AP® Biology

Course Planning and Pacing Guide 2

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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).

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

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

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Instructional Setting

J. W. Mitchell High School
New Port Richey, Florida

School	Public high school located approximately 30 miles northwest of Tampa and within a few miles of the Gulf of Mexico. The middle school and high school are located on adjacent properties and operate with a similar modified block schedule.
Student population	Enrollment of approximately 1,765 students: • 82 percent Caucasian • 10 percent Hispanic • 4 percent Indian/Middle Eastern • 2 percent Asian American • 2 percent African American
	• Approximately 18 percent of the students receive free or reduced-price lunches. • Approximately 81 percent of the students continue their education at a postsecondary institution.
Instructional time	The school year begins in mid-August and has 180 school days. Class meets four times a week. A typical week consists of a 50-minute period on Monday, 80-minute periods on Tuesday and Wednesday, and a 50-minute period on Friday. Teachers arrive at 7:40 a.m., and the student day begins at 8:40 a.m. The classroom and lab are open for an hour after school two days each week for additional work time or help. A practice AP® Biology Exam is administered on a Saturday morning approximately two weeks prior to the AP Biology Exam, and I use the final two weeks or so of class following the practice exam for review.

Student preparation	Since the middle school and high school are on adjacent properties, articulation occurs yearly, which allows middle school science teachers to become acquainted with the high school course sequence and expectations in Advanced Placement® courses. Students taking AP Biology are most often in the 11th or 12th grade, and they have taken the biology honors and chemistry honors courses. On occasion, some students have taken the AP Biology course and chemistry honors courses concurrently. I make every effort in the spring to meet each student who is interested in enrolling in AP Biology to give them an overview and explain my expectations, and these students are most often enrolled in chemistry honors. Then, any student who is interested and willing to accept the challenge is welcomed into the course. Our school's AP Program is administered in such a way as to encourage enrollment and success in AP courses, including AP Biology. We offer a boot camp in August, which provides team-building activities and sessions that help students learn the skills they will need to be successful in rigorous courses. During the school year, AP teachers design short seminars to offer students ongoing support. Themes of these seminars include: Dissecting College-Level Reading, Stress Management and Relaxation, Successful College-Level Writing, Building Support Networks, and Study Groups.
Textbooks and lab manuals	Mader, Sylvia S. *Biology*. 10th ed. New York: McGraw-Hill, 2010. *AP Biology Investigative Labs: An Inquiry-Based Approach*. New York: The College Board, 2012. *AP Biology Lab Manual*. New York: The College Board, 2001.

Overview of the Course

The AP Biology course is designed to offer students a solid curriculum in general biology concepts. By utilizing the big idea statements, enduring understandings, and science practices to guide biology instruction, I assist students in developing an appreciation for the study of life. The learning objectives and science practices in the *AP Biology Curriculum Framework* help to guide the selection of instructional activities and assessments.

Students entering AP Biology have taken full-year courses in introductory biology and chemistry. I make it a point to investigate the progress of the students through those courses by communicating with their previous teachers. I also use a questionnaire found at www.vark-learn.com to survey the learning styles of the students entering the course. The goal of instruction is to help students deepen their understanding of biological concepts, be able to apply all of the science practices, and prepare themselves for advanced studies in biology in the college and university settings. Due to the differences in learning styles, students reach this understanding in a variety of ways. My challenge is to develop activities that provide diverse ways for students to learn and be confident in the application of this knowledge. For example, the use of physical models helps visual and kinesthetic learners to better grasp a process or concept, extend their thinking, and pose questions. My questionnaire helps me to make sure I select activities that address the learning styles of my students.

I plan lectures, class discussions, inquiry-based instructional activities, and open-ended laboratory investigations that are inclusive of the learning objectives and science practices for the course. I look for additional resources that provide or help me develop laboratory investigations and activities that will interest students, relate to their lives, and challenge them as they learn biology. Although inquiry-based laboratory investigations provide experiences that naturally enable students to engage in science practices, other activities such as case studies, models, discussions, role-play, and videos also give students opportunities to engage in scientific inquiry and reasoning.

Formative assessments throughout the units check for student understanding. For example, I have students use NCR laboratory research notebooks for laboratory work, and the prelab assignment due before each investigation gives insight into student understanding. I am able to check these prelab assignments during the lab session and can work with students to further their understanding. In addition, students can collaborate on a particular task using whiteboards, where peer input and teacher monitoring occurs. Peer and teacher review of mini-posters following activities and labs provides useful feedback for revisions. Interactive whiteboard technology and clickers are also valuable in ascertaining student understanding and in allowing all students to see the progress of the class in understanding and applying biological principles. These types of assessments allow me to gauge student understanding and progress toward achievement of the learning objectives prior to the unit exam.

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: Introduction to Biology and the Chemistry of Life	This unit includes reductions in Mader, Chapters 1, 2, and 3. Students take a first-year course in biology and chemistry, and Chapters 1 and 2 are assigned for summer reading. I can save five days of instruction because of the summer homework review of life properties and basic chemistry and the elimination of rote-memorization activities for specific monomers and polymers in Chapter 3.	By saving five days of instruction, I can engage students in a student-directed inquiry (Lab 11: Animal Behavior from the *AP Biology Lab Manual* (2001), transitioned to open-ended inquiry). Furthermore, I can spend more time with activities such as using molecular kits for learning structure and function of biomolecules, and for engaging students in a case study (National Center for Case Study Teaching in Science, "A Can of Bull: Do Energy Drinks Really Provide a Source of Energy?") where they are critically thinking about the concepts learned in the unit.
Unit 2: Cells and Cellular Processes	The elimination of the rote memorization of cell organelles and functions and steps in pathways (including C4 and CAM) saves about 10 days in this unit that covers Mader, Chapters 4–8 and Section 20.2. I've moved the study of cell-to-cell communication to Unit 5 and have used it as a theme for the study of organism form and function. In addition, the use of resources such as Bozeman Biology videos for a "flipped classroom" allows more time for this unit, as well as others. By having students watch a video outside of class that connects the concepts, I have more time during class for student-directed discussion and activities. I also plan carefully for block days when I can incorporate more than one activity or assessment. As always, I rely on the students to utilize time outside of class to prepare fully for activities and assessments.	Because I can save 10 days in this unit, students have the extra time needed to complete open-ended inquiry investigations. I have modified the enzyme lab to facilitate inquiry by using probes, and I have modified the photosynthesis lab to an open-ended inquiry lab by using the DPIP/dye-reduction technique. I have incorporated the new AP investigative labs on osmosis and diffusion and cell respiration, which give an in-depth study of these processes. The extra days also allow students to develop their own scientific questions related to these topics, and to develop their own methodologies to find answers to their questions.
Unit 3: The Genetic Basis of Life	With the elimination of chapters in Unit 5 (parade through the kingdoms and body systems) and by moving viral cycles to this unit, I can save approximately seven days for this unit, which covers Mader, Chapters 9–14 and Section 20.1. I can continue to include quality activities and assessments in this unit that are inquiry based and allow students to explore and draw their own conclusions regarding contributions of notable scientists to the genetic basis of life.	AP Biology Investigation 7: Cell Division: Mitosis and Meiosis provides a thorough look at the cell cycle. To address the new curriculum framework's emphasis on gene regulation and expression and ethical issues raised from biotechnology techniques, I include six to seven extra days for the teaching of AP Biology Investigation 8: Biotechnology: Bacterial Transformation and Investigation 9: Restriction Enzyme Analysis of DNA.
Unit 4: Evolution	This unit includes Mader, Chapters 15–19 and addresses big idea 1 in the *AP Biology Curriculum Framework*. Utilizing strategies for careful planning (as in Unit 2 above), I attempt to continue to use the same approximate time for this unit that I have in the past. In addition, I count on the eliminations of chapters and content in Unit 5 to provide extra time in this unit.	Three days are added to instruction in this unit for teaching the Origin of Life student-directed inquiry lab. In addition, and since there is an emphasis on bioinformatics methods, I include five days for AP Biology Investigation 3: Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST.
Unit 5: Organism Form and Function	This unit contains reductions and eliminations within Mader, Chapters 21–25 (protist and fungi diversity), 27–30 (invertebrate and vertebrate diversity), and 41 (reproductive systems). This is a reduction of approximately 15 days of instruction. The use of chapter sections allows for illustrative examples of enduring understandings as suggested in the revised curriculum framework.	I have revised this unit to introduce and include more in-depth instruction on cell signaling. With the days saved in this unit, there is more time for emphasizing homeostatic mechanisms, cell signaling, and regulation by covering immune, nervous, and endocrine systems in depth (Mader, Chapters 26, 31, 33, 37, 38, and 40). In addition, the timing, coordination, and regulation of animal development are emphasized (Chapter 42). I have also included the student-directed transpiration lab and have connected it to the theme of cell signaling.
Unit 6: Ecology	There are no major revisions to this unit, which covers Mader, Chapters 43–47. Approximately five days saved from Unit 5 can be added here.	The extra days saved in Unit 5 will allow the inclusion of the lengthy AP Biology Investigation 10: Energy Dynamics.This student-directed investigation allows for a research environment that facilitates exploration of basic ecological concepts of energy flow, the role of producers, the role of primary consumers, and the complex interactions between organisms.

Laboratory Investigations:

- *AP Biology Lab Manual* (2001), Lab 11: Animal Behavior (transitioned to a student-directed lab activity)

Estimated Time:

2 weeks

Essential Questions: ▼ What kind of data is needed to answer scientific questions about how organisms respond to changes in their external environment? ▼ What types of molecules do organisms use for building blocks and excrete as wastes? ▼ How do structures of biologically important molecules (carbohydrates, lipids, proteins, and nucleic acids) account for their functions?

Learning Objectives	Materials	Instructional Activities and Assessments
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]	Mader, Chapter 1: "A View of Life" *AP Biology Lab Manual* (2001), Lab 11: Animal Behavior, Exercise 11A: General Observation of Behaviors (transitioned to a student-directed lab activity).	**Instructional Activity:** Students design and conduct an experiment to test the environmental factors they believe may determine where isopods live. This activity is student directed and teacher facilitated. **Formative Assessment:** Students complete lab reports in their NCR research notebooks based on their lab investigation of isopod behavior and response. I provide corrective and informative feedback during discussion with students and via comments on the specific lab components presented in the lab report. Subsequent instructional activities (i.e., lab extension activities) may be modified based on student lab report evaluation.
Justify the selection of data regarding the types of molecules an animal, plant, or bacterium will take up as necessary building blocks and excrete as waste products. [LO 2.8, SP 4.1]	Mader, Chapter 2: "Basic Chemistry"	**Instructional Activity:** Students use construction paper to make models of atoms, ions, and molecules represented in Chapter 2. Students use the models to understand and explain (with justification) how and why properties of elements (CHNOPS) make them essential to life and how pH, ions, and hydrogen bonding impact living systems. This activity is student directed and teacher facilitated. **Formative Assessment:** Students create annotated drawings that represent how water can move up a tall tree and why a pond of water doesn't freeze. I provide corrective and informative feedback via discussion on the assessment results.

This is an opportunity to utilize a lab kit (choice chambers) that I have available and to introduce students to a student-directed, teacher-facilitated inquiry. It also builds on topics that were reviewed in the Chapter 1 summer reading, specifically life characteristics such as homeostasis, responding to environmental factors, and adapting to a particular environment.

Throughout the year, the use of a research lab notebook allows students to revise their plans and work during the inquiry process. I am able to provide additional instruction as needed along the way, and students then turn in authentic work by submitting a copy of the revised lab report when inquiry is complete.

Some students can demonstrate learning best through creating visual representations such as annotated drawings. I circulate in the classroom to check understanding and ask probing questions to extend student thinking.

Essential Questions: ▼ What kind of data is needed to answer scientific questions about how organisms respond to changes in their external environment? ▼ What types of molecules do organisms use for building blocks and excrete as wastes? ▼ How do structures of biologically important molecules (carbohydrates, lipids, proteins, and nucleic acids) account for their functions?

