AP® Biology

Course Planning and Pacing Guide 3

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Welcome to the AP® Biology Course Planning and Pacing Guides

This guide is one of four Course Planning and Pacing Guides designed for AP® Biology teachers. Each provides an example of how to design instruction for the AP course based on the author's teaching context (e.g., demographics, schedule, school type, setting).

The Course Planning and Pacing Guides highlight how the components of the *AP Biology Curriculum Framework* — the learning objectives, course themes, conceptual understandings, and science practices — are addressed in the course. Each guide also provides valuable suggestions for teaching the course, including the selection of resources, instructional activities, laboratory investigations, and assessments. The authors have offered insight into the *why* and *how* behind their instructional choices — displayed in callout boxes along the right side of the individual unit plans — to aid in course planning for AP Biology teachers. Additionally, each author explicitly explains how he or she manages course breadth and increases depth for each unit of instruction.

The primary purpose of these comprehensive guides is to model approaches for planning and pacing curriculum throughout the school year. However, they can also help with syllabus development when used in conjunction with the resources created to support the AP Course Audit: the Syllabus Development Guide and the four Annotated Sample Syllabi. These resources include samples of evidence and illustrate a variety of strategies for meeting curricular requirements.

Contents

Instructional Setting

Castle Park High School
Chula Vista, California

School	Castle Park High School is one of 13 high schools in the largest secondary district in California. It is a public school (grades 9–12) located in the southern portion of the city of Chula Vista.
Student population	Enrollment of approximately 1,600 students in grades 9–12: • 89 percent Hispanic • 4 percent Caucasian • 3 percent African American • 2 percent Filipino • 1 percent Asian American • 1 percent Pacific Islander
	• 72 percent of students receive free or reduced-price lunches • 77 percent of students graduate • 67 percent of students continue their education at a postsecondary institution
Instructional time	The school year begins in mid-July and ends the first week of June. Prior to the AP Biology Exam, there are 165 instructional and lab days combined. There is one 90-minute block lab period per week, three 50-minute periods per week, and a 50-minute intervention period, totaling approximately 5 hours per week. The intervention period is held once a week as an opportunity for students to make up exams, labs, and/or homework. Additional intervention time: • 20 hours of after-school, fall- and spring-break review sessions for the AP Biology Exam, as well as in-class exams • 10 hours of Saturday and in-class review sessions for the AP Biology Exam

Student preparation	AP® Biology is offered to juniors and seniors. Prerequisites: Students take honors biology or biology in the ninth grade, and honors chemistry or chemistry in the 10th grade. Students must pass both of these classes with a C or better.
Textbooks and lab manuals	Campbell, Neil A., and Jane B. Reece. *Biology*. 8th ed. San Francisco: Pearson Benjamin Cummings, 2008 Campbell, Neil A., and Jane B. Reece. *AP Biology Lab Manual*. New York: The College Board, 2001. *AP Biology Investigative Labs: An Inquiry-Based Approach*. New York: The College Board, 2012. *AP Biology Lab Manual for Teachers*. Burlington, NC: Carolina Biological Supply Company, 2006. *AP Biology Lab Manual for Students*. Burlington, NC: Carolina Biological Supply Company, 2006.

Overview of the Course

Castle Park High School champions academic excellence and personal success by offering rigorous and advanced classes to a community of diverse learners. AP Biology, a one-year course offered to juniors and seniors, seeks to motivate students to succeed in higher education and the world of scientific work. Scientific inquiry, conceptual understanding, and the application of knowledge are at the heart of this course:

- The components of the *AP Biology Curriculum Framework* (i.e., big ideas, enduring understandings, and learning objectives) are integrated with science practices to achieve conceptual understanding and facilitate scientific inquiry and reasoning.
- Twenty-five percent of instructional time is dedicated to student-directed, inquiry-based lab investigations and activities, which are conducted to deepen conceptual understandings and provide opportunities for students to practice science.
- The curriculum is organized with a focus on instructional strategies that scaffold learning. Student-learning activities are planned around the difficulty of the content or the students' prior knowledge.
- Formative and summative assessments are used for continuous feedback between me, the students, and other teachers via personal contact and/or online communication.

Because of the diverse student body, a variety of guiding principles and instructional strategies are employed. Differentiated instruction is common in not only the AP Biology course, but also throughout our school. This type of instruction allows teachers to use students' prior knowledge and individual learning styles to design instruction which best meets the students' learning needs. For example, Cornell notes, interactive notebooks, and mini-posters are just a few of the research-based strategies used to scaffold learning. Other instructional practices that have been successful with regard to differentiating instruction include:

- direct teacher instruction via 20- to 30-minute lectures to present difficult topics and address student misconceptions
- open class discussions that encourage further inquiry and sharing of ideas and opinions
- scaffolding of smaller concepts to bigger ones through the use of:
  - graphic organizers that build academic vocabulary
  - modeling and sequencing of activities
  - prompts, cues, hints, links, partial solutions, and guides
  - cooperative-learning strategies, pairing advanced learners with developing ones, or creating small-group settings
  - apprenticeship models, whereby expert students model activities, provide peer learners with advice and examples, and guide them until they can complete the task independently
  - academic language strategies, using sentence starters to help students communicate orally or in writing so that they can express their understanding of the curriculum

To assess student understanding and progress, a variety of assessment instruments are used:

- Diagnostic assessments help me, as the teacher, better understand students' prior knowledge and misconceptions. For example, concept maps or mind maps are used to gauge students' understanding at the beginning and end of each unit.
- Formative assessments allow me to check for student understanding during the lesson and can be done orally with the entire class, in small-group settings, and/or individually via discussion with the particular student. This type of assessment allows me to provide feedback to students and to inform or modify subsequent instructional activities accordingly. For example, during mini-poster presentations, as I go around the room monitoring student discussion groups, I listen to conversations and constructively correct misconceptions or pose questions to groups of students or to the class as a whole to refocus and correct misunderstandings.
- Summative assessments are essential in determining the collective understanding of my students. Examples include multiple-choice questions, short- and free-constructed responses, and student-directed and inquiry-based lab investigations.

I strive to create a safe and nurturing environment — one that reflects respect, integrity, trust, and caring — in order to best support students as they develop the skills and knowledge they need to be successful in college as well as develop into responsible citizens and lifelong learners.

Big Ideas and Science Practices

AP Biology Big Ideas

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

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

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

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

Science Practices for AP Biology

A practice is a way to coordinate knowledge and skills in order to accomplish a goal or task. The science practices enable students to establish lines of evidence and use them to develop and refine testable explanations and predictions of natural phenomena. These science practices capture important aspects of the work that scientists engage in, at the level of competence expected of AP Biology students.

Science Practice 1: The student can use representations and models to communicate scientific phenomena and solve scientific problems.

1.1 The student can *create representations and models* of natural or man-made phenomena and systems in the domain.

1.2 The student can *describe representations and models* of natural or man-made phenomena and systems in the domain.

1.3 The student can *refine representations and models* of natural or man-made phenomena and systems in the domain.

1.4 The student can *use representations and models* to analyze situations or solve problems qualitatively and quantitatively.

1.5 The student can *reexpress key elements* of natural phenomena across multiple representations in the domain.

Science Practice 2: The student can use mathematics appropriately.

2.1 The student can *justify the selection of a mathematical routine* to solve problems.

2.2 The student can *apply mathematical routines* to quantities that describe natural phenomena.

2.3 The student can *estimate numerically* quantities that describe natural phenomena.

Science Practice 3: The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.

3.1 The student can *pose scientific questions*.

3.2 The student can *refine scientific questions*.

3.3 The student can *evaluate scientific questions*.

Science Practice 4: The student can plan and implement data collection strategies appropriate to a particular scientific question.

4.1 The student can *justify the selection of the kind of data* needed to answer a particular scientific question.

4.2 The student can *design a plan* for collecting data to answer a particular scientific question.

4.3 The student can *collect data* to answer a particular scientific question.

4.4 The student can *evaluate sources of data* to answer a particular scientific question.

Science Practice 5: The student can perform data analysis and evaluation of evidence.

5.1 The student can *analyze data* to identify patterns or relationships.

5.2 The student can *refine observations and measurements* based on data analysis.

5.3 The student can *evaluate the evidence provided by data sets* in relation to a particular scientific question.

Science Practice 6: The student can work with scientific explanations and theories.

6.1 The student can *justify claims with evidence*.

6.2 The student can *construct explanations of phenomena based on evidence* produced through scientific practices.

6.3 The student can *articulate the reasons that scientific explanations and theories are refined or replaced*.

6.4 The student can *make claims and predictions about natural phenomena* based on scientific theories and models.

6.5 The student can *evaluate alternative scientific explanations*.

Science Practice 7: The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

7.1 The student can *connect phenomena and models* across spatial and temporal scales.

7.2 The student can *connect concepts* in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

Managing Breadth and Increasing Depth

Unit	Managing Breadth	Increasing Depth
Unit 1: Ecology	Ecology is addressed at the beginning of the school year. During the summer prior to taking the AP Biology course, students must complete a multiday homework assignment consisting of various activities and research components focused on ecology. This approach allows me to save about three days of instruction, since we review and correct this assignment during the first couple of school days. Also, since I no longer teach classification (e.g., a march through the phyla), I save approximately one week of instruction.	As a result of not teaching classification, I can focus on conceptual understanding in my ecology unit. I begin by selecting some essential knowledge pieces from big idea 2 which align with Campbell and Reece, Chapters 51–55, and slowly integrate several essential knowledge pieces from big idea 4. For example, I can make connections regarding how all biological systems are affected by complex biotic and abiotic interactions and how these interactions possess complex properties. The additional instructional time allows me to use various examples in helping students explain and justify these interactions across cells and organisms, populations, communities, and ecosystems.
Unit 2: Evolution	In the past, a significant amount of my instructional time (approximately one week) was spent on organism diversity and classification, and most of that time my students spent memorizing, and trying to retain, the taxonomy of organisms. Now when I teach evolution, my focus is on the mechanisms of evolution, such as natural selection and its support from many disciplines. I now spend that one week of instruction focusing on phylogeny and the tree of life (Campbell and Reece, Chapter 26). A significant number of chapters have been eliminated from this unit. I do not have to teach Chapters 28–34, which cover protists, plant diversity, fungi, invertebrates, and vertebrates. These seven chapters include all the animal and plant diversity; removing them from the course saves a week of instruction.	The additional time for instruction on phylogenetic trees and scientific and mathematical models related to evolution gives students the opportunity to engage in activities in which they can pose scientific questions, construct cladograms, and/or analyze models of the origin of life and the biological processes of evolution.
Unit 3: Biochemistry	I don't teach Campbell and Reece, Chapter 2: "The Chemical Context of Life" unless my students' lack of prior knowledge in this area warrants it. I do a quick assessment activity by reviewing with a concept map (on which I will spend an additional day) but then continue on to Chapters 3–5, which discuss water, carbon, and macromolecules, for the biochemistry. This saves about two days of instruction.	Not teaching Chapter 2 affords me additional time to focus on biochemistry in Chapters 3–5. In this unit, three big ideas can be addressed. Specifically in Chapters 3 and 4, essential knowledge pieces, such as the exchange of matter between an organism and the environment and scientific evidence of the possible role that inorganic and organic precursors play in this exchange, can be combined.
Unit 4: Cells	In the past I taught cells/cell membrane and cell communication as separate units. Now, with the new curriculum framework, I combine them into one unit, thus helping my students make connections between big ideas and the learning of these concepts across domains. I teach pieces from multiple big ideas when I combine these two units. For example, when I teach cell membranes, I can incorporate cell-to-cell communication and the importance of proteins and molecules on the membrane for cell communication processes.	Because I have saved a few days on other units, I incorporate some of those days into the cell unit. The additional time allows me to go into depth, not just in teaching the structure and function of cells or of the membrane but in making connections with cell communication. Cell communication is not an easy concept to teach, but by incorporating the topic into this unit, I can help students observe the relevance in structure and function of cells, cell membranes, and cell signaling pathways. The topic of cell communication can be difficult for some students. This is when I take advantage of the extra time, to reinforce difficult and connecting concepts.
Unit 5: Enzymes and Metabolism	Cellular respiration and photosynthesis may seem confusing topics to teach together, but using them to compare and contrast energy processes and strategies helps students understand the ecology, evolution, and effects on all organisms. In this unit I added resource acquisition and transport in vascular plants, as a way to connect cell membrane transport, metabolism, photosynthesis, and transpiration, thus connecting two big ideas (2 and 4), and saved approximately four days of instruction.	Previously, I had my students memorize the steps in photosynthesis and cellular respiration. However, since memorization of such factoids is now unnecessary (conceptual understanding here is the key), I continue to teach these two processes but now focus on major concepts (i.e., how organisms utilize free energy to grow, reproduce, and maintain homeostasis). The four additional days enable students to engage in an in-depth examination of photosynthesis and cellular respiration by exploring the processes.

