AP® Biology

Course Planning and Pacing Guide 1

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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 boxes on the right side of the page 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

Elizabeth Andrews High School
Stone Mountain, Georgia

School	Elizabeth Andrews is a nontraditional public high school for students who wish to accelerate the completion of their remaining graduation requirements; this includes: • students wishing to enter college or join the workforce early; • students who need to make up courses for graduation; and • students who work part time or full time. Elizabeth Andrews's enrollment is only available to students 16 years of age and older who have completed six units of high school course credit, including three credits from core content areas such as English, math, science, social studies, and world language.
Student population	• 604 students in grades 9–12 • Suburban/urban community school setting • Race/ethnicity: ∘ 87 percent African American ∘ 9 percent Hispanic ∘ 2 percent Asian American ∘ 1 percent Caucasian ∘ 1 percent multiracial • 77 percent of the students receive free or reduced-price lunches • 48 percent of Elizabeth Andrews's students go on to enroll in a two- or four-year college

Instructional time	The school year lasts 180 days and generally starts early in August and ends before Memorial Day. The school operates on a block schedule, with a new "semester" beginning approximately every nine weeks. The AP® Biology course starts in October (the beginning of the second semester) and ends in March (the third semester), for approximately 90 days of core instruction in 100-minute class periods. Students can elect to stay in the course an additional semester (through May). The additional semester provides reteaching, review, and exam preparation.
Student preparation	AP Biology is offered either as a fourth-year science course or to ninth-grade students who are motivated to accept the challenge of a college-level course. Most students in the AP Biology course have taken a college-preparatory biology course as well as physical science and/or chemistry.
Textbooks and lab manuals	Campbell, Neil A., and Jane B. Reece. *Biology*. 8th ed. San Francisco: Pearson Benjamin Cummings, 2008. *AP Biology Investigative Labs: An Inquiry-Based Approach*. New York: The College Board, 2012. *AP Biology Lab Manual*. New York: The College Board, 2001.

Overview of the Course

The AP Biology course is designed to be the equivalent of a college-level introductory biology course. The intent of the course is to expose students to higher-level biological principles, concepts, and skills and allow them the opportunity to apply their knowledge to real-life applications. Rather than learning from a micro level outward, students learn from a macro level inward. Students are also expected to learn not by memorization of facts, but through content and concept application via the AP Biology science practices.

Core concepts called *enduring understandings* and their application via the science practices are the basis of the AP Biology curriculum. These concepts are organized around biological principles called *big ideas* that permeate the entire course and focus on the following topics:

- evolution
- biological systems using energy to maintain homeostasis for survival
- passing heritable information to provide continuity of life
- the interaction of biological systems with biotic and abiotic factors

In the revised AP Biology course, the teacher serves as the facilitator while the students develop as independent thinkers and learners, especially through laboratory investigations. Many concepts that are considered prerequisite knowledge for the course can be reviewed as home study through the use of rich resources such as assigned websites, WebQuests, and journal articles. In class, students are given opportunities to learn and apply their knowledge through the process of inquiry rather than learning from lectures and/or prescribed lab protocols. A sense of wonder and use of original thought are fostered as students are encouraged to extend their learning via scaffolded conceptual understandings and open inquiry.

In the new *AP Biology Investigative Labs: An Inquiry-Based Approach* (2012), 13 inquiry-based and student-directed lab investigations provide opportunities for teachers to engage students in the scientific process. Each lab includes a supplemental list of resources that provides a toolbox of activities for the teacher to build and extend lessons. There are no required labs; thus, teachers can use and conduct labs other than those in the manual to provide similar learning and investigative experiences that are student directed and inquiry based. The importance of such instructional activities is paramount in instructional planning at Elizabeth Andrews High School. These types of activities add to and deepen students' conceptual understanding and learning.

In our school, concerted efforts are also made to ensure that teachers differentiate instructional strategies and activities so that students' varied educational needs and learning styles are addressed. For example, at the beginning of the course, I work with students to develop study and note-taking skills. I have found that using a variety of instructional strategies and tools helps to address students' different learning styles and aids in their understanding of the concepts and application of the science practices. Some of these strategies and tools include note cards, Cornell notes, hands-on activities, use of interactive whiteboards, role-playing, demonstrations, and online activities.

Student assessments are also critical to the instructional process. Summative assessments at the end of a unit serve to evaluate the culmination of student learning and understanding of the AP Biology curriculum's big ideas, enduring understandings, and essential knowledge, as well as the application of that understanding through the science practices. Summative assessments can also ask students to apply or analyze concepts that require problem solving. Prior to any summative assessment, formative assessments are administered in an attempt to check students' understanding and ability. These formative assessments provide opportunities for teachers to offer corrective feedback to students so that their misconceptions or incomplete understandings can be uncovered and addressed. In most cases, formative assessments serve to inform how the instructor should modify subsequent instructional activities so that student understanding and learning are better facilitated.

The learning process in the AP Biology course should be rich and impactful. When a student completes the course, he or she should be prepared to do well on the AP Exam as well as in the sequent course in a college or university setting.

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: Evolution	Students will not be assessed on details of the methods used to date fossils nor the names and dates of the five major extinctions. This reduction/elimination of content should save approximately four instructional days.	Eliminating the details of the fossil-dating methods, in addition to the those associated with the five major extinctions (which are now illustrative examples), allows more time to be spent completing inquiry-based activities and labs such as Phylogenetic Tree Analyses based on a student-generated research question using the www.phylogenetic.fr website, the NCBI (National Center for Biotechnology Information) gene sequencing database, and the BLAST lab in *AP Biology Investigative Labs: An Inquiry-Based Approach* (2012).
Unit 2: Cellular Processes: Energy and Communication	Since cellular organelles and their functions are now considered prerequisite knowledge, approximately six to seven instructional days will be saved. This reduction represents time which would have been spent on mnemonic activities and helping students use rote memorization to learn every detail and factoid associated with photosynthesis and respiration. Most of the content in Campbell and Reece, Chapter 2 ("The Chemical Context of Life"), which focuses on the chemical foundations in biology, is not required content in the course because it is now considered prior knowledge. This will save approximately five instructional days and allow me to move more quickly into the genetics unit. Coverage of Campbell and Reece, Chapters 9–10 ("Cellular Respiration: Harvesting Chemical Energy" and "Photosynthesis") is reduced. This includes oxidation and reduction, rote memorization of names and structures of molecules, and processes and cycles in respiration. The reduction of photosynthesis material includes properties of light, structure and function of pigments, and C4 and CAM plant adaptations for carbon fixation and photorespiration.	The instructional time saved will allow more time in "flipping the classroom" and giving students meaningful homework assignments, which allows them to review concepts previously learned. The reduction in the coverage of cellular organelle and function content and the basics regarding the chemical foundations of biology (e.g., atoms, compounds, elements, bonding, matter) provides opportunities to build on prior knowledge and deepen understanding of the cell and its biochemical functions. Students are able to connect survival of the cell and the many roles of proteins. The reduction in content coverage also allows for more time to be spent on Campbell and Reece, Chapter 11: "Cell Communication." This is a topic that many students find difficult, so the additional time to delve deeper here will be appreciated.
Unit 3: Genetics and Information Transfer	In this unit, the following reductions in content have been made: content from Campbell and Reece, Chapters 16 and 17 has been eliminated as part of the scope of what students need to know. Chapter 19, "Viruses," has been moved to Unit 4. The previous content requirements pertaining to DNA replication, transcription, and translation have been reduced. It is not necessary for students to memorize the names of most enzymes involved in the process from gene to protein; this will save approximately one to two instructional days. Instead of focusing on the steps involved in the gene-to-protein process, I can now go directly into teaching more concepts involving genomics, gene regulation, and social/ethical issues surrounding advances in biotechnology.	More time is now spent on the following: • Chapter 18: regulation of gene expression • Chapter 20: genomics, ethical issues, genetic manipulation • Chapter 21: gene regulation • Chapter 22: mathematical models that support evolution • Chapter 24: evolutionary change and speciation The instructional time saved with the content reductions allows me to offer students additional inquiry-based and student-directed activities. For example, students get a closer look at genes and the role that they currently play in advancing biotechnology by performing both of the biotechnology labs (Bacterial Transformation and Restriction Enzyme Analysis of DNA) in *AP Biology Investigative Labs: An Inquiry-Based Approach* (2012). Students are able to explore heritable genes and how they relate to current issues through the analysis of Case Studies and content-related movies such as *Gattaca*.

Unit	Managing Breadth	Increasing Depth
Unit 4: Interactions	In this course, students are not expected to know plant and animal structures. Content coverage from Campbell and Reece, Chapters 27 through 35 has been reduced. Students will now use plants and animals as illustrative examples of content. Coverage of Chapters 40–44, 46, 47, and 50 has also been reduced. The required systems for students to know are immune, endocrine, and nervous. Other organ systems are used as illustrative examples. These reductions save approximately five instructional days. This unit allows the student to further apply all of the concepts that have been learned thus far in the AP Biology course to an increasing hierarchy starting from the cell to the biosphere.	More time is now spent on Chapters 43, 45, 48, and 49 (immune, endocrine, and nervous systems). There is an increased emphasis on homeostasis, chemical signaling, and regulation. Content coverage of animal development in Chapter 47 now focuses on timing, coordination, and regulation of animal development. With the reduction of time spent on the plant and animal structure/function (march through the phyla), more in-depth, student-directed, and inquiry-based activities and labs can be included. For example, my students can conduct both the Energy Dynamics and Fruit Fly Behavior labs in *AP Biology Investigative Labs: An Inquiry-Based Approach* (2012). Both of these labs require more time than I would normally dedicate to a lab in this course, but the opportunity for students to practice inquiry and enter the role of the scientist, directing their own learning, is well worth the additional time.

Laboratory Investigations:

- *AP Biology Investigative Labs* (2012), Investigation 2: Mathematical Modeling: Hardy-Weinberg
- *AP Biology Investigative Labs* (2012), Investigation 3: Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST

Estimated Time: *3 weeks*

Essential Questions: ▼ What role does evolution play in the organization of living things? ▼ What evidence supports our current models of the origin of life? ▼ How does the process of evolution drive diversity and the unity of life? ▼ How does life evolve in changing environments?

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] Analyze data to support the claim that responses to information and communication of information affect natural selection. [LO 2.38, SP 5.1] Apply mathematical methods to data from a real or simulated population to predict what will happen to the population in the future. [LO 1.3, SP 2.2] Evaluate data-based evidence that describes evolutionary changes in the genetic makeup of a population over time. [LO 1.4, SP 5.3]	Campbell and Reece, Chapter 22: "Descent with Modification: A Darwinian View of Life" and Chapter 23: "The Evolution of Populations" **Web** "Welcome to Evolution 101!"	**Instructional Activity:** Students use Berkeley's "Welcome to Evolution 101!" as a prelesson homework WebQuest to gain an understanding of evolution. Students manipulate, evaluate, and apply data to investigate "cause and effect" of populations over time, make predictions about future populations, and explain (with justification) the role of natural selection in evolution. This activity is conducted as part of the "flipped classroom"; thus, students are the directors of this learning process.
		Instructional Activity: In this student-directed activity, students are given specific vocabulary terms and concepts related to natural selection (e.g., adaptation, environment, natural selection, genetic variation, mutation, species, population) and asked to organize and connect them in a word map. The biological term/concept map is used at various times in the unit to help students explain (with justification) biotic and abiotic factors that affect natural selection. The teacher's role is that of facilitator.
	Web "Peanut Variation Lab"	**Instructional Activity:** In this inquiry-based, student-directed lab, students apply the Hardy-Weinberg equation by using peanut seeds and shells to investigate natural selection in peanuts. Two variations are investigated: length of shell and number of seeds per shell. The activity reveals how the number of seeds in peanuts is an adaptation to survival. In the open-inquiry portion of this lab, students design and conduct their own experiments to analyze the Hardy-Weinberg equilibrium principle on variables of their choosing. I serve as the facilitator during this lab.
	AP Biology Investigative Labs (2012), Investigation 2: Mathematical Modeling: Hardy-Weinberg	**Instructional Activity:** In this investigative lab, students analyze, manipulate, and convert data as they attempt to model biological phenomena using computer applications. Students explain (with justification) how genes behave in populations. I facilitate the activity, as students ultimately design and conduct their own experiments applying the Hardy-Weinberg equilibrium principle and equation.