Learning Objectives	Materials	Instructional Activities and Assessments
Construct explanations of the influence of environmental factors on the phenotype of an organism. [LO 4.23, SP 6.2] Predict the effects of a change in an environmental factor on the genotypic expression of the phenotype. [LO 4.24, SP 6.4]	Mader, Chapter 2: "Basic Chemistry"	**Instructional Activity:** "Roses are red, violets are blue, why are my hydrangeas red or blue?" In a think-pair-share activity, students make a prediction about how soil pH will affect the phenotype of hydrangea blossoms, and they develop and describe an experiment to test their prediction. Students then explain, with justification, the expected outcomes. This is a student-directed, teacher-facilitated activity.
Explain the connection between the sequence and the subcomponents of a biological polymer and its properties. [LO 4.1, SP 7.1] 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] 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]	Mader, Chapter 3: "The Chemistry of Organic Molecules" Heitz and Giffen, "How Can You Identify Organic Macromolecules?" pp. 7–11 Molecular model kits **Web** "A Can of Bull: Do Energy Drinks Really Provide a Source of Energy?"	**Instructional Activity:** Following a teacher-led lecture/discussion using model kits, students complete the activity "How Can You Identify Organic Macromolecules?" Using the molecular model kits, students explain how organic macromolecules are identified. Students make predictions (with justification) pertaining to the behavior of organic molecules, based on their structure. **Instructional Activity:** Students analyze the case study "A Can of Bull: Do Energy Drinks Really Provide a Source of Energy?" They describe and categorize chemically the components of various popular energy drinks, determine the physiological role of these components in the body, and explain scientifically how the marketing claims for these drinks are supported (or not). Students present their findings and evaluations of the marketing claims for the drinks. **Formative Assessment:** Students create a concept map that summarizes how the structures of biologically important molecules are important to their functions. I provide corrective and informative feedback via discussion during the concept map construction.
		Summative Assessment: Block period exam of 15 multiple-choice questions, three short-answer questions, and one free-response question.

The pigment in hydrangea blossoms is cyanidin, and when it functions as an acid, it loses an H+ ion. A color shift can occur. Students may remember the red cabbage pH lab if this was done in first-year chemistry. This activity provides an opportunity for students to apply genetics terms and connect them to concepts associated with pH, as they learn that environmental factors influence traits indirectly.

I use model kits for this activity and other suitable activities as they meet hands-on learning needs; they sometimes are the source of interesting questions from students that would otherwise not be asked.

It is surprising how students use the words carbohydrates, proteins, and fats synonymously as dietary terms. The development of the concept map will be a visual representation of student learning and help me determine whether students now see these as important biological molecules whose subcomponents and their sequence determine important life properties.

The summative assessment addresses the essential questions:
- What kind of data is needed to answer scientific questions about how organisms respond to changes in their external environment?
- What types of molecules do organisms use for building blocks and excrete as wastes?
- How do structures of biologically important molecules (carbohydrates, lipids, proteins, and nucleic acids) account for their functions?

Laboratory Investigations:

- *AP Biology Investigative Labs* (2012), Investigation 4: Diffusion and Osmosis
- Enzyme investigations with Vernier Labquest System (transitioned to a student-directed lab activity)
- *AP Biology Lab Manual* (2001), Lab 4: Plant Pigments and Photosynthesis (transitioned to a student-directed lab activity)
- *AP Biology Investigative Labs* (2012), Investigation 6: Cellular Respiration

Estimated Time: *5 weeks*

Essential Questions: ▼ How does cell structure and function help to maintain dynamic homeostasis in living organisms? ▼ Why do growth, reproduction, and maintenance of the organization of living systems require free energy and matter? ▼ What mechanisms and structural features of cells allow organisms to capture, store, and use free energy?

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]	Mader, Chapter 4: "Cell Structure and Function" *AP Biology Investigative Labs* (2012), Investigation 4: Diffusion and Osmosis	**Instructional Activity:** Students complete Procedure 1 of AP Biology Investigation 4: Diffusion and Osmosis. They design and conduct an experiment to test predictions they made regarding the relationship of surface area and volume in artificial cells to the diffusion rate using the phenolphthalein-NaOH agar and HCl. **Instructional Activity:** Students develop their investigative work in their NCR lab research notebooks for peer and teacher review.
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] 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]	Mader, Chapter 4: "Cell Structure and Function" and Chapter 20: "Viruses, Bacteria, and Archaea" (Section 20.2: "The Prokaryotes") Construction paper and markers/ pencils for visual representations and models	**Instructional Activity:** Students make models of eukaryotic cells and prokaryotic cells using materials they choose to bring in. In a presentation and class discussion, students explain the structure of organelles presented in Chapter 4 and make predictions about the impact of not having a certain organelle.

This activity would be enhanced by the use of a high-resolution camera (Video Flex) connected to a microscope to project images of living and stained cells (Elodea, Amoeba, stained cheek and onion cells).

Essential Questions: ▼ How does cell structure and function help to maintain dynamic homeostasis in living organisms? ▼ Why do growth, reproduction, and maintenance of the organization of living systems require free energy and matter? ▼ What mechanisms and structural features of cells allow organisms to capture, store, and use free energy?

Learning Objectives	Materials	Instructional Activities and Assessments
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] 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] 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]	Mader, Chapter 4: "Cell Structure and Function" and Chapter 20: "Viruses, Bacteria, and Archaea" **Web** "Compartmentalization"	**Instructional Activity:** Students were given the homework assignment of viewing the Bozeman video "Compartmentalization." In this video, the author addresses differences in prokaryotic/eukaryotic cells, surface-area-to-volume relationships, impact of compartmentalization seen in eukaryotic cells, and the endosymbiont hypothesis. Students defend the claims presented in this video in a student-directed, teacher-facilitated whole-class discussion. **Formative Assessment:** Interactive whiteboard technology is used to develop a 20-question clicker assessment of concepts relating to cell structure and function. I provide corrective and informative feedback via discussion on the assessment results.
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]	Mader, Chapter 5: "Membrane Structure and Function" Heitz and Giffen, "How Is the Structure of a Cell Membrane Related to Its Function?" pp. 21–25 **Web** "Build-a-Membrane"	**Instructional Activity:** Students construct a model of a membrane and complete the activity, "How Is the Structure of a Cell Membrane Related to Its Function?" Students use the models to demonstrate and explain how the structure of a cell membrane is related to its function and how this is connected to the movement of molecules across the membrane. They analyze a scenario of fish removed from a contaminated lake and placed in a tank full of clean water. Students make predictions regarding the change in toxin concentrations within the fish and in the water in the tank. They then analyze data and explain, with justification, the role of passive- and active-transport processes. This is a student-directed, teacher-facilitated activity. **Formative Assessment:** Students create an annotated visual representation that explains (with justification) why osmosis and diffusion are essential processes to an independent cell, such as a *Paramecium*, and to a human. I provide corrective and informative feedback via discussion on the assessment results.

Bozeman Biology Essentials is a YouTube homework resource that can be used in a "flipped classroom" approach. Students gain a wealth of knowledge from watching a video lecture with visual representations, and you can quickly engage them in a discussion to deepen their understanding. The use of this resource creates more time for inquiry investigations. School computers are available throughout the day for students who may not have access to the Internet at home.

If clickers are not available, small whiteboards can be used for students to work through and display answers. The use of clickers is a classroom assessment technique that enables you to differentiate assessment and capture real-time feedback on students' understanding.

Such activities allow students to engage in the science practices of using models, quantitatively and qualitatively analyzing data, and evaluating evidence.

This assessment allows me to check student understanding of the importance of transport processes in organisms. It gives me an opportunity, if needed, to include illustrative examples from the reduced content in Unit 5, such as why the large surface area of the human lungs is so vital to life.

Essential Questions: ▼ How does cell structure and function help to maintain dynamic homeostasis in living organisms? ▼ Why do growth, reproduction, and maintenance of the organization of living systems require free energy and matter? ▼ What mechanisms and structural features of cells allow organisms to capture, store, and use free energy?

Learning Objectives	Materials	Instructional Activities and Assessments
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] 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] 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] Use representations and models to analyze situations or solve problems qualitatively and quantitatively to investigate whether dynamic homeostasis is maintained by the active movement of molecules across membranes. [LO 2.12, SP 1.4]	Mader, Chapter 5: "Membrane Structure and Function" and Science Focus essay: "The Concept of Water Potential," p. 463 *AP Biology Investigative Labs* (2012), Investigation 4: Diffusion and Osmosis	**Instructional Activity:** Students complete Procedures 2 and 3 of AP Biology Investigation 4: Diffusion and Osmosis. In Procedure 2, students design experiments to measure the rate of osmosis in model cells, and in Procedure 3 students design experiments to measure water potential in plant cells. This investigation is student directed and teacher facilitated. **Formative Assessment:** The NCR research notebook is used to record work on this student-directed investigation. Mini-posters are developed for peer and teacher review prior to submitting the lab report. I provide corrective and informative feedback via discussion on the assessment results.
		Summative Assessment: One-hour exam of 15 multiple-choice questions and one free-response question.

Students often find the concept of water potential challenging to understand. A discussion of how pressure potential and solute potential determine water potential will help clarify concepts. It should be stressed that the addition of a solute to water in an open beaker lowers the solute potential and therefore decreases water potential. After students read the information on water potential, guide them through a calculation to determine water potential.

Mini-posters allow students to communicate their investigative work through a low-cost visual. More important, revisions can be easily made prior to submitting a formal graded report.

This summative assessment addresses the essential question, How does cell structure and function help to maintain dynamic homeostasis in living organisms?

Essential Questions: ▼ How does cell structure and function help to maintain dynamic homeostasis in living organisms? ▼ Why do growth, reproduction, and maintenance of the organization of living systems require free energy and matter? ▼ What mechanisms and structural features of cells allow organisms to capture, store, and use free energy?

Learning Objectives	Materials	Instructional Activities and Assessments
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]	Mader, Chapter 6: "Metabolism: Energy and Enzymes" Heitz and Giffen, "What Factors Affect Chemical Reactions in Cells?" pp. 27–29	**Instructional Activity:** Students complete the activity, "What Factors Affect Chemical Reactions in Cells?" In teams of three, students apply what they have learned about general metabolism and cellular free energy to construct a concept map. They then use the concept map to justify, through discussion, the claim that free energy is required by living systems. This is a student-directed, teacher-facilitated activity.
		Instructional Activity: Data are provided showing the relative activity of two digestive enzymes, pepsin and salivary amylase, at various pH levels. Students plot data for both enzymes on the same graph and then predict, with justification, why starch digestion by amylase starts in the mouth, ceases in the stomach, and resumes in the small intestine.
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] 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]	Mader, Chapter 6: "Metabolism: Energy and Enzymes" Enzyme investigations with Vernier Labquest System (transitioned to a student-directed lab activity using gas pressure probes)	**Instructional Activity:** After learning the basics of how to use the Vernier Labquest and probes, students design and conduct an experiment to measure and compare the initial rates of reaction for catalase with a variable of their choice. This investigation is student directed and teacher facilitated.

Once they are shown how to set up a timed experiment and then get the equation for the best fit line to analyze the slope (initial rate), students work independently, collecting data to reach answers to the scientific questions they have posed regarding enzyme catalysis. They can repeat the experiment multiple times in a short period of time.

Essential Questions: ▼ How does cell structure and function help to maintain dynamic homeostasis in living organisms? ▼ Why do growth, reproduction, and maintenance of the organization of living systems require free energy and matter? ▼ What mechanisms and structural features of cells allow organisms to capture, store, and use free energy?

Learning Objectives	Materials	Instructional Activities and Assessments
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] 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]	Mader, Chapter 7: "Photosynthesis" and Chapter 8: "Cellular Respiration" **Web** "Photosynthesis and Respiration"	**Instructional Activity:** After watching the Bozeman video "Photosynthesis and Respiration," I facilitate a student-directed discussion in which students justify the claim that all life is dependent on the ability of photosynthetic organisms to capture solar energy and produce carbohydrate molecules. Students should not memorize steps and molecules for the processes of photosynthesis and respiration. They should recognize the important outcomes of the cycles and how the processes are interrelated.
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] 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] 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] ***(learning objectives continue)***	Mader, Chapter 7: "Photosynthesis" *AP Biology Lab Manual* (2001), Lab 4: Plant Pigments and Photosynthesis, Exercise 4B: Photosynthesis/The Light Reaction (transitioned to a student-directed lab activity)	**Instructional Activity:** Students apply the DPIP-reduction technique, using a spectrophotometer, to design and conduct an experiment to answer their own questions regarding photosynthesis rates. This is a student-directed, teacher-facilitated inquiry investigation. If spectrophotometers or colorimeters are not available, the floating leaf disk procedure in *AP Biology Investigative Labs* (2012), Investigation 5: Photosynthesis is highly recommended. In the floating leaf disk procedure, students are shown how to make leaf disks sink by infiltrating them with a solution of bicarbonate ions, a carbon source for photosynthesis. If placed in sufficient light, the leaf disks will rise as oxygen is produced within the disks. Supplies and equipment are inexpensive, and sufficient materials could be set up for individual student investigations.

The video connects photosynthesis and respiration, includes evolution, and is an excellent review of these processes prior to engaging in the investigative labs. Model kits are available from science supply companies, and such kits would be a good way to meet diverse learning styles as students engage with these topics.

