contemporary evidence drawn from multiple scientific

The processing of genetic information is imperfect and is a source of genetic variation. **LO:** IST-2.E, IST-4.A, IST-4.B **EK:** IST-2.E.1, IST-2.E.2, IST-4.A.1, IST-4.A.2, IST-4.B.1 Illustrative Examples from the CED ● *Mutations in the* CFTR *gene disrupt ion transport and result in cystic fibrosis.* ● *Mutations in the* MC1R *gene give adaptive melanism in pocket mice.* ● *Antibiotic resistance mutations* ● *Pesticide resistance mutations* ● *Sickle cell disorder and heterozygote advantage*	disciplines supports the observations of Charles Darwin regarding evolution by natural selection. Then, in small groups or as a whole-class discussion or debate, they present an argument, supported by visuals, to dispel misconceptions about evolution and how it works. ***Suggested Skill: Questions and Methods*** *Science Practice Challenge* question 41 on page 1348 (PDF 1357) offers students a chance to evaluate study results and make observations about how a mutation in Tibetans is a response to their environment.
6.8 Biotechnology **Enduring Understanding: IST-1** *Heritable information provides for continuity of life.* **LO:** IST-1.P **EK:** IST-1.P.1 Illustrative Examples from the CED ● *Amplified DNA fragments can be used to identify organisms and perform phylogenetic analyses.* ● *Analysis of DNA can be used for forensic identification.* ● *Genetically modified organisms include transgenic animals.* ● *Gene cloning allows propagation of DNA fragments.* ***Exclusion Statement:*** *The details of the biotechnology processes presented in the CED are beyond the scope of this course. The focus should be on the conceptual understanding of the application of these techniques.*	The processes listed in Topic 6.8 are covered in Chapter 17, Section 17.1. Bacterial transformation is introduced in Chapter 14 (page 546, PDF 555), and DNA sequencing is the focus of Section 14.2 (page 549, PDF 558). ***Suggested Skill: Argumentation*** Cloning can be used to quickly replicate crops that have advantageous genes, such as greater disease resistance or fruit production. Cloning also produces crops that have little genetic variation. Students discuss the advantages and disadvantages of using clones as human food sources in an era when the earth is undergoing a period of climate change. How well will cloned populations of crop plants be able to adapt to climate change, compared to noncloned crop plants? Students defend their group's position against those of other groups. ***Suggested Skill: Statistical Tests and Data Analysis*** The *Investigation 8: Biotechnology: Bacterial Transformation* in the lab manual offers students the opportunity to practice techniques in biotechnology, collect and analyze data, and perform mathematical calculations.

Unit 7: Natural Selection

13-20% AP Exam Weighting, ~20-23 Class Periods

The Big Ideas covered in Unit 7 include the following:

BIG IDEA 1: *Evolution* EVO
- What conditions in a population make it more or less likely to evolve?
- Scientifically defend the theory of evolution.

BIG IDEA 4: *Systems Interactions* SYI
- How does species interaction encourage or slow changes in species?

Unit 7 Topics	Suggested OpenStax Sections/Pages
7.1 Introduction to Natural Selection **Enduring Understanding:** 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.* **LO:** EVO-1.C, EVO-1.D **EK:** EVO-1.C.1, EVO-1.C.2, EVO-1.D.1, EVO-1.D.2	Multiple chapters and sections in the text introduce the concept of natural selection and how Darwin's theory explains both the unity and diversity of life on Earth, including Sections 5.3, 18.1, 18.2, 19.1, 19.2, 19.3, 21.2, and 23.5. Sections 18.2 and 18.3 provide information on how reproduction leads to organisms with more favorable phenotypes that are more fit for survival in fluctuating environments. Concepts in Chapter 19 address the links among genetic and phenotypic diversity, natural selection, and evolutionary change. ***Suggested Skill: Visual Representations*** The *Link to Learning* resource on page 738 (PDF 747) provides an interactive animation that highlights the changes experienced by Darwin's finches, which provide a nice set of visuals to the content discussed in the sections listed above.
7.2 Natural Selection **Enduring Understanding:** 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.* **LO:** EVO-1.E **EK:** EVO-1.E.1, EVO-1.E.2, EVO-1.E.3 Illustrative Examples from the CED • *Flowering time in relation to global climate change* • *Peppered moth* • *Sickle cell anemia* • *DDT resistance in insects*	Several chapters and sections in the text take a deep dive into the concept of natural selection, especially Sections 7.3, 7.6, 18.2, 19.2, 19.3, and 36.5, which provide context for how natural selection acts on phenotypic variations in populations, affecting fitness in particular environments. ***Suggested Skill: Concept Explanation*** Students create a visual representation, such as a diagram with annotations, to explain how island chains provide ideal conditions for allopatric speciation and adaptive radiation to occur. They then design a plan for collecting data to support the claim that speciation has occurred.
7.3 Artificial Selection **Enduring Understanding:** EVO-1 *Evolution is characterized by a change in the genetic makeup of a*	References to artificial selection are made throughout the text, though the term is specifically defined on page 755 (PDF 764) in the context of question 50 as being "the selective breeding of plants and animals that possess desired traits." Sections 18.1, 18.2, and 18.3 in Chapter