When a teacher has constraints on face-to-face time, there is a need to give meaningful content-directed home-study assignments. "Flipping" the classroom and having students work at home allows more time for the teacher to get to the core of the lesson in class.

Using word maps help students make connections between the vocabulary terms and the concepts. The word map is used as a graphic organizer to help students learn vocabulary. Students are not memorizing terms but using the map to learn the meaning of the terms through context and connections to other concepts.

Evolution

(continued)

Essential Questions: ▼ What role does evolution play in the organization of living things? ▼ What evidence supports our current models of the origin of life? ▼ How does the process of evolution drive diversity and the unity of life? ▼ How does life evolve in changing environments?

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] Analyze data to support the claim that responses to information and communication of information affect natural selection. [LO 2.38, SP 5.1] Apply mathematical methods to data from a real or simulated population to predict what will happen to the population in the future. [LO 1.3, SP 2.2] Evaluate data-based evidence that describes evolutionary changes in the genetic makeup of a population over time. [LO 1.4, SP 5.3]	**Web** "Lesson 6: Why Does Evolution Matter Now?"	**Instructional Activity:** Students view a video clip from "Lesson 6: Why Does Evolution Matter Now?" which shows the transmission of tuberculosis and the evolution of multiple drug-resistant strains of TB. Students then explain (with justification) the following: 1. How does the misuse of antibiotics affect the evolution of disease-causing bacteria? 2. Why should we care about a resistant strain of bacteria in Russia? **Formative Assessment:** Students work in groups of three or four to design and carry out an inquiry-based activity that will allow them to apply the Hardy-Weinberg mathematical model. Student groups determine the population they would like to use. They explain (with justification) how their population exhibits the Hardy-Weinberg equilibrium or, if applicable, what conditions exist to prevent it from representing this model. Group results will be peer and teacher reviewed.

This activity serves as an example of how populations of organisms evolve. This example of tuberculosis and resistant drugs can be replaced by exploration of other mutations for resistance to antibiotics, pesticides, herbicides, or chemotherapy drugs/chemicals.

I provide feedback to students to correct any misconceptions or conceptual misunderstandings. Subsequent instructional activities may be adjusted based on the results of this assessment.

Essential Questions: ▼ What role does evolution play in the organization of living things? ▼ What evidence supports our current models of the origin of life? ▼ How does the process of evolution drive diversity and the unity of life? ▼ How does life evolve in changing environments?

Learning Objectives	Materials	Instructional Activities and Assessments
Evidence for Evolution Evaluate evidence provided by data from many scientific disciplines that support biological evolution. [LO 1.9, SP 5.3] Refine evidence based on data from many scientific disciplines that support biological evolution. [LO 1.10, SP 5.2] Design a plan to answer scientific questions regarding how organisms have changed over time using information from morphology, biochemistry, and geology. [LO 1.11, SP 4.2] Connect scientific evidence from many scientific disciplines to support the modern concept of evolution. [LO 1.12, SP 7.1]	Campbell and Reece, Chapter 22: "Descent with Modification: A Darwinian View of Life" Lamb, Trevor D., "Evolution of the Eye"	**Instructional Activity:** After reading the article "Evolution of the Eye," students support or refute the idea that the eye has changed due to natural selection. Students also evaluate data and evidence to support and explain (with justification) their claims about evolution and how organisms have changed over time. I host a class blog on this topic where students have the opportunity to design a plan for answering and posting scientific questions about natural selection and evolution as a whole.
	Web "Visualizing Life on Earth: Data Interpretation in Evolution"	**Instructional Activity:** In this student-directed activity, students use Berkeley's Understanding Evolution website to engage in an exploration of the patterns in the diversity of life across the planet Earth. I am present to assist with the manipulation of this online tool. Students connect scientific evidence from different disciplines to help explain why organisms change over time. They also interpret, analyze, and manipulate data, as well as apply scientific reasoning skills as they infer how evolution has affected various species.
	Web "'Instant' Evolution Seen in Darwin's Finches, Study Says" "Darwin Lives! Modern Humans Are Still Evolving"	**Instructional Activity:** Students read and analyze "'Instant' Evolution Seen in Darwin's Finches, Study Says" and "Darwin Lives! Modern Humans Are Still Evolving." Students then write a summary essay which explains (with justification) how modern concepts of evolution are supported through natural selection. This is a teacher-facilitated activity.

Essential Questions: ▼ What role does evolution play in the organization of living things? ▼ What evidence supports our current models of the origin of life? ▼ How does the process of evolution drive diversity and the unity of life? ▼ How does life evolve in changing environments?

Learning Objectives	Materials	Instructional Activities and Assessments
Cladistics Construct and/or justify mathematical models, diagrams, or simulations that represent processes of biological evolution. [LO 1.13, SP 1.1, SP 2.1] Pose scientific questions about a group of organisms whose relatedness is described by a phylogenetic tree or cladogram in order to (1) identify shared characteristics, (2) make inferences about the evolutionary history of the group, and (3) identify character data that could extend or improve the phylogenetic tree. [LO 1.17, SP 3.1] 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]	Campbell and Reece, Chapter 26: "Phylogeny and the Tree of Life" **Web** "Making Cladograms: Phylogeny, Evolution, and Comparative Anatomy"	**Instructional Activity:** Students are given examples of various cladograms, then are asked to construct and justify their own cladograms (see "Making Cladograms"). This activity allows the students to interpret and analyze common ancestry and degrees of evolutionary relationship.
	AP Biology Investigative Labs (2012), Investigation 3: Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST	**Instructional Activity:** Students explore BLAST using bioinformatics to determine evolutionary relationships in the study of diseases. They extend their learning by designing and conducting an evolutionary analysis of their chosen organism and/or researching specific diseases that interest them.
		Formative Assessment: Using a set of organisms and characteristics provided by me, students analyze characteristics (e.g., prokaryote or eukaryote, physical structures) and patterns, construct a cladogram, and answer questions reflecting their proper completion, interpretation, and application.

Modern classification is based on evolutionary history. Cladistics is the most accepted method to study phylogenetic analysis. It provides an unambiguous and testable hypothesis of relationships between organisms. Constructing and analyzing cladograms allows students to justify through diagrams the processes of biological evolution.

I review students' work and provide feedback to correct or redirect any misunderstandings or misconceptions. Subsequent instructional activities may be modified accordingly based on the students' cladograms.

Essential Questions: ▼ What role does evolution play in the organization of living things? ▼ What evidence supports our current models of the origin of life? ▼ How does the process of evolution drive diversity and the unity of life? ▼ How does life evolve in changing environments?

Learning Objectives	Materials	Instructional Activities and Assessments
Origin of Species Analyze data related to questions of speciation and extinction throughout Earth's history. [LO 1.20, SP 5.1] Design a plan for collecting data to investigate the scientific claim that speciation and extinction have occurred throughout the Earth's history. [LO 1.21, SP 4.2] Use data from a real or simulated population(s), based on graphs or models and types of selection, to predict what will happen to the population in the future. [LO 1.22, SP 6.4] Justify the selection of data that addresses questions related to reproductive isolation and speciation. [LO 1.23, SP 4.1] Describe speciation in an isolated population and connect it to a change in gene frequency, change in environment, natural selection, and/or genetic drift. [LO 1.24, SP 7.2] Describe a model that represents evolution within a population. [LO 1.25, SP 1.2] Evaluate given data sets that illustrate evolution as an ongoing process. [LO 1.26, SP 5.3]	Campbell and Reece, Chapter 24: "The Origin of Species" **Web** "Speciation in Real Time"	**Instructional Activity:** Students read the article "Speciation in Real Time" and analyze data obtained from two groups of researchers who show how mating differences can evolve in bird populations in fewer than 50 years. Students are arranged into groups to explain and analyze how evidence in the article suggests that lineage is beginning to split. Students also make predictions (with justification) about the evolution of these bird populations beyond 50 years. Using their predictions and article data, students pose scientific questions about speciation evolution. This is a teacher-facilitated activity.
	Web "Evolution: Species and Speciation"	**Instructional Activity:** Students use speciation to apply species concepts, follow speciation events in frogs, and analyze speciation case studies of mosquitoes and the Florida Panther. Through this exploration of real studies of speciation, students reason how to collect data to deduce that processes of extinction currently exist. The case study that examines mosquitoes helps the students to see how species and speciation affect disease vectors. Students determine whether the Florida Panther is a unique species outside of other puma by conducting a case study. I direct students through the various speciation events, and the students direct their own learning and analysis.
		Summative Assessment: Students work in groups to construct models that show evolutionary speciation of the state bird. Each student will write a three- to five-page report that explains (with justification and evidence) the progression of evolutionary change and the circumstances that lead to the new species.
		Summative Assessment: Students take an assessment composed of 20–25 multiple-choice questions; two to three short-response questions; and one lab-based free-response question that requires data analysis based on either Investigation 2: Mathematical Modeling: Hardy-Weinberg or Investigation 3: Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST. The assessment should take approximately 1.5 hours.

This summative assessment addresses the following essential questions:
- What role does evolution play in the organization of living things?
- What evidence supports our current models of the origin of life?

This summative assessment addresses all of the essential questions:
- What role does evolution play in the organization of living things?
- What evidence supports our current models of the origin of life?
- How does the process of evolution drive diversity and the unity of life?
- How does life evolve in changing environments?

Unit 2:

Cellular Processes: Energy and Communication

Laboratory Investigations:

- *AP Biology Investigative Labs* (2012), Investigation 4: Diffusion and Osmosis
- *AP Biology Investigative Labs* (2012), Investigation 5: Photosynthesis

Estimated Time:

5 weeks

Essential Questions: ▼ How is the cell the basic unit of life? ▼ How do materials enter and leave the cell? ▼ What role does the cell membrane play in cellular homeostasis? ▼ What are the relationships between structure and function of cell organelles? ▼ How are the characteristics of life manifested by the cell? ▼ How is free energy used in biological systems to facilitate growth, reproduction, and homeostasis sustainability? ▼ How is energy stored in biological systems? ▼ How are external signals converted into cellular responses?

Learning Objectives	Materials	Instructional Activities and Assessments
Explain how internal membranes and organelles contribute to cell functions. [LO 2.13, SP 6.2] 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]	Campbell and Reece, Chapter 6: "A Tour of the Cell" and Chapter 27: "Bacteria and Archaea" **Web** "CELLS *alive!*"	**Instructional Activity:** In the "CELLS *alive!*" student-directed activity, students construct a Venn diagram comparing prokaryotic and eukaryotic cells. Students also explain (with justification) the nature of evolutionary relationships and how the cellular organelles work together for homeostatic balance to maintain life. This is a teacher-facilitated activity. **Instructional Activity:** Students review micrograph pictures of bacteria, plant, and animal cells, making comparisons and predictions (with justification) on how interactions of the subcellular structures provide essential functions. The micrographs can be in the form of a WebQuest or pictures that I have gathered from the Internet and presented to the class during lecture/notes. I facilitate the students' learning by helping them identify specific cell organelles and their specific functions. **Instructional Activity:** Students design a 3-D representation of a specific cell organelle. The representation should be given a size requirement. Students explain (with evidence) the role the subcellular components have in maintenance of cell homeostasis. These models are peer and teacher reviewed.

Students should have prior knowledge of cell organelles and their functions. They can review previous content prior to class so that the focus can be on the dynamic homeostasis and evolutionary relationships of cells.

Looking at micrographs of cells helps students to connect understanding of how organelles and the internal membranes are integral to the functionality of the cell. It also provides relevance by allowing students to view an authentic representation of the cell rather than drawings.