Unit	Managing Breadth	Increasing Depth
Unit 6: Plant and Animal Structure and Function	A significant amount of content that my students once had to memorize, such as kingdoms and morphology of plants and animals, is reduced or eliminated. I can now spend more time on Campbell and Reece, Chapter 40: "Basic Principles of Animal Form and Function." By not teaching six chapters from the plant and animal units of the textbook, I save approximately eight instructional days.	As I focus on Chapter 40, I can make several connections between essential knowledge 2.A.1 in the curriculum framework, Unit 5 (Enzymes and Metabolism), and organisms' use of free energy to maintain body temperature and metabolism. I also use the extra instructional time to help my students observe links between the ways in which changes in energy can affect population size and/or disrupt ecosystems. As a result, I can teach more content and concepts in less time.
Unit 7: Heredity	In this unit I generally spend more time on Mendelian genetics, because students have a difficult time calculating and analyzing problems, especially the application of mathematical reasoning to problems based on probability and statistics. No instructional time is saved in this unit.	Giving students adequate time to analyze data and calculate trends gives them a chance to observe patterns they can use in drawing logical conclusions.
Unit 8: Molecular Genetics	No instructional time is saved in this unit. Actually, students require more time, specifically two weeks, to understand difficult concepts such as the flow of information from gene to protein. I include biotechnology to enhance instruction, which gives students the opportunity to learn molecular genetics by using scientific research techniques. The inquiry labs in the new *AP Biology Investigative Labs: An Inquiry-Based Approach*, specifically Lab 8 (Biotechnology: Bacterial Transformation) and Lab 9 (Biotechnology: Restriction Enzyme Analysis of DNA), help students manage the breadth of this unit.	The additional time for this unit enables students to explore the difficult concepts of the structure and function of DNA and RNA. I have more time to explain how a specific DNA or RNA sequence can cause changes in gene expression. I then connect this principle to ecology or evolution of the organism. This approach is a great way to revisit the concepts in Unit 1 as preparation for the AP Biology Exam.

Unit 1: Ecology

Laboratory Investigations

- *AP Biology Lab Manual* (2001), Lab 11: Animal Behavior (transitioned to be inquiry based and student directed)
- Alien Plant Invasion: A Field Study Project at Saguaro National Park: Sample Study Plots on the Football Field
- *AP Biology Lab Manual* (2001), Lab 12: Dissolved Oxygen and Aquatic Primary Productivity (transitioned to be inquiry based and student directed)

Estimated Time: *15 days*

Essential Questions: ▼ How do organisms use free energy to maintain organization, growth, and reproduction? ▼ How do changes in free energy available to organisms result in changes in population size and disruptions to an ecosystem? ▼ How are biological systems from cells to organisms to populations, communities, and ecosystems affected by complex biotic and abiotic interactions involving exchange of matter and free energy? ▼ In what ways do communities interact within their environments that result in the movement of matter and energy? ▼ In what ways do interactions between and within populations influence patterns of species distribution and amount of local and global ecosystem changes over time? ▼ How does the diversity of a species within an ecosystem influence the stability of the ecosystem?

Learning Objectives	Materials	Instructional Activities and Assessments
Refine scientific models and questions about the effect of complex biotic and abiotic interactions on all biological systems, from cells and organisms to populations, communities, and ecosystems. [LO 2.22, SP 1.3, SP 3.2]	Campbell and Reece, Chapter 51: "Animal Behavior"; Chapter 52: "An Introduction to Ecology and the Biosphere"; Chapter 53: "Population Ecology"; Chapter 54: "Community Ecology"; and Chapter 55: "Ecosystems"	**Instructional Activity:** Students create a concept map based on prior knowledge of biotic and abiotic interactions of different biological systems. In groups of three, students work with 20 vocabulary terms and concepts (selected by me). Students write the terms and concepts on sticky notes and arrange them to create a concept map of their current understanding of ecology. While creating the concept maps, students pose scientific questions about the different interactions, and refine their maps based on their understandings. Part of this activity is teacher directed (i.e., the selection of vocabulary terms and concepts); however, it quickly segues into a more student-directed activity, as students work to create their concept maps.
Justify scientific claims, using evidence, to describe how timing and coordination of behavioral events in organisms are regulated by several mechanisms. [LO 2.39, SP 6.1]	Campbell and Reece, Chapter 51: "Animal Behavior" *AP Biology Lab Manual* (2001), Lab 11: Animal Behavior (transitioned to be inquiry based and student directed)	**Instructional Activity:** In the transitioned Animal Behavior Lab, students design their own experiment using pill bugs to investigate and determine variables in the bugs' habitat that might affect their behavior. This lab investigation is student directed. The teacher acts as facilitator. Students record data, analysis, and conclusions in their lab notebooks.
Analyze data to support the claim that responses to information and communication of information affect natural selection. [LO 2.38, SP 5.1]		**Formative Assessment:** Students answer two short free-response questions based on the animal behavior lab, and their peers and I review their responses.
Connect concepts in and across domain(s) to predict how environmental factors affect responses to information and change behavior. [LO 2.40, SP 7.2]	Campbell and Reece, Chapter 51: "Animal Behavior" and Chapter 52: "An Introduction to Ecology and the Biosphere"	**Summative Assessment:** Students take a test on Campbell and Reece, Chapters 51–52 and corresponding science practices (as determined by the related learning objectives). This test consists of 15 multiple-choice questions, one short response, and one lab-based question.

Building required knowledge by focusing on the vocabulary with a graphic organizer helps access prior knowledge. From each of the chapters, I select biological terms and concepts that students should know and be able to apply. I sometimes add a vocabulary word that encourages students to make connections with other big ideas. How students apply these terms and concepts allows me to assess their understanding, especially those students who are English language learners.

This lab provides an opportunity for students to "take charge" of an independent investigation at the beginning of the year, boosting confidence in their ability to design and conduct experiments.

I provide corrective and informative feedback via discussion on the assessment results. Subsequent instructional activities may be modified based on student responses to the questions.

This assessment addresses two essential questions guiding this unit:

- In what ways do interactions between and within populations influence patterns of species distribution and abundance of local and global ecosystems changes over time?
- How does the diversity of a species within an ecosystem influence the stability of the ecosystem?

Essential Questions: ▼ How do organisms use free energy to maintain organization, growth, and reproduction? ▼ How do changes in free energy available to organisms result in changes in population size and disruptions to an ecosystem? ▼ How are biological systems from cells to organisms to populations, communities, and ecosystems affected by complex biotic and abiotic interactions involving exchange of matter and free energy? ▼ In what ways do communities interact within their environments that result in the movement of matter and energy? ▼ In what ways do interactions between and within populations influence patterns of species distribution and amount of local and global ecosystem changes over time? ▼ How does the diversity of a species within an ecosystem influence the stability of the ecosystem?

Learning Objectives	Materials	Instructional Activities and Assessments
Design a plan for collecting data to show that all biological systems (cells, organisms, populations, communities, and ecosystems) are affected by complex biotic and abiotic interactions. [LO 2.23, SP 4.2, SP 7.2]	Campbell and Reece, Chapter 53: "Population Ecology" **Web** "Alien Plant Invasion: A Field Study Project at Saguaro National Park: Sample Study Plots on the Football Field"	**Instructional Activity:** In small groups, students designate an area of the school football field as a plot to make observations and then design and implement a study of interactions between organisms and their environment. One group might collect data on the number of weeds versus native grass populations, to explore the effects of alien species on native species, while another group investigates insect infestation. Students then read an article from the Saguaro National Park Field Study and compare the ways in which various biological systems can be affected by complex biotic and abiotic interactions. This activity is student directed and requires little teacher facilitation.
Analyze data to identify possible patterns and relationships between a biotic or abiotic factor and a biological system (cells, organisms, populations, communities, or ecosystems). [LO 2.24, SP 5.1]		**Formative Assessment:** Students analyze the data they collected from their football field plots and formulate hypotheses as to how the biological systems are affected by complex biotic and abiotic interactions. Students discuss their hypotheses with their peers, and they critique one another's ideas.

This activity is a great way to provide real-world relevance to concepts described in the classroom, using the campus as a living laboratory.

I monitor conversations and correct misconceptions regarding patterns or relationships.

Essential Questions: ▼ How do organisms use free energy to maintain organization, growth, and reproduction? ▼ How do changes in free energy available to organisms result in changes in population size and disruptions to an ecosystem? ▼ How are biological systems from cells to organisms to populations, communities, and ecosystems affected by complex biotic and abiotic interactions involving exchange of matter and free energy? ▼ In what ways do communities interact within their environments that result in the movement of matter and energy? ▼ In what ways do interactions between and within populations influence patterns of species distribution and amount of local and global ecosystem changes over time? ▼ How does the diversity of a species within an ecosystem influence the stability of the ecosystem?

Learning Objectives	Materials	Instructional Activities and Assessments
Justify the selection of the kind of data needed to answer scientific questions about the interaction of populations within communities. [LO 4.11, SP 1.4, SP 4.1] Apply mathematical routines to quantities that describe communities composed of populations of organisms that interact in complex ways. [LO 4.12, SP 2.2]	Campbell and Reece, Chapter 53: "Population Ecology," Concepts 53.1–53.5	**Instructional Activity:** To introduce the exponential and logistic models of population growth, I select examples in the textbook to explain how to use these mathematical routines to analyze data and make predictions about the effects of change in a community if data were to change. This activity takes place in a whole-class setting and is teacher guided.
		Formative Assessment: In a think-pair-share activity, students discuss with a partner the questions listed below. Students will share their answers with another group for review. 1. An important assumption of the mark-recapture method is that marked individuals have the same probability of being recaptured as unmarked individuals. Describe a situation in which this assumption might not be valid, and explain, with justification, how the estimate of population size would be affected. 2. Explain, with justification, why a constant rate of increase (r_{max}) for a population produces a growth graph that is J-shaped rather than a straight line. 3. When a farmer abandons a field and it is quickly colonized by fast-growing weeds, are these species more likely to be K-selected or r-selected species? Use evidence to explain and justify your answer.

Because of the high population of English language learners at my school, students begin by working in pairs. I provide sentence starters for discussion and walk around the room monitoring their conversations.

I monitor group interactions and provide feedback to groups as needed.

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Learning Objectives	Materials	Instructional Activities and Assessments
Predict the effects of a change in the community's populations on the community. [LO 4.13, SP 6.4] Use visual representations to analyze situations or solve problems qualitatively to illustrate how interactions among living systems and with their environment result in the movement of matter and energy. [LO 4.15, SP 1.4]	Campbell and Reece, Chapter 54: "Community Ecology" poster paper and markers	**Instructional Activity:** Students are provided with examples of complex food webs. In groups, students add arrows to show the transfer of energy within the food webs. Students then create their own food webs, but in their labeling they must detail three to five interspecific interactions that occur within their food webs, such as competition, predation, herbivory, symbiosis, parasitism, mutualism, and/or commensalism. Once their food webs are created, students make predictions (with justification) about what might happen if a component in the food web changes. For example, what are possible consequences if a disease kills most of the plants at the producer level, or a non-native species is introduced into the ecosystem?
		Formative Assessment: Students are provided with a rubric of the identifying items that will be used to evaluate the food webs. They will have the opportunity to peer review one another's work.

By creating food webs, students provide a visual representation of their understanding of complex interactions between biotic and abiotic components in the ecosystem. Sharing diagrams with peer groups should generate lively discussion and solutions to problems caused by changes in components in the system.

I provide corrective and informative feedback during the various phases of the food web creation. This feedback will guide student self-corrections of their reasoning and may result in modifications to their food webs.

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Learning Objectives	Materials	Instructional Activities and Assessments
Apply mathematical routines to quantities that describe interactions among living systems and their environment, which result in the movement of matter and energy. [LO 4.14, SP 2.2] Predict the effects of a change of matter or energy availability on communities. [LO 4.16, SP 6.4] Explain how biological systems use free energy based on empirical data that all organisms require constant energy input to maintain organization, to grow, and to reproduce. [LO 2.1, SP 6.2] Justify a scientific claim that free energy is required for living systems to maintain organization, to grow, or to reproduce, but that multiple strategies exist in different living systems. [LO 2.2, SP 6.1] Predict how changes in free energy availability affect organisms, populations, and ecosystems. [LO 2.3, SP 6.4]	Campbell and Reece, Chapter 55: "Ecosystems," Concepts 55.1–55.4 *AP Biology Lab Manual* (2001), Lab 12: Dissolved Oxygen and Aquatic Primary Productivity (transitioned to be inquiry based and student directed)	**Instructional Activity:** Dissolved Oxygen Lab: Primary Plant Productivity (transitioned from 2001 Lab 12: Dissolved Oxygen and Aquatic Primary Productivity). Students are guided by the teacher to investigate how algae grow in various environmental conditions and how to calculate the amount of oxygen produced under normal conditions. Based on the data obtained from the lab activity, students make predictions about how different environmental conditions might affect oxygen production and then design their own experiment, choosing variables that may affect the production of oxygen in other types of algae or plants of their choice. Students record data, analysis, and conclusions in their lab notebooks. **Formative Assessment:** Students give oral presentations explaining and justifying their experimental design, and articulating their results.
Use representations or models to analyze quantitatively and qualitatively the effects of disruptions to dynamic homeostasis in biological systems. [LO 2.28, SP 1.4] Explain how the distribution of ecosystems changes over time by identifying large-scale events that have resulted in these changes in the past. [LO 4.20, SP 6.3]	Campbell and Reece, Chapter 56: "Conservation Biology and Restoration Ecology," Concepts 56.1–56.4 Waterman and Stanley, *Biological Inquiry: A Workbook of Investigative Cases*, "Back to the Bay," pp. 106–118	**Instructional Activity:** Students recognize and explain (with justification) potential issues and major topics in the investigative case study "Back to the Bay." In this student-directed activity, students, after reading a hypothetical advertisement on gull distress calls, explore the behavior of gulls . Following their work on a series of activities and data analyses, students design an experiment to investigate the population growth in gulls and the impact of human activity on environmental conditions of Chesapeake Bay. Teachers act as facilitators in this activity.

This lab investigation can be transitioned to one that is more student-directed, in which class members design and conduct their own experiment. This approach will be a new experience for students not currently engaged in practicing science in this manner. Teacher guidance is paramount.