Essential Questions: ▼ How does cell structure and function help to maintain dynamic homeostasis in living organisms? ▼ Why do growth, reproduction, and maintenance of the organization of living systems require free energy and matter? ▼ What mechanisms and structural features of cells allow organisms to capture, store, and use free energy?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) Construct explanations based on scientific evidence as to how interactions of subcellular structures provide essential functions. [LO 4.5, SP 6.2]		**Formative Assessment:** Students complete lab reports in their research notebooks based on their lab investigation of photosynthesis rates. I provide corrective and informative feedback during discussion with students and via comments on the specific lab components presented in the lab report.
Apply mathematical routines to quantities that describe interactions among living systems and their environment, which result in the movement of matter and energy. [LO 4.14, SP 2.2]	Mader, Chapter 8: "Cellular Respiration" *AP Biology Investigative Labs* (2012), Investigation 6: Cellular Respiration	**Instructional Activity:** After mastering the assembly and usage of microrespirometers and measuring and calculating rates of cellular respiration, students pose their own questions to answer by conducting a student-designed controlled experiment involving germinating seeds.
		Instructional Activity: The NCR research notebook is used to record work on this student-directed investigation. Mini-posters are developed for peer and teacher review prior to submitting the lab report.
		Formative Assessment: Given information explaining primary productivity and data of dissolved oxygen measurements from a lake at time intervals during a sunny day, students develop a graph of the data and interpret results based on knowledge of biological processes involved. They predict how the data might change on an overcast day. I provide corrective and informative feedback via discussion on the assessment results.
		Summative Assessment: A one block period exam with 20 multiple-choice questions, three short-response questions, and one free-response question.

Subsequent instructional activities (i.e., lab extension activities) may be modified based on student lab report evaluation.

This investigative lab dispels the misconception that "plants photosynthesize and animals respire." Students should understand physical laws relating to gases for this investigative study, and they should be able to manipulate PV=nRT. A quick review of chemistry gas laws or use of online resources indicated in the teacher guide for this lab might be useful.

The use of this 2001 free-response question, rewritten with added information about primary productivity that students need to know, gauges how well students are using science practices such as analyzing data, evaluating evidence, and making predictions based on scientific understanding. It is a check on whether further instruction is necessary for students to answer the essential questions addressed on the summative assessment.

This summative assessment addresses the following essential questions:
- Why do growth, reproduction, and maintenance of the organization of living systems require free energy and matter?
- What mechanisms and structural features of cells allow organisms to capture, store, and use free energy?

Unit 3:

The Genetic Basis of Life

Laboratory Investigations:

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

5 weeks

Essential Questions: ▼ How is heritable information passed to the next generation via processes that include the cell cycle and mitosis and meiosis plus fertilization? ▼ How does the chromosomal basis of inheritance provide an understanding of the pattern passage (transmission) of genes from parent to offspring? ▼ What is the primary source of heritable information, and how are cellular and molecular mechanisms involved in the expression of this heritable information? ▼ How can genetic engineering techniques manipulate the heritable information of DNA?

Learning Objectives	Materials	Instructional Activities and Assessments
Make predictions about natural phenomena occurring during the cell cycle. [LO 3.7, SP 6.4] Describe events that occur in the cell cycle. [LO 3.8, SP 1.2] Construct an explanation, using visual representations or narratives, as to how DNA in chromosomes is transmitted to the next generation via mitosis, or meiosis followed by fertilization. [LO 3.9, SP 6.2] Represent the connection between meiosis and increased genetic diversity necessary for evolution. [LO 3.10, SP 7.1] Evaluate evidence provided by data sets to support the claim that heritable information is passed from one generation to another generation through mitosis, or meiosis followed by fertilization. [LO 3.11, SP 5.3] 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] Construct an explanation of the multiple processes that increase variation within a population. [LO 3.28, SP 6.2]	Mader, Chapter 9: "The Cell Cycle and Cellular Reproduction" **Web** "WARD'S Mitotic Stage Counts Flashcards"	**Instructional Activity:** A time-lapse video of plant cell mitosis is shown, and students design a procedure for estimating the time in each phase using WARD'S mitosis flashcards. This investigation is student directed and teacher facilitated.
	Mader, Chapter 9: "The Cell Cycle and Cellular Reproduction" and Chapter 10: "Meiosis and Sexual Reproduction" *AP Biology Investigative Labs* (2012), Investigation 7: Cell Division: Mitosis and Meiosis	**Instructional Activity:** Students complete AP Biology Investigation 7: Cell Division: Mitosis and Meiosis. In parts 1 and 4, students model mitosis and meiosis. In part 2, they design and conduct an investigation to determine what substances in the environment might increase or decrease the rate of mitosis. In part 3, they investigate the loss of cell cycle control in cancer. Finally, in part 5, they investigate meiosis and crossing over in *Sordaria*. **Instructional Activity:** The NCR research notebook is used to record work on this student-directed investigation. Students develop mini-posters for peer and teacher review prior to submitting the lab report.

If an Internet search is done for time-lapse videos of mitosis, a number of sites will be shown. It is important for students to recognize the continuous process of mitosis. Avoid having students memorize the steps of mitosis; instead, they should understand the consequences of the steps.

Essential Questions: ▼ How is heritable information passed to the next generation via processes that include the cell cycle and mitosis and meiosis plus fertilization? ▼ How does the chromosomal basis of inheritance provide an understanding of the pattern passage (transmission) of genes from parent to offspring? ▼ What is the primary source of heritable information, and how are cellular and molecular mechanisms involved in the expression of this heritable information? ▼ How can genetic engineering techniques manipulate the heritable information of DNA?

Learning Objectives	Materials	Instructional Activities and Assessments
Pose questions about ethical, social, or medical issues surrounding human genetic disorders. [LO 3.13, SP 3.1]	Skloot, *The Immortal Life of Henrietta Lacks* **Web** "But I'm Too Young! A Case Study of Ovarian Cancer"	**Instructional Activity:** Students work through the case study, "But I'm Too Young!" about a college student who develops ovarian cancer. Students learn about basic cellular and genetic mechanisms that are responsible for cancer formation, gain an understanding of how cells become cancerous through genetic mutations, and learn how cancers spread through the body. During a follow-up discussion, I share *The Immortal Life of Henrietta Lacks* with students and have them write on index cards one question each regarding ethical, social, or medical issues arising from this story. A student-directed, teacher-facilitated class discussion of the questions follows.
		Instructional Activity: In teams of three, students create an annotated visual representation that predicts how the chromosomes of a cancer cell might appear when compared to a normal cell.
		Instructional Activity: Students complete a comparison chart for mitosis and meiosis, comparing and describing these processes with respect to numbers of DNA replications, divisions, daughter cells produced, and purpose/function. The chart should include a prediction of the outcome of a mistake during the meiotic process. Students explain their charts, with justification, to their peers (in small groups).

The Immortal Life of Henrietta Lacks *by Rebecca Skloot is an excellent book for students to read because of the ethical, social, and medical issues it addresses. Due to time constraints, I share the story with students and challenge them to write their own questions regarding issues surrounding the genetic disorder.*

Essential Questions: ▼ How is heritable information passed to the next generation via processes that include the cell cycle and mitosis and meiosis plus fertilization? ▼ How does the chromosomal basis of inheritance provide an understanding of the pattern passage (transmission) of genes from parent to offspring? ▼ What is the primary source of heritable information, and how are cellular and molecular mechanisms involved in the expression of this heritable information? ▼ How can genetic engineering techniques manipulate the heritable information of DNA?

Learning Objectives	Materials	Instructional Activities and Assessments
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]	Mader, Chapter 11: "Mendelian Patterns of Inheritance" and Science Focus essay: "Mendel's Laws and Meiosis," p. 195 *AP Biology Lab Manual* (2001), Lab 7: Genetics of Organisms (transitioned to a student-directed lab activity) Materials and supplies, including fruit fly crosses, for the genetics investigation	**Instructional Activity:** Student lab teams are given F_1 *Drosophila* crosses labeled A, B, and C. Students are required to design an experiment that tests a null hypothesis as to the mode of inheritance for each cross. This is a two-week study, as students need to count the F_2 generation in order to perform chi-square analyses to see if the null hypotheses were supported. Students can begin the fruit fly crosses before learning the Mendelian patterns of inheritance to accommodate the two-week life cycle. During the investigation, students can explore the life cycle of an organism. This is a student-directed, teacher-facilitated investigation.
	Mader, Chapter 11: "Mendelian Patterns of Inheritance"	**Formative Assessment:** Students complete lab reports in their NCR research notebooks based on their lab investigation of the genetics of *Drosophila*. I provide corrective and informative feedback during discussion with students and via comments on the specific lab components presented in the lab report. Subsequent instructional activities (i.e., lab extension activities) may be modified based on the student lab-report evaluation.
		Formative Assessment: Using the "whiteboarding technique," student teams work the genetics problems on page 210 of the text. I provide corrective and informative feedback via discussion on the assessment results.
		Summative Assessment: A block period exam consisting of 25 multiple-choice questions, two short-answer questions, and one free-response question are given. This summative assessment contains questions that require the use of a calculator. Using mathematics appropriately is a science practice for AP Biology, and the understanding of chi-square analysis of data is included on the new AP Exam.

I order parental crosses from a biological supply company so that when they arrive, F_1 flies are emerging. Then students can begin their observations with the F_1 flies and prepare their own F_2 crosses.

Mendel's laws hold because of the events of meiosis. The Science Focus essay on page 195 of the Mader text explains this idea, with visual representation. It is important that students make this connection between meiotic events and Mendel's laws, and using this essay for reference and review, students can present more convincing justifications as they draw conclusions from their investigative study of genetics.

For activities such as the one described here, where students are practicing mathematical routines, the small whiteboards available in our lab have proven to be an effective way to facilitate peer review and support.

This assessment addresses the following essential questions:
- How is heritable information passed to the next generation via processes that include the cell cycle and mitosis and meiosis plus fertilization?
- How does the chromosomal basis of inheritance provide an understanding of the pattern passage (transmission) of genes from parent to offspring?

Essential Questions: ▼ How is heritable information passed to the next generation via processes that include the cell cycle and mitosis and meiosis plus fertilization? ▼ How does the chromosomal basis of inheritance provide an understanding of the pattern passage (transmission) of genes from parent to offspring? ▼ What is the primary source of heritable information, and how are cellular and molecular mechanisms involved in the expression of this heritable information? ▼ How can genetic engineering techniques manipulate the heritable information of DNA?

Learning Objectives	Materials	Instructional Activities and Assessments
Construct scientific explanations that use the structures and mechanisms of DNA and RNA to support the claim that DNA and, in some cases, that RNA are the primary sources of heritable information. [LO 3.1, SP 6.5] 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]	Mader, Chapter 12: "Molecular Biology of the Gene"	**Instructional Activity:** Students analyze the work of Frederick Griffith as well as Alfred Hershey and Martha Chase in identifying the source of genetic information. Students then role-play as these scientists, presenting and defending the work done in the classic experiments. The students watching the presentations are encouraged to pose scientific questions to the presenters regarding the meanings of the experimental findings.
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] Compare and contrast processes by which genetic variation is produced and maintained in organisms from multiple domains. [LO 3.27, SP 7.2]	Mader, Chapter 20: "Viruses, Bacteria, and Archaea" (Section 20.1: "Viruses, Viroids, and Prions")	**Instructional Activity:** Using modeling clay or paper models, students in teams of three create a representation of viral lytic and lysogenic cycles in prokaryotes and explain these cycles by presenting to the class. The presentation must address the question, *Why is it beneficial to a virus if its host lives and does not die?*
Describe representations and models that illustrate how genetic information is copied for transmission between generations. [LO 3.3, SP 1.2]	Mader, Chapter 12: "Molecular Biology of the Gene"	**Instructional Activity:** Students design an experiment to test the three models of DNA replication. Students assume they have access to an experimental organism, their choice of radioactive isotopes, test tubes, food/growth media for organisms, and a centrifuge. They create posters to share and present their experiments and results to other students and the teacher.

An excellent article for students to read and analyze during this segment of instruction is "Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid" by J. D. Watson and F. H. C. Crick. This article describes the Watson and Crick work and explains the scientific reasoning behind the "copying mechanism" in DNA.

Essential Questions: ▼ How is heritable information passed to the next generation via processes that include the cell cycle and mitosis and meiosis plus fertilization? ▼ How does the chromosomal basis of inheritance provide an understanding of the pattern passage (transmission) of genes from parent to offspring? ▼ What is the primary source of heritable information, and how are cellular and molecular mechanisms involved in the expression of this heritable information? ▼ How can genetic engineering techniques manipulate the heritable information of DNA?

Learning Objectives	Materials	Instructional Activities and Assessments
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] Predict how a change in a specific DNA and RNA sequence can result in changes in gene expression. [LO 3.6, SP 6.4] Construct an explanation of the multiple processes that increase variation within a population. [LO 3.28, SP 6.2] 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]	Mader, Chapter 12: "Molecular Biology of the Gene"	**Instructional Activity:** Students construct DNA and RNA nucleotides out of colored construction paper and model the process of DNA replication and repair, as well as translation and transcription. Using the models, they make predictions (with justifications) about how changes in the DNA can result in changes in gene expression. **Formative Assessment:** Interactive whiteboard technology is used to present a 20-question assessment that checks student understanding of structure and function.

At this point, it is important to establish the concept of gene expression for upcoming units.

I provide corrective and informative feedback via discussion on the assessment results.