population over time and is supported by multiple lines of evidence. **LO:** EVO-1.F. EVO-1.G **EK:** EVO-1.F.1, EVO-1.G.1	18 describe evidence for evolution, the formation of new species through both natural and artificial selection, and conditions that influence speciation rates. ***Suggested Skill: Statistical Tests and Representing and Describing Data*** *Investigation 1: Artificial Selection* in the AP® lab manual offers students the opportunity to investigate how extreme selection can change the expression of a quantitative trait in a population in one generation.
7.4 Population Genetics **Enduring Understanding:** 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.* **LO:** EVO-1.H, EVO-1.I, EVO-1.J **EK:** EVO-1.H.1, EVO-1.I.1, EVO-1.J.1	Sections 19.1 and 19.2 in Chapter 19 cover the randomness (e.g., mutation or genetic drift) that drives evolutionary processes and introduces how the Hardy–Weinberg equilibrium concept applies to population genetics. ***Suggested Skill: Questions and Methods*** While working through *Everyday Connection for AP® Courses* on page 770 in the text, students investigate the link between diseases, vaccines, and evolution. This activity is especially relevant with the reemergence of certain contagious diseases such as measles.
7.5 Hardy-Weinberg Equilibrium **Enduring Understanding:** 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.* Illustrative Examples from the CED *Graphical analysis of allele frequencies in a population.* **LO:** EVO-1.K, EVO-1.L **EK:** EVO-1.K.1, EVO-1.K.2, EVO-1.L.1, EVO-1.L.2	The Hardy–Weinberg principle of equilibrium and its equation are addressed in detail in Chapter 19, specifically in Sections 19.1 and 19.2, with a practice *Visual Connection* on page 772 (PDF 781). The equation provides mathematical evidence for an evolving population when allele frequencies change. Section 19.2 also addresses genetics that affects small populations. ***Suggested Skill: Statistical Tests, Data Analysis, and Concept Explanation*** *Investigation 2: Mathematical Modeling: Hardy–Weinberg* in the AP® lab manual offers students the opportunity to produce and analyze spreadsheets (mathematical models) to investigate the relationship between allele frequencies in populations of organisms and evolutionary change.
7.6 Evidence of Evolution **Enduring Understanding:** 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.* **LO:** EVO-1.M, EVO-1.N, EVO-2.B **EK:** EVO-1.M.1, EVO-1.N.1, EVO-1.N.2, EVO-2.B.1, EVO-2.B.2	Chapter 18, specifically Section 18.1, identifies evidence drawn from multiple disciplines, including the fossil record, morphology, biogeography, and molecular biology, that supports evolution through natural selection. ***Suggested Skill: Data Analysis and Concept Exploration*** *Investigation 3: Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST* in the AP® lab manual introduces students to bioinformatics and how this tool using DNA sequencing and cladogram construction can be used to determine evolutionary relationships and to better understand genetic disease.
7.7 Common Ancestry **Enduring Understanding:** EVO-2 *Organisms are linked by lines of descent from common ancestry.* **LO:** EVO-2.C **EK:** EVO-2.C.1	In Chapter 1, Section 1.2 describes characteristics shared by all living organisms. Sections 4.3 and 4.4 in Chapter 4 describe features that provide evidence for common ancestry of all eukaryotes. ***Suggested Skill: Concept Exploration*** The suggested activities and discussion questions presented in *Science Practices Connection for AP® Courses* on page 166 allow students to take a deep dive into the evidence supporting common ancestry.