I provide corrective and informative feedback via discussion and modify the next instructional activities accordingly, if additional content review or deeper conceptual understanding is needed.

This workbook contains several inquiry-based activities with real-world relevance. Each activity begins with a case study designed to engage students.

Essential Questions: ▼ How do organisms use free energy to maintain organization, growth, and reproduction? ▼ How do changes in free energy available to organisms result in changes in population size and disruptions to an ecosystem? ▼ How are biological systems from cells to organisms to populations, communities, and ecosystems affected by complex biotic and abiotic interactions involving exchange of matter and free energy? ▼ In what ways do communities interact within their environments that result in the movement of matter and energy? ▼ In what ways do interactions between and within populations influence patterns of species distribution and amount of local and global ecosystem changes over time? ▼ How does the diversity of a species within an ecosystem influence the stability of the ecosystem?

Learning Objectives	Materials	Instructional Activities and Assessments
Predict consequences of human actions on both local and global ecosystems. [LO 4.21, SP 6.4] Make scientific claims and predictions about how species diversity within an ecosystem influences ecosystem stability. [LO 4.27, SP 6.4]	**Web** "Investigative Case 8: Back to the Bay"	**Instructional Activity:** Working in small groups, students choose from a variety of ethical papers on gull and human interactions to explain the consequences of human actions on ecosystems. Students then form larger groups to debate predictions based on scientific claims about the interactions of gulls and humans in our local San Diego area.
		Summative Assessment: Students take a 50-minute test containing 40 multiple-choice questions, two short-response questions, and one essay question. The two short-response questions are selected from ecological data, such as interpreting logistic or exponential predictions of growth patterns in given populations. The essay section asks students to select one of three questions.

Reading, discussing, and drawing conclusions based on ethical issues prior to analyzing our local ecological problems not only raises awareness but helps students retain concepts.

This summative assessment addresses the following essential questions:

- In what ways do communities interact within their environments that result in the movement of matter and energy?
- In what ways do interactions between and within populations influence patterns of species distribution and abundance of local and global ecosystems changes over time?
- How does the diversity of a species within an ecosystem influence the stability of the ecosystem?

Laboratory Investigations

- *AP Biology Investigative Labs* (2012), Investigation 1: Artificial Selection
- *AP Biology Investigative Labs* (2012), Investigation 3: Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST

Estimated Time: *15 days*

Essential Questions: ▼ How is natural selection a major mechanism of evolution, and in what ways does it act on phenotypic variations in a population? ▼ In what ways do organisms share many conserved core processes and features, and how do phylogenetic trees and cladograms graphically represent or model evolutionary history? ▼ What hypotheses exist with supporting scientific evidences, including mathematical models, about the natural origin of life on Earth? ▼ What changes in genotype may affect phenotypes that are subject to natural selection?

Learning Objectives	Materials	Instructional Activities and Assessments
Evaluate evidence provided by data from many scientific disciplines that support biological evolution. [LO 1.9, SP 5.3] Connect scientific evidence from many scientific disciplines to support the modern concept of evolution. [LO 1.12, SP 7.1]	Campbell and Reece, Chapter 22: "Descent with Modification: A Darwinian View of Life" **Web** *The Making of the Fittest: Natural Selection and Adaptation* (video and activity)	**Instructional Activity:** With little teacher facilitation, students watch a 10-minute video, *Natural Selection and Adaptation*, which focuses on research conducted on rock pocket mouse populations. Watching the video, students respond to several open-ended questions (to be discussed in small groups after the video). Students then analyze amino acid data described in the video and draw conclusions about the evolution of coat color phenotypes in different rock pocket mouse populations to explain natural selection through a single gene.
Design a plan to answer scientific questions regarding how organisms have changed over time, using information from morphology, biochemistry, and geology. [LO 1.11, SP 4.2] Construct and/or justify mathematical models, diagrams, or simulations that represent processes of biological evolution. [LO 1.13, SP 1.1, SP 2.1]	Campbell and Reece, Chapter 22: "Descent with Modification: A Darwinian View of Life," Concept 22.3	**Instructional Activity:** With little teacher facilitation, students complete a graphic organizer identifying characteristics in organisms that change over time — morphologically, biochemically, and geologically. Students then respond to the following from Concept Check 22.3: 1. Explain how the following statement is inaccurate: "Anti-HIV drugs have created drug resistance in the virus." 2. How does evolution account for (a) the similar mammalian forelimbs with different functions shown in Figure 22.17 and (b) the similar lifestyle of the two distantly related mammals shown in Figure 22.20?

The activity helps students activate their prior knowledge of evolution. It also helps to deepen students' understanding of how evolution is supported by amino acid data, in addition to fossil records or phenotype scientific data.

This activity allows students to visualize and devise responses to scientific questions based on scientific evidence that supports evolution.

Evolution

(continued)

Essential Questions: ▼ How is natural selection a major mechanism of evolution, and in what ways does it act on phenotypic variations in a population? ▼ In what ways do organisms share many conserved core processes and features, and how do phylogenetic trees and cladograms graphically represent or model evolutionary history? ▼ What hypotheses exist with supporting scientific evidences, including mathematical models, about the natural origin of life on Earth? ▼ What changes in genotype may affect phenotypes that are subject to natural selection?

Learning Objectives	Materials	Instructional Activities and Assessments
Convert a data set from a table of numbers that reflect a change in the genetic makeup of a population over time and apply mathematical methods and conceptual understandings to investigate the cause(s) and effect(s) of this change. [LO 1.1, SP 1.5, SP 2.2] Evaluate evidence provided by data to qualitatively and quantitatively investigate the role of natural selection in evolution. [LO 1.2, SP 2.2, SP 5.3] Apply mathematical methods to data from a real or simulated population to predict what will happen to the population in the future. [LO 1.3, SP 2.2]	Campbell and Reece, Chapter 23: "The Evolution of Populations" *AP Biology Investigative Labs* (2012), Investigation 1: Artificial Selection	**Instructional Activity:** Students investigate natural selection in Wisconsin Fast plants through several generations of plants. Students artificially select and continue to grow their plants, observing and recording qualitative data. Students then use the data to reflect on changes they observed from generation to generation. With their data, students quantitatively evaluate the Hardy-Weinberg calculations to predict what will happen to the population. This activity is teacher guided. **Formative Assessment:** Students create and present mini-posters that reflect the results, experimental protocol, methodology, and data collection of their Artificial Selection evolution lab. Mini-posters will be peer and teacher reviewed in groups of four.
Evaluate data-based evidence that describes evolutionary changes in the genetic makeup of a population over time. [LO 1.4, SP 5.3] Connect evolutionary changes in a population over time to a change in the environment. [LO 1.5, SP 7.1] Justify data from mathematical models based on the Hardy-Weinberg equilibrium to analyze genetic drift and the effects of selection in the evolution of specific populations. [LO 1.7, SP 2.1]	Buskirk and Gillen, *Inquiry in Action: Interpreting Scientific Papers*, Article 7: "Tracking the Long-Term Decline and Recovery of an Isolated Population"	**Instructional Activity:** The teacher provides Article 7: "Tracking the Long-Term Decline and Recovery of an Isolated Population." Students read the article, analyze the mathematical model of the data presented, and explain (with justifying evidence) any changes they see in the genetic makeup of the population over time.

This lab connects to concepts covered when exploring Mendelian genetics.

I provide corrective and informative feedback to the students, and use the information from their posters and our discussions to make decisions about next instructional steps.

While scientific articles can be a challenge for some English language learners, these materials provide a good opportunity for these students to learn and apply vocabulary while engaging in scientific inquiry.

Essential Questions: ▼ How is natural selection a major mechanism of evolution, and in what ways does it act on phenotypic variations in a population? ▼ In what ways do organisms share many conserved core processes and features, and how do phylogenetic trees and cladograms graphically represent or model evolutionary history? ▼ What hypotheses exist with supporting scientific evidences, including mathematical models, about the natural origin of life on Earth? ▼ What changes in genotype may affect phenotypes that are subject to natural selection?

Learning Objectives	Materials	Instructional Activities and Assessments
Make predictions about the effects of genetic drift, migration, and artificial selection on the genetic makeup of a population. [LO 1.8, SP 6.4] Use evidence to justify a claim that a variety of phenotypic responses to a single environmental factor can result from different genotypes within the population. [LO 4.25, SP 6.1] Use theories and models to make scientific claims and/or predictions about the effects of variation within populations on survival and fitness. [LO 4.26, SP 6.4]	Buskirk and Gillen, *Inquiry in Action: Interpreting Scientific Papers*, Article 7: "Tracking the Long-Term Decline and Recovery of an Isolated Population"	**Formative Assessment:** Using data from "Tracking the Long-Term Decline and Recovery of an Isolated Population" students predict (with justification) the effects of variation within prairie chicken populations on their survival and fitness.
Analyze data related to questions of speciation and extinction throughout the Earth's history. [LO 1.20, SP 5.1] Design a plan for collecting data to investigate the scientific claim that speciation and extinction have occurred throughout the Earth's history. [LO 1.21, SP 4.2]	Waterman and Stanley, Chapter 5: "Unveiling the Carboniferous"	**Instructional Activity:** With little teacher facilitation, students plan the design of a mural depicting the Carboniferous period. Before students can design the mural, they must research the scientific connection and make the design scientifically accurate. Students collect data about the types of organisms for the mural, observing the adaptations that contributed to the success of life on land during the Carboniferous period. Students then answer questions about speciation and extinction. In order for students to increase their understanding of the scientific accuracy of the relative sizes of the organisms to be used in the mural, they will be asked to collect additional data on the size of the fossils.

I provide corrective and informative feedback via discussion and modify subsequent instructional activities based on student understanding.

This type of activity allows students who have artistic talents to illustrate certain concepts and how they can apply to real-world situations.

Essential Questions: ▼ How is natural selection a major mechanism of evolution, and in what ways does it act on phenotypic variations in a population? ▼ In what ways do organisms share many conserved core processes and features, and how do phylogenetic trees and cladograms graphically represent or model evolutionary history? ▼ What hypotheses exist with supporting scientific evidences, including mathematical models, about the natural origin of life on Earth? ▼ What changes in genotype may affect phenotypes that are subject to natural selection?

Learning Objectives	Materials	Instructional Activities and Assessments
Use data from a real or simulated population(s), based on graphs or models of types of selection, to predict what will happen to the population in the future. [LO 1.22, SP 6.4] Justify the selection of data that address questions related to reproductive isolation and speciation. [LO 1.23, SP 4.1] Describe a model that represents evolution within a population. [LO 1.25, SP 1.2] Evaluate given data sets that illustrate evolution as an ongoing process. [LO 1.26, SP 5.3]	Campbell and Reece, Chapter 24: "The Origin of Species": • Figure 24.3 Inquiry (p. 489): "Does gene flow occur between widely separated populations?" • Figure 24.9 Inquiry (p. 495): "Can divergence of allopatric populations lead to reproductive isolation?" • Figure 24.12 Inquiry (p. 497): "Does sexual selection in cichlids result in reproductive isolation?"	**Formative Assessment:** In groups of three, students are assigned one of three types of "inquiry" experiments from the textbook. They will analyze the data/graphs from the experiment and address the following: 1. Summarize the experiment, including predictions and justification of the data selected for the experiment assigned to you. 2. If a variable was changed in the experiment, predict how this change would affect the evolution of that organism. 3. How does the data, as presented, help us understand the process of evolution in the particular organism? Students present their results and responses to the class for discussion.
Describe a scientific hypothesis about the origin of life on Earth. [LO 1.27, SP 1.2] Evaluate scientific questions based on hypotheses about the origin of life on Earth. [LO 1.28, SP 3.3] Describe the reasons for revisions of scientific hypotheses of the origin of life on Earth. [LO 1.29, SP 6.3]	Campbell and Reece, Chapter 25: "The History of Life on Earth" **Video** *Revealing the Origins of Life*	**Instructional Activity:** With little teacher facilitation, students watch a 30-minute NOVA video, *Revealing the Origins of Life*, that addresses the question, *Where did we come from?* Students take Cornell notes on the video and include answers to the following questions: 1. What are two scientific hypotheses that were mentioned in the video about current research on the origin of life? 2. What revisions to their hypotheses did the scientists make in order to continue their research, and why were the revisions made?

Such activities help students learn the concepts of evolution by looking at a variety of data and interpreting and predicting different models. I evaluate the presentations using a rubric and provide feedback to the students. This assessment helps me determine next instructional steps.

Essential Questions: ▼ How is natural selection a major mechanism of evolution, and in what ways does it act on phenotypic variations in a population? ▼ In what ways do organisms share many conserved core processes and features, and how do phylogenetic trees and cladograms graphically represent or model evolutionary history? ▼ What hypotheses exist with supporting scientific evidences, including mathematical models, about the natural origin of life on Earth? ▼ What changes in genotype may affect phenotypes that are subject to natural selection?