Essential Questions: ▼ How is heritable information passed to the next generation via processes that include the cell cycle and mitosis and meiosis plus fertilization? ▼ How does the chromosomal basis of inheritance provide an understanding of the pattern passage (transmission) of genes from parent to offspring? ▼ What is the primary source of heritable information, and how are cellular and molecular mechanisms involved in the expression of this heritable information? ▼ How can genetic engineering techniques manipulate the heritable information of DNA?

Learning Objectives	Materials	Instructional Activities and Assessments
Explain how the regulation of gene expression is essential for the processes and structures that support efficient cell function. [LO 3.20, SP 6.2] Use representations to describe how gene regulation influences cell products and function. [LO 3.21, SP 1.4] Explain how signal pathways mediate gene expression, including how this process can affect protein production. [LO 3.22, SP 6.2] Use representations to describe mechanisms of the regulation of gene expression. [LO 3.23, SP 1.4]	Mader, Chapter 13, "Regulation of Gene Activity" Materials to "act out" the *lac* operon and the *trp* operon	**Instructional Activity:** Students "act out" prokaryotic regulation. Using approved materials in the classroom and lab as props, students explain the *trp* operon and the *lac* operon in role-play. Students must incorporate an explanation of the advantages to prokaryotes for organizing genes in an operon, of the difference between positive control and negative control, and predict how UV light might impact an operon. This is a student-directed, teacher-facilitated activity.
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]	Mader, Chapter 13: "Regulation of Gene Activity" Moalem, *Survival of the Sickest* **Web** "Epigenetics: DNA and Histone Model"	**Instructional Activity:** Students read Chapter 7, "Methyl Madness: Road to the Final Phenotype," in Moalem's *Survival of the Sickest*. They then complete the Epigenetics: DNA and Histone Model activity, a 3-D cut-and-paste model depicting how histone, acetyl, and methyl molecules control access to DNA and affect gene expression. Students must predict and justify how epigenetic inheritance might play an important role in understanding growth, aging, and cancer.

Gene regulation can be a challenging topic because the molecular mechanisms are abstract and are not visible to the eye. The role-play activity is a differentiated approach to instruction, allowing students to apply the concepts in an interactive mode.

This is an opportunity for students to engage in interesting reading on the subject of biology with a resource other than their textbook. This activity promotes critical thinking about gene expression.

Essential Questions: ▼ How is heritable information passed to the next generation via processes that include the cell cycle and mitosis and meiosis plus fertilization? ▼ How does the chromosomal basis of inheritance provide an understanding of the pattern passage (transmission) of genes from parent to offspring? ▼ What is the primary source of heritable information, and how are cellular and molecular mechanisms involved in the expression of this heritable information? ▼ How can genetic engineering techniques manipulate the heritable information of DNA?

Learning Objectives	Materials	Instructional Activities and Assessments
Connect evolutionary changes in a population over time to a change in the environment. [LO 1.5, SP 7.1] Justify the claim that humans can manipulate heritable information by identifying *at least two* commonly used technologies. [LO 3.5, SP 6.4] Evaluate given data sets that illustrate evolution as an ongoing process. [LO 1.26, SP 5.3] Predict how a change in a specific DNA or RNA sequence can result in changes in gene expression. [LO 3.6, SP 6.4] Pose questions about ethical, social, or medical issues surrounding human genetic disorders. [LO 3.13, SP 3.1] Use representations to describe how gene regulation influences cell products and function. [LO 3.21, SP 1.4] 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] Construct an explanation of the multiple processes that increase variation within a population. [LO 3.28, SP 6.2]	Mader, Chapter 14: "Biotechnology and Genomics" *AP Biology Investigative Labs* (2012), Investigation 8: Biotechnology: Bacterial Transformation Supplies for students necessary for a plasmid transformation system	**Instructional Activity:** Students work through AP Biology Investigation 8: Biotechnology: Bacterial Transformation. They do an initial investigation to transform *E. coli* bacteria to express new genetic information. Students then have the opportunity to design and conduct experiments to explore transformation in more depth, exploring answers to questions about plasmids and transformation that might have been raised during the initial investigation. **Instructional Activity:** The NCR research notebook is used to record work on this student-directed investigation. Students develop mini-posters for peer and teacher review prior to submitting the lab report.

This investigative lab requires preparation of agar plates and starter plates three to seven days prior to the lab; transformation system kits provide detailed instructions. Teacher discussion of potential challenges prior to the lab can help students avoid mistakes. Students should be instructed on how to use microbiology techniques that avoid contamination, how to use available pipetting devices, and how to successfully transfer bacterial colonies to increase transformation efficiency.

Essential Questions: ▼ How is heritable information passed to the next generation via processes that include the cell cycle and mitosis and meiosis plus fertilization? ▼ How does the chromosomal basis of inheritance provide an understanding of the pattern passage (transmission) of genes from parent to offspring? ▼ What is the primary source of heritable information, and how are cellular and molecular mechanisms involved in the expression of this heritable information? ▼ How can genetic engineering techniques manipulate the heritable information of DNA?

Learning Objectives	Materials	Instructional Activities and Assessments
Justify the claim that humans can manipulate heritable information by identifying *at least two* commonly used technologies. [LO 3.5, SP 6.4] Pose questions about ethical, social, or medical issues surrounding human genetic disorders. [LO 3.13, SP 3.1]	Mader, Chapter 14: "Biotechnology and Genomics" *AP Biology Investigative Labs* (2012), Investigation 9: Biotechnology: Restriction Enzyme Analysis of DNA Necessary equipment and supplies	**Instructional Activity:** Students work through AP Biology Investigation 9: Biotechology: Restriction Enzyme Analysis of DNA. Students first familiarize themselves with the techniques involved in creating genetic profiles using gel electrophoresis and calculating the sizes of restriction-length polymorphisms. Students analyze profiles resulting from "ideal" gel, and use newly learned technical skills to design and conduct a procedure to determine whose blood was splattered on the classroom floor in a crime scene scenario.
		Instructional Activity: Provided with electrophoresis data of a crime scene investigation, students construct a standard curve to estimate the sizes of crime scene and suspect restriction fragments. Students determine if any of the suspect samples of DNA seem to be from the same individual as the DNA from the crime scene. Students then describe the scientific evidence that supports their conclusions.
		Summative Assessment: A block period exam consisting of 15 multiple-choice questions, four short-answer questions, and one free-response question.

This assessment addresses the following essential questions:

- What is the primary source of heritable information, and how are cellular and molecular mechanisms involved in the expression of this heritable information?
- How can genetic engineering techniques manipulate the heritable information of DNA?

Laboratory Investigations:

- *AP Biology Lab Manual* (2001), Lab 8: Population Genetics and Evolution (transitioned to a guided-inquiry, followed by student-directed investigations)
- *AP Biology Investigative Labs* (2012), Investigation 3: Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST

Estimated Time: *6 weeks*

Essential Questions: ▼ How is natural selection a major mechanism of evolution? ▼ How is biological evolution supported by scientific evidence from many disciplines, including mathematics? ▼ How is the origin of living systems explained by natural processes? ▼ How do phylogenetic trees graphically model evolutionary history?

Learning Objectives	Materials	Instructional Activities and Assessments
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] Refine evidence based on data from many scientific disciplines that support biological evolution. [LO 1.10, SP 5.2] 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]	Mader, Chapter 15: "Darwin and Evolution" Heitz and Giffen, "How Did Darwin View Evolution via Natural Selection?" pp. 123–126	**Instructional Activity:** Students complete the activity, "How Did Darwin View Evolution via Natural Selection?" Students organize evolution-related terms into a concept map and then answer questions related to the map. Students must make a prediction, with justification, regarding how environmental changes might cause individuals in a population to show reduced fitness. This is a student-directed and teacher-facilitated activity.
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] 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] 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]	Mader, Chapter 15: "Darwin and Evolution" **Video** *What Darwin Never Knew*	**Instructional Activity:** Students watch the NOVA video *What Darwin Never Knew*. The first half of the program explains the theory of evolution, including Darwin's travels, his observations in the Galapagos, and his lines of reasoning back in England. After explaining the simplicity and logical sense of natural selection, the program then examines new scientific discoveries (primarily genetic) that are furthering our understanding of evolution (and which provide further support for the theory). Students, in three groups, perform a mock panel discussion. One group represents Darwin and his colleagues, a second group represents a leading biotechnologist and his colleagues, and a third group acts as the audience that generates the scientific questions for the panels.

This video connects the concepts of big idea 1 (natural selection acts on phenotypic variations in populations) and big idea 2 (observable cell differentiation results from the expression of genes) of the AP Biology Curriculum Framework. *A new field of evolutionary developmental biology is introduced. The panel discussion provides a differentiated way of engaging students in an interactive way to explore the curriculum.*

Evolution

(continued)

Essential Questions: ▼ How is natural selection a major mechanism of evolution? ▼ How is biological evolution supported by scientific evidence from many disciplines, including mathematics? ▼ How is the origin of living systems explained by natural processes? ▼ How do phylogenetic trees graphically model evolutionary history?

Learning Objectives	Materials	Instructional Activities and Assessments
Connect scientific evidence from many scientific disciplines to support the modern concept of evolution. [LO 1.12, SP 7.1] Evaluate evidence provided by data from many scientific disciplines that support biological evolution. [LO 1.9, SP 5.3] Refine evidence based on data from many scientific disciplines that support biological evolution. [LO 1.10, 5.2]	Mader, Chapter 15: "Darwin and Evolution" **Web** "Seven Skeletons and a Mystery"	**Instructional Activity:** Students complete the case study "Seven Skeletons and a Mystery." This problem-based case uses *Archaeopteryx* to show the vital role fossils play in understanding evolutionary history and to explore the different theories for the origin of flight and the debate over a bird-dinosaur connection. Through discussion, students present arguments for the "ground up" versus the "trees down" hypotheses for the origin of bird flight.
Connect evolutionary changes in a population over time to a change in the environment. [LO 1.5, SP 7.1] 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]	Mader, Chapter 15: "Darwin and Evolution" **Video** *Evolution*	**Instructional Activity:** Students view the "Dogs and Selective Breeding" video clip from the *Evolution* DVD. Students predict, with justification, possible advantages or disadvantages selected traits might confer on individuals in different environmental conditions and share these in a class discussion.
	Mader, Chapter 15: "Darwin and Evolution"	**Instructional Activity:** Students analyze the "Thinking Scientifically" scenario #2 on p. 282 of the Mader text. A cotton farmer applies a new insecticide against the boll weevil to his crop for several years. At first, the treatment is successful, but then the insecticide becomes ineffective, and the boll weevil rebounds. Did evolution occur? Students respond in a 100-word essay explaining their answer to the question.
	Heitz and Giffen, "A Quick Review of Hardy-Weinberg Population Genetics," pp. 133–137	**Instructional Activity:** Using a whiteboarding technique, students complete the activity, "A Quick Review of Hardy-Weinberg Population Genetics." Students analyze the Hardy-Weinberg proof and use the Hardy-Weinberg theory and proof to explain and justify answers to problems and questions.

Point out that artificial selection is a model that can be used to understand natural selection. The environment, not human selection, provides the selective force for natural selection.

At the end of each chapter in the Mader text, there are two questions in a section called "Thinking Scientifically," which serves as a good resource for critical-thinking questions that give students an opportunity to reason as a scientist.

Essential Questions: ▼ How is natural selection a major mechanism of evolution? ▼ How is biological evolution supported by scientific evidence from many disciplines, including mathematics? ▼ How is the origin of living systems explained by natural processes? ▼ How do phylogenetic trees graphically model evolutionary history?

Learning Objectives	Materials	Instructional Activities and Assessments
Convert a data set from a table of numbers that reflect a change in the genetic makeup of a population over time and apply mathematical methods and conceptual understandings to investigate the cause(s) and effect(s) of this change. [LO 1.1, SP 1.5, SP 2.2] 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] Use data from mathematic 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] 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]	Mader, Chapter 16: "How Populations Evolve" *AP Biology Lab Manual* (2001), Lab 8: Population Genetics and Evolution (transitioned to a guided inquiry, followed by student-directed investigations)	**Instructional Activity:** Students complete the transitioned Lab 8: Population Genetics and Evolution. The first part of the simulation, a test of the Hardy-Weinberg population, is teacher directed to explain how to calculate allele frequencies after five generations. Students then explore the effects of selection, heterozygote advantage, and genetic drift on allele frequency in a student-directed setting. **Instructional Activity:** Students are given information about the frizzle trait in chickens and are asked to start with a flock of chickens that has 20 normal feathered birds and 30 frizzle-feathered birds. Students calculate allele and genotypic frequencies after allowing chickens to interbreed and propose a hypothesis that might account for the difference between the observed frequencies and those expected had the population attained genetic equilibrium.