7.8 Continuing Evolution **Enduring Understanding:** EVO-3 *Life continues to evolve within a changing environment.* **LO:** EVO-3.A **EK:** EVO-3.A.1, EVO-3.A.2	Sections 18.2 and 18.3 in Chapter 18 of the text describe evidence, such as antibiotic-resistant bacteria and the emergence of new diseases, to support the idea that life continues to evolve within a changing environment. ***Suggested Skill: Methodology and Data Analysis*** *Investigation 8: Biotechnology: Bacterial Transformation* in the AP® lab manual offers students the opportunity to use genetic engineering techniques to manipulate heritable information by introducing antibiotic resistance in bacteria (transformation). Students ask questions, design and implement an investigation, collect and analyze data, and draw conclusions from data while connecting previously studied concepts including cell structure, enzymes, and the operon model of the regulation of gene expression.
7.9 Phylogeny **Enduring Understanding:** EVO-3 *Life continues to evolve within a changing environment.* **LO:** EVO-3.B, EVO-3.C **EK:** EVO-3.B.1, EVO-3.C.1, EVO-3.C.2, EVO-3.C.3	Section 1.2 in Chapter 1 introduces phylogenetic trees and how they can be used to graphically show evolutionary relationships among species. Sections 20.1, 20.2, and 20.3 in Chapter 20 describe more comprehensive classification schemes and cladogram and phylogenetic-tree construction. ***Suggested Skill: Concept Exploration and Visual Representations*** The figures in the *Visual Connection* found on page 823 and 824 in the text provide visual representations of evolutionary relationships among different organisms with questions to help students interpret these representations and construct similar ones. ***Suggested Skill: Concept Exploration and Visual Representations*** *Investigation 3: Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST* in the AP® lab manual introduces students to bioinformatics and how this tool using DNA sequencing and cladogram construction can be used to determine evolutionary relationships and to better understand genetic disease. This investigation has many applications that are described in *Science Practices Connection for AP® Courses* on page 826 of the OpenStax text.
7.10 Speciation **Enduring Understanding:** EVO-3 *Life continues to evolve within a changing environment.* **LO:** EVO-3.D, EVO-3.E, EVO-3.F **EK:** EVO-3.D.1, EVO-3.D.2, EVO-3.E.1, EVO-3.E.2, EVO-3.F.1, EVO-3.F.2, EVO-3.F.3 Illustrative Examples from the CED • Hawaiian *Drosophila* • Caribbean *Anolis* • Apple maggot *Rhagoletis*	Sections 18.2 and 18.3 in Chapter 18 describe the conditions under which new species arise within a changing environment, including reproductive isolation, divergent evolution, adaptive radiation, and sympatric or allopatric speciation. ***Suggested Skill: Concept Exploration and Visual Representations*** The *Visual Connection* diagrams on pages 744 and 745 and the questions based on the diagrams address speciation, hybrid zones, reproductive barriers, hybrid fitness, and the difference between punctuated equilibrium and gradual speciation. ***Suggested Skill: Concept Exploration and Visual Representations8*** on page 740 in the text asks students to create a visual representation to explain how island chains provide ideal conditions for allopatric and adaptive radiation to occur. The included *Think About It* scenarios also provide real-world relevance to the concept of