Learning Objectives	Materials	Instructional Activities and Assessments
Evaluate scientific hypotheses about the origin of life on Earth. [LO 1.30, SP 6.5] Evaluate the accuracy and legitimacy of data to answer scientific questions about the origin of life on Earth. [LO 1.31, SP 4.4] Justify the selection of geological, physical, and chemical data that reveal early Earth conditions. [LO 1.32, SP 4.1]	Origin of Life AP Biology Kit, Carolina Biological Supply Company	**Instructional Activity:** Students simulate the primeval conditions on Earth and investigate creating coacervates to explore their lifelike properties. Students examine various models of the origin of life, simulate Alexander Oparin's 1920 origin-of-life model, and design an investigation into the various environmental factors affecting coacervate formation and movement. Guided by me, students create their own hypotheses, designs, and methods of accurate and legitimate data collection. They then justify their data selections to support their hypotheses. **Formative Assessment:** Using a teacher-created rubric, students write formal lab reports and create PowerPoint presentations. These should include their hypotheses, design, and organization of data, in a table or graph, that justifies their investigative hypotheses of the origin of life created for their coacervates.
Pose scientific questions about a group of organisms whose relatedness is described by a phylogenetic tree or cladogram in order to (1) identify shared characteristics, (2) make inferences about the evolutionary history of the group, and (3) identify character data that could extend or improve the phylogenetic tree. [LO 1.17, SP 3.1]	Campbell and Reece, Chapter 26: "Phylogeny and the Tree of Life" *AP Biology Investigative Labs* (2012), Investigation 3: Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST	**Instructional Activity:** Students first formulate, test, and revise hypotheses to investigate and compare several genes sequences. At a computer with Internet access, students use an online bioinformatics program—Basic Local Alignment Search Tool (BLAST)— to analyze biological data, identify characteristics, and pose scientific questions about a group of organisms. Students also analyze patterns using morphological data and DNA analysis. Students then use the information to construct a cladogram to demonstrate an understanding of evolutionary patterns among groups of organisms. Initial components of this lab are teacher directed, with the more inquiry-based activities becoming student directed. Students record data, analysis, and conclusions in their lab notebooks.

When I use any of the commercial interactive lab kits for investigations, I make sure that I am "transitioning" all activities so that they are student directed and inquiry based, and that they support the learning objectives within the AP Biology Curriculum Framework.

I provide informative and corrective feedback via discussion and comments on the lab report. Subsequent lab communication projects may be modified based on the results of this lab report.

Introducing students to online data repositories and resources can be useful as they seek gene-sequencing data for various organisms.

Essential Questions: ▼ How is natural selection a major mechanism of evolution, and in what ways does it act on phenotypic variations in a population? ▼ In what ways do organisms share many conserved core processes and features, and how do phylogenetic trees and cladograms graphically represent or model evolutionary history? ▼ What hypotheses exist with supporting scientific evidences, including mathematical models, about the natural origin of life on Earth? ▼ What changes in genotype may affect phenotypes that are subject to natural selection?

Learning Objectives	Materials	Instructional Activities and Assessments
Create a phylogenetic tree or simple cladogram that correctly represents evolutionary history and speciation from a provided data set. [LO 1.19, SP 1.1] Evaluate evidence provided by a data set in conjunction with a phylogenetic tree or a simple cladogram to determine evolutionary history and speciation. [LO 1.18, SP 5.3]	Waterman and Stanley, Chapter 4: "Tree Thinking"	**Instructional Activity:** Students are provided a case study, "Tree Thinking," that shows meat samples being tested for whale, dolphin, shark, and even horse DNA. Students are introduced to the controversial black market in Asia on which U.S. Customs is cracking down. Students make morphological observations, identifying characteristics in *Dendrogrammaceae* (imaginary family of flowering plants) and record them on a spreadsheet. After constructing a cladogram suggesting relatedness among the taxa, students revise their cladogram based on primitive or derived characters.
		Formative Assessment: Students are provided with additional data and a phylogenetic tree. Using both, students respond to the following prompts based on evolutionary relatedness and speciation: 1. List three characters that you could observe in living whales that white-tailed deer or other even-toed ungulates do not seem to share. 2. Name a character you would expect to find in fossils of early whales that would provide evidence that whales have a common ancestor with other even-toed ungulates. 3. Which tree shows whales and hippos sharing the closest relationship? 4. After reviewing descriptions of various hypotheses, describe one of the hypotheses and explain what it tells us about the relationship between perissodactyls and artiodactyls.
		Summative Assessment: Students take a 50-minute test containing 20 multiple-choice questions, two short-response questions, and one essay question. The two short-response questions are selected from data representing evolutionary characteristics and phylogenetic trees. The essay question asks students to select one of three options.

Practice, practice, practice is the key for students in understanding how to create, understand, and interpret various types of data to create a phylogenetic tree.

I provide written feedback about students' trees, and we have a class discussion about the assignment. When students are practicing and completing phylogenetic tree problems, receiving immediate feedback via discussion and in written format helps them to refine their trees and to be certain that their tree representations are accurate.

This summative assessment addresses the following essential questions:

- How is natural selection a major mechanism of evolution, and in what ways does it act on phenotypic variations in a population?
- In what ways do organisms share many conserved core processes and features, and how do phylogenetic trees and cladograms graphically represent, or model, evolutionary history?
- What hypotheses exist with supporting scientific evidences, including mathematical models, about the origin of life on Earth?

Laboratory Investigations

- Chemistry of Water and Its Effects on Pond Ecology

Estimated Time: *15 days*

Essential Questions: ▼ How do molecules and atoms from the environment build new molecules? ▼ In what ways do DNA and RNA molecules have similarities and differences that define their function? ▼ In what ways do the subcomponents of biological molecules and their sequences determine the properties of those molecules? ▼ What interactions between molecules affect their structure and function?

Learning Objectives	Materials	Instructional Activities and Assessments
Represent graphically or model quantitatively the exchange of molecules between an organism and its environment, and the subsequent use of these molecules to build new molecules that facilitate dynamic homeostasis, growth, and reproduction. [LO 2.9, SP 1.1, SP 1.4]	Campbell and Reece, Chapter 3: "Water and the Fitness of the Environment" and Chapter 4: "Carbon and the Molecular Diversity of Life" **Web** "Chemistry of Water and Its Effects on Pond Ecology"	**Instructional Activity:** This activity includes a set of three lab stations that demonstrate surface tension, capillary action, and water as a temperature buffer. In station #1 (surface tension), students attempt to float a needle on distilled water. Students will then be able to test various substances and their effect on surface tension by adding detergent, oil, and/or other substances. In station #2, students investigate capillary action, testing several capillary tubes to investigate how plants transpire. Student discussion questions are based on cohesion and adhesion properties. In station #3, students test water as a temperature buffer and compare how temperature rises with water, alcohol, and air. **Formative Assessment:** Students set up the same lab (see previous activity) for first-year biology students and act as the mentors or teacher assistants at each of the stations, explaining the responses that were discussed in class as they experienced it. First-year biology students evaluate the AP students' lab setup, information provided, and knowledge regarding the discussion questions in a survey they take at the end of the activity. I evaluate the surveys and provide feedback to the AP Biology class. We then discuss how we can modify the lab activities, the information, and/or delivery thereof.
Explain the connection between the sequence and the subcomponents of a biological polymer and its properties. [LO 4.1, SP 7.1] Refine representations and models to explain how the subcomponents of a biological polymer and their sequence determine the properties of that polymer. [LO 4.2, SP 1.3] Use models to predict and justify that changes in the subcomponents of a biological polymer affect the functionality of the molecule. [LO 4.3, SP 6.1, SP 6.4]	Campbell and Reece, Chapter 5: "The Structure and Function of Large Biological Molecules" **Web** "The Chemical Building Blocks of Life: Building Macromolecules"	**Instructional Activity:** In this hands-on, student-directed, teacher-facilitated activity, class members construct and refine their representations of macromolecules out of smaller subunits, using paper, scissors, and tape. Students build and manipulate macromolecules in four activities (carbohydrate, lipid, protein, and DNA). In all four activities, students use the models they have created and manipulated to predict and justify how the macromolecules' shapes affect their functionality.

This activity helps students understand the basic properties of macromolecules, how they function, and their importance to organisms. Students see and kinesthetically explore how those molecules, once built, facilitate homeostasis and reproduction for the environment of populations.

By teaching others, my students gain leadership skills while reinforcing their own learning.

The hands-on nature of this activity allows students to create models they can identify and manipulate.

Essential Questions: ▼ How do molecules and atoms from the environment build new molecules? ▼ In what ways do DNA and RNA molecules have similarities and differences that define their function? ▼ In what ways do the subcomponents of biological molecules and their sequences determine the properties of those molecules? ▼ What interactions between molecules affect their structure and function?

Learning Objectives	Materials	Instructional Activities and Assessments
Construct explanations based on evidence of how variation in molecular units provides cells with a wider range of functions. [LO 4.22, SP 6.2] Analyze data to identify how molecular interactions affect structure and function. [LO 4.17, SP 5.1]	**Web** "The Chemical Building Blocks of Life: Building Macromolecules"	**Formative Assessment:** Students respond to the following prompts based on the molecule-building activity, using their models to help them explain how the variation in each macromolecule provides the cell with a wider range of functionality: 1. Suppose you eat a serving of green beans. What reactions must occur for the amino acid monomers in the protein to be converted to proteins in your body? 2. What would happen to a cow given antibiotics that killed all the prokaryotes in its stomach? 3. Suppose a membrane surrounded an oil droplet, as it does in the cells of plant seeds. Describe and explain the form the molecule might take.
		Summative Assessment: Students take a test containing 15 multiple-choice questions, two short-response questions, and one long free-response question. This assessment addresses the following essential questions: • *How do molecules and atoms from the environment build new molecules?* • *In what ways do DNA and RNA molecules have similarities and differences that define their function?* • *In what ways do the subcomponents of biological molecules and their sequences determine the properties of those molecules?* • *What interactions between molecules affect their structure and function?* • *How do variations within molecule units provide cells with a wider range of functions?*

I provide informative and corrective feedback to address any misconceptions or misunderstandings regarding the building or breaking down of molecules, as well as their interactions and functionality. This approach should allow students to transfer their understanding of those concepts to a variety of real-world scenarios and problems.

Students no longer have to memorize the names of proteins or enzymes as preparation for the AP Biology Exam. Thus I can concentrate on having students explain the wider range of functions that macromolecules possess, from organismal to environmental.

Laboratory Investigations

- *AP Biology Investigative Labs* (2012), Investigation 4: Diffusion and Osmosis
- Osmosis in a Plant Cell: Plant Cell Plasmolysis

Estimated Time:
20 days

Essential Questions: ▼ How do surface-area-to-volume ratios affect the ability of biological systems to obtain necessary resources or eliminate waste products? ▼ How is growth and dynamic homeostasis maintained by the constant movement of molecules across membranes? ▼ In what ways do eukaryotic cells' internal membranes and organelles contribute to cell functions? ▼ How do cells communicate, transmit, and receive chemical signals, and how does signal transmission within and between cells mediate gene expression and cell function?

Learning Objectives	Materials	Instructional Activities and Assessments
Use calculated surface area-to-volume ratios to predict which cell(s) might eliminate wastes or procure nutrients faster by diffusion. [LO 2.6, SP 2.2] Explain how cell size and shape affect the overall rate of nutrient intake and the rate of waste elimination. [LO 2.7, SP 6.2]	Campbell and Reece, Chapter 6: "A Tour of the Cell" and Chapter 7: "Membrane Structure and Function" *AP Biology Investigative Labs* (2012), Investigation 4: Diffusion and Osmosis (Procedure 1)	**Instructional Activity:** In Procedure 1: Surface Area and Cell Size, students first learn about water potential with a class demonstration I conduct. Students then design and conduct independent investigations based on the predictions they've made regarding the relationship of surface area-to-volume ratios of agar (simulating artificial cells), with an acid (HCl) and a base (NaOH).
Justify the selection of data regarding the types of molecules that an animal, plant, or bacterium will take up as necessary building blocks and excrete as waste products. [LO 2.8, SP 4.1] Represent graphically or model quantitatively the exchange of molecules between an organism and its environment, and the subsequent use of these molecules to build new molecules that facilitate dynamic homeostasis, growth, and reproduction. [LO 2.9, SP 1.1, SP 1.4] Use representations and models to pose scientific questions about the properties of cell membranes and selective permeability based on molecular structure. [LO 2.10, SP 1.4, SP 3.1] Construct models that connect the movement of molecules across membranes with membrane structure and function. [LO 2.11, SP 1.1, SP 7.1, SP 7.2]	*AP Biology Investigative Labs* (2012), Investigation 4: Diffusion and Osmosis (Procedures 2 and 3)	**Instructional Activity:** In Procedure 2: Modeling Diffusion and Osmosis, students investigate the relationship between cell surface area and cell size as well as diffusion depth in simulated agar cells. They construct models of living cells, using dialysis tubing, and fill their model cells with different solutions to determine diffusion rates across the cell membranes. Students independently design, select, and justify the experiment and data they will use. All students must make their own solutions (i.e., sucrose, NaCl, or glucose) and make predictions on the diffusion of those solutions. In Procedure 3: Observing Osmosis in Living Cells, students qualitatively observe osmosis in living cells and predict how solutions affect the homeostatic conditions of the *Elodea* cells. Students also design, experiment, justify, and analyze the effects of a variety of materials (potatoes, sweet potatoes, or yams) on cell membranes.

On lab days, I have students set up their own equipment, make their own solutions, create their own data table(s), and decide how they will collect data. Placing the responsibility on the students to design their own investigations allows them to take ownership of their work.

Essential Questions: ▼ How do surface-area-to-volume ratios affect the ability of biological systems to obtain necessary resources or eliminate waste products? ▼ How is growth and dynamic homeostasis maintained by the constant movement of molecules across membranes? ▼ In what ways do eukaryotic cells' internal membranes and organelles contribute to cell functions? ▼ How do cells communicate, transmit, and receive chemical signals, and how does signal transmission within and between cells mediate gene expression and cell function?

