AP® Biology

Course Planning and Pacing Guide 4

Julianne M. Zedalis
The Bishop's School
La Jolla, California

About the College Board

The College Board is a mission-driven not-for-profit organization that connects students to college success and opportunity. Founded in 1900, the College Board was created to expand access to higher education. Today, the membership association is made up of more than 5,900 of the world's leading educational institutions and is dedicated to promoting excellence and equity in education. Each year, the College Board helps more than seven million students prepare for a successful transition to college through programs and services in college readiness and college success — including the SAT® and the Advanced Placement Program®. The organization also serves the education community through research and advocacy on behalf of students, educators, and schools.

For further information, visit www.collegeboard.org.

AP® Equity and Access Policy

The College Board strongly encourages educators to make equitable access a guiding principle for their AP programs by giving all willing and academically prepared students the opportunity to participate in AP. We encourage the elimination of barriers that restrict access to AP for students from ethnic, racial, and socioeconomic groups that have been traditionally underserved. Schools should make every effort to ensure their AP classes reflect the diversity of their student population. The College Board also believes that all students should have access to academically challenging course work before they enroll in AP classes, which can prepare them for AP success. It is only through a commitment to equitable preparation and access that true equity and excellence can be achieved.

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).

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

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

Contents

Instructional Setting

The Bishop's School
La Jolla, California

School	Independent college-preparatory school in suburban community. Mission Statement: *The Bishop's School is an academic community pursuing intellectual, artistic, and athletic excellence in the context of the Episcopal tradition. We are dedicated to offering the highest-quality education to a diverse student body and to fostering integrity, imagination, moral responsibility, and commitment to serving the larger community.*
Student population	Approximately 780 students in grades six to 12. Students are: • 64 percent of European heritage • 15 percent Asian American • 13 percent Hispanic • 8 percent African American Approximately 25 percent of students receive financial assistance. Ninety-eight percent of Bishop's students matriculate to college.
Instructional time	Academic year begins mid-August and ends mid-May; approximately 175 days of instruction. Prior to AP® Exam: • 34 weeks of instruction and one week for in-class review • Two 50-minute periods/week and two 100-minute lab periods/week for total of 300 minutes/week Additional time: • 18 one-hour after-school AP Exam review sessions • One six-hour Saturday AP Exam review session • Six 50-minute in-class AP Exam review sessions

Student preparation	AP Biology is offered in the junior year; many students opt to take the AP Biology prep course offered during the preceding summer. The prerequisites for students are: • physics or honors physics in ninth grade • chemistry or honors chemistry in 10th grade
Textbooks and lab manuals	Campbell, Neil A., and Jane B. Reece. *Biology*. 7th ed. San Francisco: Pearson Benjamin Cummings, 2005. *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

AP Biology is the equivalent of a one-year college or university course in biology, taught within the parameters of high school. Students explore the question, *How do we know what we know?* by investigating six topic areas: the chemistry of life, cells, cell processes (energy and cell communication), genetics, evolution, and biodiversity and ecology. Integrated into the six topic areas are big ideas, enduring understandings, and learning objectives from the *AP Biology Curriculum Framework* that merge concepts with science practices at the molecular, cellular, organism, population, and ecosystem levels. All students sit for the AP Biology Exam.

The course merges rigor with creativity and offers students myriad opportunities for learning through scientific inquiry, development of laboratory skills, and assessment. Rather than simply presenting information, teachers use formative assessments to guide instruction and work *with* students, instilling in them a sense of pride and ownership in what they learn. Knowledge attained in the classroom is applied to real-world issues, including the impact of biotechnology on society and global ecological concerns.

The instructional strategies suggested here both introduce concepts and connect and apply previously studied material. They include lectures, laboratory investigations, class discussions, videos and online media, journal readings, and other projects and activities designed to encourage students to think critically and develop written and verbal communication skills. The curriculum accommodates different learning styles, knowledge bases, and abilities, while providing depth of content and opportunities for students to demonstrate mastery of science practices along with conceptual understandings of course topics.

The laboratory program at Bishop's has transitioned from traditional "cookbook-style" experiments to more teacher-guided, inquiry-based investigations conducted with available equipment and resources within budget. Students attend the quarterly Science Lecture Series; guest speakers have included Nobel Laureates from the San Diego community.

As teachers, our job is to make knowledge relevant and applicable while helping students develop critical skills and connect concepts to see the big picture. This is often accomplished by differentiating instruction and providing a variety of instructional activities and projects which take into account student prior knowledge and/or learning styles. For example, when describing the complex biochemical pathways of photosynthesis, have students write letters to politicians and chiefs of industry expressing concern for the ecological ramifications of natural disasters and human impact on habitats or global ecosystems. When discussing DNA, ask students to compose a short story, poem, or significant piece of art describing a day in the life of a teenager afflicted with a genetic disorder. Stimulate ethical discussion by asking, "Just because science *can* do something, does that mean that it *should*?"

As teachers, we must model adult competence and demand excellence not only from our students but also from ourselves. We should create a learning environment in which students can take appropriate risks as they ask questions, explore answers, and collect, process, and communicate information. Encourage students to follow one question by asking another. When a classroom becomes less teacher driven and more student directed, an artist who previously abhorred science can find pleasure creating a plant cell out of clay, while a writer can describe chemiosmosis through poetry. A "less is more" approach, in which breadth of content is replaced by depth, provides students with a framework for applying existing skills and knowledge to new areas of study as they explore the living world.

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: The Chemistry of Life	The concepts detailed in Campbell and Reece, Chapter 2: "The Chemical Context of Life" are now considered prior knowledge. The topics include: matter, elements, atomic structure, molecules and compounds, chemical reactions, bonding, pH, etc. With a cursory review of these concepts, I save approximately five to seven days of instructional time and can jump right into the biochemistry of biomolecules, including structure and function of enzymes. (In the past, I've assigned Chapters 1–4 as required summer reading, and some students elect to take our AP Biology Prep course that covers this material during summer school.)	Students are required to take a year of physics in the ninth grade and a year of chemistry in the 10th grade; thus, more time is available to explore in more depth the structure and function of molecules essential for life processes. This is accomplished by using molecule-modeling kits to build complex polymers (e.g., carbohydrates, lipids, proteins, nucleic acids, and ATP) and by using the models to illustrate the processes of dehydration synthesis and hydrolysis in their assembly and degradation.
Unit 2: The Cell	Because AP Biology at Bishop's is most students' first course in biology, I cannot assume that all students have prior knowledge of the structure and function of cellular organelles. However, I save time by having students investigate cell features through a comprehensive project in which they build a specialized cell with a working organelle that demonstrates the primary function of their exemplar cell. This reduction in content saves me approximately two days of instructional time.	By reducing time spent learning and/or reviewing basic chemistry, I allow students time to explore in more depth the required concepts in Campbell and Reece, Chapters 6 and 7 (cells) and Chapter 8 (enzyme activity).
Unit 3: Cell Processes: Energy and Communication	Required concepts from Chapters 8–10 (energy, respiration, and photosynthesis) are outlined in the curriculum framework, but focus can be reduced on other topics in this unit. Since students have taken physics and chemistry prerequisite courses, I can spend less time on the following concepts from Chapter 8: forms of energy, catabolic versus anabolic pathways, first and second Laws of Thermodynamics, and exergonic versus endergonic reactions. Because the information covered in Chapter 2 is considered prior knowledge, I can move the study of enzymes and enzymatic reactions to Unit 1. In Chapter 9, I reduce or eliminate time spent on details regarding oxidation-reduction reactions and the rote memorization of name and structure of molecules, processes, and cycles involved in cellular respiration (e.g., cytochromes in ETC, molecules in glycolysis and Kreb's cycle). In Chapter 10, I reduce or eliminate focus on properties of light, structure, and function of pigments other than chlorophylls a and b, and C4 and CAM plant adaptations for carbon fixation and photorespiration. These reductions in content will save approximately five days of instructional time.	By focusing less on minutiae and memorization, students are able to spend more time exploring key concepts in the capture, storage, and use of free energy in the processes of cellular respiration and photosynthesis. With the additional time available, students can dive more deeply into concepts by tackling inquiry-based laboratory investigations based on respiration and photosynthesis. In addition, students focus on connecting concepts by refining and revising models, such as chemiosmosis. By reducing some content pertaining to photosynthesis and cellular respiration, I give students time to explore in more depth the concepts in Chapter 11: "Cell Communication." Students typically find concepts of molecular signaling and transduction pathways difficult, which makes the extra time available to cover these topics especially valuable.

Managing Breadth and Increasing Depth *(continued)*

Unit	Managing Breadth	Increasing Depth
Unit 4: From Gene to Protein	The required concepts for Chapters 16–17 (DNA replication, transcription, and translation) are outlined in the curriculum framework. The required concepts for Chapter 18: "The Genetics of Viruses and Bacteria" are also outlined in the curriculum framework. Structure and life cycles of viruses are covered in Unit 6. Reductions in content will save approximately two days of instructional time.	In Chapter 19: "Eukaryotic Genomes: Organization, Regulation, and Evolution," more concepts about gene regulation are required. In Chapter 20: "DNA Technology and Genomics," more attention is focused on details about concepts relating to genomics and ethical issues raised by genetic manipulation by humans. In Chapter 21: "The Genetic Basis of Development," there are more details about concepts relating to the regulation of development of gene expression. In Chapter 22: "Descent with Modification: A Darwinian View of Life," there is more instruction about mathematical models to support evolution. In Chapter 24: "The Origin of Species," there are more details about evolutionary change and concepts relating to the genetic regulation of development/speciation/evolution.
Unit 5: Evolution	No significant reductions	
Unit 6: Biodiversity and Ecology	In Chapters 27–34 (prokaryotes to vertebrates: "march through the phyla"), the content consists of illustrative examples to support concepts outlined in the curriculum framework. The content in Chapter 35: "Plant Structure, Growth, and Development" is no longer required, which leaves more time to focus on other topics. The required systems in Chapter 40–49 (animal form and function, "organ of the day") are immune, endocrine, and nervous, with essential concepts described in the curriculum framework. Other organ systems can be used as illustrative examples to support concepts (e.g., homeostatic mechanisms, structural and physiological adaptations to environments, evolution of systems).	For Chapters 43, 45, and 48 (immune, endocrine, and nervous systems), required content/concepts are outlined in the curriculum framework, with increased emphasis on homeostasis, chemical signaling, and regulation. For Chapter 47: "Animal Development," required elements about the timing, coordination, and regulation of development are outlined in the curriculum framework with emphasis on inductive signaling.