	speciation and continuing evolution.
7.11 Extinction **Enduring Understanding:** **EVO-3** *Life continues to evolve within a changing environment.* **LO:** EVO-3.G, EVO-3.H, EVO-3.I, EVO-3.J **EK:** EVO-3.G.1, EVO-3.G.2, EVO-3.H.1, EVO-3.I.1, EVO-3.J.1	In Chapter 38, Sections 38.1, 38.2, 38.3, and 38.4 address multiple factors, both natural and those attributed to human activity, that can affect biodiversity and lead to species endangerment and extinction. Discussion about the effect or effects of climate change on biodiversity and extinction rates on pages 1752–1753 (PDF 1763-1764) is particularly relevant. ***Suggested Skill: Concept Exploration, Questions and Methods, and Argumentation*** The *Science Practices Connection for AP® Courses* on page 1752 in the text asks students to investigate the potential effects of introducing nonnative species into established communities in their local environment or environments.
7.12 Variations in Populations **Enduring Understanding:** **SYI-3** *Naturally occurring diversity among and between components within biological systems affects interactions with the environment.* **LO:** SYI-3.D **EK:** SYI-3.D.1 Illustrative Examples from the CED • *California condors* • *Black-footed ferrets* • *Potato blight* • *Antibiotic resistance in bacteria*	Section 38.1 in Chapter 38 describes how phenotypic variation resulting from genetic variation affects population dynamics and fitness within a changing environment. Diverse populations are more resilient to environmental change. ***Suggested Skill: Concept Exploration and Argumentation*** Ask students to provide scientific evidence to support the claim that global climate change can affect species diversity on Earth and that populations with more variation have a better chance of survival in a changing environment.
7.13 Origin of Life on Earth **Enduring Understanding:** **SYI-3** *Naturally occurring diversity among and between components within biological systems affects interactions with the environment.* **LO:** SYI-3.E **EK:** SYI-3.E.1, SYI-3.E.2	Section 3.1 of Chapter 3, specifically pages 88 and 91 (PDF 97 and 100), describes the abiogenesis theory (organic precursors of complex biological molecules were present on primitive Earth and aggregated to form the earliest form of life), which might explain the origin of life. Information in Section 3.2 describes how complex polymers necessary for life functions form from monomers. Information in Sections 22.1 (Chapter 22) and Section 4.2 (Chapter 4), explains why scientists think that archaea were the first organisms to evolve in the conditions of primitive Earth, including an anaerobic environment. ***Suggested Skill: Concept Exploration and Questions and Methods*** The *Everyday Connection* on page 91 in the text describes the Miller–Urey model that led to the theory that organic molecules could have come together to form the earliest form of life about 3.5 billion years ago. The *Think About It* questions from the *Science Practices Connection for AP® Courses*, also on page 91, ask students to explain how this model supports the abiogenesis theory about the origin of life on Earth. ***Suggested Skill: Concept Exploration and Questions and Methods*** The *Science Practices Connection for AP® Courses* found on page 893 in the text links the Miller–Urey theory to other ideas about the origin of life on Earth and asks students to investigate other theories about life's origins and evaluate the evidence that may or may not

	support these alternative theories (e.g., life arrived from an extraterrestrial object).

Unit 8: Ecology

10-15% AP Exam Weighting, ~18-21 Class Periods

The Big Ideas covered in Unit 8 include the following:

BIG IDEA 1: *Evolution* EVO
- How does diversity among and between species in a biological system affect the evolution of species within the system?

BIG IDEA 2: *Energetics* ENE
- How does the acquisition of energy relate to the health of a biological system?
- How do communities and ecosystems change, for better or worse, due to biological disruption?

BIG IDEA 3: *Information Storage and Transmission* IST
- How does a disruption of a biological system affect genetic information storage and transmission?

BIG IDEA 4: *Systems Interactions* SYI
- How do species interactions affect the survival of an ecosystem?

Unit 8 Topics	Suggested OpenStax Sections/Pages
8.1 Responses to the Environment **Enduring Understanding: ENE-3** *Timing and coordination of biological mechanisms involved in growth, reproduction, and homeostasis depend on organisms responding to environmental cues.* **Enduring Understanding: IST-5** *Naturally occurring diversity among and between components within biological systems affects interactions with the environment.* **LO:** ENE-3.D, IST-5.A **EK:** ENE-3.D.1, ENE-3.D.2, IST-5.A.1, IST-5.A.2, IST-5.A.3 <ins>Illustrative Examples from the CED</ins> • *Nocturnal and diurnal activity* • *Fight-or-flight responses* • *Pack behavior in animals* • *Courtship and mating behaviors* • *Predator warning* ***Exclusion Statement:*** *No specific behavioral or physiological mechanism is required for teaching this concept. The details of the various communications and community behavioral systems are beyond the scope of the course and the AP®*	Multiple chapters and sections of the text address concepts related to ecology and the interactions among organisms and their environments, including Sections 6.1, 9.2, 9.4, 21.2, 35.1, 35.2, 35.3, 35.4, 35.5, 36.1, 36.2, 36.3, 36.4, and 36.5. All of Chapter 35 is devoted to how organisms perceive and respond to environmental changes and communicate this information. Response to environmental change is crucial for natural selection and survival. Section 35.5 addresses the effects of global climate change on ecosystems. All sections in Chapter 36 address concepts revolving around population and community ecology. ***<ins>Suggested Skill: Questions and Methods and Data Analysis</ins>*** *Investigation 11: Transpiration* in the AP® lab manual allows students to investigate factors, including environmental variables, that affect the rate of transpiration in plants. After students investigate the relationships among leaf surface area, number of stomata, and the rate of transpiration, they design and implement experiments to explore the effects of other environmental factors, such as temperature. ***<ins>Suggested Skill: Questions and Methods and Data Analysis</ins>*** In Investigation 12: *Fruit Fly Behavior* in the AP® lab manual, students explore environmental factors that trigger behavioral responses in fruit flies, identifying possible patterns and