Learning Objectives	Materials	Instructional Activities and Assessments
Use representations and models to analyze situations or solve problems qualitatively and quantitatively to investigate whether dynamic homeostasis is maintained by the active movement of molecules across membranes. [LO 2.12, SP 1.4] Explain how internal membranes and organelles contribute to cell functions. [LO 2.13, SP 6.2] Use representations and models to describe differences in prokaryotic and eukaryotic cells. [LO 2.14, SP 1.4]	**Web** "Osmosis in a Plant Cell: Plant Cell Plasmolysis"	**Formative Assessment:** In groups of three, students do a think-pair-share on the following challenge: *In the front of the room are six flasks of different sucrose solutions. The flasks contain solutions that are either 0M, 0.2M, 0.4M, 0.6M, 0.8M, or 1.0M. Unfortunately, we have a problem: My colleague, Mr. Clueless, forgot to label the flasks.* Students devise a method for quantitatively determining which flask holds which solution. Students must analyze the situation, solve the problem in the challenge, and quantitatively show how they responded successfully to the challenge. I monitor the progress of each group by observing and providing feedback as needed for guidance in solving the challenge.
Construct explanations of cell communication through cell-to-cell direct contact or through chemical signaling. [LO 3.34, SP 6.2] Create representation(s) that depict how cell-to-cell communication occurs by direct contact or from a distance through chemical signaling. [LO 3.35, SP 1.1]	Campbell and Reece, Chapter 11: "Cell Communication" **Web** *X-2 Theme Park Ride* "The Inside Story of Cell Communication" "An Example of Cell Communication: The Fight or Flight Response"	**Instructional Activity:** Students are shown the YouTube video *X-2 Theme Park Ride*. It depicts a ride in Magic Mountain (a theme park in California). Students discuss and record responses to the physiological symptoms they feel as they watch the video. Students also complete KWL graphic organizers on what they know about the fight or flight response. Students watch the 4-minute video, "An Example of Cell Communication: The Fight or Flight Response." After viewing, they construct an explanation of what they've learned about cell communication as depicted in the video (via chemical signaling), and, on their KWL graphic organizers, relate those findings to the way the cell membrane contributes to cell function. **Formative Assessment:** Students use their KWL graphic organizers to summarize the information they learned about cell signaling and relate it to the fear or excitement they may feel as they board an unfamiliar thrill ride at a theme park. Students may discuss their summaries with a peer and describe the signaling (where and how it takes place) from the moment they experience fear or excitement to the symptoms that occur.

Students often already have an answer to this challenge and are eager to share with their classmates, since errors such as improper labeling occur one out of three times in the independent lab activities. Students may not know that there is a quantitative way to resolve these errors. I monitor and join conversations to provide informative and corrective feedback. Their performance on this assessment informs my decisions about next instructional steps.

With difficult concepts such as cell communication and signaling, I incorporate a graphic organizer such as a KWL chart to help guide students' thought processes.

I review and discuss the content on the KWL charts with the students, providing informative and corrective feedback. Subsequent cell-signaling activities may be modified based on this feedback and student understanding.

Essential Questions: ▼ How do surface-area-to-volume ratios affect the ability of biological systems to obtain necessary resources or eliminate waste products? ▼ How is growth and dynamic homeostasis maintained by the constant movement of molecules across membranes? ▼ In what ways do eukaryotic cells' internal membranes and organelles contribute to cell functions? ▼ How do cells communicate, transmit, and receive chemical signals, and how does signal transmission within and between cells mediate gene expression and cell function?

Learning Objectives	Materials	Instructional Activities and Assessments
Use representation(s) and appropriate models to describe features of a cell signaling pathway. [LO 3.33, SP 1.4]	**Web** "Dropping Signals" "The Inside Story of Cell Communication"	**Instructional Activity:** In the Dropping Signals activity, students use an online interactive model to explore how cell signals travel through the body. The model describes the response of various cell types to different types of signals, depending on the type of cell the signal reaches. Students read and summarize "The Inside Story of Cell Communication," which describes other types of cell signaling models. Students add to the "Learned" portion of their KWL graphic organizers and summarize features of cell signaling they have learned.
Explain how signal pathways mediate gene expression, including how this process can affect protein production. [LO 3.22, SP 6.2] Use representations to describe mechanisms of the regulation of gene expression. [LO 3.23, SP 1.4]	Waterman and Stanley, Chapter 10: "Shh: Silencing the Hedgehog Pathway"	**Instructional Activity:** In groups of three, students investigate a case in Chapter 10. With my help, students identify and explain how molecules are involved in reception, transduction, and response in the hedgehog pathway. They also use a model of the hedgehog pathway to explain the mechanism of the regulation of the gene.

Essential Questions: ▼ How do surface-area-to-volume ratios affect the ability of biological systems to obtain necessary resources or eliminate waste products? ▼ How is growth and dynamic homeostasis maintained by the constant movement of molecules across membranes? ▼ In what ways do eukaryotic cells' internal membranes and organelles contribute to cell functions? ▼ How do cells communicate, transmit, and receive chemical signals, and how does signal transmission within and between cells mediate gene expression and cell function?

Learning Objectives	Materials	Instructional Activities and Assessments
Describe a model that expresses key elements to show how change in signal transduction can alter cellular response. [LO 3.38, SP 1.5] Justify claims based on scientific evidence that changes in signal transduction pathways can alter cellular response. [LO 3.37, SP 6.1] Construct an explanation of how certain drugs affect signal reception and, consequently, signal transduction pathways. [LO 3.39, SP 6.2]	Waterman and Stanley, Chapter 10: "Shh: Silencing the Hedgehog Pathway"	**Instructional Activity:** Students continue in their groups from the previous activity, using the hedgehog pathway investigative case to learn how changes in the signal transductions can alter cellular responses. Students read about cyclopean lambs and explain how a failure of cell division at a critical time during development could produce lambs with only one eye. After describing the effects of cyclopamine on the signal reception, and thus on the signal transduction of the pathway, students make the connection to the cause of the one-eyed lambs. This activity is student directed and teacher facilitated.
		Formative Assessment: Students blog with classmates about their constructed explanations of this investigation. They are instructed to answer one question and respond to two answers from their peers. Blogging allows them to modify their answers or to relearn the concepts of signal transduction. I moderate their discussion online with leading questions and provide constructive feedback.
Describe basic chemical processes for cell communication shared across evolutionary lines of descent. [LO 3.31, SP 7.2] Generate scientific questions involving cell communication as it relates to the process of evolution. [LO 3.32, SP 3.1]		**Instructional Activity:** Students analyze an amino acid sequence produced by the conserved region of a gene in the hedgehog family of genes to investigate evolutionary questions. This activity is conducted via a think-pair-share approach. The questions include: 1. How could phylogenetic trees help inform researchers interested in designing experiments to study the hedgehog pathway? 2. Based on the amino acid sequence, which animal has the hedgehog protein most like the one in humans? 3. Which organism has the hedgehog protein that is most dissimilar to that of humans? Student pairs share responses with the entire class for discussion.

Signal transduction is a difficult concept to learn. Using technology in this way facilitates communication among the students and helps them to better grasp the concepts by giving them access to their peers' thought processes.

Essential Questions: ▼ How do surface-area-to-volume ratios affect the ability of biological systems to obtain necessary resources or eliminate waste products? ▼ How is growth and dynamic homeostasis maintained by the constant movement of molecules across membranes? ▼ In what ways do eukaryotic cells' internal membranes and organelles contribute to cell functions? ▼ How do cells communicate, transmit, and receive chemical signals, and how does signal transmission within and between cells mediate gene expression and cell function?

Learning Objectives	Materials	Instructional Activities and Assessments
		Summative Assessment: Students take a test containing 15 multiple-choice questions based on the concepts of cell membranes and cell communication. The test also includes two short-answer questions (one asks students to evaluate scientific data on diffusion and osmosis; the other asks them to connect phenomena and models of cell communication to the importance of cell membranes) and one free-response question on the way cell communication relates to the process of evolution.

In this unit, I combined the topics of cell membranes and cell communication; students understand these concepts better if combined. This summative assessment addresses the following essential questions:

- How do surface area-to-volume ratios affect a biological system's ability to obtain resources or eliminate waste products?
- How are growth and dynamic homeostasis maintained by the constant movement of molecules across membranes?
- In what ways do eukaryotic cells' internal membranes and organelles contribute to cell functions?
- How do cells communicate, transmit, and receive chemical signals, and how does signal transmission within and between cells mediate gene expression and cell function?

Unit 5: Enzymes and Metabolism

Laboratory Investigations

- *AP Biology Investigative Labs* (2012), Investigation 6: Cellular Respiration
- *AP Biology Investigative Labs* (2012), Investigation 5: Photosynthesis (floating leaf disk procedure)
- *AP Biology Lab Manual* (2001), Lab 9: Transpiration (transitioned to be inquiry based and student directed)
- *AP Biology Investigative Labs* (2012), Investigation 13: Enzyme Activity

Estimated Time:

20 days

Essential Questions: ▼ In what ways do all living systems require a constant input of free energy? ▼ How do organisms capture and store free energy for use in biological processes? ▼ How do interactions between molecules affect their structure and function?

Learning Objectives	Materials	Instructional Activities and Assessments
Predict how changes in free energy availability affect organisms, populations and ecosystems. [LO 2.3, SP 6.4] Analyze data to identify how molecular interactions affect structure and function. [LO 4.17, SP 5.1]	Campbell and Reece, Chapter 8: "An Introduction to Metabolism" *AP Biology Investigative Labs* (2012), Investigation 13: Enzyme Activity	**Instructional Activity:** In this student-guided investigation, students justify the claim that free energy is required for all living systems by extracting enzymes from various sources, such as peroxidase in turnips, tyrosinase in mushrooms, catalase in beef liver, and amylase in saliva. Students predict and test the effects of enzymes, using a variety of temperature ranges. They investigate claims on how different pH buffers affect the rate of reaction, and which factor has a greater effect on the rate of reaction — changing the concentration of the enzyme, or changing the concentration of the substrate.
Justify a scientific claim that free energy is required for living systems to maintain organization, to grow, or to reproduce, but that multiple strategies exist in different living systems. [LO 2.2, SP 6.1]		**Formative Assessment:** At the end of the period, students complete an exit slip with the following questions: 1. What are three or four factors that vary in the environment in which organisms live? 2. Which of those factors do you think can affect enzyme activity? 3. How would you modify your basic assay to test your hypothesis? I collect and evaluate the exit slips and read them to begin discussion the following day. I may follow up with individual students who remain unclear about the concepts in these three questions.

Using enzymes from various organisms helps students identify how molecular interactions affect the structure and function of all organisms.

The exit slip gives students a chance to reflect on their claims and perspectives and the investigative approach in their experimental procedures.

Essential Questions: ▼ In what ways do all living systems require a constant input of free energy? ▼ How do organisms capture and store free energy for use in biological processes? ▼ How do interactions between molecules affect their structure and function?

Learning Objectives	Materials	Instructional Activities and Assessments
Predict how changes in free energy availability affect organisms, populations, and ecosystems. [LO 2.3, SP 6.4] Use representations to pose scientific questions about what mechanisms and structural features allow organisms to capture, store, and use free energy. [LO 2.4, SP 1.4, SP 3.1] Explain how biological systems use free energy based on empirical data that all organisms require constant energy input to maintain organization, to grow, and to reproduce. [LO 2.1, SP 6.2]	*AP Biology Investigative Labs* (2012), Investigation 6: Cellular Respiration	**Instructional Activity:** In groups of four, students design, predict, and conduct an experiment to investigate scientific questions on the mechanisms and structural features of cellular respiration on a chosen organism. Students learn how to calculate the rate of cellular respiration by using a respirometer. In this student-directed activity, students use a variety of organisms to answer questions they pose about cellular respiration. **Formative Assessment:** Using the four-corners strategy, students are asked a series of questions about their observations of the cellular respiration lab: 1. How did your group measure the rate of cellular respiration — by the amount of glucose consumed, the amount of oxygen consumed, the amount of carbon dioxide produced, or as measured another way? 2. What type of organism did you decide to use: insects, worms, seeds, or plants? 3. Cellular respiration uses glucose and oxygen, which have high levels of free energy, and releases CO2 and water, which have low levels of free energy. Is respiration spontaneous or not? (2 corners) Is it exergonic or endergonic? (2 corners) What happens to the energy released from glucose—is it stored, or is it used? (2 corners) As questions are asked, I evaluate student corner choices and discuss their responses with informative and corrective feedback.

In this strategy, each corner of the classroom is assigned a particular answer. As questions are asked, students move to the corner that represents their chosen response; they then explain why they made that choice. This activity is a quick and easy way to assess student understanding of the lab — especially to identify student misconceptions of the concepts.

Essential Questions: ▼ In what ways do all living systems require a constant input of free energy? ▼ How do organisms capture and store free energy for use in biological processes? ▼ How do interactions between molecules affect their structure and function?

Learning Objectives	Materials	Instructional Activities and Assessments
Justify the scientific claim that organisms share many conserved core processes and features that evolved and are widely distributed among organisms today. [LO 1.16, SP 6.1] Construct explanations of the mechanisms and structural features of cells that allow organisms to capture, store, or use free energy. [LO 2.5, SP 6.2] Construct explanations based on scientific evidence as to how interactions of subcellular structures provide essential functions. [LO 4.5, SP 6.2] Apply mathematical routines to quantities that describe interactions among living systems and their environment, which result in the movement of matter and energy. [LO 4.14, SP 2.2]	Campbell and Reece, Chapter 10: "Photosynthesis" *AP Biology Investigative Labs* (2012), Investigation 5: Photosynthesis (floating leaf disk procedure)	**Instructional Activity:** Students pose scientific questions, then design and conduct an experiment on the mechanisms of photosynthesis. Students can collect data and apply mathematical routines based on a number of variables they are testing. Students explain how the interactions of these variables inhibit or promote the interaction of subcellular structures to provide functions essential to photosynthesis. **Formative Assessment:** Students record their scientific questions, collect data, and use mathematical methods to write a formal lab report they will turn in for homework.