The use of a computer spreadsheet model to study how a hypothetical gene pool changes is illustrated in AP Biology Investigation 2: Mathematical Modeling: Hardy-Weinberg. This is an effective tool with which to study Hardy-Weinberg genetics and avoid the limitations of a small classroom population. I use the transitioned AP Lab 8 (2001) due to time constraints.

Essential Questions: ▼ How is natural selection a major mechanism of evolution? ▼ How is biological evolution supported by scientific evidence from many disciplines, including mathematics? ▼ How is the origin of living systems explained by natural processes? ▼ How do phylogenetic trees graphically model evolutionary history?

Learning Objectives	Materials	Instructional Activities and Assessments
Use data from a real or simulated population(s), based on graphs or models of types of selection, to predict what will happen to the population in the future. [LO1.22, SP 6.4]	Mader, Chapter 16: "How Populations Evolve"	**Instructional Activity:** Students work in think-pair-share groups to discuss the "Thinking Scientifically" scenario #2 on p. 298 of the Mader text. Phenotypes in a grouse population are described and mating data are provided. Students form a hypothesis to explain why females apparently prefer bright-feathered males, explain the concept of selective advantage in choosing a particular mate, and justify the kind of data that could be collected to test the hypothesis.
Justify the selection of data that address 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]	Mader, Chapter 17: "Speciation and Macroevolution" **Web** "Speciation"	**Instructional Activity:** After reading and studying Chapter 17 and viewing the Bozeman Biology video "Speciation," teams of students create posters that depict an example of each of the modes of speciation and the evidence needed to support hypotheses that species arose in those ways. Students explain and share their work during presentations and class discussions.
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] Justify the selection of data that address questions related to reproductive isolation and speciation. [LO1.23, SP 4.1] ***(learning objectives continue)***	Mader, Chapter 17: "Speciation and Macroevolution" **Web** "As the Worm Turns: Speciation and the Apple Maggot Fly"	**Instructional Activity:** Students read and study "As the Worm Turns: Speciation and the Apple Maggot Fly." They explore the question, *At what point in evolutionary development does a group of individuals become two distinct species?* Students decide whether apple maggot flies are distinct as a species from hawthorn maggot flies by examining different models of speciation and considering the primary forces that affect evolutionary change. Students propose a biologically reasonable scenario that explains how apple maggot flies evolved and share their proposals during a whole-class discussion of the case. **Formative Assessment:** Students are given a scenario describing an example similar to the one studied in the previous case study, "As the Worm Turns." A multiple-choice question is provided, and students must write a clear and convincing justification for accepting one of the possible answer choices and for rejecting the other choices. I provide corrective and informative feedback via discussion on the assessment results.

In this example, students are engaged in a science practice, as they are making claims and predictions based on scientific theories and models.

In this activity, students are analyzing data to identify relationships and justifying the selection of data to further explore the speciation question. They are also connecting concepts across enduring understandings in big idea 1 (speciation) and big idea 3 (genetic variation). Case studies are selected because they provide challenging opportunities to deepen student understanding of biological concepts and to engage in scientific practices.

In this formative assessment, students are sharpening their problem-solving skills as they describe why they are accepting one choice and rejecting the others. The corrective and informative feedback clarifies misunderstandings and can encourage students to be more careful readers.

Essential Questions: ▼ How is natural selection a major mechanism of evolution? ▼ How is biological evolution supported by scientific evidence from many disciplines, including mathematics? ▼ How is the origin of living systems explained by natural processes? ▼ How do phylogenetic trees graphically model evolutionary history?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) 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]		**Summative Assessment:** A block period is used for an exam of 15 multiple-choice questions, three short-response questions, and one free-response question.
Describe a scientific hypothesis about the origin of life on Earth. [LO 1.27, SP 1.2] Evaluate scientific questions based on hypotheses about the origin of life on Earth. [LO 1.28, SP 3.3] Describe the reasons for revisions of scientific hypotheses of the origin of life on Earth. [LO 1.29, SP 6.3] Evaluate scientific hypotheses about the origin of life on Earth. [LO 1.30, SP 6.5] Evaluate the accuracy and legitimacy of data to answer scientific questions about the origin of life on Earth. [LO 1.31, SP 4.4] Justify the selection of geological, physical, and chemical data that reveal early Earth conditions. [LO 1.32, SP 4.1]	Mader, Chapter 18: "Origin and History of Life" Origin of Life Kit for AP Biology, Carolina Biological Supply Company	**Instructional Activity:** Using kit materials, students explore the origin of life by creating coacervates — phospholipid vesicles similar to those created in the laboratory by Alexander Oparin in the 1920s. Extending their new knowledge of coacervate formation and properties, students design an investigation into the various environmental factors affecting coacervate formation and movement.
		Instructional Activity: The NCR research notebook is used to record work on this student-directed investigation. Students create mini-posters for peer and teacher review prior to submitting the lab report.
	Heitz and Giffen, "What Do We Know about the Origin of Life on Earth?" pp. 151–153	**Formative Assessment:** Students complete the activity "What Do We Know about the Origin of Life on Earth?" Student teams of three construct a concept map of conditions of the early Earth and the origin of life forms. They display their work for a gallery walk.
Analyze data related to questions of speciation and extinction throughout the Earth's history. [LO 1.20, SP 5.1]	Mader, Chapter 18: "Origin and History of Life" **Web** "GEOLogic: The Big Five Mass Extinctions"	**Instructional Activity:** Students complete the activity "GEOLogic: The Big Five Mass Extinctions." Students are asked to match up the five largest mass extinction events with their relative dates, approximate duration, and severity (percentage of species that became extinct) based on clues given from various perspectives. Students are exposed to real geologic data and must explain and justify their matches. A class discussion reviews the outcome of student work.

This assessment addresses the following essential questions:
- How is natural selection a major mechanism of evolution?
- How is biological evolution supported by scientific evidence from many disciplines, including mathematics?

This investigative activity provides students with the opportunity to explore with a microscope, and they are intrigued as coacervates form. Have several materials (e.g., egg albumin, sodium sulfate, Congo red stain, rubbing alcohol) available for students to use to develop their own questions about the formation of coacervates.

Teacher and peer review during the gallery walk provides corrective and informative feedback.

Essential Questions: ▼ How is natural selection a major mechanism of evolution? ▼ How is biological evolution supported by scientific evidence from many disciplines, including mathematics? ▼ How is the origin of living systems explained by natural processes? ▼ How do phylogenetic trees graphically model evolutionary history?

Learning Objectives	Materials	Instructional Activities and Assessments
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]	Mader, Chapter 19: "Systematics and Phylogeny" Heitz and Giffen, "How Are Phylogenies Constructed?" pp. 157–181. **Web** "Phylogenetics"	**Instructional Activity:** After reading and studying the chapter and viewing the video "Phylogenetics," students complete the activity "How are Phylogenies Constructed?" Students first make a concept map to explore how phylogenies are constructed. They then answer questions relating to their concept maps, including review of characteristics of three major domains that have been proposed based on DNA sequence analysis. Both the video and the activity make reference to the proposal of three major domains of life based on DNA sequence analysis, connecting big idea 1 (organisms are linked by lines of descent from common ancestry) and big idea 3 (heritable information provides for continuity of life). In small groups, students explain, justify, and share their thinking. They also pose scientific questions to one another regarding their analyses.

Having students view the video "Phylogenetics" before class to explore concepts of phylogeny allows more time in class for students to work in teams to explain, justify, and share thinking on this topic.

Evolution

(continued)

Essential Questions: ▼ How is natural selection a major mechanism of evolution? ▼ How is biological evolution supported by scientific evidence from many disciplines, including mathematics? ▼ How is the origin of living systems explained by natural processes? ▼ How do phylogenetic trees graphically model evolutionary history?

Learning Objectives	Materials	Instructional Activities and Assessments
Evaluate data-based evidence that describes evolutionary changes in the genetic makeup of a population over time. [LO 1.4, SP 5.3] Evaluate evidence provided by a data set in conjunction with a phylogentic tree or a simple cladogram to determine evolutionary history and speciation. [LO 1.18, SP 5.3] Evaluate evidence provided by data from many scientific disciplines that support biological evolution. [LO 1.9, SP 5.3] Construct and/or justify mathematical models, diagrams, or simulations that represent processes of biological evolution. [LO 1.13, SP 1.1, SP 2.1] Create a phylogentic tree or simple cladogram that correctly represents evolutionary history and speciation from a provided data set. [LO 1.19, SP 1.1] 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]	Mader, Chapter 19: "Systematics and Phylogeny" *AP Biology Investigative Labs* (2012), Investigation 3: Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST	**Instructional Activity:** Students complete AP Biology Investigation 3: Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST. Students use BLAST to compare several genes, and then use the information to construct a cladogram. Students design and conduct independent investigations after they explore with the BLAST process. **Formative Assessment:** Students complete lab reports in their NCR research notebooks based on their lab investigation of Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST.
	Web "Classroom Cladogram of Vertebrate/Human Evolution"	**Instructional Activity:** Given some groups of organisms and some of their distinguishing characteristics, students construct a cladogram and properly interpret and analyze that cladogram in terms of how it shows common ancestry and degrees of evolutionary relationships. Students display their work on posters for a gallery walk for peer and teacher review. **Summative Assessment:** A block period exam of 15 multiple-choice questions, four short-response questions, and one free-response question is given.

Bioinformatics is a relatively new field for students to explore. This investigative lab enables students to quickly compare entire genomes in order to detect genetic similarities and differences.

I provide corrective and informative feedback during discussion with students and via comments on the specific lab components presented in the lab report. Subsequent instructional activities (i.e., lab extension activities) may be modified based on the student lab report evaluation.

This assessment addresses the following essential questions:
- How is the origin of living systems explained by natural processes?
- How do phylogenetic trees graphically model evolutionary history?

Unit 5: Organism Form and Function

Laboratory Investigations:

- *AP Biology Lab Manual* (2001), Lab 10: Physiology of the Circulatory System (transitioned to a student-directed lab activity)
- *AP Biology Investigative Labs* (2012), Investigation 11: Transpiration
- Bronston and Cowles, *AP Biology: Cell-to-Cell Communication — Cell Signaling* (transitioned to student-directed inquiry)

Estimated Time:
7 weeks

Essential Questions: ▼ How do homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments? ▼ How do cell-to-cell signaling pathways regulate important complex responses in living systems? ▼ How are signaling pathways involved in the functioning of the nervous and immune systems? ▼ What important mechanisms are responsible for normal development of an organism?

Learning Objectives	Materials	Instructional Activities and Assessments
Justify the 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] 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]	Mader, Chapter 31: "Animal Organization and Homeostasis" and Chapter 40: "Hormones and Endocrine Systems" (Section 40.3: "Other Endocrine Glands and Hormones")	**Instructional Activity:** After reading and studying the chapter that introduces body organization (Chapter 31), student pairs create a visual representation (e.g., a poster) that defines homeostasis, explains negative feedback mechanisms and positive feedback mechanisms with clear examples, and suggests evidence that would justify the examples. Students present their visual representations to the class and are required to defend their claims regarding homeostasis as other students pose questions following the presentations. This is a student-directed, teacher-facilitated activity.

It is important to point out that homeostasis must occur in all organisms. In unicellular organisms, it occurs at the cellular level with each cell carrying out its own exchanges with the external environment.

Essential Questions: ▼ How do homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments? ▼ How do cell-to-cell signaling pathways regulate important complex responses in living systems? ▼ How are signaling pathways involved in the functioning of the nervous and immune systems? ▼ What important mechanisms are responsible for normal development of an organism?

Learning Objectives	Materials	Instructional Activities and Assessments
Use representation(s) or models to analyze quantitatively and qualitatively the effects of disruptions to dynamic homeostasis in biological systems. [LO 2.28, SP 1.4]	Mader, Chapter 32: "Circulation and Cardiovascular Systems" (Section 32.1: "Transport in Invertebrates") *AP Biology Lab Manual* (2001), Lab 10: Physiology of the Circulatory System, Exercise 10C: Heart Rate and Temperature (transitioned to a student-directed lab activity)	**Instructional Activity:** Through guided inquiry, students are led to an open-ended, student-directed investigation where they develop their own questions and design and conduct controlled experiments to test the effect of an environmental variable on the heart rate of *Daphnia magna*. The teacher is a facilitator in this activity. **Formative Assessment:** Students are given sample data from an experiment that tests a hypothesis that caffeine will increase the heart rate in *Daphnia magna*. Students are expected to graph the data correctly, analyze data to identify patterns or relationships, and justify claims with the evidence as they form conclusions. I provide corrective and informative feedback via discussion on the assessment results.
Construct explanations based on scientific evidence that homeostatic mechanisms reflect continuity due to common ancestry and/or divergence due to adaptation in different environments. [LO 2.25, SP 6.2] Analyze data to identify phylogentic patterns or relationships, showing that homeostatic mechanisms reflect both continuity due to common ancestry and change due to evolution in different environments. [LO 2.26, SP 5.1] Connect differences in the environment with the evolution of homeostatic mechanisms. [LO 2.27, SP 7.1] Use representations and models to analyze how cooperative interactions within organisms promote efficiency in the use of energy and matter. [LO 4.18, SP 1.4]	Mader, Chapter 36: "Body Fluid Regulation and Excretory Systems" and Chapter 35: "Respiratory Systems" **Web** "Homeostatic Evolution"	**Instructional Activity:** Students view "Homeostatic Evolution" before class. The video explains how the excretory system shows continuity through flatworms, earthworms, and vertebrates. It explains how the respiratory system shows change as organisms move onto land. Students prepare a poster presentation explaining how homeostasis reflects evolution through time. The presentation should explain homeostatic mechanisms and should include suggested experiments that would confirm principles learned. **Instructional Activity:** The "Homeostatic Evolution" posters are displayed in a gallery walk for peer and teacher review.