Exam.	relationships between environmental factors and a living organism. Students design and implement controlled experiments.
8.2 Energy Flow Through Ecosystems **Enduring Understanding: SYI-3** *Naturally occurring diversity among and between components within biological systems affects interactions with the environment.* **LO:** ENE-1.M, ENE-1.N, ENE-1.O **EK:** ENE-1.M.1, ENE-1.N.1, ENE-1.N.2, ENE-1.O.1, ENE-1.O.2 Illustrative Examples from the CED ● *Seasonal reproduction in animals and plants* ● *Food chains or webs*	Concepts related to strategies for capture and transfer in ecosystems are discussed in multiple chapters and sections of the text: Sections 6.1, 6.3 (bioenergetics and energy transfer); 7.1, 7.2, 7.3, 7.4, 7.5 (cellular respiration); 8.1, 8.2, 8.3 (photosynthesis); and 24.3 (thermoregulation in endotherms and ectotherms). All of Chapter 37 is devoted to energy dynamics in ecosystems: 37.1 (biotic and abiotic components and food chains), 37.2 (productivity and ecological pyramids), and 37.3 (biogeochemical cycles). ***Suggested Skill: Argumentation*** The *Visual Connection* found on page 1693 asks students to interpret a visual model of energy flow through an ecosystem and present an argument based on evidence from the model that supports the claim that the value for gross primary productivity equals the value for total heat and respiration. ***Suggested Skill: Questions and Methods and Data Analysis*** *Investigation 10: Energy* in the AP® lab manual allows students to investigate factors that govern energy capture, allocation, storage, and transfer between producers and consumers in a terrestrial ecosystem. After asking questions, students investigate answers by carrying out an independent research project.
8.3 Population Ecology **Enduring Understanding: SYI-3** *Naturally occurring diversity among and between components within biological systems affects interactions with the environment.* **LO:** SYI-1.G **EK:** SYI-1.G.1, SYI-1.G.2	Chapter 36 is devoted to population dynamics in an ecosystem, including applications of equations for determining population growth and the factors that influence this growth. Specifically, Sections 36.1 and 36.2 discuss interactions between organisms within a population and with the environment and mathematical methods to model population dynamics. Components of the equations for population growth rate and exponential growth rate are explained on pages 1606–1607 (PDF 1615-1616. ***Suggested Skill: Representing and Describing Data*** The *Visual Connection* on pages 1609–1610 asks students to analyze and draw conclusions from several graphs representing differences in population growth and the reasons for these differences. Also relevant is the *Science Practices Connection for AP® Courses* on page 1695 (PDF 1704).
8.4 Effect of Density of Populations **Enduring Understanding: SYI-3** *Naturally occurring diversity among and between components within biological systems affects interactions with the environment.* **LO:** SYI-1.H **EK:** SYI-1.H.1, SYI-1.H.2	Chapter 36, which is about population and community ecology, contains information about factors, such as resource availability, that affect population density: 36.1 (population size and density), 36.3 (exponential and logistic growth and the applicable mathematical equations), and 36.4 (density-dependent and density-independent factors that influence carrying capacity). ***Suggested Skill: Statistical Tests and Data Analysis*** The *Visual Connection* on pages 1609–1610 (PDF 1618-1619) asks students to analyze and draw conclusions from several