By posing scientific questions at the start of the activity, students can focus on what they want to investigate and on what type of investigative or research approach they will use.

I review the labs and provide individual feedback for each student. This review process (and possible subsequent discussion) lets me know whether I'll need to make modifications to the student investigations in the next lab activity.

Essential Questions: ▼ In what ways do all living systems require a constant input of free energy? ▼ How do organisms capture and store free energy for use in biological processes? ▼ How do interactions between molecules affect their structure and function?

Learning Objectives	Materials	Instructional Activities and Assessments
Predict how changes in free energy availability affect organisms, populations, and ecosystems. [LO 2.3, SP 6.4] Use representations to pose scientific questions about what mechanisms and structural features allow organisms to capture, store, and use free energy. [LO 2.4, SP 1.4, SP 3.1] Make a prediction about the interactions of subcellular organelles. [LO 4.4, SP 6.4] Construct explanations based on scientific evidence as to how interactions of subcellular structures provide essential functions. [LO 4.5, SP 6.2] Use representations and models to analyze situations qualitatively to describe how interactions of subcellular structures, which possess specialized functions, provide essential functions. [LO 4.6, SP 1.4]	*AP Biology Lab Manual* (2001), Lab 9: Transpiration (transitioned to be inquiry based and student directed)	**Instructional Activity:** In groups of four, students pose scientific questions regarding the mechanisms and structural features that affect the transpiration rates of certain plants and variables of their choice. Students predict transpiration rates of their chosen plants, construct explanations of their observations, and use their representations to analyze their investigations qualitatively. Students record the lab results in their lab notebooks. **Formative Assessment:** Student groups create PowerPoint presentations with data tables, graphs, and diagrams explaining how the interactions of subcellular structures provide essential functions for transpiration. They should also explain how the variables and the questions posed were answered, making sure that predictions of subcellular interactions were included. Students post their PowerPoint presentations on a blog and comment on two other presentations they review.
		Summative Assessment: Students are given a test containing 20 multiple-choice questions based on the concepts of cellular respiration and photosynthesis; two short-answer questions (one on photosynthesis, the other on cellular respiration); and one free-response question, which asks students to compare and contrast the process of photosynthesis and cellular respiration in relation to the way organisms require, capture, store, and use free energy. Combining cellular respiration and photosynthesis, along with the plant lab investigation, helps students make connections between big ideas 2 and 4 in the curriculum framework.

I evaluate presentations and students' comments that offer informative and corrective feedback to their classmates.

This summative assessment addresses the following essential questions:

- In what ways do all living systems require a constant input of free energy?
- How do organisms capture and store free energy for use in biological processes?
- How do interactions between molecules affect their structure and function?

Unit 6: Plant and Animal Structure and Function

Laboratory Investigations:

- *AP Biology Investigative Labs* (2012), Investigation 12: Fruit Fly Behavior

Estimated Time:

20 days

Essential Questions: ▼ In what ways are timing and coordination of specific events necessary for the normal development of an organism, and how are these events regulated? ▼ In what ways are timing and coordination of behavior regulated by various mechanisms, and how are they important in natural selection? ▼ How do organisms use feedback mechanisms to regulate growth and reproduction, and maintain dynamic homeostasis? ▼ What types of chemical defenses do plants and animals have against infections that affect their homeostasis? ▼ In what ways do the nervous systems of animals detect external and internal signals, transmit and integrate information, and produce responses?

Learning Objectives	Materials	Instructional Activities and Assessments
Connect concepts in and across domains to show that timing and coordination of specific events are necessary for normal development in an organism and that these events are regulated by multiple mechanisms. [LO 2.31, SP 7.2] Use a graph or diagram to analyze situations or solve problems (quantitatively or qualitatively) that involve timing and coordination of events necessary for normal development in an organism. [LO 2.32, SP 1.4] Justify scientific claims with scientific evidence to show that timing and coordination of several events are necessary for normal development in an organism and that these events are regulated by multiple mechanisms. [LO 2.33, SP 6.1] Connect concepts in and across domain(s) to predict how environmental factors affect responses to information and change behavior. [LO 2.40, SP 7.2] Create representations or models to describe nonspecific immune defenses in plants and animals. [LO 2.30, SP 1.1, SP 1.2]	Campbell and Reece, Chapter 38: "Angiosperm Reproduction and Biotechnology" Waterman and Stanley, Chapter 6: "Corn Under Construction"	**Instructional Activity:** Students review the case analysis of the "Corn Under Construction." They answer specific questions concerning reproduction in corn. Students analyze data to investigate corn morphology and the impact, on growth, of a model of insect damage. Students explain, with justification, the damage done to leaves by the insect and make predictions, with justification, on the growth after the damage.

When students explore short cases (stories or scenarios) based on decisions people face every day, they have the opportunity to apply biological concepts and principles to real-world situations.

Essential Questions: ▼ In what ways are timing and coordination of specific events necessary for the normal development of an organism, and how are these events regulated? ▼ In what ways are timing and coordination of behavior regulated by various mechanisms, and how are they important in natural selection? ▼ How do organisms use feedback mechanisms to regulate growth and reproduction, and maintain dynamic homeostasis? ▼ What types of chemical defenses do plants and animals have against infections that affect their homeostasis? ▼ In what ways do the nervous systems of animals detect external and internal signals, transmit and integrate information, and produce responses?

Learning Objectives	Materials	Instructional Activities and Assessments
Describe the role of programmed cell death in development and differentiation, the reuse of molecules, and the maintenance of dynamic homeostasis. [LO 2.34, SP 7.1] Design a plan for collecting data to support the scientific claim that the timing and coordination of physiological events involve regulation. [LO 2.35, SP 4.2] Justify scientific claims with evidence to show how timing and coordination of physiological events involve regulation. [LO 2.36, SP 6.1] Connect concepts that describe mechanisms that regulate the timing and coordination of physiological events. [LO 2.37, SP 7.2] Analyze data to support the claim that responses to information and communication of information affect natural selection. [LO 2.38, SP 5.1] Justify scientific claims, using evidence, to describe how timing and coordination of behavioral events in organisms are regulated by several mechanisms. [LO 2.39, SP 6.1]	Waterman and Stanley, Chapter 6: "Additional Investigation" Campbell and Reece, Chapter 40: "Basic Principles of Animal Form and Function," Concept 40.3	**Instructional Activity:** Using the Internet, students investigate an open-ended question about the gene from Antarctic fish that allows the fish to avoid freezing. Students justify the scientific claim regarding the way the cells in the fish differentiate, reuse molecules, and maintain homeostasis. Students design a plan for collecting data to support the scientific claim. Students identify other genes that might be valuable for crop management, enhanced growth, or nutritional quality. They identify the source of the gene and the target crop. I monitor students' work and, via discussion, provide informative and corrective feedback. **Formative Assessment:** I assess the open-ended investigation regarding the gene from the Antarctic fish by having students record their investigation in an interactive notebook. The investigation must include: 1. Information on claims 2. Predictions 3. Design and plan of data collection 4. Analysis and conclusion to support the claim

When I assign an open-ended investigation, I guide my students through the process by having them turn in parts of the investigation as they are completed, so that I may monitor and provide ongoing feedback.

Essential Questions: ▼ In what ways are timing and coordination of specific events necessary for the normal development of an organism, and how are these events regulated? ▼ In what ways are timing and coordination of behavior regulated by various mechanisms, and how are they important in natural selection? ▼ How do organisms use feedback mechanisms to regulate growth and reproduction, and maintain dynamic homeostasis? ▼ What types of chemical defenses do plants and animals have against infections that affect their homeostasis? ▼ In what ways do the nervous systems of animals detect external and internal signals, transmit and integrate information, and produce responses?

Learning Objectives	Materials	Instructional Activities and Assessments
Justify a claim made about the effect(s) on a biological system at the molecular, physiological, or organismal level when given a scenario in which one or more components within a negative regulatory system is altered. [LO 2.15, SP 6.1]	Campbell and Reece, Chapter 40: "Basic Principles of Animal Form and Function"	**Instructional Activity:** Students answer the following questions about homeostasis from Concept Check 40.3 (p. 868) and then discuss with the class: 1. What mode of heat exchange is involved in "wind chill," when moving air feels colder than still air at the same temperature? 2. Flowers differ in how much sunlight they absorb. Why might this matter to a hummingbird seeking nectar on a cool morning? Students use visual representations to illustrate the alteration of components within a negative regulatory system.

Essential Questions: ▼ In what ways are timing and coordination of specific events necessary for the normal development of an organism, and how are these events regulated? ▼ In what ways are timing and coordination of behavior regulated by various mechanisms, and how are they important in natural selection? ▼ How do organisms use feedback mechanisms to regulate growth and reproduction, and maintain dynamic homeostasis? ▼ What types of chemical defenses do plants and animals have against infections that affect their homeostasis? ▼ In what ways do the nervous systems of animals detect external and internal signals, transmit and integrate information, and produce responses?

Learning Objectives	Materials	Instructional Activities and Assessments
Justify that positive feedback mechanisms amplify responses in organisms. [LO 2.20, SP 6.1] Justify the selection of the kind of data needed to answer scientific questions about the relevant mechanism that organisms use to respond to changes in their external environment. [LO 2.21, SP 4.1] Construct explanations based on scientific evidence that homeostatic mechanisms reflect continuity due to common ancestry and/or divergence due to adaptation in different environments. [LO 2.25, SP 6.2] Analyze data to identify phylogenetic patterns or relationships, showing that homeostatic mechanisms reflect both continuity due to common ancestry and change due to evolution in different environments. [LO 2.26, SP 5.1] Connect differences in the environment with the evolution of homeostatic mechanisms. [LO 2.27, SP 7.1] Use representations or models to analyze quantitatively and qualitatively the effects of disruptions to dynamic homeostasis in biological systems. [LO 2.28, SP 1.4]	*AP Biology Investigative Labs* (2012), Investigation 12: Fruit Fly Behavior	**Instructional Activity:** With this lab on fruit fly behavior, students revisit the topic of animal behavior from Unit 1. Their previous lab experience will assist them in their investigation of the behavior and environmental choices of fruit flies. In this lab, students pose and evaluate scientific questions about the relevant mechanisms that organisms use in response to changes in their environment. Students also justify their selection of data, construct explanations based on an environmental model, and analyze their data to qualitatively explain the effects of changes made to the flies' environment. Students explain how positive feedback mechanisms may amplify responses in the fly population. This lab investigation is teacher facilitated and student self-guided.

This investigation begins as a structured-inquiry lab by having the teacher provide a general procedure for performing the lab. After students get an idea of what to do, they are encouraged to work independently, using their own scientific claims and justifications for their selection of data.

Essential Questions: ▼ In what ways are timing and coordination of specific events necessary for the normal development of an organism, and how are these events regulated? ▼ In what ways are timing and coordination of behavior regulated by various mechanisms, and how are they important in natural selection? ▼ How do organisms use feedback mechanisms to regulate growth and reproduction, and maintain dynamic homeostasis? ▼ What types of chemical defenses do plants and animals have against infections that affect their homeostasis? ▼ In what ways do the nervous systems of animals detect external and internal signals, transmit and integrate information, and produce responses?

Learning Objectives	Materials	Instructional Activities and Assessments
Create representations and models to describe immune responses. [LO 2.29, SP 1.1, SP 1.2] Create representations or models to describe nonspecific immune defenses in plants and animals. [LO 2.30, SP 1.1, SP 1.2]	Waterman and Stanley, Chapter 9: "Influenza in the Media"	**Instructional Activity:** Students review a case study that explores flu antigens, genetics, and replication. As a class, they discuss the spread of H5N1 Avian Influenza, then complete an Internet activity in which they search for images to create a visual representation to describe nonspecific and specific immune defenses in plants and animals. Students answer questions based on the innate immunity and acquired immunity of all animals. Students will present their visual presentation to the class.
Construct an explanation, based on scientific theories and models, about how nervous systems detect external and internal signals, transmit and integrate information, and produce responses. [LO 3.43, SP 6.2, SP 7.1] Create a visual representation to describe how nervous systems detect external and internal signals. [LO 3.48, SP 1.1] Create a visual representation to describe how nervous systems transmit information. [LO 3.49, SP 1.1]	Campbell and Reece, Chapter 48: "Neurons, Synapses, and Signaling" **Web** "Design a Functional Neuron"	**Instructional Activity:** In pairs, students create a visual representation of a neuron, using simple household items. The model should demonstrate the flow of information through a neuron and should include components that represent dendrites, cell body, and axon. Pairs should also create a poster that shows a labeled version of the neuron model. On the poster, students describe the model and explain how it functions. Students present their posters to the class.
Create a visual representation of complex nervous systems to describe/explain how these systems detect external and internal signals, transmit and integrate information, and produce responses. [LO 3.47, SP 1.1] Create a visual representation to describe how the vertebrate brain integrates information to produce a response. [LO 3.50, SP 1.1]	Campbell and Reece, Chapter 49: "Nervous Systems" **Web** "Neurotransmitters, Drugs, and the Nervous System"	**Instructional Activity:** Students use the Internet and their textbook to determine the effect of an assigned neurotransmitter and to identify the receptor type, neuron type, and action stimulated by the neurotransmitter. Students design a three-dimensional model of the receptor that binds the assigned ligand. The assigned neurotransmitters include acetylcholine, GABA, serotonin, and dopamine. Students participate in a gallery walk, reviewing one another's three-dimensional models. Students explain (with justification) how the neurotransmitter in the vertebrate brain integrates information from a neurotransmitter to produce a response.