The Chemistry of Life

Laboratory Investigations:

- Building Biomolecules
- *AP Biology Investigative Labs* (2012), Investigation 13: Enzyme Activity

Estimated Time:

3 weeks

Essential Questions:
- ▼ How are biological molecules necessary for organisms to grow, to reproduce, and to maintain organization?
- ▼ How do the subcomponents of biological molecules determine the properties of that molecule?

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 create mini-posters to explain how either the carbon or nitrogen cycles provide essential chemical elements to support life in an ecosystem. Students make predictions about the impact of human activity on the cycles. This activity is student directed and teacher facilitated.
		Instructional Activity: Based on water's molecular properties, students create visual representations (e.g., diagrams or models) with annotations to explain how water travels up a 300-ft. California redwood tree. This activity is student directed and teacher facilitated.
		Formative Assessment: Students create visual representations with annotations (e.g., diagrams or models) to explain how water's molecular structure results in unique properties and how these properties are vital to life processes.
Explain the connection between the sequence and the subcomponents of a biological polymer and its properties. [LO 4.1, SP 7.1] Construct explanations based on evidence of how variation in molecular units provides cells with a wider range of functions. [LO 4.22, SP 6.2] Represent graphically or model quantitatively the exchange of molecules between an organism and its environment, and the subsequent uses of these molecules to build new molecules that facilitate dynamic homeostasis, growth, and reproduction. [LO 2.9, SP 1.1, SP 1.4]	Campbell and Reece, Chapter 5: "The Structure and Function of Macromolecules" Molecular model kits or alternative (e.g., foam balls and toothpicks)	**Instructional Activity:** Using molecular model kits, students justify the claim that organisms need the SPONCH elements to build complex molecules and recycle elements necessary for life by constructing models of key biomolecules from their monomers. This activity is student directed and teacher facilitated. **Formative Assessment:** Students explain either through narrative or visual representations (e.g., diagram with annotation) how the SPONCH elements move from the environment to synthesize complex biomolecules (e.g., carbohydrates, lipids, proteins, nucleic acids, ATP) necessary for cellular processes.

Here is an opportunity to apply chemistry to a contemporary ecological issue.

While students are constructing their diagrams, I circulate among them, ask probing questions, and adjust instructional activities accordingly. This tactic is applicable to most formative assessments.

Students can justify claims and ideas in a variety of ways (differentiated instruction) but typically use pen and paper. Another option (and one that is more engaging) is to have them create models. In this case, building molecular models helps students visualize three-dimensional images that are used to demonstrate the processes of dehydration synthesis and hydrolysis.

Essential Questions:
- ▼ How are biological molecules necessary for organisms to grow, to reproduce, and to maintain organization?
- ▼ How do the subcomponents of biological molecules determine the properties of that molecule?

Learning Objectives	Materials	Instructional Activities and Assessments
Refine representations and models to explain how the subcomponents of a biological polymer and their sequence determine the properties of that polymer. [LO 4.2, SP 1.3] Use models to predict and justify that changes in the subcomponents of a biological polymer affect the functionality of the molecule. [LO 4.3, SP 6.1, SP 6.4] Analyze data to identify how molecular interactions affect structure and function. [LO 4.17, SP 5.1]	Campbell and Reece, Chapter 8: "An Introduction to Metabolism," pp.149–158 *AP Biology Investigative Labs* (2012), Investigation 13: Enzyme Activity Waterman and Stanley, *Biological Inquiry: A Workbook of Investigative Cases*, "Picture Perfect"	**Instructional Activity:** "Picture Perfect." An inquiry-based case study built on concepts relating to enzymatic activity. Students design an experiment to examine factors affecting the action of amylase on starch to identify a stain on an antique dress. This activity is student directed and requires limited teacher facilitation. **Instructional Activity:** AP Biology Investigation 13: Enzyme Activity. Students design and conduct investigations to explore the effects of environmental variables on the rates of enzymatic reactions. This lab is student directed and teacher facilitated.
		Summative Assessment: Exam consisting of 25 multiple-choice questions, two short free-response questions, and one long free-response question with emphasis on the application of quantitative skills, science practices, and data analysis.

The case study or the lab investigation can be used to introduce students to the role of catalytic enzymes in cellular chemical reactions or to provide a means of applying concepts when they have a fairly solid understanding of enzyme structure and function. For each lab activity, I use a variety of assessment tactics: mini-posters, formal lab reports, and notations in student lab notebooks. Some students keep an online version of all their lab work.

This lab investigation is a modification of the enzyme catalysis lab from the 2001 AP Biology Lab Manual. *Teachers should feel free to use or modify "favorite labs" from various sources as long as they reflect transition from teacher-directed "cookbook" labs to more student-directed and inquiry-based investigations.*

The summative assessment addresses the following essential questions:
- How are biological molecules necessary for organisms to grow, to reproduce, and to maintain organization?
- How do the subcomponents of biological molecules determine the properties of that molecule?

Laboratory Investigations:

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

Estimated Time:
3 weeks

Essential Questions: ▼ How do shared conserved cellular processes support the idea that all organisms are linked by lines of descent from common ancestry? ▼ How do cells create and maintain internal environments that are different from their external environments? ▼ How do structure and function of subcellular components and their interactions provide essential cellular processes? ▼ How do cells maintain dynamic homeostasis by the movement of molecules across membranes?

Learning Objectives	Materials	Instructional Activities and Assessments
Use calculated surface area-to-volume ratios to predict which cell(s) might eliminate wastes or procure nutrients faster by diffusion. [LO 2.6, SP 2.2] Explain how cell size and shape affect the overall rate of nutrient intake and the rate of waste elimination. [LO 2.7, SP 6.2]	Campbell and Reece, Chapter 6: "A Tour of the Cell"; Chapter 27: "Prokaryotes" *AP Biology Investigative Labs* (2012), Investigation 4: Diffusion and Osmosis, Procedure 1: Surface Area and Cell Size **Multimedia** *The Domains of Life: Life's Three Great Branches: Archaea, Bacteria, and Eukarya*	**Instructional Activity:** AP Biology Investigation 4: Diffusion and Osmosis, Procedure 1: Surface Area and Cell Size. Students model surface area-to-volume relationships using agar blocks and phenolphthalein. This activity is student directed and teacher facilitated. **Formative Assessment:** Students create a diagram with annotation to explain how approximately 300 million alveoli in a human lung increase surface area for gas exchange to the size of a tennis court. Students should use the diagram to explain how the cellular structures of alveoli, capillaries, and red blood cells allow for rapid diffusion of O_2 and CO_2 between them.
Explain how internal membranes and organelles contribute to cell functions. [LO 2.13, SP 6.2] Use representations and models to describe differences in prokaryotic and eukaryotic cells. [LO 2.14, SP 1.4] Make a prediction about the interactions of subcellular organelles. [LO 4.4, SP 6.4] Construct explanations based on scientific evidence as to how interactions of subcellular structures provide essential functions. [LO 4.5, SP 6.2] Use representations and models to analyze situations qualitatively to describe how interactions of subcellular structures, which possess specialized functions, provide essential functions. [LO 4.6, SP 1.4]	Campbell and Reece, Chapter 6: "A Tour of the Cell"	**Instructional Activity:** Using inexpensive and common household items, students create a model of a specific cell (e.g., neuron, white blood cell, plant leaf cell, *Paramecium*, sperm cell, bacterium) that includes a *working* organelle that defines the overall function of the cell. Students explain their cell and organelle to the class. **Formative Assessment:** Students create a visual representation, such as a diagram with annotation or a PowerPoint slide, to explain how four organelles work together to perform a specific function in a cell of your choice. Students should predict how a defect in the function of one of the organelles can affect the overall function of the cell. Students present their visual representations to the class for review and revision.

Students struggle with geometric relationships between surface area and volume: the smaller the cell, the higher surface area-to-volume ratio to facilitate movement of molecules into and out of the cell. Having students model surface area-to-volume relationships using agar blocks and phenolphthalein provides visual clarification.

Although required content pertaining to the human organ systems was reduced significantly in the course, teachers can incorporate these systems to illustrate concepts. Exploring the exchange of gases in the lungs is one way to apply surface area-to-volume relationships and the process of diffusion to a biological system.

Students often have misconceptions about the "simplicity" of prokaryotic cells. Clarify that prokaryotes have internal organization and a great number of metabolic pathways and biochemical adaptations to almost all environments. It is important to emphasize that living cells are not static, rigid structures but dynamic.

Formative assessments that ask students to present their work to the class for review and revision are an effective means to assess where students are in their understanding of concepts and provide an opportunity for immediate feedback from peers and the teacher.