Essential Questions: ▼ How is the cell the basic unit of life? ▼ How do materials enter and leave the cell? ▼ What role does the cell membrane play in cellular homeostasis? ▼ What are the relationships between structure and function of cell organelles? ▼ How are the characteristics of life manifested by the cell? ▼ How is free energy used in biological systems to facilitate growth, reproduction, and homeostasis sustainability? ▼ How is energy stored in biological systems? ▼ How are external signals converted into cellular responses?

Learning Objectives	Materials	Instructional Activities and Assessments
Use representations and models to pose scientific questions about the properties of cell membranes and selective permeability based on molecular structure. [LO 2.10, SP 1.4, SP 3.1] Construct models that connect the movement of molecules across membranes with membrane structure and function. [LO 2.11, SP 1.1, SP 7.1, SP 7.2] Use representations and models to analyze situations or solve problems qualitatively or quantitatively to investigate whether dynamic homeostasis is maintained by the active movement of molecules across membranes. [LO 2.12, SP 1.4] 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 7: "Membrane Structure and Function"	**Instructional Activity:** I provide an introduction to the movement-across-the-membrane lesson by showing a wilted plant and asking students to explain (with justification) their responses to the following questions: 1. I forgot to water this pant. Is it dead? 2. What has caused it to wilt? 3. How can the wilting be reversed? Students pose scientific questions regarding the wilted plant and selective permeability, the properties of cell membranes, and the movement of molecules across the membranes.
	Web "Cell Size"	**Instructional Activity:** Students create visual representations that illustrate and explain examples of passive transport across the membrane; the role of proteins in cellular transport; hypotonic, hypertonic, and isotonic cellular environments; and movement of large molecules (exocytosis and endocytosis).
	AP Biology Investigative Labs (2012), Investigation 4: Diffusion and Osmosis	**Instructional Activity:** Students design and conduct experiments to investigate processes of diffusion and osmosis in the transport of molecules across cell membranes. Students also analyze how surface-area-to-volume ratio affects the rate of diffusion by measuring the movement of acid into agar blocks with phenolphthalein. This lab is student directed and teacher facilitated.
		Formative Assessment: Students make three cube boxes using specific dimensions to determine whether cell size is important in the homeostasis of cells. The focus is on the surface-area-to-volume ratio. Students explain (with justification) their responses to the following: 1. Which box would be more efficient as a cell? 2. What role does the surface-area-to-volume ratio have in cell efficiency?

Teachers should strive to assess student knowledge and understanding of diffusion and osmosis. This will provide a starting point for instruction.

I provide feedback through discourse with the students. The nature of student responses may inform which subsequent activities they will complete next.

Essential Questions: ▼ How is the cell the basic unit of life? ▼ How do materials enter and leave the cell? ▼ What role does the cell membrane play in cellular homeostasis? ▼ What are the relationships between structure and function of cell organelles? ▼ How are the characteristics of life manifested by the cell? ▼ How is free energy used in biological systems to facilitate growth, reproduction, and homeostasis sustainability? ▼ How is energy stored in biological systems? ▼ How are external signals converted into cellular responses?

Learning Objectives	Materials	Instructional Activities and Assessments
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]	Campbell and Reece, Chapter 2: "The Chemical Context of Life"; Chapter 3: "Water and the Fitness of the Environment"; and Chapter 4: "Carbon and the Molecular Diversity of Life"	**Instructional Activity:** Students work in small groups, using vocabulary/ concept cards to construct a large-scale representation or model of the carbon or nitrogen cycle. (I assign each group specific ecosystems.) Student artifacts depict and explain the abiotic and biotic factors in the cycles. During group presentations, students should justify their selections and explanations. This is a student-directed and teacher-facilitated activity.
Explain the connection between the sequence and the subcomponents of a biological polymer and its properties. [LO 4.1, SP 7.1] Construct explanations based on evidence of how variation in molecular units provides cells with a wider range of functions. [LO 4.22, SP 6.2] Represent graphically or model quantitatively the exchange of molecules between an organism and its environment, and the subsequent use of these molecules to build new molecules that facilitate dynamic homeostasis, growth, and reproduction. [LO 2.9, SP 1.1, SP 1.4]		**Formative Assessment:** Students are given an exit ticket as a closing to the lesson or an entry ticket as a follow-up to the lesson on the next day. On the ticket, the students respond briefly, with justification, to the following constructed-response question: *What role do carbon and nitrogen play in the production of complex organic molecules such as amino acids, proteins, and nucleic acids in living organisms?* The assessment should take no more than 15 minutes. **Instructional Activity:** Students are assigned a water property to depict as a superhero for a comic strip. They create and draw a five-panel comic strip that illustrates and explains the important role water has in biological systems. Students will explain and present their water superheroes on the wall for me and their peers to view.

An exit or entry ticket is a way for me to ensure that students understand that carbon and nitrogen are integral to biological processes. I provide feedback on inaccuracies and misconceptions presented on the students' tickets the next day in class. My feedback is discussed with specific students as needed.

Essential Questions: ▼ How is the cell the basic unit of life? ▼ How do materials enter and leave the cell? ▼ What role does the cell membrane play in cellular homeostasis? ▼ What are the relationships between structure and function of cell organelles? ▼ How are the characteristics of life manifested by the cell? ▼ How is free energy used in biological systems to facilitate growth, reproduction, and homeostasis sustainability? ▼ How is energy stored in biological systems? ▼ How are external signals converted into cellular responses?

Learning Objectives	Materials	Instructional Activities and Assessments
Explain the connection between the sequence and the subcomponents of a biological polymer and its properties. [LO 4.1, SP 7.1] Construct explanations based on evidence of how variation in molecular units provides cells with a wider range of functions. [LO 4.22, SP 6.2] Represent graphically or model quantitatively the exchange of molecules between an organism and its environment, and the subsequent 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 5: "The Structure and Function of Large Biological Molecules"	**Formative Assessment:** Each student is given a picture of bacteria, plants, or animals. Each picture has the same guiding question (see below) that provides a springboard to write three to five paragraphs explaining the role of chemistry in biological systems. Guiding Question: *Explain with justification the role of SPONCH elements in the environment depicted on your card and how they are integral parts of the macromolecules essential to living systems.* This activity is student directed and teacher facilitated.
		Instructional Activity: Students create molecular models demonstrating the SPONCH elements that form the macromolecules important to the homeostasis of living systems and the sustainability of environmental systems. The models should be ones that students can manipulate to represent concepts such as dehydration and synthesis. This activity is teacher facilitated and student driven.
		Formative Assessment: Students use food nutritional labels to explain the role of macromolecules in the human body. Small groups of students each fold a large piece of paper into four squares, labeling each square with the name of a macromolecule. Students explain and justify how the food item will or will not supply the macromolecule sources, describe the types of molecules that a human requires as essential building blocks, and explain why it is necessary to continue to take in food for homeostatic purposes. Groups present and defend (with justification) their findings to the class. I correct misconceptions and content inaccuracies verbally and also provide feedback on sticky notes, which I place on the graphic organizers. All models are posted in the classroom for student study and peer review.

I review students' written responses and discuss them with the students as needed to correct any misconceptions or misunderstandings.

Giving the students the opportunity to create molecular models allows them to manipulate the structure (SPONCH level to molecular level). The students can see the water being removed and added in the dehydration and synthesis reactions. The models can be kit based, or use materials such as straws, toothpicks, foam balls, or other materials.

This activity is done on large paper so it can be displayed for later student study and review. The sticky notes provide reminders of what is important, what is missing, or misconceptions.

Essential Questions: ▼ How is the cell the basic unit of life? ▼ How do materials enter and leave the cell? ▼ What role does the cell membrane play in cellular homeostasis? ▼ What are the relationships between structure and function of cell organelles? ▼ How are the characteristics of life manifested by the cell? ▼ How is free energy used in biological systems to facilitate growth, reproduction, and homeostasis sustainability? ▼ How is energy stored in biological systems? ▼ How are external signals converted into cellular responses?

<table>
<tr><th>Learning Objectives</th><th>Materials</th><th>Instructional Activities and Assessments</th></tr>
<tr><td rowspan="2">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 change in the subcomponents of a biological polymer affect the functionality of the molecule. [LO 4.3, SP 6.1, SP 6.4]

Analyze data to identify how molecular interactions affect structure and function. [LO 4.17, SP 5.1]</td><td>Campbell and Reece, Chapter 8: “An Introduction to Metabolism”

Web
“LabBench Activity: Enzyme Catalysis”</td><td>Instructional Activity:

Students study some of the basic principles of molecular movement in solution and perform a series of activities to investigate these processes. The LabBench enzyme catalysis activity allows students to explore how enzymes catalyze reactions by lowering the activation energy necessary for a reaction to occur. The teacher is a facilitator in this student-directed activity.</td></tr>
<tr><td>Web
“Enzymes Help Us Digest Food”</td><td>Instructional Activity:

In the hands-on activity “Enzymes Help Us Digest Food,” students explore enzyme specificity and function by analyzing the molecular basis for lactose intolerance. The activity requires them to justify the role of enzymes and to identify and predict the action of unknown enzymes. They use glucose test strips to authenticate a solution containing lactase, lactose, or no enzyme. I make up solutions prior to the activity. I facilitate the activity by walking around and answering questions to clear up any procedure issues that may arise. Students engage in self-directed work in groups of two or three.</td></tr>
</table>

Essential Questions: ▼ How is the cell the basic unit of life? ▼ How do materials enter and leave the cell? ▼ What role does the cell membrane play in cellular homeostasis? ▼ What are the relationships between structure and function of cell organelles? ▼ How are the characteristics of life manifested by the cell? ▼ How is free energy used in biological systems to facilitate growth, reproduction, and homeostasis sustainability? ▼ How is energy stored in biological systems? ▼ How are external signals converted into cellular responses?

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] Pose scientific questions that correctly identify essential properties of shared, core life processes that provide insights into the history of life on Earth. [LO 1.14, SP 3.1]	Campbell and Reece, Chapter 6: "A Tour of the Cell"; Chapter 25: "The History of Life on Earth" ; and Chapter 26: "Phylogeny and the Tree of Life," pp. 523–526	**Instructional Activity:** Students view slides or micrographs (cytoskeleton, mitochondria, chloroplasts, linear chromosomes, and nuclear envelope) that justify the scientific claim that organisms share core features. By viewing these representations, students are able to see structural evidence to support common ancestry between eukaryotes. This activity also provides students the opportunity to use microscopy and deduce the relationship of cell size and how organelles perform specific roles for maintaining homeostasis in organisms. The activity is student directed. I supervise the individual use of the microscope.
		Instructional Activity: Students individually research Lynn Margulis's hypothesis of endosymbiosis, then work in groups of four to "pool" their information. Each group responds to the following prompts to justify the scientific claim that organisms share many conserved core processes: 1. Based on Margulis's hypothesis, how would the endosymbiont lose its autonomy and become an organelle in eukaryotic cells? 2. Provide examples and justify evidence supporting the endosymbiotic theory for the origin of eukaryotes. 3. Provide evidence to refute Margulis's hypothesis that prokaryotes gave rise to eukaryotes. I facilitate a discussion that supports Margulis's hypothesis and offers room to disprove it. At the end of the lesson, students are asked to form their own personal opinions based on the evidence collected and discussed.
		Formative Assessment: Students construct a concept map to illustrate the relationships between the three domains of life: archaea, bacteria, and eukaryotes. Students should be able to explain the molecular processes and cellular features that are common to life. Students present their concepts to me and the class for review.

The teacher can use either slides or micrograph pictures for this activity. The micrograph pictures can be copied and laminated for reuse. Students prefer something "concrete" when they are learning and applying concepts. Slides and micrographs provide a close-up view and allow students to see features of the organelles that help support the roles they play in living systems.

I want the students to think of themselves as scientists during their investigations. Teachers should encourage students to be independent learners. As they gather information, I think it is important for students to form their own opinions (as in the case of Lynn Margulis).

Through discussions with students, I address any misconceptions or content inaccuracies.