Students should not memorize the parts of the neuron as they label and represent the parts, but instead be able to use the model to explain how the neuron's flow of information works with the nervous system to detect, transmit, and integrate information to produce a response.

Essential Questions: ▼ In what ways are timing and coordination of specific events necessary for the normal development of an organism, and how are these events regulated? ▼ In what ways are timing and coordination of behavior regulated by various mechanisms, and how are they important in natural selection? ▼ How do organisms use feedback mechanisms to regulate growth and reproduction, and maintain dynamic homeostasis? ▼ What types of chemical defenses do plants and animals have against infections that affect their homeostasis? ▼ In what ways do the nervous systems of animals detect external and internal signals, transmit and integrate information, and produce responses?

Learning Objectives	Materials	Instructional Activities and Assessments
Describe how nervous systems detect external and internal signals. [LO 3.44, SP 1.2] Describe how nervous systems transmit information. [LO 3.45, SP 1.2] Describe how the vertebrate brain integrates information to produce a response. [LO 3.46, SP 1.2]		**Formative Assessment:** Students demonstrate the model of the neuron with the aid of the poster and explain how the nervous system transmits and integrates information.
		Summative Assessment: In a 50-minute period, students must answer 25 multiple-choice questions and one free-response question about the timing and coordination of the behavior of an organism tied with the immune system and/or the nervous system. They also select two out of four questions created by the teacher which cover the following essential questions: • *In what ways are timing and coordination of behavior regulated by various mechanisms, and how are they important in natural selection?* • *How do organisms use feedback mechanisms to regulate growth and reproduction and to maintain dynamic homeostasis?* • *What types of chemical defenses do plants and animals have against infections that have an impact on their homeostasis?* • *In what ways do the nervous systems of animals detect external and internal signals, transmit and integrate information, and produce responses?*

I use a rubric to evaluate the content, student explanations, organization, conventions, impact, and task-specific criteria. I also provide informative and corrective feedback via discussions with the students.

When students are taught certain concepts at the same time, such as feedback systems and the nervous and immune systems, they begin to understand the connections between the systems.

Unit 7: Heredity

Laboratory Investigations:

- ***AP Biology Investigative Labs*** **(2012), Investigation 7: Cell Division: Mitosis and Meiosis**
- ***AP Biology Lab Manual*** **(2001), Lab 7: Genetics of Organisms (transitioned to be inquiry based and student directed)**

Estimated Time:

30 days

Essential Questions: ▼ How is heritable information passed to the next generation in eukaryotes, and how do changes in genotype result in changes in phenotype of an organism? ▼ In what ways does the chromosomal basis of inheritance provide an understanding of the patterns of transmission of genes from parent to offspring, and how are inheritance patterns of many traits explained other than through simple Mendelian genetics? ▼ What multiple processes increase genetic variation in biological systems, and how do environmental factors influence the expression of the genotype in an organism? ▼ In what ways does the diversity of a species within an ecosystem influence the stability of the ecosystem?

Learning Objectives	Materials	Instructional Activities and Assessments
Make predictions about natural phenomena occurring during the cell cycle. [LO 3.7, SP 6.4] Construct an explanation, using visual representations or narratives, as to how DNA in chromosomes is transmitted to the next generation via mitosis, or meiosis followed by fertilization. [LO 3.9, SP 6.2] Represent the connection between meiosis and increased genetic diversity necessary for evolution. [LO 3.10, SP 7.1] Describe the events that occur in the cell cycle. [LO 3.8, SP 1.2] Evaluate evidence provided by data sets to support the claim that heritable information is passed from one generation to another generation through mitosis, or meiosis followed by fertilization. [LO 3.11, SP 5.3] Construct an explanation of the multiple processes that increase variation within a population. [LO 3.28, SP 6.2]	Campbell and Reece, Chapter 12: "The Cell Cycle" *AP Biology Investigative Labs* (2012), Investigation 7: Cell Division: Mitosis and Meiosis Campbell and Reece, Chapter 13: "Meiosis and Sexual Life Cycles," Concepts 13.1–13.3	**Instructional Activity:** This activity contains four parts: 1. Modeling mitosis: Students model mitosis with pipe cleaners and beads as a prelab activity. 2. Effects of environment on mitosis: Students set up an experiment and make predictions about the effects of lectin on onion root-tip cells undergoing mitosis in the environment. Students compare and count onion cells in various phases and record their data. Students make predictions and construct explanations as to how DNA in chromosomes is transmitted to the next generation via mitosis. They then calculate chi-square for the expected number of cells versus the actual counted. 3. Loss of cell cycle control in cancer: Students use HeLa cells and karyotype pictures of normal cells to form hypotheses as to how chromosomes of a cancer cell might appear in comparison to a normal cell. 4. Modeling meiosis: Students use household items to model meiosis and crossing-over events and to simulate nondisjunction and the relationship to genetic disorders. Students devise explanations of multiple processes that increase variation by measuring cross-over frequencies and genetic outcomes in fungus *Sordaria*.
Compare and contrast processes by which genetic variation is produced and maintained in organisms from multiple domains. [LO 3.27, SP 7.2]	Campbell and Reece, Chapter 13: "Meiosis and Sexual Life Cycles," Concept 13.4	**Formative Assessment:** Students record their experiments, including the design, methods, data, results, and conclusions, in a lab notebook.

The investigations in AP Biology Investigative Labs *scaffold student learning and skill acquisition by having the lab activities done in subsequent and progressive parts.*

I use a rubric to evaluate the various components of the lab and provide informative and corrective feedback before students conduct the next investigation (Lab 7: Genetics of Organisms). Students' performance on this assessment informs my decisions about next instructional steps.

Essential Questions: ▼ How is heritable information passed to the next generation in eukaryotes, and how do changes in genotype result in changes in phenotype of an organism? ▼ In what ways does the chromosomal basis of inheritance provide an understanding of the patterns of transmission of genes from parent to offspring, and how are inheritance patterns of many traits explained other than through simple Mendelian genetics? ▼ What multiple processes increase genetic variation in biological systems, and how do environmental factors influence the expression of the genotype in an organism? ▼ In what ways does the diversity of a species within an ecosystem influence the stability of the ecosystem?

Learning Objectives	Materials	Instructional Activities and Assessments
Construct a representation that connects the process of meiosis to the passage of traits from parent to offspring. [LO 3.12, SP 1.1, SP 7.2] Apply mathematical routines to determine Mendelian patterns of inheritance provided by data sets. [LO 3.14, SP 2.2] Construct explanations of the influence of environmental factors on the phenotype of an organism. [LO 4.23, SP 6.2] Make scientific claims and predictions about how species diversity within an ecosystem influences ecosystem stability. [LO 4.27, SP 6.4] Predict the effects of a change in an environmental factor on the genotypic expression of the phenotype. [LO 4.24, SP 6.4]	Campbell and Reece, Chapter 14: “Mendel and the Gene Idea” *AP Biology Lab Manual* (2001), Lab 7: Genetics of Organisms (transitioned to be inquiry based and student directed	**Instructional Activity:** Students construct representations that connect the process of meiosis by investigating an independent assortment of two genes and determining whether they are autosomal or sex-linked. Students collect and analyze data from a genetic cross they will perform with fruit flies and mathematically determined Mendelian patterns of inheritance. Students perform a chi-square analysis of the results and predict the diversity of flies (i.e., influences the ecosystem). Students also make predictions (with justification) on the effects of a change in environment on the genotype expression of the fruit flies, by investigating changes students may add or manipulate in the flies’ environment.

Essential Questions: ▼ How is heritable information passed to the next generation in eukaryotes, and how do changes in genotype result in changes in phenotype of an organism? ▼ In what ways does the chromosomal basis of inheritance provide an understanding of the patterns of transmission of genes from parent to offspring, and how are inheritance patterns of many traits explained other than through simple Mendelian genetics? ▼ What multiple processes increase genetic variation in biological systems, and how do environmental factors influence the expression of the genotype in an organism? ▼ In what ways does the diversity of a species within an ecosystem influence the stability of the ecosystem?

Learning Objectives	Materials	Instructional Activities and Assessments
Explain deviations from Mendel's model of the inheritance of traits. [LO 3.15, SP 6.5] Explain how the inheritance patterns of many traits cannot be accounted for by Mendelian genetics. [LO 3.16, SP 6.3] Describe representations of an appropriate example of inheritance patterns that cannot be explained by Mendel's model of the inheritance of traits. [LO 3.17, SP 1.2] Explain the connection between genetic variations in organisms and phenotypic variations in populations. [LO 3.26, SP 7.2] Predict how a change in genotype, when expressed as a phenotype, provides a variation that can be subject to natural selection. [LO 3.24, SP 6.4, SP 7.2]	Campbell and Reece, Chapter 15: "The Chromosomal Basis of Inheritance," Concepts 15.1–15.5 and "Testing Your Knowledge: Genetics Problems," pp. 303–304	**Instructional Activity:** In groups of three, students work on genetics problems, using calculators and their understanding of Mendel's model of inheritance to explain patterns of inheritance. They predict (with justification) how a change in genotype provides variation that can be subject to natural selection. Students present their work to the class, explaining and justifying their calculations and answers.
Pose questions about ethical, social, or medical issues surrounding human genetic disorders. [LO 3.13, SP 3.1]	Campbell and Reece, Chapter 15: "The Chromosomal Basis of Inheritance," Concept 15.4 **Web** "Sickle Cell Bioinformatics"	**Instructional Activity:** Students learn about sickle cell bioinformatics by role-playing. Each student, acting as a public health specialist, designs a DNA probe to diagnose carriers of sickle cell anemia, using the UCSC Genome Browser. Students pose questions about the medical issues surrounding this human genetic disorder.

Completing genetics problems gives students the opportunity to apply their quantitative skills in novel situations representing Mendel's model of inheritance.

Essential Questions: ▼ How is heritable information passed to the next generation in eukaryotes, and how do changes in genotype result in changes in phenotype of an organism? ▼ In what ways does the chromosomal basis of inheritance provide an understanding of the patterns of transmission of genes from parent to offspring, and how are inheritance patterns of many traits explained other than through simple Mendelian genetics? ▼ What multiple processes increase genetic variation in biological systems, and how do environmental factors influence the expression of the genotype in an organism? ▼ In what ways does the diversity of a species within an ecosystem influence the stability of the ecosystem?

Learning Objectives	Materials	Instructional Activities and Assessments
		Summative Assessment: In a 50-minute period, students answer 15 multiple-choice questions and select one of four free-response questions.

This summative assessment addresses the following essential questions:

- How is heritable information passed to the next generation in eukaryotes, and how do changes in genotype result in changes in phenotype of an organism?
- In what ways does the chromosomal basis of inheritance provide an understanding of the patterns of transmission of genes from parent to offspring, and how are inheritance patterns of many traits explained other than through simple Mendelian genetics?
- Which multiple processes increase genetic variation in biological systems, and how do environmental factors influence the expression of the genotype in an organism?
- In what ways does the diversity of a species within an ecosystem influence the stability of the ecosystem?

Laboratory Investigations:

- *AP Biology Investigative Labs* (2012), Investigation 8: Biotechnology: Bacterial Transformation
- *AP Biology Investigative Labs* (2012), Investigation 9: Biotechnology: Restriction Enzyme Analysis of DNA

Estimated Time: *30 days*

Essential Questions: ▼ How is DNA, and in some cases RNA, the primary source of heritable information? ▼ How does gene regulation result in differential gene expression, leading to cell specialization? ▼ In what ways do a variety of intercellular and intracellular signal transmissions mediate gene expression? ▼ How does viral replication result in genetic variation, and how can viral infection introduce genetic variation into the hosts? ▼ How do interactions between external stimuli and regulated gene expression result in specialization of cells, tissues, and organs?

Learning Objectives	Materials	Instructional Activities and Assessments
Justify the selection of data from historical investigations that support the claim that DNA is the source of heritable information. [LO 3.2, SP 4.1]	Campbell and Reece, Chapter 16: "The Molecular Basis of Inheritance" **Web** "DNAi Timeline: A Scavenger Hunt"	**Instructional Activity:** Provided with a time line and information on DNA investigations, students, in groups of three, learn about scientists whose work has contributed to the understanding of DNA. Students use the DNAi website to answer questions embedded in a scavenger hunt activity. They use clues to navigate through the DNAi time line, justify the selection of data to solve problems, and view the contributions scientists made regarding DNA from a historical perspective. I monitor their use of the DNAi website and their collection of scavenger hunt items as students respond to the clues on their activity handout.
		Instructional Activity: Students develop a poster series featuring a scientist or the work of a scientist highlighted on a time line. Students select and highlight the investigational data they think best supports the claim that DNA is the source of heritable information and defend their claim as they present it to the class.

Exploring a time line, selecting a scientist, and defending the scientist's historical investigations helps students search for the justifications that DNA is the source of heritable information.

Essential Questions: ▼ How is DNA, and in some cases RNA, the primary source of heritable information? ▼ How does gene regulation result in differential gene expression, leading to cell specialization? ▼ In what ways do a variety of intercellular and intracellular signal transmissions mediate gene expression? ▼ How does viral replication result in genetic variation, and how can viral infection introduce genetic variation into the hosts? ▼ How do interactions between external stimuli and regulated gene expression result in specialization of cells, tissues, and organs?