Essential Questions: ▼ How do shared conserved cellular processes support the idea that all organisms are linked by lines of descent from common ancestry? ▼ How do cells create and maintain internal environments that are different from their external environments? ▼ How do structure and function of subcellular components and their interactions provide essential cellular processes? ▼ How do cells maintain dynamic homeostasis by the movement of molecules across membranes?

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]	Campbell and Reece, Chapter 7: "Membrane Structure and Function" *AP Biology Investigative Labs* (2012), Investigation 4: Diffusion and Osmosis	**Instructional Activity:** Provided with a simple diagram of the fluid mosaic model of cell membrane structure, students revise and/or refine the diagram to illustrate the arrangement of the membrane's molecular components. This activity is student directed.
		Instructional Activity: AP Biology Investigation 4: Diffusion and Osmosis. Students explore the phenomenon of water potential and then model osmosis and diffusion using dialysis tubing. Using plant tissues and various sucrose solutions, students design and conduct an experiment to determine the water potential of the plant tissues. This lab is student directed and teacher facilitated.
		Instructional Activity: Using the revised cell membrane diagrams they created, students pose three questions about the relationship between the structure of the membrane and the movement of molecules across it (e.g., polar and non-polar molecules, small and large molecules). Then students explain how answers to the questions can be investigated.

Modeling is an important skill for students. Using dialysis tubing to model a selectively permeable cell membrane reinforces the science practice.

The concept of water potential is difficult for students because they cannot relate water potential to the measure of its potential energy, with water moving to a state of lower free energy. Modeling osmosis helps clarify the concept.

Essential Questions: ▼ How do shared conserved cellular processes support the idea that all organisms are linked by lines of descent from common ancestry? ▼ How do cells create and maintain internal environments that are different from their external environments? ▼ How do structure and function of subcellular components and their interactions provide essential cellular processes? ▼ How do cells maintain dynamic homeostasis by the movement of molecules across membranes?

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: "Phylogeny and Systematics"; and Chapter 26: "The Tree of Life: An Introduction to Biological Diversity," pp. 523–526 Chen, "The Emergence of Cells During the Origin of Life" **Multimedia** *The Domains of Life:* *The Eukaryotic Cell Evolves*	**Instructional Activity:** Mystery Cell ID. Using a microscope, students identify the general type of cell (e.g., prokaryote/eukaryote, plant/animal) and support their observations by describing two distinctive features of each mystery cell. This activity is student directed and teacher facilitated.
		Instructional Activity: Ten-Minute Debate. Working in small teams, students create a visual representation to support the claim that eukaryotes evolved from symbiotic relationships between groups of prokaryotes. Then students identify one or two unanswered questions about Margulis's endosymbiont hypothesis.
		Formative Assessment: Students construct a diagram to explain the relationships that exist between the three domains of life (Archaea, Bacteria, and Eukarya) based on molecular processes and cellular features. Students present their diagrams to the class for review and revision.
		Summative Assessment: One-hour exam consisting of 20 multiple-choice questions, two short-response questions, and one lab-based free-response question with data analysis based on the relationship between cell membrane structure and the processes of osmosis, diffusion, and active transport.

This activity asks students to apply a skill (microscopy) to content (identification of cell types). The activity also provides an opportunity for students to explore the relationship between magnification and real size.

This activity asks students to synthesize information from multiple sources — textbook, class discussion, science reading, and video — and evaluate evidence in support of a notable hypothesis about the origin of the eukaryotic cell.

This formative assessment is a simple but effective way to introduce cladogram construction, which will be an essential tool as students delve more deeply into evolutionary relationships in Unit 5.

The summative assessment addresses the following essential questions:
- How do shared conserved cellular processes support the idea that all organisms are linked by lines of descent from common ancestry?
- How do cells create and maintain internal environments that are different from their external environments?
- How do structure and function of subcellular components and their interactions provide essential cellular processes?
- How do cells maintain dynamic homeostasis by the movement of molecules across membranes?

Unit 3: Cell Processes: Energy and Communication

Laboratory Investigations:

- Respiration of Sugars by Yeast (Vernier)
- *AP Biology Investigative Labs* (2012), Investigation 6: Cellular Respiration
- *AP Biology Investigative Labs* (2012), Investigation 5: Photosynthesis

Estimated Time: *4 weeks*

Essential Questions: ▼ How do biological systems utilize free energy to grow, to reproduce, and to maintain homeostasis? ▼ How do organisms capture, use, and store free energy? ▼ How are external signals converted into cellular responses?

Learning Objectives	Materials	Instructional Activities and Assessments
Energy Explain how biological systems use free energy based on empirical data that all organisms require constant energy input to maintain organization, to grow, and to reproduce. [LO 2.1, SP 6.2] Justify a scientific claim that free energy is required for living systems to maintain organization, to grow, or to reproduce, but that multiple strategies exist in different living systems. [LO 2.2, SP 6.1] Predict how changes in free energy availability affect organisms, populations, and ecosystems. [LO 2.3, SP 6.4] Use representations and models to analyze how cooperative interactions within organisms promote efficiency in the use of energy and matter. [LO 4.18, SP 1.4] Use representations to pose scientific questions about what mechanisms and structural features allow organisms to capture, store, and use free energy. [LO 2.4, SP 1.4, SP 3.1] Construct explanations of the mechanisms and structural features of cells that allow organisms to capture, store, or use free energy. [LO 2.5, SP 6.2] Describe specific examples of conserved core biological processes and features shared by all domains or within one domain of life, and how these shared, conserved core processes and features support the concept of common ancestry for all organisms. [LO 1.15, SP 7.2]	Campbell and Reece, Chapter 8: "An Introduction to Metabolism," pp. 141–149; Chapter 9: "Cellular Respiration: Harvesting Chemical Energy"; and Chapter 10: "Photosynthesis," pp. 181–141 Waterman and Stanley, "Bean Brew" Redding and Masterman, *Biology with Vernier*, "Respiration of Sugars by Yeast" *AP Biology Investigative Labs* (2012), Investigation 6: Cellular Respiration *AP Biology Investigative Labs* (2012), Investigation 5: Photosynthesis	**Instructional Activity:** Students engage in "Bean Brew," an inquiry-based investigative case study on the fermentation process used to develop soy sauce. The activity is student directed and requires minimum teacher facilitation. **Instructional Activity:** Lab: Respiration of Sugars by Yeast. Students design and conduct experiments to investigate whether yeasts are able to metabolize a variety of sugars, using gas pressure sensors to measure CO_2 production. This lab is student directed and teacher facilitated. **Instructional Activity:** AP Biology Investigation 6: Cellular Respiration. Students use microrespirometers or gas pressure sensors to investigate factors that affect the rate of cellular respiration in multicellular organisms. This lab is student directed and teacher facilitated. **Instructional Activity:** AP Biology Investigation 5: Photosynthesis. Using the floating leaf disk procedure, students investigate factors that affect the rate of photosynthesis in living leaves. This lab is student directed and teacher facilitated. **Instructional Activity:** Online investigation: Students research the connections between paraquat (or other herbicides), the pathways of photosynthesis, and possible effects of herbicides on ecosystems. (An article about paraquat appeared in a 1978 issue of *Rolling Stone* magazine.) **Formative Assessment:** In teams, students create a visual representation (e.g., diagram with annotation) to explain the interdependent relationships of cellular respiration and photosynthesis and how the processes of cellular respiration and photosynthesis support life on Earth. Visual representations are displayed in the classroom for peer review and revision and to generate questions for further investigation.

Cellular respiration and photosynthesis are typically challenging topics for students to grasp, because they cannot make connections between the processes and their relevance to higher levels of biological organization, such as plant and animal physiology or energy flow in ecosystems.

Formative assessments that allow students to engage with one another provide unique learning opportunities. I tell students, "You really don't understand something until you have to teach it to someone else." I provide guidance to students on how to offer feedback to their peers on the clarity and accuracy of the visual explanations. After the activity, we discuss the effectiveness of the feedback and what the activity's outcomes tell us about the students' learning.

Essential Questions: ▼ How do biological systems utilize free energy to grow, to reproduce, and to maintain homeostasis? ▼ How do organisms capture, use, and store free energy? ▼ 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 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] Construct an explanation of how certain drugs affect signal reception and, consequently, signal transduction pathways. [LO 3.39, SP 6.2]	Campbell and Reece, Chapter 11: "Cell Communication," pp. 201–205, 208–209, 212–214	**Instructional Activity:** Online investigation: Students explain and justify the mechanism by which a specific disease is caused by a defective signaling pathway *and* investigate one drug that works by blocking a signaling pathway. **Formative Assessment:** Students create an interactive model using cutout pieces of construction paper to describe the key features/components in a G-protein receptor system and explain the three stages of cell signaling: reception, transduction, and cellular response. Students share models for review and revision. **Summative Assessment:** One-hour exam consisting of 20 multiple-choice questions, two short-response questions (including one on cell signaling) and one lab-based free-response question with data analysis based on the lab investigations.

Cell signaling mechanisms are challenging for students to grasp because they focus on memorization of minute details rather than the big picture. Focus on one or two illustrative examples of applicability of cell signaling concepts, such as how a familiar drug works or how the symptoms of a disease occur, to pique student engagement. Slowly guide students through the three primary stages: reception, transduction, and response.

Using this modeling activity as a means of formative assessment is effective for engaging students, especially if they work in small groups to create the model. The teacher visits each group, asks questions, and provides feedback.

The summative assessment addresses the following essential questions:

- How do biological systems utilize free energy to grow, to reproduce, and to maintain homeostasis?
- How do organisms capture, use, and store free energy?
- How are external signals converted into cellular responses?