Essential Questions: ▼ How is the cell the basic unit of life? ▼ How do materials enter and leave the cell? ▼ What role does the cell membrane play in cellular homeostasis? ▼ What are the relationships between structure and function of cell organelles? ▼ How are the characteristics of life manifested by the cell? ▼ How is free energy used in biological systems to facilitate growth, reproduction, and homeostasis sustainability? ▼ How is energy stored in biological systems? ▼ How are external signals converted into cellular responses?

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] Pose scientific questions that correctly identify essential properties of shared, core life processes that provide insights into the history of life on Earth. [LO 1.14, SP 3.1]		**Summative Assessment** The students take an assessment that is made up of 20–25 multiple-choice questions, two to three short-response questions, and one lab-based free-response question that requires data analysis based on movement of molecules through membranes: osmosis and diffusion. The assessment should take approximately 1.5 hours.
Energy Explain how biological systems use free energy based on empirical data that all organisms require constant energy input to maintain organization, to grow, and to reproduce. [LO 2.1, SP 6.2] Justify a scientific claim that free energy is required for living systems to maintain organization, to grow, or to reproduce, but that multiple strategies exist in different living systems. [LO 2.2, SP 6.1] Predict how changes in free energy availability affect organisms, populations, and ecosystems. [LO 2.3, SP 6.4] ***(learning objectives continue)***	Campbell and Reece, Chapter 8: "An Introduction to Metabolism"; Chapter 9: "Cellular Respiration: Harvesting Chemical Energy"; and Chapter 10: "Photosynthesis"	**Instructional Activity:** Students research how fermentation occurs in yogurt, cheese, chocolate, vinegar, or sourdough bread. They then write a two- to three-page paper using the following questions as a guide: 1. What metabolic pathway is used in the fermentation process? 2. What substrate is involved in the process? 3. What are the products that result from the process? 4. How is fermentation accomplished? 5. How is the product prepared for consumption? This activity is student directed and teacher facilitated. **Instructional Activity:** Students use research and their understanding of fermentation to design and conduct an experiment to investigate how yeasts are able to metabolize a variety of sugars. I serve as the facilitator in this activity.

The summative assessment will address the following essential questions:

- How is the cell the basic unit of life?
- How do materials enter and leave the cell?
- What role does the cell membrane play in cellular homeostasis?
- What are the relationships between structure and function of cell organelles?
- How are the characteristics of life manifested by the cell?

Students like to take ownership in the learning process. Allowing students to research a variety of resources regarding fermentation provides them the opportunity to extend their learning. Many times it can be a learning experience for the teacher, too, because students may uncover information that the teacher was not aware of.

Essential Questions: ▼ How is the cell the basic unit of life? ▼ How do materials enter and leave the cell? ▼ What role does the cell membrane play in cellular homeostasis? ▼ What are the relationships between structure and function of cell organelles? ▼ How are the characteristics of life manifested by the cell? ▼ How is free energy used in biological systems to facilitate growth, reproduction, and homeostasis sustainability? ▼ How is energy stored in biological systems? ▼ How are external signals converted into cellular responses?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) Use representations and models to analyze how cooperative interactions within organisms promote efficiency in the use of energy and matter. [LO 4.18, SP 1.4] Use representations to pose scientific questions about what mechanisms and structural features allow organisms to capture, store, and use free energy. [LO 2.4, SP 1.4, SP 3.1] Construct explanations of the mechanisms and structural features of cells that allow organisms to capture, store, or use free energy. [LO 2.5, SP 6.2] Describe specific examples of conserved core biological processes and features shared by all domains or within one domain of life, and how these shared, conserved core processes and features support the concept of common ancestry for all organisms. [LO 1.15, SP 7.2]	*AP Biology Investigative Labs* (2012), Investigation 5: Photosynthesis	**Instructional Activity:** Using the floating leaf disk procedure, students investigate factors that affect the rate of photosynthesis in living leaves. Students design and conduct investigations using variables that may affect photosynthesis. This activity is student directed and teacher facilitated. **Instructional Activity:** Students read a teacher-selected article on research that justifies how herbicides block the metabolic pathways that allow a plant to photosynthesize. Students pose scientific questions about the research article and construct explanations (with justification) regarding how mechanisms and structural features of the plant disallow the plan to capture, store, or use free energy. **Formative Assessment:** In teams, students create a visual representation (e.g., poster) to explain the interdependent relationships of cellular respiration and photosynthesis, and how the processes of cellular respiration and photosynthesis affect a runner in a marathon race. Students should use few words and focus on using graphics to represent the cyclic processes. Visual representations will be peer and teacher reviewed.

I differentiate instruction by choosing a variety of articles (e.g., at various reading levels) that are appropriate for my students. These may include scholarly articles, science news and current events in local newspapers, and articles from a variety of K–12 online science news sources. Teachers will need to do a little research to find appropriate articles.

I discuss the visual representations with the students and offer feedback to correct misunderstandings and misconceptions. The accuracy of their visual representations guides my decisions on next instructional steps.

Essential Questions: ▼ How is the cell the basic unit of life? ▼ How do materials enter and leave the cell? ▼ What role does the cell membrane play in cellular homeostasis? ▼ What are the relationships between structure and function of cell organelles? ▼ How are the characteristics of life manifested by the cell? ▼ How is free energy used in biological systems to facilitate growth, reproduction, and homeostasis sustainability? ▼ How is energy stored in biological systems? ▼ How are external signals converted into cellular responses?

Learning Objectives	Materials	Instructional Activities and Assessments
Cell Communication/Signaling Describe basic chemical processes for cell communication shared across evolutionary lines of descent. [LO 3.31, SP 7.2] Generate scientific questions involving cell communication as it relates to the process of evolution. [LO 3.32, SP 3.1] Use representation(s) and appropriate and models to describe features of a cell signaling pathway. [LO 3.33, SP 1.4] Construct explanations of cell communication through cell-to-cell direct contact or through chemical signaling. [LO 3.34, SP 6.2] Create representation(s) that depict how cell-to-cell communication occurs by direct contact or from a distance through chemical signaling. [LO 3.35, SP 1.1] Describe a model that expresses the key elements of signal transduction pathways by which a signal is converted to a cellular response. [LO 3.36, SP 1.5] Justify claims based on scientific evidence that changes in signal transduction pathways can alter cellular response. [LO 3.37, SP 6.1] Describe a model that expresses key elements to show how change in signal transduction can alter cellular response. [LO 3.38, SP 1.5] ***(learning objectives continue)***	Campbell and Reece, Chapter 11: "Cell Communication" **Web** "Amazing Cells: Cells Communicate"	**Instructional Activity:** Students engage in an online investigation that addresses how the cell communicates through signals aided by pathways made of mostly proteins. During this activity, students will: • View a 3-D animation for cell communication, the fight or flight response. • Examine an in-depth view of how cells communicate during a fight or flight response. • Engage in an interactive exploration called "Dropping Signals." • Learn what happens when cell communication goes wrong. • Look at the inside story of cell communication. This activity is student directed and teacher facilitated. **Instructional Activity:** Students create a model using cutout pieces of construction paper to illustrate the key features/components in a G-protein receptor system and the three stages of cell signaling: reception, transduction, and cellular response. Students describe and present models for peer and teacher review and revision.

Essential Questions: ▼ How is the cell the basic unit of life? ▼ How do materials enter and leave the cell? ▼ What role does the cell membrane play in cellular homeostasis? ▼ What are the relationships between structure and function of cell organelles? ▼ How are the characteristics of life manifested by the cell? ▼ How is free energy used in biological systems to facilitate growth, reproduction, and homeostasis sustainability? ▼ How is energy stored in biological systems? ▼ How are external signals converted into cellular responses?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) Construct an explanation of how certain drugs affect signal reception and, consequently, signal transduction pathways. [LO 3.39, SP 6.2]		**Summative Assessment:** The students take an assessment that is made up of 20–25 multiple-choice questions, two to three short-response questions (including cell signaling), and one lab-based free-response question that requires data analysis based on photosynthesis and/or diffusion and osmosis. The assessment should take approximately 1.5 hours.

The summative assessment addresses these essential questions:
- How is free energy used in biological systems to facilitate growth, reproduction, and homeostasis sustainability?
- How is energy stored in biological systems?
- How are external signals converted into cellular responses?

Unit 3: Genetics and Information Transfer

Laboratory Investigations:

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

Estimated Time:

6 weeks

Essential Questions: ▼ How are traits passed from one generation to the next? ▼ How do eukaryotic cells store, retrieve, and transmit genetic information? ▼ How does genotype affect phenotype? ▼ How are genotype and human disorder related? ▼ How does gene expression control the cell and determine its metabolism? ▼ What are the current trends in genetic engineering techniques that guide manipulation of genetic information? ▼ What social and ethical issues are raised by advances in genetic engineering?

Learning Objectives	Materials	Instructional Activities and Assessments
The Cell Cycle, Mitosis, and Meiosis Make predictions about natural phenomena occurring during the cell cycle. [LO 3.7, SP 6.4] Describe events that occur in the cell cycle. [LO 3.8, SP 1.2] Construct an explanation, using visual representations or narratives, as to how DNA in chromosomes is transmitted to the next generation via mitosis, or meiosis followed by fertilization. [LO 3.9, SP 6.2] Represent the connection between meiosis and increased genetic diversity necessary for evolution. [LO 3.10, SP 7.1] Evaluate evidence provided by data sets to support the claim that heritable information is passed from one generation to another through mitosis, or meiosis followed by fertilization. [LO 3.11, SP 5.3]	Campbell and Reece, Chapter 12: "The Cell Cycle"; Chapter 13: "Meiosis and Sexual Life Cycles"; and Chapter 21: "Genomes and Their Evolution"	**Instructional Activity:** Students make slides of onion root tips to view mitotic cell division. They explain (with justification) why more cells will be in interphase. Students make predictions (with justification) about the events that occur during the cell cycle. This activity has components that are both student directed and teacher directed.
	Web "Microscopic Close Up: Mammal Cell Undergoing Mitosis in Orange Environment"	**Instructional Activity:** Students watch and analyze time-lapse video clips of mitotic cell division. The events in the video clips illustrate that mitosis is a continuous process with observable structural features and different phases. Students then construct a pictorial representation that shows the following processes in mitosis: replication, alignment, separation. This activity is student directed. I guide students as they use microscopes during this activity.
		Instructional Activity: Students create a Venn diagram comparing the process of eukaryotes passing heritable information to next generations of cells by mitosis and by meiosis. They support this comparison with evidence provided by data sets. Students make and explain connections between mitosis and meiosis and increased genetic diversity and evaluate and explain differences and similarities between mitosis and meiosis. This activity is student driven and teacher facilitated.

It is beyond the scope of the AP Biology Exam for students to memorize the names of the phases of mitosis. However, it is important for them to understand that the cell cycle is complex and regulated. Viewing cells in mitotic division allows students to understand the relevance of the cycle. Interphase is important in the preparation of the cell for mitotic division. Understanding what takes place during interphase is integral to understanding how the cell grows and synthesizes DNA.

Although students do not need to memorize the steps, what is important is that they can differentiate replication, alignment, and separation of the mitotic cell cycle.

Essential Questions: ▼ How are traits passed from one generation to the next? ▼ How do eukaryotic cells store, retrieve, and transmit genetic information? ▼ How does genotype affect phenotype? ▼ How are genotype and human disorder related? ▼ How does gene expression control the cell and determine its metabolism? ▼ What are the current trends in genetic engineering techniques that guide manipulation of genetic information? ▼ What social and ethical issues are raised by advances in genetic engineering?