Learning Objectives	Materials	Instructional Activities and Assessments
Construct scientific explanations that use the structures and mechanisms of DNA and RNA to support the claim that DNA and, in some cases, that RNA are the primary sources of heritable information. [LO 3.1, SP 6.5] Connect evolutionary changes in a population over time to a change in the environment. [LO 1.5, SP 7.1] Describe representations and models that illustrate how genetic information is copied for transmission between generations. [LO 3.3, SP 1.2] Justify the claim that humans can manipulate heritable information by identifying *at least two* commonly used technologies. [LO 3.5, SP 6.4] Predict how a change in a specific DNA or RNA sequence can result in changes in gene expression. [LO 3.6, SP 6.4]	Campbell and Reece, Chapter 16: "The Molecular Basis of Inheritance"; Chapter 17: "From Gene to Protein"; Chapter 18: "Regulation of Gene Expression"; Chapter 19: "Viruses"; Chapter 20: "Biotechnology"; and Chapter 21: "Genomes and Their Evolution" *AP Biology Investigative Labs* (2012), Investigation 8: Biotechnology: Bacterial Transformation	**Instructional Activity:** In this four-day lab investigation, students construct scientific explanations based on the structures and mechanisms of DNA by transforming bacterial cells with plasmid DNA. Students apply mathematical routines to describe the efficiency with which genetic information is transferred. Although this is a student-directed investigation, I monitor student data collection and representation and review the explanations of their results in their lab notebooks.
	Campbell and Reece, Chapter 16: "The Molecular Basis of Inheritance"; Chapter 17: "From Gene to Protein"; Chapter 18: "Regulation of Gene Expression"; Chapter 19: "Viruses"; Chapter 20: "Biotechnology"; and Chapter 21: "Genomes and Their Evolution"	**Formative Assessment:** Individually, students investigate several applications of genetic transformation related to the manipulation of DNA by biotechnology. These applications are to be displayed on mini-posters with context, explanations, and justifications.

In addition to molecular genetics and biotechnology, this lab addresses many concepts my students have learned throughout the course, such as natural selection, the effect of changes in genotype on phenotype, and the multiple processes of biological systems that increase genetic variation. Thus, by conducting this lab investigation, students make content and concept connections across the big ideas in the AP Biology Curriculum Framework.

As students present their mini-posters for me and their peers to review, they are provided with informative and corrective feedback. This assessment informs my decisions about next instructional steps.

Essential Questions: ▼ How is DNA, and in some cases RNA, the primary source of heritable information? ▼ How does gene regulation result in differential gene expression, leading to cell specialization? ▼ In what ways do a variety of intercellular and intracellular signal transmissions mediate gene expression? ▼ How does viral replication result in genetic variation, and how can viral infection introduce genetic variation into the hosts? ▼ How do interactions between external stimuli and regulated gene expression result in specialization of cells, tissues, and organs?

Learning Objectives	Materials	Instructional Activities and Assessments
Describe a model that represents evolution within a population. [LO 1.25, SP 1.2] Justify the claim that humans can manipulate heritable information by identifying *at least two* commonly used technologies. [LO 3.5, SP 6.4] Describe the connection between the regulation of gene expression and observed differences between different kinds of organisms. [LO 3.18, SP 7.1] Describe the connection between the regulation of gene expression and observed differences between individuals in a population. [LO 3.19, SP 7.1]	*AP Biology Investigative Labs* (2012), Investigation 9: Biotechnology: Restriction Enzyme Analysis of DNA	**Instructional Activity:** In this lab investigation, students use the technique of gel electrophoresis and restriction enzyme analysis of DNA to solve a DNA profiling investigation. Students conduct a data analysis to determine the approximate sizes of DNA fragments produced by the restriction enzymes. In the last part of the lab, students design and conduct an experiment (and investigation) of their own, based on the knowledge and skills developed earlier in the lab. Although some components in this lab are student directed, I act as facilitator by monitoring or correcting investigative skills, lab techniques, and specific misunderstandings. Students record data, analysis, and conclusions in their lab notebooks.

Essential Questions: ▼ How is DNA, and in some cases RNA, the primary source of heritable information? ▼ How does gene regulation result in differential gene expression, leading to cell specialization? ▼ In what ways do a variety of intercellular and intracellular signal transmissions mediate gene expression? ▼ How does viral replication result in genetic variation, and how can viral infection introduce genetic variation into the hosts? ▼ How do interactions between external stimuli and regulated gene expression result in specialization of cells, tissues, and organs?

Learning Objectives	Materials	Instructional Activities and Assessments
Describe representations and models illustrating how genetic information is translated into polypeptides. [LO 3.4, SP 1.2] Explain how the regulation of gene expression is essential for the processes and structures that support efficient cell function. [LO 3.20, SP 6.2] Use representations to describe how gene regulation influences cell products and function. [LO 3.21, SP 1.4] Explain how signal pathways mediate gene expression, including how this process can affect protein production. [LO 3.22, SP 6.2] Use representations to describe mechanisms of the regulation of gene expression. [LO 3.23, SP 1.4] Create a visual representation to illustrate how changes in a DNA nucleotide sequence can result in a change in the polypeptide produced. [LO 3.25, SP 1.1]	Campbell and Reece, Chapter 16: "The Molecular Basis of Inheritance"; Chapter 17: "From Gene to Protein"; Chapter 18: "Regulation of Gene Expression"; Chapter 19: "Viruses"; Chapter 20: "Biotechnology"; and Chapter 21: "Genomes and Their Evolution" **Web** "DNA from the Beginning: Molecules of Genetics Activities 21–24"	**Instructional Activity:** Students use the DNA from the Beginning website to access concept explanations, animations, photo galleries, videos, and questions or problems. Based on artifacts and data obtained, students create a PowerPoint presentation to describe the regulation of gene expression mechanisms via transcription, translation, and protein synthesis. Students will illustrate one of the following: 1. How genetic information is translated into polypeptides 2. How regulation of gene expression is essential to the process of efficient cell function 3. How genes regulate and influence the function of a cell A rubric is provided to guide students' PowerPoint creation, preparation, and presentation. I use the rubric to evaluate student presentations. **Formative Assessment:** Using the presentation rubric and the activity they were assigned, students present their PowerPoint projects to the class.

When students are assigned to present concepts regarding protein synthesis (which can be a difficult concept to understand), I provide direction on obtaining the information as well as a rubric to guide their planning. This approach allows students to focus on learning the concepts rather than on the technicalities of presenting the information.

I address any misconceptions that become evident in PowerPoint presentations, then provide additional corrective and informative feedback.

Essential Questions: ▼ How is DNA, and in some cases RNA, the primary source of heritable information? ▼ How does gene regulation result in differential gene expression, leading to cell specialization? ▼ In what ways do a variety of intercellular and intracellular signal transmissions mediate gene expression? ▼ How does viral replication result in genetic variation, and how can viral infection introduce genetic variation into the hosts? ▼ How do interactions between external stimuli and regulated gene expression result in specialization of cells, tissues, and organs?

Learning Objectives	Materials	Instructional Activities and Assessments
Construct an explanation of how viruses introduce genetic variation in host organisms. [LO 3.29, SP 6.2] Use representations and appropriate models to describe how viral replication introduces genetic variation in the viral population. [LO 3.30, SP 1.4] Refine representations to illustrate how interactions between external stimuli and gene expression result in specialization of cells, tissues, and organs. [LO 4.7, SP 1.3] Construct explanations based on evidence of how variation in molecular units provides cells with a wider range of functions. [LO 4.22, SP 6.2] Compare and contrast processes by which genetic variation is produced and maintained in organisms from multiple domains. [LO 3.27, SP 7.2]	Campbell and Reece, Chapter 16: "The Molecular Basis of Inheritance"; Chapter 17: "From Gene to Protein"; Chapter 18: "Regulation of Gene Expression"; Chapter 19: "Viruses"; Chapter 20: "Biotechnology"; and Chapter 21: "Genomes and Their Evolution"	**Instructional Activity:** In this activity, students work in groups of three to complete a graffiti carousel. Questions and prompts are displayed on poster board around the room, and students examine and address the queries: • Compare the structures of the tobacco mosaic virus and the influenza virus, and how they differentiate in introducing genetic variation in a host organism. • Compare the effect on the host cell of a lytic (virulent) phage and a lysogenic (temperate) phage. • How do some viruses reproduce without possessing or ever synthesizing DNA? • Why is HIV considered a retrovirus? • Describe two ways a preexisting virus can become an emerging virus.
		Summative Assessment: In a 50-minute period, students answer 15 multiple-choice questions and three free-response questions.

In this graffiti carousel, students "tag" their responses to the questions. Student responses may be in the form of visual representations, models, or brief explanations. Students often enjoy reading the responses of their peers; when they see a possible misinterpretation, they label it "misconception" with a sticky note. I monitor and provide accuracy checks to the class on the answers to the questions, as well as feedback on any misconceptions.

This assessment addresses the following essential questions:

- How does gene regulation result in differential gene expression, leading to cell specialization?
- In what ways does a variety of intercellular and intracellular signal transmission mediate gene expression?
- How does viral replication result in genetic variation, and how can viral infection introduce genetic variation into the hosts?
- How do interactions between external stimuli and regulated gene expression result in specialization of cells, tissues, and organs?

Resources

General Resources

AP Biology Investigative Labs: An Inquiry-Based Approach. New York: The College Board, 2012.

AP Biology Lab Manual for Students. Burlington, NC: Carolina Biological Supply Company, 2006. (Item #746682 on the Carolina Biological website.)

AP Biology Lab Manual for Teachers. Burlington, NC: Carolina Biological Supply Company, 2006. (Item #746681 on the Carolina Biological website.)

AP Biology Lab Manual. New York: The College Board, 2001.

Campbell, Neil A., and Jane B. Reece. *Biology*. 8th ed. San Francisco: Pearson Benjamin Cummings, 2008.

Waterman, Margaret, and Ethel Stanley. *Biological Inquiry: A Workbook of Investigative Cases*. 3rd ed. (Supplement to Campbell and Reece, Biology). San Francisco: Pearson Benjamin Cummings, 2011.

Unit 1 (Ecology) Resources

"Alien Plant Invasion: A Field Study Project at Saguaro National Park: Football Field Plot Study." Accessed October 17, 2011. http://biology.arizona.edu/sciconn/lessons2/Carpenter/Activities.htm.

"Investigative Case 8: Back to the Bay." Investigative Case Based Learning. Accessed December 29, 2011. http://bioquest.org/icbl/casebook/gullcontrol/.

Unit 2 (Evolution) Resources

Buskirk, Ruth, and Christopher M. Gillen. *Inquiry in Action: Interpreting Scientific Papers*. 2nd ed. (Supplement to Campbell and Reece, *Biology*.) San Francisco: Pearson Benjamin Cummings, 2011.

"The Making of the Fittest: Natural Selection and Adaptation." HHMI's BioInteratcive. Accessed October 20, 2011. http://www.hhmi.org/biointeractive/activities/pocketmouse.html.

Origin of Life AP Biology Kit, Carolina Biological Supply Company. http://www.carolina.com/product/life+science/ap+biology/ap+biology+kits/origin+of+life+8-station+kit+for+ap*+biology.do?sortby=ourPicks.

Revealing the Origins of Life. NOVA. PBS. Video. Accessed October 22, 2011. http://www.pbs.org/wgbh/nova/evolution/origins-life.html.

Unit 3 (Biochemistry) Resources

"The Chemical Building Blocks of Life: Building Macromolecules." Explore Biology Accessed October 22, 2011. http://www.explorebiology.com/documents/MolecularModels/MolecularModelInstructions.pdf.

"Chemistry of Water and Its Effects on Pond Ecology." British Ecological Society. Accessed October 20, 2011. http://www.britishecologicalsociety.org/documents/education/water_mainactivity.pdf.

Unit 4 (Cells) Resources

"Dropping Signals." Genetic Science Learning Center: *Learn.Genetics*. Accessed October 25, 2011. http://learn.genetics.utah.edu/content/begin/cells/signals/.

"An Example of Cell Communication: The Fight or Flight Response." Genetic Science Learning Center: *Learn.Genetics*. Accessed October 25, 2011. http://learn.genetics.utah.edu/content/begin/cells/cellcom/.

"The Inside Story of Cell Communication." Genetic Science Learning Center: *Learn.Genetics*. Accessed October 25, 2011. http://learn.genetics.utah.edu/content/begin/cells/insidestory/.

"Osmosis in a Plant Cell: Plant Cell Plasmolysis." Explore Biology. Accessed October 22, 2011. http://www.explorebiology.com/documents/LabC-OsmosisDiffusion2009.pdf.

X-2 Theme Park Ride. Accessed October 25, 2011. http://www.youtube.com/watch?v=eOnsrPTzEfo.

Unit 5 (Enzymes and Metabolism) Resources

No unit-specific resources.

Unit 6 (Plant and Animal Structure and Function) Resources

"Design a Functional Neuron." Lesson by Eric Renfro. Accessed November 1, 2011. http://biology.arizona.edu/sciconn/lessons2/renfro/lesson_1.htm.

"Neurotransmitters, Drugs, and the Nervous System." Lesson by Eric Renfro. Accessed November 1, 2011. http://biology.arizona.edu/sciconn/lessons2/renfro/lesson_2.htm.

Unit 7 (Heredity) Resources

"Sickle Cell Bioinformatics." Explore Biology. Accessed November 5, 2011. http://www.explorebiology.com/apbiology/labs/lab25.html.

Unit 8 (Molecular Genetics) Resources

"DNA from the Beginning: Molecules of Genetics Activities 21–24." DNA Learning Center. Accessed November 10, 2011. http://www.dnaftb.org.

"DNAi Timeline: A Scavenger Hunt." DNAi Teacher Guide. Accessed November 10, 2011. http://www.dnai.org/teacherguide/guide.html.