Encourage some students with cell phone video access to capture videos of Daphnia *projected on a screen (Video Flex connected to a microscope). Heartbeat data can be collected later by viewing and slowing down the video with computer technology. This type of differentiated instruction will motivate some of the more technologically advanced students.*

This would be a perfect time for informative feedback to relate this study to endothermic organisms and how the circulatory system helps maintain dynamic homeostasis within the organism by working with the digestive system, the respiratory system, and the urinary system.

Essential Questions: ▼ How do homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments? ▼ How do cell-to-cell signaling pathways regulate important complex responses in living systems? ▼ How are signaling pathways involved in the functioning of the nervous and immune systems? ▼ What important mechanisms are responsible for normal development of an organism?

Learning Objectives	Materials	Instructional Activities and Assessments
Use representation(s) and appropriate models to describe features of a cell signaling pathway. [LO 3.33, SP 1.4] Describe a model that expresses key elements to show how change in signal transduction can alter cellular response. [LO 3.38, SP 1.5]	**Web** "Pathways With Friends"	**Instructional Activity:** In the activity "Pathways with Friends," students model cell communication by acting as components in a cell signaling pathway. This teacher-directed activity provides a model for cell communication and introduces students to cell signaling pathways. The student-directed class discussion of the activity allows them to explain cell communication and to predict, with justification, what would happen if "someone didn't do their job" (conformational changes in the components of cell signaling).
Describe basic chemical processes for cell communication shared across evolutionary lines of descent. [LO 3.31, SP 7.2] Use representation(s) and appropriate models to describe features of a cell signaling pathway. [LO 3.33, SP 1.4] 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]	Mader, Chapter 26: "Flowering Plants: Control of Growth Responses" (Section 26.1: "Plant Hormones") and Chapter 40: "Hormones and Endocrine Systems" (Section 40.1: "Endocrine Glands") Materials to make models of signal transduction pathways in plants and animals (modeling clay, construction paper)	**Instructional Activity:** Using modeling clay or pieces of construction paper, students build models of signal transduction in plants (figure 26.1 in the text), the action of a peptide hormone (figure 40.4 in the text), and the action of a steroid hormone (figure 40.5 in the text). Students demonstrate their models in a presentation to the class, making predictions, with justification, of what might cause the amplification of the signal. This is a student-directed, teacher-facilitated activity.
	Mader, Chapter 26: "Flowering Plants: Control of Growth Responses"	**Formative Assessment:** Using the photograph of a buttercup, *Ranunculus fiscaria*, curving toward and tracking a source of light on page 473 of the text, students work in small groups to formulate hypotheses as to why this plant response may be occurring. This think-pair-share activity is student directed and teacher facilitated.

This activity provides for a kinesthetic, interactive method of introducing cell communication concepts, which will differentiate instruction. It is important to help students recall that the cell membrane has receptor proteins and cell recognition proteins that play important roles in cell-to-cell communication.

I provide corrective and informative feedback via discussion on the assessment results. By circulating and listening, I can determine if students understand the underlying causes of plant responses due to signal transduction pathways.

Essential Questions: ▼ How do homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments? ▼ How do cell-to-cell signaling pathways regulate important complex responses in living systems? ▼ How are signaling pathways involved in the functioning of the nervous and immune systems? ▼ What important mechanisms are responsible for normal development of an organism?

Learning Objectives	Materials	Instructional Activities and Assessments
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]	Mader, Chapter 24: "Flowering Plants: Structure and Organization"	**Instructional Activity:** In this student-directed, teacher-facilitated activity, students create posters that justify the claim that the organs and systems within a plant are essential to biological activities within the plant. Students defend their ideas through class discussion, and they refine and revise their work as discussion ensues.

Essential Questions: ▼ How do homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments? ▼ How do cell-to-cell signaling pathways regulate important complex responses in living systems? ▼ How are signaling pathways involved in the functioning of the nervous and immune systems? ▼ What important mechanisms are responsible for normal development of an organism?

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] Justify the selection of data regarding the types of molecules than an animal, plant, or bacterium will take up as necessary building blocks and excrete as waste products. [LO 2.8, SP 4.1] Represent graphically or model quantitatively the exchange of molecules between an organism and its environment, and the subsequent use of these molecules to build new molecules that facilitate dynamic homeostasis, growth, and reproduction. [LO 2.9, SP 1.1, SP 1.4] Apply mathematical routines to quantities that describe interactions among living systems and their environment, which result in the movement of matter and energy. [LO 4.14, SP 2.2] Use visual representations to analyze situations or solve problems qualitatively to illustrate how interactions among living systems and with their environment result in the movement of matter and energy. [LO 4.15, SP 1.4]	Mader, Chapter 24: "Flowering Plants: Structure and Organization" (Section 24.1: "Organs of Flowering Plants") and Chapter 25: "Flowering Plants: Nutrition and Transport" (Section 25.3: "Transport Mechanisms in Plants") *AP Biology Investigative Labs* (2012), Investigation 11: Transpiration	**Instructional Activity:** Students complete AP Biology Investigation 11: Transpiration. They prepare stomatal peels using nail polish, make a wet mount of leaf epidermal tissue and calculate number of stomata/surface area, and continue using potometers in an inquiry-based, student-directed investigation answering questions they have posed regarding transpiration rates. **Formative Assessment:** Students complete lab reports in their NCR research notebooks based on their transpiration lab investigation.

This transpiration investigative lab allows me to review principles of water potential that were learned during the diffusion and osmosis investigative lab. Although the transpiration lab was written for big idea 4 (biological systems interact), I use it in this unit on animal form and function. The claim that abscisic acid brings about the closing of stomata when a plant is under water stress is used for an upcoming activity.

I provide corrective and informative feedback during discussion with students and via comments on the specific lab components presented in the lab report. Subsequent instructional activities (i.e., lab extension activities) may be modified based on student lab report evaluation.

Essential Questions: ▼ How do homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments? ▼ How do cell-to-cell signaling pathways regulate important complex responses in living systems? ▼ How are signaling pathways involved in the functioning of the nervous and immune systems? ▼ What important mechanisms are responsible for normal development of an organism?

Learning Objectives	Materials	Instructional Activities and Assessments
Design a plan for collecting data to support the scientific claim that the timing and coordination of physiological events involve regulation. [LO 2.35, SP 4.2] Justify scientific claims with evidence to show how timing and coordination of physiological events involve regulation. [LO 2.36, SP 6.1] Connect concepts that describe mechanisms that regulate the timing and coordination of physiological events. [LO 2.37, SP 7.2]	Mader, Chapter 26: “Flowering Plants: Control of Growth Responses”	**Instructional Activity:** Presented with the claims that abscisic acid brings about the closing of stomata when a plant is under water stress and that photoperiodism results in flowering in long-day and short-day plants, students choose one claim and design an experiment that could test the claim. They present their research plan in a think-pair-share activity.
		Formative Assessment: Interactive whiteboard technology is used to present a 10-question clicker quiz that assesses understanding of homeostatic mechanisms in organisms and introductory cell signaling concepts. I provide corrective and informative feedback via discussion on the assessment results.
		Summative Assessment: One block period exam of 15 multiple-choice questions, four short-answer questions, and one free-response question.
Create representations and models to describe immune responses. [LO 2.29, SP 1.1, SP 1.2]	Mader, Chapter 32: “Circulation and Cardiovascular Systems” (Section 32.4: “Blood, a Transport Medium”) and Chapter 33: “Lymph Transport and Immunity” (Section 33.3: “Specific Defense Against Disease”) Heitz and Giffen, “How Does the Immune System Keep the Body Free of Pathogens?” pp. 251–252	**Instructional Activity:** Students complete “How Does the Immune System Keep the Body Free of Pathogens?” In this student-directed activity, students construct a model to demonstrate and explain, with justification, how the components of the immune system interact to rid the body of a pathogen.

Following the transpiration investigation, this activity brings about a more in-depth look at how the stomata might be regulated by cell signaling under certain conditions.

This assessment addresses the following essential questions:
- How do homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments?
- How do cell-to-cell signaling pathways regulate important complex responses in living systems?

Essential Questions: ▼ How do homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments? ▼ How do cell-to-cell signaling pathways regulate important complex responses in living systems? ▼ How are signaling pathways involved in the functioning of the nervous and immune systems? ▼ What important mechanisms are responsible for normal development of an organism?

Learning Objectives	Materials	Instructional Activities and Assessments
Create representations and models to describe immune responses. [LO 2.29, SP 1.1, SP 1.2]	Mader, Chapter 33: "Lymph Transport and Immunity"	**Instructional Activity:** Students create posters with annotated drawings and explanations that illustrate the differences in nonspecific defense against disease and specific defense against disease. Students display and explain their work (with justification) in a gallery walk for peer and teacher review. This activity is student directed and teacher facilitated.
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]	Mader, Chapter 33: "Lymph Transport and Immunity" **Web** "A Bad Reaction: A Case Study in Immunology"	**Instructional Activity:** Students are assigned to groups to work through "A Bad Reaction: A Case Study in Immunology." The case involves the transfer of a food allergy to a patient who received a combined kidney and liver transplant from a donor who died as a result of an allergic reaction. Each group is assigned a research team to role-play. The team has been awarded a grant to cover costs of examining case histories of three patients. The goal is to make a diagnosis from these records and design a testable experiment that can be used to obtain future funding. This activity is student directed and teacher facilitated.
		Formative Assessment: Student teams each create a mini-poster display that depicts findings and plans for experimentation from the case study "A Bad Reaction: A Case Study in Immunology." Student work must explain, with justification, the roles of immune cells and cell signaling pathways that occur in the immune system.
Describe how nervous systems transmit information. [LO 3.45, SP 1.2] Create a visual representation to describe how nervous systems transmit information. [LO 3.49, SP 1.1]	Mader, Chapter 37: "Neurons and Nervous Systems" Heitz and Giffen, "How Do Neurons Function to Transmit Information?" pp. 275–278	**Instructional Activity:** After reading and studying the lecture/discussion of nervous tissue, students complete an activity in which they investigate how neurons function with regard to transmitting information. Working in groups of three or four, students construct a dynamic model of an action potential along a neuron and then across a synapse to generate an action potential in a postsynaptic neuron. Students explain and present the model to other student groups and the teacher.

This case study involves real-life situations, and it is likely that students have heard about medical issues involved with organ transplants or know someone with a peanut allergy. The case also involves evaluating evidence, forming hypotheses, and planning experiments. The selection of this instructional activity allows students the opportunity to engage in science practices outside of the laboratory. Furthermore, it allows students to think critically about how cell signaling is involved in immunological responses.

The displays are peer and teacher reviewed prior to final assessment.

Essential Questions: ▼ How do homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments? ▼ How do cell-to-cell signaling pathways regulate important complex responses in living systems? ▼ How are signaling pathways involved in the functioning of the nervous and immune systems? ▼ What important mechanisms are responsible for normal development of an organism?

Learning Objectives	Materials	Instructional Activities and Assessments
Describe how nervous systems transmit information. [LO 3.45, SP 1.2] Create a visual representation to describe how nervous systems transmit information. [LO 3.49, SP 1.1] 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] Construct an explanation of how certain drugs affect signal reception and, consequently, signal transduction pathways. [LO 3.39, SP 6.2]	Mader, Chapter 37: "Neurons and Nervous Systems" **Web** "Jumpin' the Gap"	**Instructional Activity:** Students role-play communication at the neural level by behaving as pre-synaptic vesicles, neurotransmitters, post-synaptic receptors, secondary messengers, and re-uptake transporters in the activity "Jumpin' the Gap." The first part is teacher directed. Then, students assume the direction of the role-playing by modifying the activity to illustrate the effects of drugs on the synapse (cocaine, methamphetamine, and ecstasy).
Describe how nervous systems detect external and internal signals. [LO 3.44, 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] Create a visual representation to describe how the vertebrate brain integrates information to produce a response. [LO 3.50, SP 1.1]	Mader, Chapter 37: "Neurons and Nervous Systems" and Chapter 38: "Sense Organs"	**Instructional Activity:** Students, in teams of three, develop a PowerPoint presentation that explains how one of the sense organs works and how it enables animals to survive in changing environments. The presentation must demonstrate an understanding of concepts from Chapter 37, including an understanding of the central nervous system. Students share the PowerPoint presentations with the class, and discussion and questioning ensue. This is a student-directed, teacher-facilitated activity.