Learning Objectives	Materials	Instructional Activities and Assessments
The Cell Cycle, Mitosis, and Meiosis Make predictions about natural phenomena occurring during the cell cycle. [LO 3.7, SP 6.4] Describe events that occur in the cell cycle. [LO 3.8, SP 1.2] Construct an explanation, using visual representations or narratives, as to how DNA in chromosomes is transmitted to the next generation via mitosis, or meiosis followed by fertilization. [LO 3.9, SP 6.2] Represent the connection between meiosis and increased genetic diversity necessary for evolution. [LO 3.10, SP 7.1] Evaluate evidence provided by data sets to support the claim that heritable information is passed from one generation to another through mitosis, or meiosis followed by fertilization. [LO 3.11, SP 5.3]	**Web** "Mitosis & Meiosis: Doing It on the Table"	**Formative Assessment:** Students reinforce their understanding of mitosis and meiosis by using pipe cleaners to model critical distinctions between what happens to chromosomes during the cell cycles. Students work individually or in pairs to manipulate one pair of chromosomes in mitosis. Once students have modeled and explained mitosis correctly, they can move on to meiosis (repeating the process of modeling and explaining). This activity is student directed and teacher facilitated.
	Skloot, *The Immortal Life of Henrietta Lacks*	**Instructional Activity:** Students read and analyze *The Immortal Life of Henrietta Lacks* as a two-week project. They work in small groups to discuss and explain the nature of cancer cells and the cell cycle, use of HeLa cells in scientific research, and legal and ethical questions regarding using human cells and tissues for scientific research without consent. I facilitate this activity, while the students direct their own learning.
	AP Biology Investigative Labs (2012), Investigation 9: Biotechnology: Restriction Enzyme Analysis of DNA	**Instructional Activity:** Students explore and explain how to use genetic information to identify and profile individuals. They apply mathematical routines to determine the approximate sizes of DNA fragments produced by restriction enzymes. Students also design and conduct experiments based on their own questions. Parts of this activity are student directed and others are teacher directed.
		Summative Assessment: Students take an assessment that is made up of 15–20 multiple-choice questions, one to two short-answer questions, and one lab-based mitosis and meiosis free-response question. The assessment should take approximately 50 minutes.

I monitor and provide feedback via discussions with each student or pair.

The summative assessment addresses the following essential questions:

- How are traits passed from one generation to the next?
- What are the current trends in genetic engineering techniques that guide manipulation of genetic information?
- What social and ethical issues are raised by advances in genetic engineering?

Essential Questions: ▼ How are traits passed from one generation to the next? ▼ How do eukaryotic cells store, retrieve, and transmit genetic information? ▼ How does genotype affect phenotype? ▼ How are genotype and human disorder related? ▼ How does gene expression control the cell and determine its metabolism? ▼ What are the current trends in genetic engineering techniques that guide manipulation of genetic information? ▼ What social and ethical issues are raised by advances in genetic engineering?

Learning Objectives	Materials	Instructional Activities and Assessments
Mendel's Model Construct a representation that connects the process of meiosis to the passage of traits from parent to offspring. [LO 3.12, SP 1.1, SP 7.2] Pose questions about the ethical, social, or medical issues surrounding human genetic disorders. [LO 3.13, SP 3.1] Apply mathematical routines to determine Mendelian patterns of inheritance provided by data sets. [LO 3.14, SP 2.2] Explain deviations from Mendel's model of the inheritance of traits. [LO 3.15, SP 6.5] Explain how the inheritance patterns of many traits cannot be accounted for by Mendelian genetics. [LO 3.16, SP 6.3] ***(learning objectives continue)***	Campbell and Reece, Chapter 14: "Mendel and the Gene Idea" and Chapter 15: "The Chromosomal Basis of Inheritance" **Web** "Who's the Father?"	**Instructional Activity:** Students conduct a long-term activity using Wisconsin Fast Plants that connects the process of meiosis to the passage of traits from parent to offspring. This exploration is an introduction to genetics. Students will be self-directed in their observation and collection of data. They will: 1. Water their plants. 2. Articulate a hypothesis about the inheritance of genes. 3. Gather evidence in a notebook. 4. Determine whether their evidence supports their hypotheses. 5. Explain inheritance of a single trait in Wisconsin Fast Plants based on their evidence. 6. Determine the father's (P2) stem color, based on their explanation of inheritance. 7. Use the chi-square test to explain deviations between an expected and observed result. I serve as a facilitator in the activity.

This is a great hands-on research assignment. The activity takes about 10 weeks. Teachers should plan around days that school will be out to make sure the best results are achieved. The ultimate goal of the lesson is for students to deduce the connection of meiosis and genes passed from parent to offspring.

Essential Questions: ▼ How are traits passed from one generation to the next? ▼ How do eukaryotic cells store, retrieve, and transmit genetic information? ▼ How does genotype affect phenotype? ▼ How are genotype and human disorder related? ▼ How does gene expression control the cell and determine its metabolism? ▼ What are the current trends in genetic engineering techniques that guide manipulation of genetic information? ▼ What social and ethical issues are raised by advances in genetic engineering?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) Describe representations of an appropriate example of inheritance patterns that cannot be explained by Mendel's model of the inheritance of traits. [LO 3.17, SP 1.2] Construct explanations of the influence of environmental factors on the phenotype of an organism. [LO 4.23, SP 6.2] Use evidence to justify a claim that a variety of phenotypic responses to a single environmental factor can result from different genotypes within the population. [LO 4.25, SP 6.1]		**Instructional Activity:** Students examine an ear of corn and determine the type of cross and genes responsible for the coloration and texture of the corn kernels. Students pose scientific questions and form a hypothesis as they attempt to determine whether there is a significant difference between the expected frequencies and the observed frequencies in color and texture. This is a student-guided, teacher-facilitated activity.
	Web "Genetic Disease Information — *pronto!*"	**Instructional Activity:** Students use the Human Genome research site to explore single-gene disease disorders (sickle-cell anemia, Tay-Sachs disease, Huntington's disease, X-linked color blindness, Trisomy 21/Down syndrome, and Klinefelter's syndrome). After researching these diseases individually, students work in small groups to discuss ethical, social, and medical issues that surround human disorders. At the end of the lesson the groups report in a class discussion for which I serve as facilitator.
		Formative Assessment: Students solve monohybrid and dihybrid test crosses. The focus of the assessment is student understanding of phenotypic and genotypic ratios and how traits are passed from one generation to the next. Students report their results to the class for peer and teacher review. The lesson is student directed and teacher facilitated.
		Summative Assessment: The students take an assessment that is made of 15–20 multiple-choice questions, two short-answer questions, and one free-response question based on data including chi-square. The assessment should take approximately 50 minutes.

I correct misconceptions and reteach as needed.

This summative assessment will address the following essential questions:
- How are traits passed from one generation to the next?
- How does genotype affect phenotype?

Essential Questions: ▼ How are traits passed from one generation to the next? ▼ How do eukaryotic cells store, retrieve, and transmit genetic information? ▼ How does genotype affect phenotype? ▼ How are genotype and human disorder related? ▼ How does gene expression control the cell and determine its metabolism? ▼ What are the current trends in genetic engineering techniques that guide manipulation of genetic information? ▼ What social and ethical issues are raised by advances in genetic engineering?

Learning Objectives	Materials	Instructional Activities and Assessments
Gene to Protein Construct scientific explanations that use the structures and mechanisms of DNA and RNA to support the claim that DNA and, in some cases, that RNA are the primary sources of heritable information. [LO 3.1, SP 6.5] Justify the selection of data from historical investigations that support the claim that DNA is the source of heritable information. [LO 3.2, SP 4.1] Describe representations and models that that illustrate how genetic information is copied for transmission between generations. [LO 3.3, SP 1.2] Describe representations and models illustrating how genetic information is translated into polypeptides. [LO 3.4, SP 1.2] Create a visual representation to illustrate how changes in a DNA nucleotide sequence can result in a change in the polypeptide produced. [LO 3.25, SP 1.1] ***(learning objectives continue)***	Campbell and Reece, Chapter 16: "The Molecular Basis of Inheritance" and Chapter 17: "From Gene to Protein" **Web** "Cracking the Code of Life: See Your DNA"	**Instructional Activity:** Students perform a DNA extraction of their own cheek cells. After the lab, students explain (with justification) how advances in biotechnology have been used in real-life applications. Students debate the ethical issues that surround DNA information. This activity is student directed and teacher facilitated. **Instructional Activity:** Students are arranged into small groups to research and justify data supporting important milestones in the identification of DNA as genetic material. Each group presents to the entire class and to the teacher. Students pose questions that are still unanswered about DNA. Students predict (with current data-based justification) what advances in DNA use and biotechnology are to come. I facilitate the activity while the students work in self-guided groups. **Instructional Activity:** Students are self-directed in this activity as they justify how genetic information is the source of heritable information. After reviewing historical data, information, and representations, students role-play in a debate between past scientific experiments and current scientific views. Students can emulate Frederick Griffith, Alfred Hershey, Martha Chase, James Watson, and Francis Crick to debate current scientists. I serve as the facilitator in this activity.

This activity justifies for students that DNA is the source of heritable information.

Essential Questions: ▼ How are traits passed from one generation to the next? ▼ How do eukaryotic cells store, retrieve, and transmit genetic information? ▼ How does genotype affect phenotype? ▼ How are genotype and human disorder related? ▼ How does gene expression control the cell and determine its metabolism? ▼ What are the current trends in genetic engineering techniques that guide manipulation of genetic information? ▼ What social and ethical issues are raised by advances in genetic engineering?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) Predict how a change in a specific DNA or RNA sequence can result in changes in gene expression. [LO 3.6, SP 6.4]	**Web** "A Science Odyssey: You Try It: DNA Workshop"	**Instructional Activity:** Students explore the interactive activity, "DNA Workshop." In this student-directed activity, students justify the role of DNA replication being the starting point toward the goal of protein synthesis. Students manipulate online models to create representations of DNA replication, transcription, and translation. I am the facilitator in this activity.
		Instructional Activity: Students use construction paper, markers, and scissors to construct a model of DNA using at least 24 nucleotides. Students use the model to distinguish between DNA and RNA; to model and explain the processes of replication, transcription, and translation; and to predict (with justification) the effects of change (mutation) on the original nucleotide sequence. The activity is student directed and teacher facilitated.
		Formative Assessment: Students work in self-directed groups to place puzzle pieces together that illustrate the structures of DNA, RNA, and DNA replication, transcription, and translation. I am the facilitator in the activity. I work with students to ensure that the representation illustrates how genetic information is translated into polypeptides leading to protein production. I will also manipulate the representation to depict changes in DNA nucleotide sequence. Students remain in small groups to predict and justify how the changes in a DNA or RNA sequence can affect how the genes are expressed. At the end of the lesson I provide a summary.
		Summative Assessment: The students take an assessment that is made up of 15–20 multiple-choice questions, one to two short-answer questions, and one free-response question with analysis of representations of the DNA structure, DNA replication, and DNA transcription and translation. The assessment should take approximately 50 minutes.

I walk around to each group and validate their work or correct misconceptions and reteach as needed.

This summative assessment will address the following essential question, How do eukaryotic cells store, retrieve, and transmit genetic information?

Essential Questions: ▼ How are traits passed from one generation to the next? ▼ How do eukaryotic cells store, retrieve, and transmit genetic information? ▼ How does genotype affect phenotype? ▼ How are genotype and human disorder related? ▼ How does gene expression control the cell and determine its metabolism? ▼ What are the current trends in genetic engineering techniques that guide manipulation of genetic information? ▼ What social and ethical issues are raised by advances in genetic engineering?

Learning Objectives	Materials	Instructional Activities and Assessments
Gene Expression Describe the connection between the regulation of gene expression and observed differences between different kinds of organisms. [LO 3.18, SP 7.1] Describe the connection between the regulation of gene expression and observed differences between individuals in a population. [LO 3.19, SP 7.1] Explain how the regulation of gene expression is essential for the processes and structures that support efficient cell function. [LO 3.20, SP 6.2] Use representations to describe how gene regulation influences cell products and function. [LO 3.21, SP 1.4] Refine representations to illustrate how interactions between external stimuli and gene expression result in specialization of cells, tissues, and organs. [LO 4.7, SP 1.3] Justify a claim made about the effect(s) on a biological system at the molecular, physiological, or organismal level when given a scenario in which one or more components within a negative regulatory system is altered. [LO 2.15, SP 6.1] ***(learning objectives continue)***	Campbell and Reece, Chapter 20: "Biotechnology" and Chapter 21: "Genomes and Their Evolution"	**Instructional Activity:** In this student-guided activity, students use construction paper or other creative materials to construct models of the *lac* and/or *tryp* operons that include a regulator, promoter, operator, and structural genes. Students use the model to make predictions (with justification) about the effects of mutations in any of the regions on gene expression. I facilitate this activity.
		Instructional Activity: Students create PowerPoint presentations to distinguish between embryonic versus adult stem cells. Students work in small groups to explain (with justification) their arguments for and against stem cell research. This activity is student directed and teacher facilitated.
	Web "Rediscovering Biology: Unit 7: Genetics of Development: Animations and Images"	**Instructional Activity:** Students watch animations and explain (with justification) how the normal hedgehog signaling pathway can be blocked, why the level of hedgehog protein that the cell binds to is important, and how the hedgehog signaling pathway can trigger expression of developmentally important genes. Components of this activity are both student directed and teacher directed.
		Formative Assessment: As an exit ticket, students respond to the question, *What role does the hedgehog protein play in embryonic development?*

Operons in gene regulation are used as an illustrative example to foster student understanding of negative feedback mechanisms. Temperature regulation in animals and plant responses to water limitations are two other examples.