Unit 4: From Gene to Protein

Laboratory Investigations:

- *AP Biology Investigative Labs* (2012), Investigation 7: Mitosis and Meiosis
- DNA Extraction (DNA Necklace Kit, Carolina Biological Supply Company)
- *AP Biology Investigative Labs* (2012), Investigation 8: Biotechnology: Bacterial Transformation
- *AP Biology Investigative Labs* (2012), Investigation 9: Biotechnology: Restriction Enzyme Analysis of DNA

Estimated Time:

9 weeks

Essential Questions:

▼ How do living systems store, retrieve, and transmit genetic information critical to life processes? ▼ How does the expression of genetic material control cell products which, in turn, determine the metabolism and nature of the cell? ▼ What is the relationship between changes in genotype and phenotype and evolution? ▼ How can humans use genetic engineering techniques to manipulate genetic information? What are ethical issues raised by the application of these techniques?

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 the events that occur in the cell cycle. [LO 3.8, SP 1.2] Construct an explanation, using visual representations or narratives, as to how DNA in chromosomes is transmitted to the next generation via mitosis, or meiosis followed by fertilization. [LO 3.9, SP 6.2] Represent the connection between meiosis and increased genetic diversity necessary for evolution. [LO 3.10, SP 7.1] Evaluate evidence provided by data sets to support the claim that heritable information is passed from one generation to another through mitosis, or meiosis followed by fertilization. [LO 3.11, SP 5.3]	Campbell and Reece, Chapter 12: "The Cell Cycle"; Chapter 13: "Meiosis and Sexual Life Cycles"; and Chapter 19: "Eukaryotic Genomes: Organization, Regulation, and Evolution," pp. 359–361 *AP Biology Investigative Labs* (2012), Investigation 7: Mitosis and Meiosis Skloot, *The Immortal Life of Henrietta Lacks*	**Instructional Activity:** Students create a cartoon-like "flip book" to animate the events in mitosis to illustrate that the process is continuous.
		Instructional Activity: AP Biology Investigation 7: Mitosis and Meiosis. After exploring and modeling mitosis and meiosis, students conduct independent investigations to determine the effect(s) of biotic or abiotic factors on the rate of mitosis in plant roots. This lab is student directed and teacher facilitated.
		Instructional Activity: Students create a series of diagrams with annotations that compare, contrast, and analyze the processes of mitosis and meiosis, focusing on the chromosome number of the resulting daughter cells.
		Instructional Activity: Based on information gleaned by reading *The Immortal Life of Henrietta Lacks*, students design and implement a project that reflects an issue raised by the author (e.g., the relationship between cancer cells and cell cycle control, the use of HeLa cells in scientific research, the legal and ethical questions raised in the book).
		Formative Assessment: Students use the projects they created in the instructional activity described above to explain how meiosis followed by fertilization increases genetic variation, whereas mitosis usually results in genetically identical daughter cells. Students should use the model to make prediction(s) about the effect of genetic mutation on both processes.
		Summative Assessment: Quiz consisting of 10 multiple-choice questions, one short, lab-based free-response question, and five "identify the process" microscope slides/lab activities.

Students often think that DNA duplication is a precursor only to mitotic cell division and that haploid cells cannot reproduce by mitosis.

Reading a best-selling book or viewing a commercial movie that is applicable to concepts studied in class helps motivate and engage students. For example, many students have family members who have or have had cancer and can relate to issues raised by the Henrietta Lacks story.

Immediately following this activity, I discuss with the class their predictions. I ask probing questions to determine how the students have progressed toward the learning objectives, and then I use that feedback to make decisions about next instructional steps.

The summative assessment addresses the essential question, How do living systems store, retrieve, and transmit genetic information critical to life processes?

Essential Questions:
▼ How do living systems store, retrieve, and transmit genetic information critical to life processes? ▼ How does the expression of genetic material control cell products which, in turn, determine the metabolism and nature of the cell? ▼ What is the relationship between changes in genotype and phenotype and evolution? ▼ How can humans use genetic engineering techniques to manipulate genetic information? What are ethical issues raised by the application of these techniques?

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] 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] ***(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:** Investigation activity using Wisconsin Fast Plants. "Who's the Father?" is a quick but engaging way to review or to introduce Mendelian inheritance. This activity is student directed and teacher facilitated.
		Instructional Activity: Students make predictions about expected phenotypic ratios in genetic crosses and then use the chi-square test to explain any deviations between the expected and observed ratios. Students should use provided data *or* experiments using Fast Plants (or *Drosophila*).
		Instructional Activity: A Day in the Life. Students compose a short story, PowerPoint presentation, video, poem, song, or significant piece of art to describe a day in the life of a teenager afflicted with a single gene disorder or chromosomal abnormality. Students should include the science behind the disorder (i.e., causes and effects) and identify a social, medical, or ethical issue(s) associated with human genetic disorders.

Students must be able to connect Mendelian inheritance patterns, mitosis and meiosis, and phenotype. Mendel's laws of inheritance can be explained by the behavior of chromosomes during meiosis. Have students incorporate drawings of chromosomes carrying alleles to relate Punnett squares to meiosis, haploid gamete formation, and fertilization.

This project reinforces for students that we are products of the genetic hand we were dealt, and that we all contribute to human diversity. The project serves to dispel stereotyping.

Essential Questions: ▼ How do living systems store, retrieve, and transmit genetic information critical to life processes? ▼ How does the expression of genetic material control cell products which, in turn, determine the metabolism and nature of the cell? ▼ What is the relationship between changes in genotype and phenotype and evolution? ▼ How can humans use genetic engineering techniques to manipulate genetic information? What are ethical issues raised by the application of these techniques?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) 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]		**Formative Assessment:** Students work in pairs to solve a daily genetics problem (e.g., monohybrid, dihybrid, test cross, co-dominance versus incomplete dominance, sex-linkage, crossing over, pedigrees). The first pair with a solution comes to the board and works the problem for peer review. **Summative Assessment:** One-hour exam consisting of 20 multiple-choice questions and two free-response questions. The free-response questions are based on data and include chi-square analysis.

The summative assessment addresses the essential question, How do living systems store, retrieve, and transmit genetic information critical to life processes?

Essential Questions: ▼ How do living systems store, retrieve, and transmit genetic information critical to life processes? ▼ How does the expression of genetic material control cell products which, in turn, determine the metabolism and nature of the cell? ▼ What is the relationship between changes in genotype and phenotype and evolution? ▼ How can humans use genetic engineering techniques to manipulate genetic information? What are ethical issues raised by the application of these techniques?

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 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" Watson and Crick, "Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid." **Video** *Cracking the Code of Life* **Web** DNA Necklace Kit, Carolina Biological Supply Company	**Instructional Activity:** Lab: DNA Extraction (DNA Necklace Kit). Students investigate the chemical properties of DNA — and learn a forensic technique. This lab is teacher directed.
		Instructional Activity: Provided with evidence relating to how the Frederick Griffith and Hershey-Chase experiments supported the identification of DNA as *the* genetic material, students pose questions that remained unanswered by these historical experiments.
		Instructional Activity: The Watson and Crick Model of DNA. Students develop a model of the structure of DNA based solely on Watson and Crick's original *Nature* article, "Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid."
		Instructional Activity: Students design an experiment to test the three models of DNA replication. Assume access in a laboratory to the following: experimental organism, radioactive isotopes, test tubes and centrifuge, and growth media for organisms.
		Instructional Activity: Using construction paper, markers, and scissors, students construct a model of DNA using at least 24 nucleotides. Students use the model to distinguish between DNA and RNA; to model the processes of replication, transcription, and translation; and to predict the effects of change (mutation) on the original nucleotide sequence.

When isolating DNA from cheek cells, students likely will make the connection between DNA and criminal investigations — which foreshadows a biotechnology lab.

Ask students to come up with an analogy for the phenomenon of the "leading" and "lagging" strands of DNA. For example, if an escalator is moving upward and Susie rides it upward, she is riding up the "leading" strand. However, if she tries to ride up an escalator that is moving downward, she will have trouble traveling up this "lagging" strand — unless she travels in leaps or bounds (i.e., Okazaki fragments).

Engage students in the processes of DNA replication, transcription, and translation by asking them to model the processes. I circulate among the groups and ask students to explain their models. I can assess their understanding by asking probing questions that might lead students to revise their work.

Essential Questions: ▼ How do living systems store, retrieve, and transmit genetic information critical to life processes? ▼ How does the expression of genetic material control cell products which, in turn, determine the metabolism and nature of the cell? ▼ What is the relationship between changes in genotype and phenotype and evolution? ▼ How can humans use genetic engineering techniques to manipulate genetic information? What are ethical issues raised by the application of these techniques?

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]		**Instructional Activity:** Students create a board game to take players through the key steps in translation — and have classmates play the game!
		Formative Assessment: Provided with incomplete diagrams (or diagrams with errors) illustrating the structures of DNA and RNA, DNA replication, transcription, and translation, students refine or revise the diagrams and share the edited versions for critical review.
		Summative Assessment: One-hour exam consisting of 20 multiple-choice questions, two short-response questions, and one long free-response question involving analysis of models of the structure of DNA, DNA replication, transcription, and translation.

The summative assessment addresses the following essential questions:

- How do living systems store, retrieve, and transmit genetic information critical to life processes?
- How does the expression of genetic material control cell products which, in turn, determine the metabolism and nature of the cell?
- What is the relationship between genotype and phenotype and evolution?

Essential Questions:
▼ How do living systems store, retrieve, and transmit genetic information critical to life processes? ▼ How does the expression of genetic material control cell products which, in turn, determine the metabolism and nature of the cell? ▼ What is the relationship between changes in genotype and phenotype and evolution? ▼ How can humans use genetic engineering techniques to manipulate genetic information? What are ethical issues raised by the application of these techniques?