This role-play focuses attention on one example of cell signaling that is usually of great interest to students: the effect of drugs on the nervous system. This is an opportunity to go further in depth with one illustrative example to help students reach the goal of understanding how cell signaling operates in the nervous system.

Essential Questions: ▼ How do homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments? ▼ How do cell-to-cell signaling pathways regulate important complex responses in living systems? ▼ How are signaling pathways involved in the functioning of the nervous and immune systems? ▼ What important mechanisms are responsible for normal development of an organism?

Learning Objectives	Materials	Instructional Activities and Assessments
Connect concepts in and across domains to show that timing and coordination of specific events are necessary for normal development in an organism and that these events are regulated by multiple mechanisms. [LO 2.31, SP 7.2] 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] Describe the connection between the regulation of gene expression and observed differences between different kinds of organisms. [LO 3.18, SP 7.1] 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]	Mader, Chapter 42: "Animal Development" (Sections 42.1: "Early Developmental Stages" and 42.2: "Developmental Processes")	**Instructional Activity:** Students create a visual representation of development processes in *Drosophila melanogaster*, including signaling pathways and gene expression concepts. Students then compare these developmental processes to those in *Caenorhabditis elegans*. Students explain and share their representations within small groups. This activity is student directed and teacher facilitated.

Essential Questions: ▼ How do homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments? ▼ How do cell-to-cell signaling pathways regulate important complex responses in living systems? ▼ How are signaling pathways involved in the functioning of the nervous and immune systems? ▼ What important mechanisms are responsible for normal development of an organism?

Learning Objectives	Materials	Instructional Activities and Assessments
Explain how signal pathways mediate gene expression, including how this process can affect protein production. [LO 3.22, SP 6.2] Use representations to describe mechanisms of the regulation of gene expression. [LO 3.23, SP 1.4] Connect concepts in and across domains to show that timing and coordination of specific events are necessary for normal development in an organism and that these events are regulated by multiple mechanisms. [LO 2.31, SP 7.2] Use a graph or diagram to analyze situations or solve problems (quantitatively or qualitatively) that involve timing and coordination of events necessary for normal development in an organism. [LO 2.32, SP 1.4] Justify scientific claims with scientific evidence to show that timing and coordination of several events are necessary for normal development in an organism and that these events are regulated by multiple mechanisms. [LO 2.33, SP 6.1]	Mader, Chapter 42: "Animal Development" (Sections 42.1: "Early Developmental Stages" and 42.2: "Developmental Processes") and Chapter 13: "Regulation of Gene Activity" (Section 13.3: "Regulation Through Gene Mutations") Waterman and Stanley, *Biological Inquiry: A Workbook of Investigative Cases*, Chapter 10: "Shh: Silencing the Hedgehog Pathway"	**Instructional Activity:** Working in teams of three, students complete the investigative case "Shh: Silencing the Hedgehog Pathway." While engaged in Investigations 1 (Cell Signaling Pathways) and 3 (Stem Cells and Gene Expression), students apply concepts of cell communication and signaling pathways to the hedgehog signaling pathway. Students engage in graph reading and figure interpretation, extend understanding of differential gene expression while differentiating between embryonic and adult cells, and consider the usefulness of stem cell research in treatment of diseases and injuries.

This investigative case provides an additional activity allowing students to further think critically about what controls development in organisms. Working in groups provides opportunities for students to practice active listening and to challenge the ideas of others. Students are encouraged to use multiple resources for this activity. To reduce time that students spend looking for information to supplement their text, materials could be put on reserve in the media center or a page of relevant Web links could be provided.

Essential Questions: ▼ How do homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments? ▼ How do cell-to-cell signaling pathways regulate important complex responses in living systems? ▼ How are signaling pathways involved in the functioning of the nervous and immune systems? ▼ What important mechanisms are responsible for normal development of an organism?

Learning Objectives	Materials	Instructional Activities and Assessments
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] Pose questions about ethical, social, or medical issues surrounding human genetic disorders. [LO 3.13, SP 3.1]	Mader, Chapter 42: "Animal Development"	**Instructional Activity:** After reading "Human Embryonic Stem Cell Research" on p. 797 of the Mader text, students debate the following questions: 1. Should embryonic stem cell research continue to be permitted? 2. Should it be supported by government funding? 3. Do the origins of embryonic stem cell lines make a difference? **Instructional Activity:** Students write a 100-word response to the question, *How are signaling mechanisms and gene expression involved in the development of an organism?*
Generate scientific questions involving cell communication as it relates to the process of evolution. [LO 3.32, SP 3.1]	Mader, Chapter 20: "Viruses, Bacteria and Archaea"; Chapter 21: "Protist Evolution and Diversity"; and Chapter 22: "Fungi Evolution and Diversity"	**Instructional Activity:** Students have 15 minutes to do a "walk-through" of Chapters 20–22 (prokaryotes to fungi). They then consider the fact that cell-to-cell communication has been found to be ubiquitous in all three domains and write a scientific question they want to investigate on the evolution of cell-to-cell communication. They place questions on sticky notes and post them on the board. A student-directed whole-class discussion further explores these questions. The teacher is a facilitator in this activity.

The Howard Hughes Medical Institute video Potent Biology: Stem Cells, Cloning, and Regeneration *is an excellent resource in that it provides animation and lectures on the stem cell topic. The animation serves to meet various learning needs, and the lectures further explain stem cell research.*

This is an opportunity to use content from chapters that have been reduced or eliminated. The activity helps students meet the learning objective. Examples of questions that show student thinking might be: Can a particular virus infect a cell in any organism? Do bacteria communicate? Do mating strains in black bread mold use chemical signaling to recognize one another?

Essential Questions: ▼ How do homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments? ▼ How do cell-to-cell signaling pathways regulate important complex responses in living systems? ▼ How are signaling pathways involved in the functioning of the nervous and immune systems? ▼ What important mechanisms are responsible for normal development of an organism?

Learning Objectives	Materials	Instructional Activities and Assessments
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]	Bronston and Cowles, *AP Biology: Cell-to-Cell Communication — Cell Signaling* Dialysis tubing, iodine, starch solution, and other materials as needed to set up the open-ended inquiry	**Instructional Activity:** Students use the dialysis-tubing model of a cell and starch/iodine reaction to design and conduct an experiment that answers the question, *Is there an exchange of chemical information between cells?* This is a teacher-facilitated activity.
		Formative Assessment: Students complete lab reports in their NCR research notebooks based on their investigation of cell-to-cell communication between model cells.
		Formative Assessment: Students answer the following in a 100-word essay: Using two types of cells and chemical messages passed by each, explain, with justification, how your examples illustrate cell-to-cell communication. I provide corrective and informative feedback via discussion on the assessment results.
		Summative Assessment: A block period exam with 15 multiple-choice questions, four short-response questions, and one free-response question is given.

I provide corrective and informative feedback during discussion with students and via comments on the specific lab components presented in the lab report. Subsequent instructional activities (i.e., lab extension activities) may be modified based on student lab report evaluation.

The nature of the responses will indicate if any further review is needed to deepen understanding of cell communication concepts. Students should be able to clearly explain and justify claims regarding cell-to-cell communication with examples learned about during class.

This assessment addresses the following essential questions:
- How are signaling pathways involved in the functioning of the nervous and immune systems?
- What important mechanisms are responsible for the normal development of an organism?

Laboratory Investigations:

- *AP Biology Investigative Labs* (2012), Investigation 12: Fruit Fly Behavior
- *AP Biology Investigative Labs* (2012), Investigation 10: Energy Dynamics

Estimated Time: *6 weeks*

Essential Questions: ▼ What mechanisms regulate the timing and coordination of behavioral events in animals? ▼ What results from the interactions of populations within a community? ▼ What factors govern energy capture, allocation, storage, and transfer between producers and consumers in a terrestrial ecosystem? ▼ What are the consequences of human actions on both local and global ecosystems?

Learning Objectives	Materials	Instructional Activities and Assessments
Design a plan for collecting data to support the scientific claim that timing and coordination of physiological events involve regulation. [LO 2.35, SP 4.2] Justify scientific claims, using evidence, to describe how timing and coordination of behavior 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]	Mader, Chapter 43: "Behavioral Ecology" Heitz and Giffen, "What Determines Behavior?" pp. 291–293	**Instructional Activity:** Students complete "What Determines Behavior?" In this student-directed, teacher-facilitated activity, students read scenarios regarding animal behavior. For each scenario, they respond to these questions: • *What questions would you need to ask to determine what physiological mechanisms mediate the response?* • *What questions would you need to ask to determine if the behavior aids in survival and reproduction?* • *What is the behavior's evolutionary history?* • *What kinds of experiments would you need to develop to answer your questions?* **Formative Assessment:** In a "whip around" exercise, students share their questions and experiments. I provide corrective and informative feedback via discussion on the assessment results.

"Whip around" is a technique that allows you to quickly assess students' understanding of a topic. Students stand by chairs and are called on randomly to share responses to the questions in the exercise. They sit down once all of their answers have been shared with the group.

Essential Questions: ▼ What mechanisms regulate the timing and coordination of behavioral events in animals? ▼ What results from the interactions of populations within a community? ▼ What factors govern energy capture, allocation, storage, and transfer between producers and consumers in a terrestrial ecosystem? ▼ What are the consequences of human actions on both local and global ecosystems?

Learning Objectives	Materials	Instructional Activities and Assessments
Design a plan for collecting data to show that all biological systems (cells, organisms, populations, communities, and ecosystems) are affected by complex biotic and abiotic interactions. [LO 2.23, SP 4.2, SP 7.2] 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] 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] Apply mathematical routines to quantities that describe interactions among living systems and their environment, which result in the movement of matter and energy. [LO 4.14, SP 2.2] Use visual representations to analyze situations or solve problems qualitatively to illustrate how interactions among living systems with their environment result in the movement of matter and energy. [LO 4.15, SP 1.4] Predict the effects of a change of matter or energy availability on communities. [LO 4.16, SP 6.4]	Mader, Chapter 43: "Behavioral Ecology" *AP Biology Investigative Labs* (2012), Investigation 12: Fruit Fly Behavior	**Instructional Activity:** Students complete AP Biology Investigation 12: Fruit Fly Behavior. Students first make initial observations of fruit fly behavior and then develop their own questions and experimental designs to explore the environmental choices that fruit flies make. This is a student-directed and teacher-facilitated activity. Students should work as a team to count fruit flies as accurately as possible. One technique is to divide the chamber into quadrants that are counted separately by four students. Vestigial flies may be easier to count as they do not fly. If flies are refrigerated 10 minutes before transfer, they are immobile and are easy to transfer. **Instructional Activity:** NCR research notebooks are used to record work on this student-directed investigation. Students create mini-posters for peer and teacher review prior to submitting the lab report.

Essential Questions: ▼ What mechanisms regulate the timing and coordination of behavioral events in animals? ▼ What results from the interactions of populations within a community? ▼ What factors govern energy capture, allocation, storage, and transfer between producers and consumers in a terrestrial ecosystem? ▼ What are the consequences of human actions on both local and global ecosystems?

Learning Objectives	Materials	Instructional Activities and Assessments
Analyze data to support the claim that responses to information and communication of information affect natural selection. [LO 2.38, SP 5.1]	Mader, Chapter 43: "Behavioral Ecology" **Web** "A Deadly Passion: Sexual Cannibalism in the Australian Redback Spider"	**Instructional Activity:** Students view and discuss the PowerPoint presentation "A Deadly Passion: Sexual Cannibalism in the Australian Redback Spider." The activity involves distinguishing between proximate and ultimate causes of behavior, explaining how animal behavior may be linked in their evolutionary history, and using experimental data to support or reject hypotheses. Students make predictions about the outcomes to behavior scenarios involving the spiders. The interactive whiteboard and clicker system are used to assess student understanding as they respond to the questions on the case study concepts throughout the presentation.
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]	Mader, Chapter 43: "Behavioral Ecology" **Web** "My Brother's Keeper: A Case Study in Evolutionary Biology and Animal Behavior"	**Instructional Activity:** Students complete "My Brother's Keeper," a case study involving *Spermophilus beldingi* (ground squirrels). Students develop hypotheses about the frequency of predator calls, analyze data of experiments, and explain how behaviors in squirrels occur. **Formative Assessment:** On index cards, students write questions pertaining to mechanisms that regulate the timing and coordination of behavior events in animals. They place these in a container, I draw out cards, and the class is expected to provide answers. I provide corrective and informative feedback via discussion on the assessment results. **Summative Assessment:** Students take a one-hour exam consisting of 15 multiple-choice questions and one free-response question.