Hedgehog signaling is a concept pertaining to tumor growth that doctors may use in their discussion with a patient. In this activity, students are given an opportunity to justify application of modern biology.

I review the responses and provide feedback. Based on student responses, I may need to review or reteach.

Essential Questions: ▼ How are traits passed from one generation to the next? ▼ How do eukaryotic cells store, retrieve, and transmit genetic information? ▼ How does genotype affect phenotype? ▼ How are genotype and human disorder related? ▼ How does gene expression control the cell and determine its metabolism? ▼ What are the current trends in genetic engineering techniques that guide manipulation of genetic information? ▼ What social and ethical issues are raised by advances in genetic engineering?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) Explain how signal pathways mediate gene expression, including how this process can affect protein production. [LO 3.22, SP 6.2] Use representations to describe mechanisms of the regulation of gene expression. [LO 3.23, SP 1.4] Connect concepts in and across domains to show that 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] 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]		**Formative Assessment:** Students distinguish between the terms *determination* and *differentiation* with regard to gene expressions. Students work in pairs to provide an example and explanation of experimental evidence that supports the claim that different cell types result from differential gene expression in cells with the same DNA. This activity is teacher guided and student driven. **Summative Assessment:** The students take an assessment that is made up of 15–20 multiple-choice questions, one to two short-answer questions, and one free-response question. The assessment should take approximately 50 minutes.

I provide feedback to students regarding any misunderstandings or misconceptions noted. Subsequent activities may be modified based on student explanations.

This assessment addresses the essential question, How does gene expression control the cell and determine its metabolism?

Essential Questions: ▼ How are traits passed from one generation to the next? ▼ How do eukaryotic cells store, retrieve, and transmit genetic information? ▼ How does genotype affect phenotype? ▼ How are genotype and human disorder related? ▼ How does gene expression control the cell and determine its metabolism? ▼ What are the current trends in genetic engineering techniques that guide manipulation of genetic information? ▼ What social and ethical issues are raised by advances in genetic engineering?

Learning Objectives	Materials	Instructional Activities and Assessments
Genetic Engineering Justify the claim that humans can manipulate heritable information by identifying *at least two* commonly used technologies. [LO 3.5, SP 6.4] Predict how a change in genotype, when expressed as a phenotype, provides a variation that can be subject to natural selection. [LO 3.24, SP 6.4, SP 7.2] Explain the connection between genetic variations in organisms and phenotypic variations in populations. [LO 3.26, SP 7.2] Predict the effects of a change in an environmental factor on the genotypic expression of the phenotype. [LO 4.24, SP 6.4]	Campbell and Reece, Chapter 20: "Biotechnology" *AP Biology Investigative Labs* (2012), Investigation 8: Biotechnology: Bacterial Transformation	**Instructional Activity:** Students explore how to use genetic-engineering techniques to manipulate heritable information. They will also apply mathematical routines to determine transformation efficiency. Components of this lab are student and teacher directed.
	Campbell and Reece, Chapter 20: "Biotechnology" **Video** *Gattaca*	**Instructional Activity:** Students view and analyze the film *Gattaca*. During the film, students make notations of biotechnology applications. After the film, students justify their notations and explain (with evidence) whether the science was real or could become real. Students evaluate advances in biotechnology and how ethical issues may get in the way of its advancement. The activity is student driven and teacher facilitated.
		Formative Assessment: Students describe future scenarios (written and/or illustrated) that reflect advancement in our current knowledge of biotechnology. The futuristic scenarios are shared with the class. The students and I participate in a discussion that poses ideas and questions about genetic engineering and ethical and/or medical issues raised by human manipulation of DNA. This activity is both teacher and student lead.
		Summative Assessment: The students respond to free-response questions based on AP Biology Investigation 8: Biotechnology: Bacterial Transformation and Investigation 9: Biotechnology: Restriction Enzyme Analysis of DNA.

Gattaca *is a film that takes applications of current biotechnology to the future. It provides a great platform for students to discuss social and ethical issues, and how they can affect our present way of life.*

Students, peers, and I critique the scenarios and offer constructive feedback.

The summative assessment addresses the essential questions:

- What are the current trends in genetic-engineering techniques that guide manipulation of genetic information?
- What social and ethical issues are raised by advances in genetic engineering?

Laboratory Investigations:

- *AP Biology Investigative Labs* (2012), Investigation 11: Transpiration
- *AP Biology Investigative Labs* (2012), Investigation 12: Fruit Fly Behavior

Estimated Time: *4 weeks*

Essential Questions: ▼ How do interactions between and within populations influence patterns of species distribution and abundance? ▼ How do living things use energy and matter to survive in an ecosystem? ▼ How do humans impact the biodiversity of ecosystems? ▼ What role does the environment play in sustaining homeostasis in biological systems?

Learning Objectives	Materials	Instructional Activities and Assessments
Origin of Life Describe a scientific hypothesis about the origin of life on Earth. [LO 1.27, SP 1.2] Evaluate scientific questions based on hypotheses about the origin of life on Earth. [LO 1.28, SP 3.3] Describe the reasons for revisions of scientific hypotheses of the origin of life on Earth. [LO 1.29, SP 6.3] 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]	Campbell and Reece, Chapter 26: "Phylogeny and the Tree of Life" **Web** "Exploring Life's Origins: A Timeline of Life's Evolution"	**Instructional Activity:** I begin this activity with a class discussion about the origin of life. Students propose a hypothesis regarding how the Earth formed. Students then write a description of early Earth using biotic and biotic factors, and explore a web-based time line that details events in the history of life on Earth. Through this exploration, students will describe and evaluate scientific hypotheses about the origin of the Earth. Students will also evaluate their personal hypotheses against the web-based model of the origin and evolution of Earth. The initial classroom discussion is led by me; however, the remaining parts of this activity are student directed.

There are several hypotheses about the natural origin of life on Earth. Many students have their own personal opinions based on their culture and life experiences. Students should reflect on their own ideas as they explore scientific hypotheses about origins of life on Earth. After gathering additional knowledge, students should be able to evaluate and discuss the hypotheses of the origin of life on Earth.

Essential Questions: ▼ How do interactions between and within populations influence patterns of species distribution and abundance? ▼ How do living things use energy and matter to survive in an ecosystem? ▼ How do humans impact the biodiversity of ecosystems? ▼ What role does the environment play in sustaining homeostasis in biological systems?

Learning Objectives	Materials	Instructional Activities and Assessments
Viruses vs. Cells Construct an explanation of how viruses introduce genetic variation in host organisms. [LO 3.29, SP 6.2] Use representations and appropriate models to describe how viral replication introduces genetic variation in the viral population. [LO 3.30, SP 1.4]	Campbell and Reece, Chapter 19: "Viruses" **Web** "Genetic Variation Increases HIV Risk in Africans"	**Instructional Activity:** Students read and analyze the article "Genetic Variation Increases HIV Risk In Africans" (*Science Daily*). The article presents an explanation of how viral replication can introduce genetic variation in a viral population. As a follow-up to their reading, students write a one-page summary, explaining (with justification) how viruses introduce genetic variation into host organisms. Students share their summaries with the class. I will provide a final summary of the role viruses play in genetic variation. My role is facilitator, and the students are self-guided.
		Instructional Activity: In this student-directed activity, students make a Venn diagram to describe the differences between viruses and human cells. This activity provides the basis for student understanding of viruses and how they introduce genetic variation into host cells. Students work in small groups to explain (with justification) how viruses are not living, but play an important role in biological systems. As the facilitator, I monitor and work with the groups answering questions. At the end of the activity, I choose different student volunteers to provide a summary.
	Web "What You Should Know About Flu Antiviral Drugs"	**Formative Assessment:** Students research and analyze scholarly articles at www.cdc.gov, seeking to prove or disprove the idea that antiviral drugs work. Students work in small groups to report and share their findings. Students explain (with justification) why it's difficult to pinpoint which strain to produce with antiviral drugs.

Students are familiar with HIV but are unfamiliar with viral replication and how it provides genetic variation. Students will be able to appreciate learning more about a disease that is prevalent in the United States. Ask students what social or ethical issues can arise when we talk about fighting the AIDS virus.

The Internet is a valuable source of information if it is used in the right way. Students need to learn how to conduct research and to evaluate their sources. The cdc.gov website is a great site for the students to explore to gather useful information. Students can search the site for antiviral articles beyond what is listed under Unit 4 Resources. I provide feedback to address and correct student misunderstandings and misconceptions.

Essential Questions: ▼ How do interactions between and within populations influence patterns of species distribution and abundance? ▼ How do living things use energy and matter to survive in an ecosystem? ▼ How do humans impact the biodiversity of ecosystems? ▼ What role does the environment play in sustaining homeostasis in biological systems?

Learning Objectives	Materials	Instructional Activities and Assessments
Maintaining Homeostasis Connect how organisms use negative feedback to maintain their internal environments. [LO 2.16, SP 7.2] Evaluate data that show the effect(s) of changes in concentrations of key molecules on negative feedback mechanisms. [LO 2.17, SP 5.3] Make predictions about how organisms use negative feedback mechanisms to maintain their internal environments. [LO 2.18, SP 6.4] Make predictions about how positive feedback mechanisms amplify activities and processes in organisms based on scientific theories and models. [LO 2.19, SP 6.4] Justify that positive feedback mechanisms amplify responses in organisms. [LO 2.20, SP 6.1] ***(learning objectives continue)***	Campbell and Reece, Chapter 1: "INTRODUCTION: Themes in the Study of Life"; Chapter 39: "Plant Responses to Internal and External Signals"; Chapter 40: "Basic Principles of Animal Form and Function"; Chapter 45: "Hormones and the Endocrine System"; and Chapter 55: "Ecosystems"	**Instructional Activity:** Students create a diagram of an organism (of their choice) which shows how that organism maintains homeostasis. The diagram should include the control center, sensor, stimulus, effect, normal temperature, negative feedback, and positive feedback. Students' diagrams should include annotations that explain how organisms use negative feedback to maintain their internal environments. The students are self-directed in this activity, and I am the facilitator.
		Instructional Activity: Students are self-guided as they research a disease and explain (with justification) which body system the disease impacts as well as how it relates to homeostasis. The students should focus on the specific homeostatic mechanism that is affected by the disease. Students make predictions (with justification) regarding how pharmaceutical companies will need to design drugs that will fight the disease based on the negative feedback mechanisms the organism has. Students report their predictions and justification to the class. As facilitator, I provide a summary to the lesson.
		Formative Assessment: Students are assigned a body system (nervous, immune, or endocrine) to explain how the system helps to maintain homeostasis within the body. They write a short essay explaining (with justification) what role the system has in the homeostasis of the body. The essay should also include three examples of ways in which this system may be damaged.

I review the essays and discuss assessments with students to address all misconceptions and misunderstandings.