	graphs representing differences in population growth and the reasons for these differences. Also relevant is the *Science Practices Connection for AP® Courses* section *Think About It* on page 1608 (PDF 1617), which asks students to describe the various components of the J-shaped curve of logistic growth.
8.5 Community Ecology **Enduring Understanding:** **SYI-3** *Naturally occurring diversity among and between components within biological systems affects interactions with the environment.* **LO:** ENE-4.A, ENE-4.B, ENE-4.C **EK:** ENE-4.A.1, ENE-4.B.1, ENE-4.B.2, ENE-4.B.3, ENE-4.B.4, ENE-4.C.1	Chapter 36 is rich with information about community dynamics in an ecosystem: 36.1 (species diversity and distribution as well as population research methods), 36.6 (species richness and diversity and factors that can influence each), and 36.6 (species interactions, such as predator-prey, herbivory, and symbiotic relationships and group behaviors, such as communication and altruism). Sections 37.1 and 37.2 in Chapter 37 discuss energy dynamics in ecosystems, including trophic levels. Although the equation for Simpson's Diversity Index is not described in the text, students should be able to understand and manipulate the components in the equation based on the mathematical models presented in 36.1 (species diversity and distribution). ***Suggested Skill: Statistical Tests and Data Analysis*** The *Science Practice Connection for AP® Courses* on page 1643 in chapter 36 presents a scenario with data to think about and analyze. Data is drawn from a study investigating genetic variability in Trinidad guppies. After reading the study, students respond to several questions about the relationship between coloration and predation.
8.6 Biodiversity **Enduring Understanding:** **SYI-3** *Naturally occurring diversity among and between components within biological systems affects interactions with the environment.* **LO:** SYI-3.F, SYI-3.G **EK:** SYI-3.F.1, SYI-3.F.2, SYI-3.G.1, SYI-3.G.2	Concepts related to the importance of biodiversity and the interactions of species with the environment are discussed in multiple chapters and sections of the text: 18.1 (variation and natural selection), 19.2 (genetic and environmental variance, genetic drift, and bottlenecks), 35.1 (ecosystem ecology), 35.2 (biogeography and biome diversity), and 36.6 (keystone species). These sections also describe the effects of removal or addition of components to an ecosystem, such as by the introduction of exotic species or human activity. ***Suggested Skill: Argumentation*** The *Visual Connection* on page 1533 provides students with a graph to interpret and asks them to connect the world's biomes with temperature and amount of precipitation and then make predictions about the effects of change, such as climate change, on the biodiversity of these regions.
8.7 Disruptions to Ecosystems **Enduring Understanding:** **SYI-3** *Naturally occurring diversity among and between components within biological systems affects interactions with the environment.* **LO:** EVO-1.O, SYI-2.A, SYI-2.B, SYI-2.C **EK:** EVO-1.O.1, EVO-1.O.2, SYI-2.A.1, SYI-2.A.2, SYI-2.B.1, SYI-2.B.2, SYI-2.C.1 Illustrative Examples from the CED ● *Kudzu and zebra mussels*	Concepts related to the consequences of disruptions to ecosystems appear in multiple chapters and sections of the text: 18.1 (adaptation, natural selection, and geological changes), 19.2 (mutations and genetic variation), 35.5 (biogeographical changes and global climate change), 36.6, 36.7 (competition and cooperation, altruism, behaviors, and communication), and 38.3 (invasive or exotic species). Sections 36.5 and 38.3 call out the consequences and threats of human population growth and the negative impacts of human activity, such as deforestation and industrialization on biodiversity. Section 38.2 discusses the importance of maintaining and protecting the earth's biodiversity. ***Suggested Skill: Statistical Tests and Data Analysis***

• *Dutch elm disease, potato blight, and smallpox* • *Global climate change, logging, urbanization, and monocropping* • *El Niño, continental drift, and meteor impact on dinosaurs*	The *Evolution Connection* on page 1565 (*Global Decline of Coral Reefs*) asks students to describe the threats of climate change and human activity on coral reefs based on scientific data. ***Suggested Skill: Argumentation*** The *Everyday Connection* on page 1633 asks students to evaluate the effects of invasive or exotic species on ecosystems. The *Science Practices Connection for AP® Courses* on page 1752 takes this concept to a deeper level by asking students to use their local environment or environments to make predictions about the effect or effects of introducing nonnative species.

*The OpenStax team recognizes and thanks **Julianne Zedalis**, lead author of the OpenStax™ AP® Biology text and Balgrosky-Hinshaw Chair of Biology at the Bishop's School (La Jolla, CA), for her assistance in preparing this resource.*

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