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 18: "The Genetics of Viruses and Bacteria," pp. 352–356; Chapter 19: "Eukaryotic Genomes: Organization, Regulation, and Evolution," pp. 362–370, 371–373, 374–381; and Chapter 21: "The Genetic Basis of Development," pp. 411–428 Waterman and Stanley, "Shh: Silencing the Hedgehog Pathway," Parts I and III	**Instructional Activity:** Students use construction paper or more elaborate materials to create a model of the *lac* and *tryp* operons that include a regulator, promoter, operator, and structural genes. Students use the model to make predictions about the effects of mutations in any of the regions on gene expression. **Instructional Activity:** Students create a diagram to distinguish between the products of embryonic versus adult stem cells. What are some arguments for and against embryonic stem cell research? **Instructional Activity:** "Shh: Silencing the Hedgehog Pathway," Parts I and III. Students engage in an investigative case study of the hedgehog signaling pathway and its role in embryonic development. **Formative Assessment:** In a short written narrative, students describe one example of experimental evidence that supports the claim that different cell types result from differential gene expression in cells with the same DNA. Then, in small groups, students share and discuss their examples and distinguish between *determination* and *differentiation*.

Students often have difficulty distinguishing between inducible and repressible operons. Remind students of the role of each type of operon in cell metabolism.

The concepts underlying the genetic basis of development are difficult for students to understand. It is recommended that students focus on the developmental pattern of one illustrative organism, such as Drosophila.

Stem cell research and cloning are "hot topics" in contemporary biology. Helping students gain scientific literacy is integral to their understanding of modern biology.

Essential Questions: ▼ How do living systems store, retrieve, and transmit genetic information critical to life processes? ▼ How does the expression of genetic material control cell products which, in turn, determine the metabolism and nature of the cell? ▼ What is the relationship between changes in genotype and phenotype and evolution? ▼ How can humans use genetic engineering techniques to manipulate genetic information? What are ethical issues raised by the application of these techniques?

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 the timing and coordination of specific events are necessary for normal development in an organism and that these events are regulated by multiple mechanisms. [LO 2.31, SP 7.2] Use a graph or diagram to analyze situations or solve problems (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]		**Summative Assessment:** One long free-response question that asks students to connect their understanding of mitosis, DNA and genes, and cell signaling pathways to differential protein expression in a model organism.

The summative assessment addresses the essential question, How does the expression of genetic material control cell products which, in turn, determine the metabolism and nature of the cell?

Essential Questions:
▼ How do living systems store, retrieve, and transmit genetic information critical to life processes? ▼ How does the expression of genetic material control cell products which, in turn, determine the metabolism and nature of the cell? ▼ What is the relationship between changes in genotype and phenotype and evolution? ▼ How can humans use genetic engineering techniques to manipulate genetic information? What are ethical issues raised by the application of these techniques?

<table>
<tr><th>Learning Objectives</th><th>Materials</th><th>Instructional Activities and Assessments</th></tr>
<tr><td rowspan="5">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]</td><td rowspan="5">Campbell and Reece, Chapter 20: “DNA Technology and Genomics,” pp. 384–394, 402–408

AP Biology Investigative Labs (2012), Investigation 8: Biotechnology: Bacterial Transformation

AP Biology Investigative Labs (2012), Investigation 9: Biotechnology: Restriction Enzyme Analysis of DNA

Video
Gattaca</td><td>Instructional Activity:

AP Biology Investigation 8: Biotechnology: Bacterial Transformation. Students investigate how genetic engineering techniques can be used to manipulate heritable information using Escherichia coli. After learning fundamental skills, students can design their own experiments to manipulate DNA. This lab is student directed and teacher facilitated.</td></tr>
<tr><td>Instructional Activity:

AP Biology Investigation 9: Biotechnology: Restriction Enzyme Analysis of DNA. Beginning with a forensic mystery, students investigate how genetic information can be used to identify and profile individuals. This lab is student directed and teacher facilitated.</td></tr>
<tr><td>Instructional Activity:

Using information from the film Gattaca and other pieces that we read and discuss in class, students reflect on the idea explored in Michael Crichton’s Jurassic Park that just because science can do something doesn’t mean that it should.</td></tr>
<tr><td>Formative Assessment:

Students create a mini-poster for peer review to explain several applications of genetic engineering and possible ethical, social, or medical issues raised by human manipulation of DNA.</td></tr>
<tr><td>Summative Assessment:

Quiz consisting of two free-response questions based on data from experiments pertaining to bacterial transformation and restriction enzyme analysis of DNA.</td></tr>
</table>

Teaching students about the risks and benefits of human manipulation of DNA both engages and educates. Ask students what the Human Genome Project has revealed about our evolution and genetic relationships to other organisms.

Gattaca *is a film that foreshadows contemporary issues about the ethics of genetic manipulation by humans and opens a door for discussion and debate.*

The summative assessment addresses the following essential questions:
- How can humans use genetic engineering techniques to manipulate genetic information?
- What are ethical issues raised by the application of these techniques?

Laboratory Investigations:

- ***AP Biology Lab Manual*** **(2001), Lab 8: Population Genetics and Evolution**
- ***AP Biology Investigative Labs*** **(2012), Investigation 1: Artificial Selection**
- ***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: *6 weeks*

Essential Questions: ▼ How does evolution by natural selection drive the diversity and unity of life? ▼ What scientific evidence from many disciplines, including mathematics, supports models about the origin of life on Earth and biological evolution? ▼ How can phylogenetic trees and cladograms be used to graphically model evolutionary history among species?

Learning Objectives	Materials	Instructional Activities and Assessments
Population Genetics Convert a data set from a table of numbers that reflect a change in the genetic makeup of a population over time and apply mathematical methods and conceptual understandings to investigate the cause(s) and effect(s) of this change. [LO 1.1, SP 1.5, SP 2.2] Evaluate evidence provided by data to qualitatively and quantitatively investigate the role of natural selection in evolution. [LO 1.2, SP 2.2, SP 5.3] Analyze data to support the claim that responses to information and communication of information affect natural selection. [LO 2.38, SP 5.1] Apply mathematical methods to data from a real or simulated population to predict what will happen to the population in the future. [LO 1.3, SP 2.2] Evaluate data-based evidence that describes evolutionary changes in the genetic makeup of a population over time. [LO 1.4, SP 5.3] Connect evolutionary changes in a population over time to a change in the environment. [LO 1.5, SP 7.1] ***(learning objectives continue)***	Campbell and Reece, Chapter 22: "Descent with Modification: A Darwinian View of Life," pp. 438–448; and Chapter 23: "The Evolution of Populations" *AP Biology Lab Manual* (2001), Lab 8: Population Genetics and Evolution or *AP Biology Investigative Labs* (2012), Investigation 2: Mathematical Modeling: Hardy-Weinberg *AP Biology Investigative Labs* (2012), Investigation 1: Artificial Selection Leslie, "Kidney Disease is Parasite-Slaying Protein's Downside" Genovese, et al., "Association of Trypanolytic ApoL1 Variants with Kidney Diseases in African Americans"	**Instructional Activity:** AP Lab 8: Population Genetics and Evolution or AP Biology Investigation 2: Mathematical Modeling: Hardy-Weinberg. Introduces students to application of the Hardy-Weinberg equation to study changes in allele frequencies in a population and to examine possible causes for these changes. Although the first part of this lab is teacher directed, inquiry based questions for students to answer are included. **Instructional Activity:** AP Biology Investigation 1: Artificial Selection. Using Wisconsin Fast Plants, students explore evolution by conducting an artificial selection investigation. Students then can apply principles to determine if extreme selection can change expression of a quantitative trait. **Instructional Activity:** Students read the two articles from *Science* about genetic variants/kidney disease/*Trypanosoma*. They then answer the following question either in writing or class discussion: *How does the information apply to the study of population genetics and support the concept of continuing evolution by natural selection?* **Instructional Activity:** Provided with data from real or simulated populations, students apply the Hardy-Weinberg mathematical model to determine if selection is occurring. If it is determined that the populations are *not* in H-W equilibrium, students should describe possible reasons for the deviation(s).

Students often do not grasp how and when to use the Hardy-Weinberg equation. Provide scenarios and data, then ask students to apply the H-W model and explain possible reasons why a population is not in H-W equilibrium.

Using a mathematical program/spreadsheet to model Hardy-Weinberg requires sufficient time and computer resources. However, mathematical modeling is a contemporary tool for exploring historical work.

The two scientific papers about genetic variants linking polycystic kidney disease with resistance to Trypanosoma *(sleeping sickness) provide real-world relevance to concepts discussed in class and provide an example to support continuing evolution of populations through natural selection, including our own.*

Essential Questions: ▼ How does evolution by natural selection drive the diversity and unity of life? ▼ What scientific evidence from many disciplines, including mathematics, supports models about the origin of life on Earth and biological evolution? ▼ How can phylogenetic trees and cladograms be used to graphically model evolutionary history among species?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) Use data from mathematical models based on the Hardy-Weinberg equilibrium to analyze genetic drift and effects of selection in the evolution of specific populations. [LO 1.6, SP 1.4, SP 2.1] Justify data from mathematical models based on the Hardy-Weinberg equilibrium to analyze genetic drift and the effects of selection in the evolution of specific populations. [LO 1.7, SP 2.1] Use theories and models to make scientific claims and/or predictions about the effects of variation within populations on survival and fitness. [LO 4.26, SP 6.4] Make predictions about the effects of genetic drift, migration, and artificial selection on the genetic makeup of a population. [LO 1.8, SP 6.4]		

Essential Questions: ▼ How does evolution by natural selection drive the diversity and unity of life? ▼ What scientific evidence from many disciplines, including mathematics, supports models about the origin of life on Earth and biological evolution? ▼ How can phylogenetic trees and cladograms be used to graphically model evolutionary history among species?