Essential Questions: ▼ How do interactions between and within populations influence patterns of species distribution and abundance? ▼ How do living things use energy and matter to survive in an ecosystem? ▼ How do humans impact the biodiversity of ecosystems? ▼ What role does the environment play in sustaining homeostasis in biological systems?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) Justify the selection of the kind of data needed to answer scientific questions about the relevant mechanism that organisms use to respond to changes in their external environment. [LO 2.21, SP 4.1] Design a plan for collecting data to support the scientific claim that the timing and coordination of physiological events involve regulation. [LO 2.35, SP 4.2]	**Web** "How the Pill Works"	**Instructional Activity:** After watching the PBS animation "How the Pill Works," students use note cards to explain and justify scientific claims that timing and coordination of certain events are necessary for normal development and are regulated by multiple mechanisms. This animation depicts how the menstrual cycle works and how it is affected by the contraceptive pill. Students complete a chart to represent the different hormones that are released with and without the pill. Students provide an explanation and justification for how the hormones in the pill can disrupt the dynamic homeostatic clock in a female reproductive system. The students are self-guided in this activity and I am the facilitator.
Justify scientific claims with evidence to show how timing and coordination of physiological events involve regulation. [LO 2.36, SP 6.1] Use representations or models to analyze quantitatively and qualitatively the effects of disruptions to dynamic homeostasis in biological systems. [LO 2.28, SP 1.4]		**Instructional Activity:** Students choose two types of environmental disasters (e.g., hurricanes, floods, droughts, oil spills, earthquakes, tsunamis, disease epidemics) to explain how the distribution of changes in the ecosystem over time may affect changes in the future. Each student then makes a visual representation (e.g., poster) with annotation of one of those disasters, showing the before and after effects related to evolution. Students are self-guided, and I am the facilitator.
Explain how the distribution of ecosystems changes over time by identifying large-scale events that have resulted in these changes in the past. [LO 4.20, SP 6.3] Analyze data to identify phylogenetic patterns or relationships, showing that homeostatic mechanisms reflect both continuity due to common ancestry and change due to evolution in different environments. [LO 2.26, SP 5.1] ***(learning objectives continue)***		**Instructional Activity:** Students research and analyze articles that include data on the effects of hormone replacement drugs. Students complete an article analysis focusing on the evaluation of collected data that supports the claim that timing and coordination of physiological events are regulated by multiple mechanisms. I guide the students as they review and evaluate the data in the articles. The research is self-guided for the student after I have provided research guidelines.

Many students will be interested in how timing and coordination affect regulation of the menstrual cycle. Overall, students have many misconceptions and questions on this topic.

Students can relate to disasters that have made headlines in the news. Some students may have a personal link through a family member or friend. Many of these disasters reappear in the news periodically when social and environmental issues arise. This activity should be interesting and relevant for the learner.

Students should be able to analyze data to identify possible patterns. The teacher can differentiate how to have students find and evaluate articles by providing a variety of materials (which address various reading levels, learning styles, etc.). For some students, scientific research articles can be difficult to read and will require support from the teacher. However, reading and evaluating scientific research increase the students' depth of knowledge.

Essential Questions: ▼ How do interactions between and within populations influence patterns of species distribution and abundance? ▼ How do living things use energy and matter to survive in an ecosystem? ▼ How do humans impact the biodiversity of ecosystems? ▼ What role does the environment play in sustaining homeostasis in biological systems?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) Connect differences in the environment with the evolution of homeostatic mechanisms. [LO 2.27, SP 7.1]		**Instructional Activity:** Role-playing and using materials available in the classroom, students in small groups demonstrate the details of timing and coordination of physiological events. Groups choose either a plant or animal example. Examples of plant physiological events are phototropism and photoperiodism. Examples of animal physiological events are circadian rhythms, diurnal/nocturnal cycles, jet lag, seasonal responses, and the effect of pheromones. This activity is student directed, and I am in the role of facilitator.
		Summative Assessment: The students take an assessment that consists of 20–25 multiple-choice questions, two to three short-response questions (including cell signaling), and one long free-response question. The long free-response question is based on a scenario with data analysis covering homeostasis and regulatory mechanisms in biological systems (from cells to ecosystems). The assessment should take approximately 1.5 hours.

There are many examples of physiological events that are regulated by multiple mechanisms for students to demonstrate. I choose to assign examples or have students sign up for them to ensure varied examples among the groups. This activity allows students to be creative and innovative. The demonstrations are presented to the class for review.

This summative assessment should address the following essential questions:

- How do living things use energy and matter to survive in an ecosystem?
- What role does the environment play in sustaining homeostasis in biological systems?

Essential Questions: ▼ How do interactions between and within populations influence patterns of species distribution and abundance? ▼ How do living things use energy and matter to survive in an ecosystem? ▼ How do humans impact the biodiversity of ecosystems? ▼ What role does the environment play in sustaining homeostasis in biological systems?

Learning Objectives	Materials	Instructional Activities and Assessments
Interactions with Environment Refine scientific models and questions about the effect of complex biotic and abiotic interactions on all biological systems, from cells and organisms to populations, communities, and ecosystems. [LO 2.22, SP 1.3, SP 3.2] Design a plan for collecting data to show that all biological systems (cells, organisms, populations, communities, and ecosystems) are affected by complex biotic and abiotic interactions. [LO 2.23, SP 4.2, SP 7.2] Analyze data to identify possible patterns and relationships between a biotic or abiotic factor and a biological system (cells, organisms, populations, communities, or ecosystems). [LO 2.24, SP 5.1]	Campbell and Reece, Chapter 52: "An Introduction to Ecology and the Biosphere" and Chapter 36: "Transport in Vascular Plants"	**Instructional Activity:** Students create travel magazines that depict and describe the five different biomes. For each biome, the student will start from the macro level drilling down (biome, country, city/town, specific ecosystem, specific animal, and specific plant). Students explain (with justification) unique adaptations for their selected plant and animal that allow for survival in the biome. Students should include abiotic and biotic factors. The activity is student guided and I am the facilitator.
	Web "The Habitable Planet: Interactive Labs: Disease Lab"	**Instructional Activity:** In this student-directed and inquiry-based activity, students participate in an interactive lesson that explores various types of diseases. Each disease represents a fast-spreading epidemic with a high mortality rate. Students explain how abiotic and biotic factors affect the spread of diseases, and what we can do to counter them. My role is that of facilitator.
	AP Biology Investigative Labs (2012), Investigation 11: Transpiration	**Instructional Activity:** In this lab investigation, students need little supervision to design and conduct experiments as they investigate the effects of environmental variables on transpiration rates. Students determine how biological systems are affected by complex biotic and abiotic interactions. I am the facilitator during this lab activity.
		Formative Assessment: Students are self-guided as they use the data from the AP Biology Investigation 11: Transpiration to graph and analyze their results and draw conclusions. Students explain (with justification) the role of abiotic and biotic factors in their analyses.
		Summative Assessment: The students take an assessment that is made up of 10 multiple-choice questions, one short-response question, and one lab-based free-response question that requires data analysis based on AP Biology Investigation 11: Transpiration. The assessment should take approximately 50 minutes.

Students should be able to refine their understanding of the effects of complex biotic and abiotic interactions on biological systems. This activity provides the opportunity for students to connect their knowledge of biology across systems and scales.

I provide feedback to students regarding any misconceptions or misunderstandings present in their analyses.

This summative assessment will address the following essential questions:
- How do interactions between and within populations influence patterns of species distribution and abundance?
- What role does the environment play in sustaining homeostasis in biological systems?

Essential Questions: ▼ How do interactions between and within populations influence patterns of species distribution and abundance? ▼ How do living things use energy and matter to survive in an ecosystem? ▼ How do humans impact the biodiversity of ecosystems? ▼ What role does the environment play in sustaining homeostasis in biological systems?

Learning Objectives	Materials	Instructional Activities and Assessments
Behavior Justify scientific claims, using evidence, to describe how timing and coordination of behavioral events in organisms are regulated by several mechanisms. [LO 2.39, SP 6.1] Connect concepts in and across domain(s) to predict how environmental factors affect responses to information and change behavior. [LO 2.40, SP 7.2] Analyze data that indicate how organisms exchange information in response to internal changes and external cues, and which can change behavior. [LO 3.40, SP 5.1] Create a representation that describes how organisms exchange information in response to internal changes and external cues, and which can result in changes in behavior. [LO 3.41, SP 1.1] Describe how organisms exchange information in response to internal changes or environmental cues. [LO 3.42, SP 7.1]	Campbell and Reece, Chapter 51: "Animal Behavior" **Web** "Circadian Rhythms"	**Instructional Activity:** Students independently explore an interactive tutorial on circadian rhythms. This tutorial includes examples of measurements of biological rhythms. Students use this activity to explain and justify how timing and coordination of behavioral events in organisms are regulated. The students are self-guided and I am the facilitator.
	AP Biology Investigative Labs (2012), Investigation 12: Fruit Fly Behavior	**Instructional Activity:** In this lab investigation, students construct choice chambers to investigate behaviors that underlie chemotaxis. Students will design and conduct experiments based on their own research questions. This lab is student directed and facilitated by me.
		Instructional Activity: Students choose and observe specific behaviors in three different breeds of dogs. In written reports, students describe how dogs exchange information in response to internal changes and external cues. Students make recommendations to determine which type of dog is best suited to live on a farm, in a loft apartment, and/or in a condominium. This activity is student guided and facilitated by me.

Interactions

(continued)

Essential Questions: ▼ How do interactions between and within populations influence patterns of species distribution and abundance? ▼ How do living things use energy and matter to survive in an ecosystem? ▼ How do humans impact the biodiversity of ecosystems? ▼ What role does the environment play in sustaining homeostasis in biological systems?

Learning Objectives	Materials	Instructional Activities and Assessments
Responses and Defenses Create representations and models to describe immune responses. [LO 2.29, SP 1.1, SP 1.2] Create representations or models to describe nonspecific immune defenses in plants and animals. [LO 2.30, SP 1.1, SP 1.2] Construct an explanation, based on scientific theories and models, about how nervous systems detect external and internal signals, transmit and integrate information, and produce responses. [LO 3.43, SP 6.2, SP 7.1] Describe how nervous systems detect external and internal signals. [LO 3.44, SP 1.2] Describe how nervous systems transmit information. [LO 3.45, SP 1.2] Describe how the vertebrate brain integrates information to produce a response. [LO 3.46, SP 1.2] Create a visual representation of complex nervous systems to describe/explain how these systems detect external and internal signals, transmit and integrate information, and produce responses. [LO 3.47, SP 1.1] ***(learning objectives continue)***	Campbell and Reece, Chapter 39: "Plant Responses to Internal and External Signals"; Chapter 43: "The Immune System"; and Chapter 49: "Nervous Systems"	**Instructional Activity:** Students create posters that describe the immune system. Each poster should show examples of how plants or animals use chemical defenses against infectious diseases. This lesson is student directed and facilitated by me. **Formative Assessment:** Students write a one-page response to the following statement: *A baby is born with its mother's immune system.* After students complete their responses, I initiate a discussion by asking students to share those responses with the class.
	ABO-Rh Blood Typing with Synthetic Blood Kit	**Instructional Activity:** Students are self-guided as they use simulated blood and sera to investigate the relationship between antigens and antibodies. The students use ABO-Rh blood typing to describe a nonspecific immune defense found in the human body. I am the facilitator in this activity.

Students can relate to diseases that affect plants they are familiar with. They also relate to diseases that can affect them. By making a poster, they can easily see how living organisms have a first line of defense to fight diseases.

I provide feedback to clarify or correct any student misconceptions.