This assessment technique reviews topics that were unclear, and it gives students who might be reluctant to ask questions in front of their peers a chance to present a question to the instructor. I can obtain feedback on level of understanding of concepts that help answer the essential question in the unit.

This assessment addresses the essential question, What mechanisms regulate the timing and coordination of behavioral events in animals?

Essential Questions: ▼ What mechanisms regulate the timing and coordination of behavioral events in animals? ▼ What results from the interactions of populations within a community? ▼ What factors govern energy capture, allocation, storage, and transfer between producers and consumers in a terrestrial ecosystem? ▼ What are the consequences of human actions on both local and global ecosystems?

Learning Objectives	Materials	Instructional Activities and Assessments
Justify the selection of the kind of data needed to answer scientific questions about the interaction of populations within communities. [LO 4.11, SP 1.4, SP 4.1] Apply mathematical routines to quantities that describe communities composed of populations of organisms that interact in complex ways. [LO 4.12, SP 2.2] Predict the effects of a change in the community's populations on the community. [LO 4.13, SP 2.2]	Mader, Chapter 44: "Population Ecology" Heitz and Giffen, "What Methods Can You Use to Determine Population Density and Distribution?" and "What Models Can You Use to Calculate How Quickly a Population Can Grow?" pp. 303–311	**Instructional Activity:** In a student-directed, teacher-facilitated activity, students complete two activities from the Heitz and Giffen book. Students analyze scenarios to determine population density and distribution and explore the population growth model dN/dt=rN.
	Heitz and Giffen, "Test Your Understanding," p. 306	**Instructional Activity:** Students complete the "Test Your Understanding" activity. They are presented with data from experiments to test the hypothesis that one or more species of parasites causes fatalities in a salamander population, and the death rate varies with salamander population density. Based on the results of an experiment, students develop an argument as to which parasite is more likely to cause the extinction of the salamander population, and they present their arguments in a class discussion.
Predict the effects of a change of matter or energy availability on communities. [LO 4.16, SP 6.4] Predict consequences of human actions on both local and global ecosystems. [LO 4.21, SP 6.4]	Mader, Chapter 45: "Community and Ecosystem Ecology" and Chapter 47: "Conservation of Biodiversity"	**Instructional Activity:** A science center in the school district is working with an adjacent state park to collect water quality data from storm water after heavy rains. Baseline data are available. Students visit the site to collect data using water quality kits provided and upload the data on a Web-based database. Students analyze the data to determine the effects of water run-off on water quality in the state park. This is a student-directed and teacher-facilitated activity.
		Formative Assessment: Written accounts of experiences of this long-term project and student analysis of data are uploaded on the Moodle forum page at intervals for peer and teacher review. I provide corrective and informative feedback via discussion on the assessment results.

Peer tutoring for this activity will allow those students who may be challenged by the mathematics involved to have a better chance at success in understanding the concepts. If roles are switched during the course of the activity, then the opportunity to explain a concept to someone else helps extend both students' learning.

This activity could be continued beyond the AP Biology Exam in May to facilitate ongoing instruction through the end of year.

Moodle (Modular Object-Oriented Dynamic Learning Environment) is an e-learning software platform that the school district uses as a learning management system. You can create a Moodle page for a class and use it to post documents, link to websites, or create a forum page as described here for student–student and student–teacher online communication. Alternatively, an in-class bulletin board log would also serve the purpose of peer and teacher review for this community involvement project.

Essential Questions: ▼ What mechanisms regulate the timing and coordination of behavioral events in animals? ▼ What results from the interactions of populations within a community? ▼ What factors govern energy capture, allocation, storage, and transfer between producers and consumers in a terrestrial ecosystem? ▼ What are the consequences of human actions on both local and global ecosystems?

Learning Objectives	Materials	Instructional Activities and Assessments
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] 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] ***(learning objectives continue)***	Mader, Chapter 45: "Community and Ecosystem Ecology" *AP Biology Investigative Labs* (2012), Investigation 10: Energy Dynamics	**Instructional Activity:** Students complete AP Biology Investigation 10: Energy Dynamics in teams of three. A prelab activity helps students establish a context for energy dynamics in living systems. Students then develop skills needed to monitor the biomass in growing plants and butterfly larvae. Then, students investigate their own questions via a long-term study of energy dynamics. This study includes collecting biomass data at different intervals and during the observations of the interactions of the organisms. Students design and investigate experiments to answer their questions. Wisconsin Fast Plants (*Brassica rapa*) and cabbage white butterflies (*Pieris rapae*) are used for this study of the basic ecological concepts of energy flow, role of producers, primary consumers, and complex interactions between organisms.
		Instructional Activity: The NCR research notebook is used to record work on this student-directed investigation. Students create mini-posters for peer review and teacher review prior to submitting the lab report.
		Instructional Activity: Students develop a food web from the class marine aquarium on a poster. A gallery walk provides time for peer and teacher review.

Essential Questions: ▼ What mechanisms regulate the timing and coordination of behavioral events in animals? ▼ What results from the interactions of populations within a community? ▼ What factors govern energy capture, allocation, storage, and transfer between producers and consumers in a terrestrial ecosystem? ▼ What are the consequences of human actions on both local and global ecosystems?

Learning Objectives	Materials	Instructional Activities and Assessments
(continued) Apply mathematical routines to quantities that describe interactions among living systems and their environment, which result in the movement of matter and energy. [LO 4.14, SP 2.2] Use visual representations to analyze situations or solve problems qualitatively to illustrate how interactions among living systems and with their environment result in the movement of matter and energy. [LO 4.15, SP 1.4] Predict the effects of a change of matter or energy availability on communities. [LO 4.16, SP 6.4]		**Formative Assessment:** Students are presented with this scenario: *In order to improve species richness, you decide to add phosphate to a pond. Design an experiment to determine how much phosphate to add in order to avoid eutrophication.* Students explain and present their ideas for peer and teacher questioning and review.

Peer and teacher feedback helps students (as well as me) to gauge their understanding, and it provides guidance for me on the need for reteaching.

Essential Questions: ▼ What mechanisms regulate the timing and coordination of behavioral events in animals? ▼ What results from the interactions of populations within a community? ▼ What factors govern energy capture, allocation, storage, and transfer between producers and consumers in a terrestrial ecosystem? ▼ What are the consequences of human actions on both local and global ecosystems?

Learning Objectives	Materials	Instructional Activities and Assessments
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] Make scientific claims and predictions about how species diversity within an ecosystem influences ecosystem stability. [LO 4.27, SP 6.4]	Mader, Chapter 46: "Major Ecosystems of the Biosphere" and Chapter 47: "Conservation of Biodiversity"	**Instructional Activity:** Students in teams of three create a visual representation that addresses the following prompts relating to a terrestrial or aquatic biome of their choice: • Explain, with justification, the events that have impacted the ecosystem over time. • Make predictions, with justification, how changes in climate and biodiversity could impact the ecosystem. • Explain the claims and predictions about how species diversity within an ecosystem influences ecosystem stability. • Predict, with justification, how the ecosystem could be conserved. Student teams present their findings to the class.
	Mader, Chapter 47: "Conservation of Biodiversity" **Web** "You Poured It Where? A Case Study in Invasive Species"	**Instructional Activity:** The case study "You Poured It Where?" is used to introduce students to invasive species and review dynamics of an ecosystem. The study involves two students tearing down a saltwater aquarium; one of the students discovers that the other one plans to dump the water into a nearby storm drain.
		Formative Assessment: The case study "You Poured It Where?" is in a PowerPoint format, and questions regarding ecology concepts are dispersed throughout the presentation. The interactive whiteboard and clicker system are used to assess student understanding throughout the study.
		Summative Assessment: A block period exam with 15 multiple-choice questions, four short-response questions, and one free-response question is given. Paper-and-pencil exams are widely used for summative assessments. Alternatively, an individual or group project could be utilized (e.g., PowerPoint or poster presentations) to assess understanding of unit concepts. The value of this type of presentation would be to meet the needs of students who might be able to demonstrate learning well in an oral presentation.

Students are encouraged to research the human actions that are reducing biodiversity in the ecosystem on which they are reporting, and to suggest and predict consequences of those human actions. Guide students to think of biodiversity in terms of a nonrenewable resource, since lost species, and ultimately lost ecosystems, cannot be replaced. Understanding that biodiversity must be maintained at the genetic and ecosystem levels of organization allows students to connect and relate knowledge in and across enduring understandings and big ideas.

The clicker system and the ensuing discussions about students' responses help students and me to assess their level of understanding, and it provides guidance for me regarding the need for reteaching prior to the summative assessment.

This assessment addresses the following essential questions:
- What results from the interactions of populations within a community?
- What factors govern energy capture, allocation, storage, and transfer between producers and consumers in a terrestrial ecosystem?
- What are the consequences of human actions on both local and global 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.

Heitz, Jean and Cynthia Giffen. *Practicing Biology, A Student Workbook*. 3rd ed. San Francisco: Pearson Benjamin Cummings, 2008.

Mader, Sylvia S. *Biology*. 10th ed. New York: McGraw-Hill, 2010.

Unit 1 (Introduction to Biology and the Chemistry of Life) Resources

"A Can of Bull: Do Energy Drinks Really Provide a Source of Energy?" National Center for Case Study Teaching in Science. Accessed December 15, 2011. http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=203&id=203.

Unit 2 (Cells and Cellular Processes) Resources

"Build-a-Membrane." Genetic Science Learning Center: *Teach.Genetics*. Accessed November 13, 2011. http://teach.genetics.utah.edu/content/begin/cells/print/BuildAMembrane.pdf.

"Compartmentalization." Bozeman Biology. YouTube video. Accessed November 13, 2011. http://www.youtube.com/watch?v=2rihCCBzqMc.

Masterman, David, and Kelly Redding. *Advanced Biology with Vernier*. Beaverton, OR: Vernier, 2008.

"Photosynthesis and Respiration." Bozeman Biology. YouTube video. Accessed December 15, 2011. http://www.youtube.com/watch?v=0IJMRsTcwcg.

Unit 3 (The Genetic Basis of Life) Resources

"But I'm Too Young! A Case Study of Ovarian Cancer." National Center for Case Study Teaching in Science. Accessed November 13, 2011. http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=481&id=481.

"Epigenetics: DNA and Histone Model." http://teach.genetics.utah.edu/content/epigenetics/print/DNA%20Histone%20ModelFinal.pdf.

Moalem, Sharon. *Survival of the Sickest: The Surprising Connections Between Disease and Longevity*. New York: HarperCollins, 2007.

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

"WARD'S Mitotic Stage Counts Flashcards." WARD'S Natural Science. (Available for purchase at http://wardsci.com/product.asp_Q_pn_E_IG0015737.)

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

Unit 4 (Evolution) Resources

"As the Worm Turns: Speciation and the Apple Maggot Fly." National Center for Case Study Teaching in Science. Accessed November 13, 2011. http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=328&id=328.

"Classroom Cladogram of Vertebrate/Human Evolution." ENSI (Evolution & the Nature of Science Institutes). Accessed November 13, 2011. http://www.indiana.edu/~ensiweb/lessons/c.bigcla.html.

Evolution. Chevy Chase, MD: Howard Hughes Medical Institute, 2005. DVD. (Available for ordering at www.biointeractive.org.)

"GEOLogic: The Big Five Mass Extinctions." Teaching Quantitative Skills in the Geosciences. Last modified July 27, 2011. http://serc.carleton.edu/quantskills/activities/geologic_extinctions.html.

Origin of Life Kit for AP Biology. Carolina Biological Supply Company. (Available for purchase at http://www.carolina.com.)

"Phylogenetics." Bozeman Biology. YouTube video. Accessed December 15, 2011. http://www.youtube.com/watch?v=fQwI90bkJI4.

"Seven Skeletons and a Mystery." National Center for Case Study Teaching in Science. Accessed November 13, 2011. http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=440&id=440.

"Speciation." Bozeman Biology. YouTube video. Accessed November 13, 2011. http://www.youtube.com/watch?v=rlfNvoyijmo.

What Darwin Never Knew. PBS/NOVA, 2009. Video. Accessed November 13, 2011. http://video.pbs.org/video/1372073556/.

Unit 5 (Organism Form and Function) Resources

"A Bad Reaction: A Case in Immunology." National Center for Case Study Teaching in Science. Accessed November 13, 2011. http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=496&id=496.

Bronston, Carolyn Schofield, and Elizabeth A. Cowles. *AP Biology: Cell-to-Cell Communication — Cell Signaling*. Edited by Julia Kay Christensen Eichman. New York: The College Board, 2008. http://apcentral.collegeboard.com/apc/public/repository/ap-sf-bio-cell-to-cell-communication.pdf.

"Homeostatic Evolution." Bozeman Biology. YouTube video. Accessed November 13, 2011. http://www.youtube.com/watch?v=O5oe6j99Npw.

"Jumpin' the Gap." Genetic Science Learning Center: *Teach.Genetics*. Accessed November 13, 2011. http://teach.genetics.utah.edu/content/addiction/jumpgap.html.

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