Learning Objectives	Materials	Instructional Activities and Assessments
Evidence for Evolution Evaluate evidence provided by data from many scientific disciplines to support biological evolution. [LO 1.9, SP 5.3] Refine evidence based on data from many scientific disciplines that support biological evolution. [LO 1.10, SP 5.2] Design a plan to answer scientific questions regarding how organisms have changed over time using information from morphology, biochemistry, and geology. [LO 1.11, SP 4.2] Connect scientific evidence from many scientific disciplines to support the modern concept of evolution. [LO 1.12, SP 7.1]	Campbell and Reece, Chapter 22: "Descent with Modification: A Darwinian View of Life," pp. 448–452 Weiner, *The Beak of the Finch: A Story of Evolution in Our Time* **Web** "Lesson 3: What is the Evidence for Evolution? Activity 1: Evolution and Time" **Video** *Beyond Genesis: The Origin of Species*	**Instructional Activity:** Students work through the online PBS activity "Evolution and Time," following the instructions to create a journal entry to evaluate and describe the geological ecosystem of a particular time period. **Instructional Activity:** Students read teacher-selected excerpts from Weiner's *The Beak of the Finch* (either aloud in class or as a homework assignment) and highlight evidence that supports evolution by natural selection as an explanation for the observed differences in beak sizes over several seasons. **Formative Assessment:** Using excerpts from *The Beak of the Finch,* students write a brief narrative explaining how evidence from many scientific disciplines supports the observations of Charles Darwin as well as Peter and Rosemary Grant regarding differences in beak sizes and, thus, supports evolution by natural selection. Then, in small groups, students share and discuss their explanations. **Summative Assessment:** Thirty-minute quiz consisting of 10 multiple-choice questions and two short free-response questions based on (1) the application of the Hardy-Weinberg equation and (2) evidence for evolution by natural selection within a population(s).

Time scales can be difficult for students to interpret. The PBS online activity helps students appreciate that the biodiversity we see today reflects millions of years of evolution.

Many students think that natural selection is purposeful and goal-driven. Stress that new phenotypes result from random mutation and sexual recombination; a trait that increases the fitness of individuals in their environment likely will persist in the population. Having students read excerpts from Weiner's The Beak of the Finch *helps dispel misconceptions while putting a modern twist on Darwin's historical observations.*

The summative assessment addresses the following essential questions:
- How does evolution by natural selection drive the diversity and unity of life?
- What scientific evidence from many disciplines, including mathematics, supports models about the origin of life on Earth and biological evolution?

Essential Questions: ▼ How does evolution by natural selection drive the diversity and unity of life? ▼ What scientific evidence from many disciplines, including mathematics, supports models about the origin of life on Earth and biological evolution? ▼ How can phylogenetic trees and cladograms be used to graphically model evolutionary history among species?

Learning Objectives	Materials	Instructional Activities and Assessments
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 25: "Phylogeny and Systematics" Waterman and Stanley, "Tree Thinking" *AP Biology Investigative Labs* (2012), Investigation 3: Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST	**Instructional Activity:** "Tree Thinking." An inquiry-based, investigative set of activities that introduces students to cladogram and phylogenetic tree construction and then asks them to apply systematics and biotechnology to a forensic study. **Instructional Activity:** AP Biology Investigation 3: Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST. Students use BLAST to compare several genes from different organisms and then use the information to construct a cladogram to visualize evolutionary relatedness among species. This lab introduces students to methods of bioinformatics with many applications, including to better understand genetic disease. This lab is student directed and teacher facilitated. **Formative Assessment:** Provided with a data table identifying shared characteristics among a group of organisms, students construct a phylogenetic tree or cladogram to reflect the evolutionary history of the group. Students then share the cladogram with peers for review and revision.

Students often cannot distinguish between homologous and analogous structures. Ask them to explain why bird and bat wings are homologous as vertebrate forelimbs but analogous as wings. Clarify for students that complex structures evolve step-by-step by natural selection and modification of pre-existing variation. Many examples can be used to provide clarification, including the evolution of tetrapods and the move of vertebrates from aquatic to terrestrial habitats.

Essential Questions: ▼ How does evolution by natural selection drive the diversity and unity of life? ▼ What scientific evidence from many disciplines, including mathematics, supports models about the origin of life on Earth and biological evolution? ▼ How can phylogenetic trees and cladograms be used to graphically model evolutionary history among species?

Learning Objectives	Materials	Instructional Activities and Assessments
Origin of Species Analyze data related to questions of speciation and extinction throughout the Earth's history. [LO 1.20, SP 5.1] Design a plan for collecting data to investigate the scientific claim that speciation and extinction have occurred throughout the Earth's history. [LO 1.21, SP 4.2] Use data from a real or simulated population(s), based on graphs or models of types of selection, to predict what will happen to the population in the future. [LO 1.22, SP 6.4] Justify the selection of data that addresses questions related to reproductive isolation and speciation. [LO 1.23, SP 4.1] Describe speciation in an isolated population and connect it to change in gene frequency, change in environment, natural selection, and/or genetic drift. [LO 1.24, SP 7.2] Describe a model that represents evolution within a population. [LO 1.25, SP 1.2] Evaluate given data sets that illustrate evolution as an ongoing process. [LO 1.26, SP 5.3]	Campbell and Reece, Chapter 24: "The Origin of Species"	**Instructional Activity:** Students conduct online research to identify examples of recent or ongoing speciation events and prepare a poster or PowerPoint slide(s) to share their speciation event with the class for discussion. **Instructional Activity:** Back to the Birds. Students make predictions about what the data might reflect and what conclusions might be drawn about natural selection and evolution if researchers were to visit the Galapagos Islands today and reexamine beak sizes in finches. **Formative Assessment:** Beginning with an extant, familiar species, students imagine its evolution to a new species and create a mini-poster showing their ideas. They should include at least five intermediate stages that reflect concepts of speciation explored in class. Students then share the posters with peers for review, discussion, and revision. **Summative Assessment:** One-hour test consisting of 20–25 multiple-choice questions, two short-response questions, and one long-response question drawing from data pertaining to evidence supporting natural selection and evolution.

Students often think that although extinction of species is occurring, no new species are forming. To dispel this misconception, use examples of speciation involving organisms that are familiar or local.

Students often struggle with relating evolutionary change to genetic change. Reiterate that biochemical pathways, morphological features, physiological traits, and behaviors evolve step-by-step by natural selection, with each step conferring a fitness benefit.

The summative assessment addresses the following essential questions:
- How does evolution by natural selection drive the diversity and unity of life?
- What scientific evidence from many disciplines, including mathematics, supports models about the origin of life on Earth and biological evolution?
- How can phylogenetic trees and cladograms be used to graphically model evolutionary history among species?

Laboratory Investigations:

- *AP Biology Investigative Labs* (2012), Investigation 11: Transpiration
- *AP Biology Investigative Labs* (2012), Investigation 12: Fruit Fly Behavior
- Field Study: Seals of La Jolla

Estimated Time: *10 weeks*

Essential Questions: ▼ How are growth and homeostasis of a biological system influenced by the system's environment? ▼ How do interactions among living systems and with their environment result in the movement of matter and energy? ▼ How do interactions between and within populations influence patterns of species distribution and abundance? ▼ How does human activity affect the biodiversity of ecosystems?

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 about 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: "The Tree of Life: An Introduction to Biological Diversity," pp. 512–520	**Instructional Activity:** Provided with a list of terms, definitions, and descriptions of processes, students construct a concept map of conditions on the early Earth that support scientific hypotheses about the origin of life-forms.

Students likely have exposure to myriad ideas and beliefs about the origin of life on Earth but need to be able to separate non-scientific ideas from those supported by evidence drawn from numerous scientific disciplines. That evolutionary change in organisms has occurred over 3.8 billion years is fact.

Essential Questions:
- How are growth and homeostasis of a biological system influenced by the system's environment?
- How do interactions among living systems and with their environment result in the movement of matter and energy?
- How do interactions between and within populations influence patterns of species distribution and abundance?
- How does human activity affect the biodiversity of ecosystems?

Learning Objectives	Materials	Instructional Activities and Assessments
Viruses *versus* Cells Construct an explanation of how viruses introduce genetic variation in host organisms. [LO 3.29, SP 6.2] Use representations and appropriate models to describe how viral replication introduces genetic variation in the viral population. [LO 3.30, SP 1.4]	Campbell and Reece, Chapter 18: "The Genetics of Viruses and Bacteria," pp. 334–345 Waterman and Stanley, "The Donor's Dilemma"	**Instructional Activity:** "The Donor's Dilemma." Students engage in an inquiry-based, investigative set of activities that explore the transmission of West Nile virus with an application to genetic engineering techniques. **Instructional Activity:** Students list and describe characteristics that viruses share with living organisms and then provide evidence for why viruses do not fit our usual definition of life. Students share answers with peers. **Formative Assessment:** Working with a partner or small group, students compose responses to the following questions and then share and explain their answers with the entire class for feedback: *While there are many different antibiotics for treating bacterial infections, there are relatively few drugs available to treat viral infections. Why are anti-viral drugs difficult to manufacture? How do viruses differ from bacteria?*

Teaching about viruses provides an opportunity to familiarize students with common health issues and treatments. Ask them to assess the concerns of some parents regarding mandatory vaccination.