Essential Questions: ▼ How do interactions between and within populations influence patterns of species distribution and abundance? ▼ How do living things use energy and matter to survive in an ecosystem? ▼ How do humans impact the biodiversity of ecosystems? ▼ What role does the environment play in sustaining homeostasis in biological systems?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) 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] 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 39: "Plant Responses to Internal and External Signals"; Chapter 43: "The Immune System"; and Chapter 49: "Nervous Systems"	**Instructional Activity:** Students work in small groups to design a teaching model of the nervous system to be used for patients in a doctor's office. In this activity, the students explain how the nervous system transmits information and how the brain integrates this information to produce a response. Students also create brochures that could be given to patients. The brochure explains (with justification) how the nervous system transmits information, how it detects external and internal signals, and how the brain integrates information to produce a response. This activity is student guided and facilitated by me.
Living Together Evaluate scientific questions concerning organisms that exhibit complex properties due to the interaction of their constituent parts. [LO 4.8, SP 3.3] Predict the effects of a change in a component(s) of a biological system on the functionality of an organism(s). [LO 4.9, SP 6.4] ***(learning objectives continue)***	Campbell and Reece, Chapter 53: "Population Ecology"; Chapter 54: "Community Ecology"; Chapter 55, "Ecosystems"; Chapter 40: "Basic Principles of Animal Form and Function"; and Chapter 56: "Conservation Biology and Restoration Ecology"	**Instructional Activity:** Students work in groups to describe five talking points (each) regarding populations, communities, and ecosystems. The students explain (with justification) the talking points on chart paper. Each group posts their paper on the wall in different places in the classroom for a gallery walk. Groups visit each posted paper and discuss how the three topics relate to one another. These posts are reviewed by me and other students. This activity is student focused and facilitated by me.

Essential Questions: ▼ How do interactions between and within populations influence patterns of species distribution and abundance? ▼ How do living things use energy and matter to survive in an ecosystem? ▼ How do humans impact the biodiversity of ecosystems? ▼ What role does the environment play in sustaining homeostasis in biological systems?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) Refine representations and models to illustrate biocomplexity due to interactions of the constituent parts. [LO 4.10, SP 1.3] Justify the selection of the kind of data needed to answer scientific questions about the interaction of populations within communities. [LO 4.11, SP 1.4, SP 4.1] Apply mathematical routines to quantities that describe communities composed of populations of organisms that interact in complex ways. [LO 4.12, SP 2.2] Predict the effects of a change in the community's populations on the community. [LO 4.13, SP 6.4] Predict the effects of a change of matter or energy availability on communities. [LO 4.16, 6.4] Use data analysis to refine observations and measurements regarding the effect of population interactions on patterns of species distribution and abundance. [LO 4.19, SP 5.2] Predict consequences of human actions on both local and global ecosystems. [LO 4.21, SP 6.4] ***(learning objectives continue)***		**Summative Assessment:** Students create visual representations that illustrate biocomplexity and interactions in the environment. Each representation should be a depiction across systems (starting from the biosphere and going to the habitat of an organism). The following should also be included: biosphere, biome, ecosystem, community, population, organism, habitat, and niche. Abiotic and biotic factors should be included where applicable.
	Heitz and Giffen, *Practicing Biology: A Student Workbook,* Activity 43.1	**Instructional Activity:** Students work through activity 43.1 in the Heitz and Giffen workbook to explore models that scientists use to calculate population growth rates. Students apply the growth model $dN/dt=rN$ to several different populations and make predictions (with justification) regarding the effects of changes in populations. The students are self-guided in this activity, and I am the facilitator.
		Formative Assessment: Students create posters that illustrate the effect of a change in matter and energy availability in an ecosystem. Students are self-guided as they describe the trophic structure of the ecosystem and explain how organisms receive inputs of energy and nutrients, where outputs go, and the effects each organism has on the others. They include energy transformations and transfers based on the hypothetical assumption that 10,500 J of net energy is available at the producer level, and they determine the organisms that are placed in each trophic level. Students share their posters with the class for peer review. My role in this assessment is one of facilitator.

This summative assessment addresses the following essential questions:

- How do living things use energy and matter to survive in an ecosystem?
- What role does the environment play in sustaining homeostasis in biological systems?

I use the discussions about students' presentations to determine whether students understand the topic or if reteaching is required.

Essential Questions: ▼ How do interactions between and within populations influence patterns of species distribution and abundance? ▼ How do living things use energy and matter to survive in an ecosystem? ▼ How do humans impact the biodiversity of ecosystems? ▼ What role does the environment play in sustaining homeostasis in biological systems?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) Make scientific claims and predictions about how species diversity within an ecosystem influences ecosystem stability. [LO 4.27, SP 6.4]		**Instructional Activity:** Students are self-guided as they research how the oil spill in the Gulf of Mexico (April 20, 2010) affected marine life. Students extend learning to researching what effect the gulf spill had globally. Students report on the current forecast for marine life in the gulf as a result of the spill. I am the facilitator in this activity.
	Web "Are All Invasive Species Bad?"	**Instructional Activity:** Students are self-guided as they read and analyze the article, "Are All Invasive Species Bad?" (usnews.com). Students complete an article analysis and include a personal response to the article's claims. The teacher is the facilitator in this activity and provides a summary of the student analyses and personal responses.
		Instructional Activity: Students are self-guided as they research rubber as a Brazilian rainforest product and explain how it is harvested. Students make connections between the role of humans and the effect the rubber production business has had on the Amazon rainforest environment. I am the facilitator in this activity.
		Instructional Activity: Students are self-guided as they research the biology and natural history of the cougar, its status in the habitats of North America, and how cougars and humans interact. Through their research, students determine the best way to reconcile human land development with cougar survival. I am the facilitator in this activity.
		Summative Assessment: Students take an assessment that is made up of 20–25 multiple-choice questions, two to three short-response questions, and one lab-based free-response question based on a scenario and data analysis with application of quantitative skills and science practices. The assessment should take approximately 1.5 hours.

This activity allows students to research a topic that most are familiar with. This activity could be guided by a media specialist as students gather information to report on the effects of the gulf oil spill.

This summative assessment addresses all of the essential questions for this unit:

- How do interactions between and within populations influence patterns of species distribution and abundance?
- How do living things use energy and matter to survive in an ecosystem?
- How do humans impact the biodiversity of ecosystems?
- What role does the environment play in sustaining homeostasis in biological systems?

Resources

General Resources

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

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.

Unit 1 (Evolution) Resources

"Darwin Lives! Modern Humans Are Still Evolving." Eben, Harrell. Time.com. Accessed December 19, 2011. http://www.time.com/time/health/article/0,8599,1931757,00.html.

"Evolution: Species and Speciation." Connecting Concepts: Interactive Lessons in Biology. Accessed December 19, 2011. http://ats.doit.wisc.edu/biology/ev/sp/sp.htm.

"'Instant' Evolution Seen in Darwin's Finches, Study Says." Inman, Mason. National Geographic News. Accessed November 30, 2011. http://news.nationalgeographic.com/news/2006/07/060714-evolution.html.

Lamb, Trevor D. "Evolution of the Eye." *Scientific American* 305, no. 1 (2011): 64–69.

"Lesson 6: Why Does Evolution Matter Now?" PBS. Accessed December 7, 2011. http://www.pbs.org/wgbh/evolution/educators/lessons/lesson6/index.html.

"Making Cladograms: Phylogeny, Evolution, and Comparative Anatomy." ENSI (Evolution & the Nature of Science Institutes). Accessed November 30, 2011. http://www.indiana.edu/~ensiweb/lessons/mclad.html.

"Peanut Variation Lab." Accessed December 13, 2011. http://www.biology.fourcroy.org/chapters/90_ca_std/handouts/05peanutlab.htm.

"Speciation in Real Time." Understanding Evolution. Accessed December 19, 2011. http://evolution.berkeley.edu/evolibrary/news/100201_speciation.

"Visualizing Life on Earth: Data Interpretation in Evolution." Understanding Evolution. Accessed December 13, 2011. http://evolution.berkeley.edu/evolibrary/article/0_0_0/ldg_01.

"Welcome to Evolution 101!" Understanding Evolution. Accessed December 7, 2011. http://evolution.berkeley.edu/evolibrary/article/evo_01.

Supplementary Resources

"Hardy-Weinberg Equilibrium." Stanhope, Judith. Accessed December 13, 2011. http://www.woodrow.org/teachers/bi/1994/hwintro.html.

Unit 2 (Cellular Processes: Energy and Communication) Resources

"Amazing Cells: Cells Communicate." Genetic Science Learning Center: *Learn.Genetics*. Accessed November 30, 2011. http://learn.genetics.utah.edu/content/begin/cells/.

"CELLS *alive!*" Accessed December 19, 2011. http://cellsalive.com/.

"Cell Size." Massengale's Biology Junction. Accessed November 30, 2011. http://www.biologyjunction.com/cell_size.htm.

"Enzymes Help Us Digest Food." Hands-on Activities for Teaching Biology to High School or Middle School Students. Serendip. Accessed November 30, 2011. http://serendip.brynmawr.edu/sci_edu/waldron/#enzymes.

"LabBench Activity: Enzyme Catalysis." PHSchool — The Biology Page. Pearson. Accessed November 30, 2011. http://www.phschool.com/science/biology_place/labbench/lab2/intro.html.

Unit 3 (Genetics and Information Transfer) Resources

"Cracking the Code of Life: See Your DNA." NovaTeachers. PBS. Accessed November 30, 2011. http://www.pbs.org/wgbh/nova/teachers/activities/2809_genome.html.

Gattaca. Directed by Andrew Niccol. 1997. Culver City, CA: Sony, 1998. DVD.

"Genetic Disease Information — *pronto!*" Human Genome Project Information. Genomics.energy.gov. Accessed November 30, 2011. http://www.ornl.gov/sci/techresources/Human_Genome/medicine/assist.shtml.

"Microscopic Close Up: Mammal Cell Undergoing Mitosis in Orange Environment." Google Videos. Accessed November 30, 2011. http://video.google.com/videoplay?docid=8057806780595432977#.

"Mitosis & Meiosis: Doing It on the Table." ENSI (Evolution & the Nature of Science Institutes). Accessed December 19, 2011. http://www.indiana.edu/~ensiweb/lessons/gen.mm.html.

"Rediscovering Biology: Unit 7: Genetics of Development: Animations and Images." Annenberg Learner. Accessed November 30, 2011. http://www.learner.org/courses/biology/units/gendev/images.html.

"A Science Odyssey: You Try It: DNA Workshop." PBS. Accessed December 19, 2011. http://www.pbs.org/wgbh/aso/tryit/dna/.

Skloot, Rebecca. *The Immortal Life of Henrietta Lacks*. New York: Random House, 2010.

"Who's the Father?" Wisconsin Fast Plants. Accessed December 19, 2011. www.fastplants.org/pdf/WTF_mono.pdf.

Unit 4 (Interactions) Resources

ABO-Rh Blood Typing with Synthetic Blood Kit. Carolina Supply Company. http://www.carolina.com/product/700101.do.

"Are All Invasive Species Bad?" Arnold, Carrie. *US News and World Report: Science*. Accessed December 19, 2011. http://www.usnews.com/science/articles/2011/08/31/are-all-invasive-species-bad.

"Circadian Rhythms." Accessed December 19, 2011. http://bcs.whfreeman.com/thelifewire/content/chp52/5202002.html.

"Exploring Life's Origins: A Timeline of Life's Evolution." Exploring Life's Origins. Accessed November 30, 2011. http://exploringorigins.org/timeline.html.

"Genetic Variation Increases HIV Risk in Africans." *ScienceDaily*: Science News. Accessed December 19, 2011. http://www.sciencedaily.com/releases/2008/07/080716121355.htm.

"The Habitable Planet: Interactive Labs: Disease Lab." Annenberg Learner. Accessed November 30, 2011. http://www.learner.org/courses/envsci/interactives/disease/.

Heitz, Jean, and Cynthia Giffen. *Practicing Biology: A Student Workbook*. 4th ed. (Supplement to Campbell Biology). San Francisco: Benjamin Cummings, 2011.

"How the Pill Works." American Experience. PBS. Accessed December 19, 2011. http://www.pbs.org/wgbh/amex/pill/sfeature/sf_cycle.html.

"What You Should Know About Flu Antiviral Drugs." Centers for Disease Control and Prevention. Accessed December 19, 2011. http://www.cdc.gov/flu/antivirals/whatyoushould.htm.

Supplementary Resources

"H1N1 Flu: Questions & Answers: Antiviral Drugs, 2009–2010 Flu Season." Centers for Disease Control and Prevention. Accessed November 30, 2011. http://www.cdc.gov/h1n1flu/antiviral.htm.