This activity provides an opportunity for students to review concepts they studied previously about characteristics of life and the cell theory.

Essential Questions:
- How are growth and homeostasis of a biological system influenced by the system's environment?
- How do interactions among living systems and with their environment result in the movement of matter and energy?
- How do interactions between and within populations influence patterns of species distribution and abundance?
- How does human activity affect the biodiversity of ecosystems?

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] 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] ***(learning objectives continue)***	Campbell and Reece, Chapter 1: "Introduction: Exploring Life," pp. 9–12; Chapter 39: "Plants Responses to Internal and External Signals," pp. 791–812; Chapter 40: "Basic Principles of Animal Form and Function," pp. 832–841; Chapter 45: "Chemical Signals in Animals"; and Chapter 54: "Ecosystems" Heitz and Giffen, *Practicing Biology: A Student Workbook*, Activity 45.1 **Video** *Life*, Programme 9: "Plants"	**Instructional Activity:** Students work through Activity 45.1 in the Heitz and Giffen workbook to investigate the questions, *How do hormones regulate cell functions? What is the link between hormone activity and cellular response?* **Formative Assessment:** Students create a visual representation to illustrate the regulation of blood sugar levels, growth spurts in teenagers, and events associated with labor and childbirth. Students then explain how disruptions to these regulatory processes (e.g., failure to produce insulin) affect homeostasis in the organism. I provide verbal and/or written feedback to each student regarding their visual representation and explanation. This assessment informs my decisions about next instructional steps. **Instructional Activity:** Based on an example of phenomena described in lecture, students design a plan for collecting data to support the claim that the timing and coordination of physiological events involve regulation. **Instructional Activity:** Earth has seen its share of recent environmental disasters, including hurricanes, floods, drought, wildfires, oil spills, earthquakes, tsunamis, and disease epidemics. Students investigate the short-term and long-term effects of two of these types of disruptions to populations or ecosystems. Students then present the results of their investigations in the form of a mini-poster. **Instructional Activity:** Students create a mini-poster to compare, contrast, and analyze one physiological process in three different organisms from three different environments (e.g., osmoregulatory mechanisms in marine fish, desert reptiles, and tropical plants).

Students often think of plants as static and unresponsive to their environment when, in fact, they are plastic. Time-lapse film clips show that plants are active and that their responses result from hormonal activity.

Rather than have students memorize names and functions of hormones, guide students to look for patterns in hormonal control pathways and means of regulation in both plants and animals.

Relating homeostasis and the regulation of physiological events to familiar phenomena such as jet lag in humans or flowering in plants provides real-world relevance for what can be difficult concepts to grasp.

Here's an opportunity for students to compare and contrast physiological processes in different organisms to accommodate the reduction in content in "march through the phyla," most of which is represented as illustrative examples in the curriculum framework.

Essential Questions: ▼ How are growth and homeostasis of a biological system influenced by the system's environment? ▼ How do interactions among living systems and with their environment result in the movement of matter and energy? ▼ How do interactions between and within populations influence patterns of species distribution and abundance? ▼ How does human activity affect the biodiversity of ecosystems?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) Justify scientific claims with evidence to show how timing and coordination of physiological events involve regulation. [LO 2.36, SP 6.1] Use representations or models to analyze quantitatively and qualitatively the effects of disruptions to dynamic homeostasis in biological systems. [LO 2.28, SP 1.4] Explain how the distribution of ecosystems changes over time by identifying large-scale events that have resulted in these changes in the past. [LO 4.20, SP 6.3] Analyze data to identify phylogenetic patterns or relationships, showing that homeostatic mechanisms reflect both continuity due to common ancestry and change due to evolution in different environments. [LO 2.26, SP 5.1] Connect differences in the environment with the evolution of homeostatic mechanisms. [LO 2.27, SP 7.1]		**Summative Assessment:** One-hour test consisting of 20 multiple-choice questions, two to three short-response questions, and one long free-response question consisting of scenario and data analysis based on homeostasis and regulatory mechanisms in biological systems, from cells to ecosystems.

The summative assessment addresses the essential question, How are growth and homeostasis of a biological system influenced by the system's environment?

Essential Questions: ▼ How are growth and homeostasis of a biological system influenced by the system's environment? ▼ How do interactions among living systems and with their environment result in the movement of matter and energy? ▼ How do interactions between and within populations influence patterns of species distribution and abundance? ▼ How does human activity affect the biodiversity of ecosystems?

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 50: "An Introduction to Ecology and the Biosphere"; and Chapter 36: "Transport in Vascular Plants" *AP Biology Investigative Labs* (2012), Investigation 11: Transpiration **Web** "Mathbiology: How to Model a Disease"	**Instructional Activity:** For five different terrestrial or aquatic biomes, students create a visual representation to describe each biome and factors that affect its climate. Then they explain unique adaptations for one plant and one animal in each biome that help those plants and animals survive. **Instructional Activity:** Students use a basic mathematical model to study disease in an idealized population of rabbits. The SIR (susceptible, infected, and recovered) model allows students to investigate the mechanisms of transmission and predictions about future outbreaks of infectious diseases. **Instructional Activity:** AP Biology Investigation 11: Transpiration. Students design and conduct experiments to investigate the effects of environmental variables on transpiration rates. This lab requires minimal teacher facilitation and is student directed and inquiry based. **Formative Assessment:** Provided with a data table reflecting the results of an experiment investigating the effect of a biotic or abiotic factor on transpiration in plants, students graph the data and draw conclusions. Students work in teams and present their conclusions to the class in the form of a mini-poster for review and discussion.

Students underestimate the interdependence of populations within communities. The importance of the network of interactions among organisms and with their environment cannot be overemphasized.

Essential Questions:
- How are growth and homeostasis of a biological system influenced by the system's environment?
- How do interactions among living systems and with their environment result in the movement of matter and energy?
- How do interactions between and within populations influence patterns of species distribution and abundance?
- How does human activity affect the biodiversity of ecosystems?

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 and Behavioral Ecology" Heitz and Giffen, Activity 51.1 *AP Biology Investigative Labs* (2012), Investigation 12: Fruit Fly Behavior **Video** *March of the Penguins*	**Instructional Activity:** Students work through Activity 51.1 in the Heitz and Giffen workbook to investigate the question, *What determines behavior?* The scenarios in the activity help students differentiate between proximate and ultimate causations of behavior in a variety of organisms. **Instructional Activity:** AP Biology Investigation 12: Fruit Fly Behavior. Students use choice chambers to explore behaviors that underlie chemotaxis. This lab is student directed and teacher facilitated. **Instructional Activity:** Seals of La Jolla Field Study. Students design and conduct a field study in animal behavior and/or interactions between seals and biotic or abiotic factors based on observations of a colony of harbor seals off the coast of San Diego.

Clarify to students that proximate and ultimate questions are legitimate approaches to the study of behavior — proximate is the "how" and ultimate is the "why" behaviors occur.

Students recall that fruit flies are often used to study genetics. They may raise questions about the relationship between genetic makeup and behavior. Explain that genes do play a role(s) in behavior. Students may have the misconception that single genes determine complex human behaviors such as depression or alcoholism.

Animal behavior can be studied in nearly every environment. Field studies can be conducted in a local park, zoo, athletic field, playground, or anywhere on campus, even in the classroom.

Essential Questions: ▼ How are growth and homeostasis of a biological system influenced by the system's environment? ▼ How do interactions among living systems and with their environment result in the movement of matter and energy? ▼ How do interactions between and within populations influence patterns of species distribution and abundance? ▼ How does human activity affect the biodiversity of ecosystems?

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] Create a visual representation to describe how nervous systems detect external and internal signals. [LO 3.48, SP 1.1] ***(learning objectives continue)***	Campbell and Reece, Chapter 39: "Plant Responses to Internal and External Signals," pp. 812–814; Chapter 43: "The Immune System"; and Chapter 48: "Nervous Systems" Heitz and Giffen, Activity 43.1 ABO-Rh Blood Typing with Synthetic Blood Kit, Carolina Biological Supply Company Waterman and Stanley, "Shh: Silencing the Hedgehog Pathway," Part IV **Video** *Life*, Programme 1: "The Challenges of Life" *Stimulus Response*	**Instructional Activity:** Students create a mini-poster to compare non-specific defense systems in plants and animals. **Instructional Activity:** Students work through activity 43.1 in the Heitz and Giffen workbook to investigate the question, *How does the immune system keep the body free of pathogens?* Students develop a dynamic model (or Rube Goldberg cartoon-type diagram) to demonstrate how components of the animal immune system interact. **Instructional Activity:** ABO-Rh Blood Typing. Students use simulated blood and sera to investigate the relationship between antigens and antibodies. **Instructional Activity:** "Shh: Silencing the Hedgehog Pathway," Part IV. An inquiry-based set of activities that asks students to investigate the role of hedgehog antibodies in chemotherapy. The activity supplements exploration of the immune system. **Formative Assessment:** Don't Eat Fugu: Understanding the Neuron. Students create a model of a neuron to explain how the vertebrate nervous system detects signals and transmits information. (Students should use the clips from *Stimulus Response* for inspiration.) Students use the model to predict how abnormal cell structure, drugs, and toxins can affect impulse transmission. Students should explain the differences in nervous system physiology in two different animal phyla. They present their models to the class for discussion and peer feedback.

The animal immune system is complex. Begin by discussing how the system recognizes cells that are "self" and cells that are "non-self." (This is an opportunity for students to review the functions of proteins associated with cell membranes.) When students think of plant defense systems, they immediately think of thorns or cactus spines. Help them make the connection between plant chemical defenses and pharmaceuticals such as digitalis.

The sequence of events during the generation of an action potential can be confusing to students. Here's an opportunity to review the formation of ion gradients along cell membranes and the role of membrane proteins in transport.

Clips from videos such as Stimulus Response *reinforce the link between animal behavior and the nervous and endocrine systems. During the presentations, I provide feedback to students and note common issues or questions that arise. This informs my decisions about next instructional steps.*

Essential Questions:
- How are growth and homeostasis of a biological system influenced by the system's environment?
- How do interactions among living systems and with their environment result in the movement of matter and energy?
- How do interactions between and within populations influence patterns of species distribution and abundance?
- How does human activity affect the biodiversity of ecosystems?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) 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]		**Summative Assessment:** One-hour exam consisting of 20 multiple-choice questions, two to three short-response questions, and one long-response with emphasis on behavior, defense, response mechanisms, quantitative skills, and data analysis.
Living Together Evaluate scientific questions concerning organisms that exhibit complex properties due to the interaction of their constituent parts. [LO 4.8, SP 3.3] Predict the effects of a change in a component(s) of a biological system on the functionality of an organism(s). [LO 4.9, SP 6.4] Refine representations and models to illustrate biocomplexity due to interactions of the constituent parts. [LO 4.10, SP 1.3] Justify the selection of the kind of data needed to answer scientific questions about the interaction of populations within communities. [LO 4.11, SP 1.4, SP 4.1] Apply mathematical routines to quantities that describe communities composed of populations of organisms that interact in complex ways. [LO 4.12, SP 2.2] ***(learning objectives continue)***	Campbell and Reece, Chapter 52: "Population Ecology"; Chapter 53: "Community Ecology"; Chapter 54: "Ecosystems"; Chapter 40: "Basic Principles of Animal Form and Function," pp. 828–831; and Chapter 55: "Conservation Biology and Restoration Ecology" Heitz and Giffen, Activities 53.1 and 53.2 **Video** *Life*, Programme 7: "Hunters and Hunted"	**Instructional Activity:** Students conduct an online investigation of the relationship(s) between two vertebrate organ systems (e.g., circulatory and respiratory) and/or between two plant systems (e.g., leaves and roots). They then explain how a change in one system can affect the other. Students create mini-posters to share results. **Instructional Activity:** Students work through activity 53.1 in the Heitz and Giffen workbook to investigate the methods that scientists use to determine population density and distribution. Students apply quantitative skills to determine the composition of populations. **Instructional Activity:** Students work through activity 53.2 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. **Instructional Activity:** Introducing a new species into a community can have a number of possible effects. Students design an experiment to predict some of these effects that should be conducted *before* the importation of the non-native species. (Use clips from "Hunters and Hunted" for inspiration.)

The summative assessment addresses the essential question, How do interactions between and within populations influence patterns of species distribution and abundance?

Since the curriculum framework no longer requires an exhaustive and often superficial study of myriad organ systems in myriad phyla, this is an opportunity for students to explore structure and function in systems and organisms of their choice.

Students who are not as strong in math may not fully understand the exponential and logistic models of population growth. There are numerous online resources for introducing students to these skills in addition to Activity 53.2.

Students recognize that organisms have adapted to survive and reproduce in their native environments. Point out that the metabolic activities of organisms also modify the environment. Ask them to consider the statement, "Life itself has created the world in which we live."

Essential Questions:
- ▼ How are growth and homeostasis of a biological system influenced by the system's environment?
- ▼ How do interactions among living systems and with their environment result in the movement of matter and energy?
- ▼ How do interactions between and within populations influence patterns of species distribution and abundance?
- ▼ How does human activity affect the biodiversity of ecosystems?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) 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, SP 6.4] Use data analysis to refine observations and measurements regarding the effect of population interactions on patterns of species distribution and abundance. [LO 4.19, SP 5.2] Predict consequences of human actions on both local and global ecosystems. [LO 4.21, SP 6.4] Make scientific claims and predictions about how species diversity within an ecosystem influences ecosystem stability. [LO 4.27, SP 6.4]	Campbell and Reece, Chapter 52: "Population Ecology"; Chapter 53: "Community Ecology"; Chapter 54: "Ecosystems"; Chapter 40: "Basic Principles of Animal Form and Function," pp. 828–831; and Chapter 55: "Conservation Biology and Restoration Ecology"	**Instructional Activity:** Don't Trash the Campus. Students investigate the impact of school litter on a surrounding ecosystem. They use data to create a proposal of short- and long-term solutions to the trash problem. Students may submit their proposal to the Student Council for consideration.
		Formative Assessment: The Fox and the Chicken. Working in small teams, students think-pair-share a solution to the following question: *When stranded on a space ship, in what sequence would you consume your cargo — a red fox, 10 kg of corn, and two chickens (a hen and a rooster) — to ensure the best chance of surviving until help arrives?* Students share their answers with other groups, and then the class as a whole determines the best possible solution to the problem.
		Formative Assessment: An ecosystem consists of earthworms, heterotrophic soil bacteria, grass, deer, beetles, and a lion. Students create mini-posters to describe the trophic structure of the ecosystem, how each organism receives inputs of energy and nutrients, where outputs (e.g., wastes) go, and the effect(s) each organism has on the others. Students should include all energy transformations and transfers based on the hypothetical assumption that 9,500 J of net energy is available at the producer level. Students then present and explain their descriptions to the class for peer feedback.
		Summative Assessment: One-hour exam consisting of 25 multiple-choice questions, two to three short free-response questions, and one long free-response question based on a scenario and data analysis with application of quantitative skills and science practices.

Students often think that environmental damage is irreversible. This activity provides a "close to home" practical example of how ecosystems can recover from moderate levels of human-caused disturbance.

Energy accountability in food chains, food webs, and ecosystems can be a difficult concept for students. Clarify that the pyramid of production is based on the productivity of each trophic level and is measured in energy per unit area per unit time or in biomsass added to the ecosystem per unit area per unit time.

During the presentations, I also provide feedback to students and note common issues or questions that arise. This informs my decisions about next instructional steps.

The summative assessment addresses the following essential questions:
- How do interactions among living systems and with their environment result in the movement of matter and energy?
- How do interactions between and within populations infl uence patterns of species distribution and abundance?
- How does human activity affect the biodiversity of ecosystems?

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*. 7th ed. San Francisco: Pearson Benjamin Cummings, 2005.

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

Unit 1 (The Chemistry of Life) Resources

No unit-specific resources.

Unit 2 (The Cell) Resources

Chen, Irene A. "The Emergence of Cells During the Origin of Life." *Science* Vol. 314, no. 5805 (2006): 1558–1559. Accessed December 19, 2011. http://www.sciencemag.org/content/314/5805/1558.full.

The Domains of Life: Life's Three Branches: Archaea, Bacteria, and Eukarya. Beaufort, SC: BioMedia Associates, 2006. Video program with CD-ROM Learning Guide. (Available for purchase at http://v1.ebiomedia.com/The-Domains-of-Life/View-all-products.html?limitstart=0.)

The Domains of Life: The Eukaryotic Cell Evolves. Beaufort, SC: BioMedia Associates, 2006. Video program with CD-ROM Learning Guide. (Available for purchase at http://v1.ebiomedia.com/The-Domains-of-Life/View-all-products.html?limitstart=0.)

Unit 3 (Cell Processes: Energy and Communication) Resources

Redding, Kelly, and David Masterman. "Respiration of Sugars by Yeast." In *Biology with Vernier*. Beaverton, OR: Vernier, 2007.

Unit 4 (From Gene to Protein) Resources

Cracking the Code of Life. 2001. Boston: Nova/WGHB, 2004. DVD. (Available online at http://video.pbs.org/video/1841308959/.)

DNA Necklace Kit. Carolina Biological Supply Company. http://www.carolina.com/product/dna+necklace+kit.do?keyword=dna+necklace+kit&sortby=bestMatches.

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

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

Watson, James D., and F. H. C. Crick. "Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid." *Nature* 171 (1953): 737–738.

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

Supplementary Resources

Clone. Washington D.C.: National Geographic, 2002. DVD.

Unit 5 (Evolution) Resources

Beyond Genesis: The Origin of Species. Princeton, NJ: Films for the Humanities and Sciences, 1994.

Genovese, Guilio, David J. Friedman, Michael D. Ross, Laurence Lecordier, Pierrick Uzureau, Barry I. Freedman, Donald W. Bowden, et al. "Association of Trypanolytic ApoL1 Variants with Kidney Diseases in African Americans." *Science*. 13 August 2010. Vol. 329, no. 5993: 841–845.

Leslie, Mitch. "Kidney Disease is Parasite-Slaying Protein's Downside." *Science*. 16 July 2010. Vol. 329, no. 5989: 263.

"Lesson 3: What is the Evidence for Evolution? Activity 1: Evolution and Time." PBS. Accessed December 19, 2011. http://www.pbs.org/wgbh/evolution/educators/lessons/lesson3/act1.html.

Weiner, Jonathan. *The Beak of the Finch: A Story of Evolution in Our Time*. New York: Random House, 1994.

Unit 6 (Biodiversity and Ecology) Resources

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

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

Life. BBC Earth video series. BBC Natural History Unit and Discovery Channel, 2010.

March of the Penguins. Directed by Luc Jacquet. Burbank, CA: Warner Home Video, 2005. DVD.

"Mathbiology: How to Model a Disease." Houston Teachers Institute. Accessed December 19, 2011. http://hti.math.uh.edu/curriculum/units/2002/04/02.04.01.php.

Stimulus Response. Princeton, NJ: Films for the Humanities and Sciences, 1997. (Available online at http://www.teachkind.org/sr-resources.asp.)