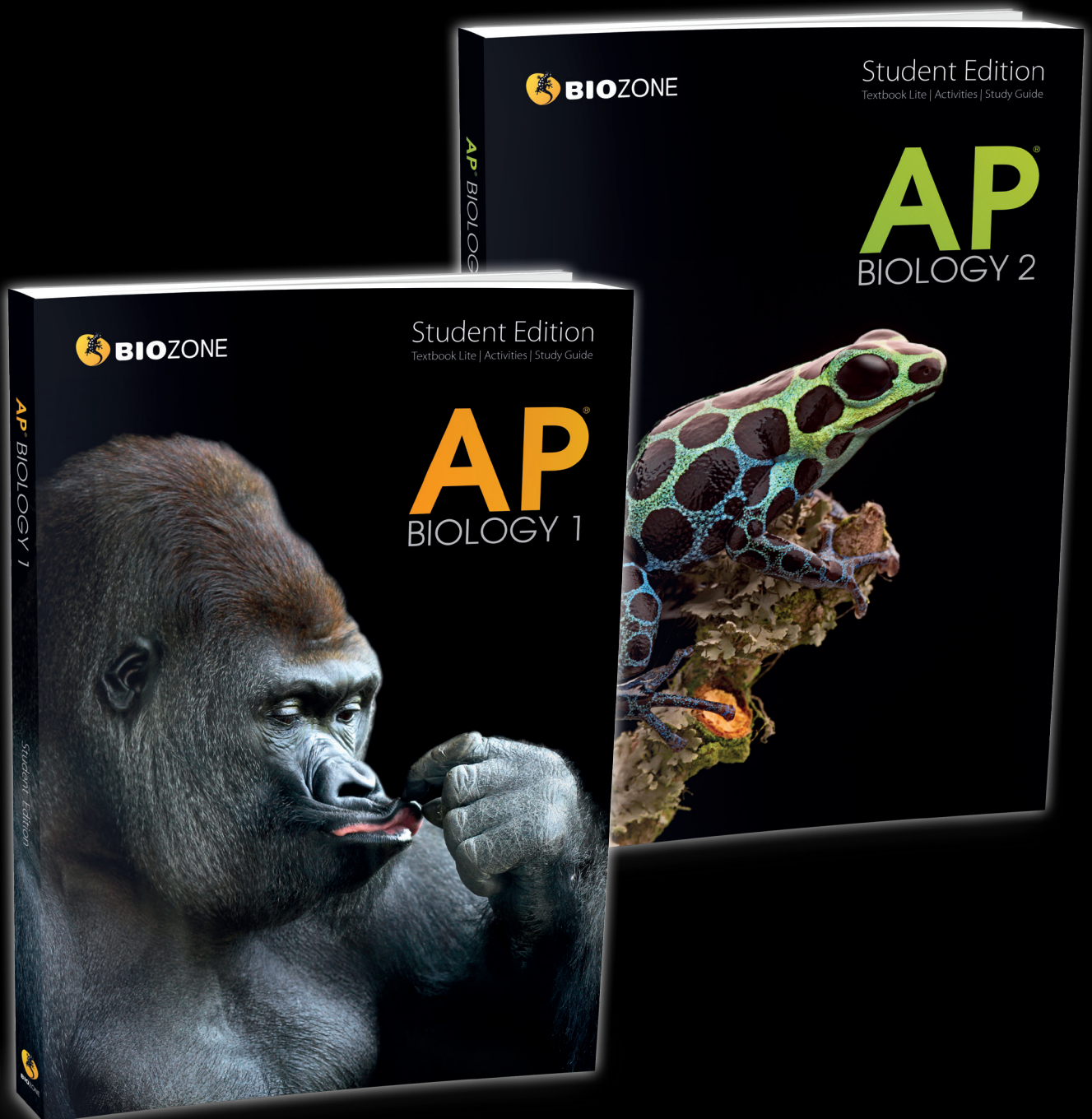




CLASSROOM GUIDE

AP[®] BIOLOGY



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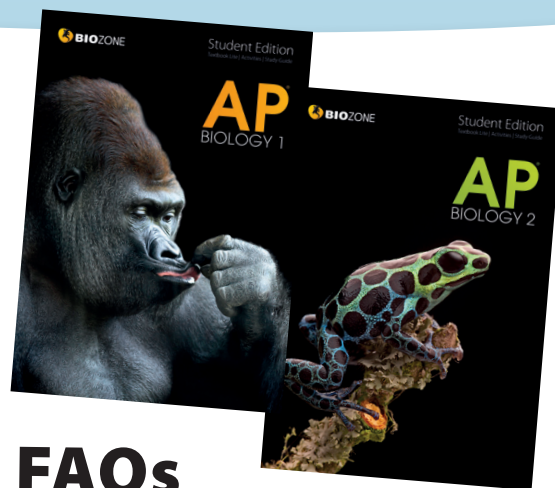
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FAQs

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Creating Lifelong Learners

We want today's biology students to be self-motivated, lifelong learners, to develop a sound grasp of biological knowledge, to plan and evaluate their work, and to think critically and independently. We have addressed five key competencies (the five Es) relating to these competencies. BIOZONE's books and associated products provide a varied and interesting suite of resources which, if used effectively, can help your students achieve key competencies in all areas of biology. Implicit in achieving these aims is the requirement for a flexible resource; one that can be used in a variety of ways, alongside the many other resources that are now available to teachers in various topic areas. BIOZONE's books provide this flexibility, with activities that can be used in a variety of ways.



BIOZONE encourages the development of the AP learner profile using the 5 Es model

The Five Es

- Engage:** make connections between past and present learning experiences.
- Explore:** become actively involved in the activity.
- Explain:** communicate the learning experience.
- Elaborate:** expand on the concepts learned.
- Evaluate:** assess understanding of the concepts.

ENGAGE: Highly visual activities	Use activities in class to engage a student when introducing a topic, or to consolidate student understanding and summarize the material covered by other methods. Using activities in class provides valuable opportunities for peer-to-peer learning.
ENGAGE: A connected plan of study	The check-box format of the contents pages and the chapter introductions provides a focus for planning achievement.
EXPLORE: Independent, self directed study	Activities are self-contained so students are encouraged to be independent learners and seek the answers to questions posed by the activity. Capable students can work quickly and independently through the material and can use the time for extension. Less able students can review or finish activities at home. Most activities are supported by web-based resources in the form of animations and video clips.
EXPLAIN: Communicating is the key to consolidation	All activities first engage the student with a key idea and a visually inviting delivery of content. Student engagement with this material leads them to the questions in which they must communicate their understanding of the content. Students are encouraged to use appropriate biological terms as referenced in the chapter introduction (key terms).
ELABORATE: Building up	Most introductory activities are supported by activities in which students apply their understanding of ideas to a new situation. These 'follow-on' activities often involve data analysis, and support science practices.
EVALUATE: Easy assessment	Encourage self assessment with chapter reviews (these can be graded if desired) or use specific activities to evaluate a student's skills and understanding or ideas. This is also the phase in which students might provide evidence for changes to their understanding.
WHAT ABOUT HOMEWORK?	Assign activities as homework to review a completed topic, explore a related concept, or introduce a topic prior to in-class practical work.

AP Biology Guide

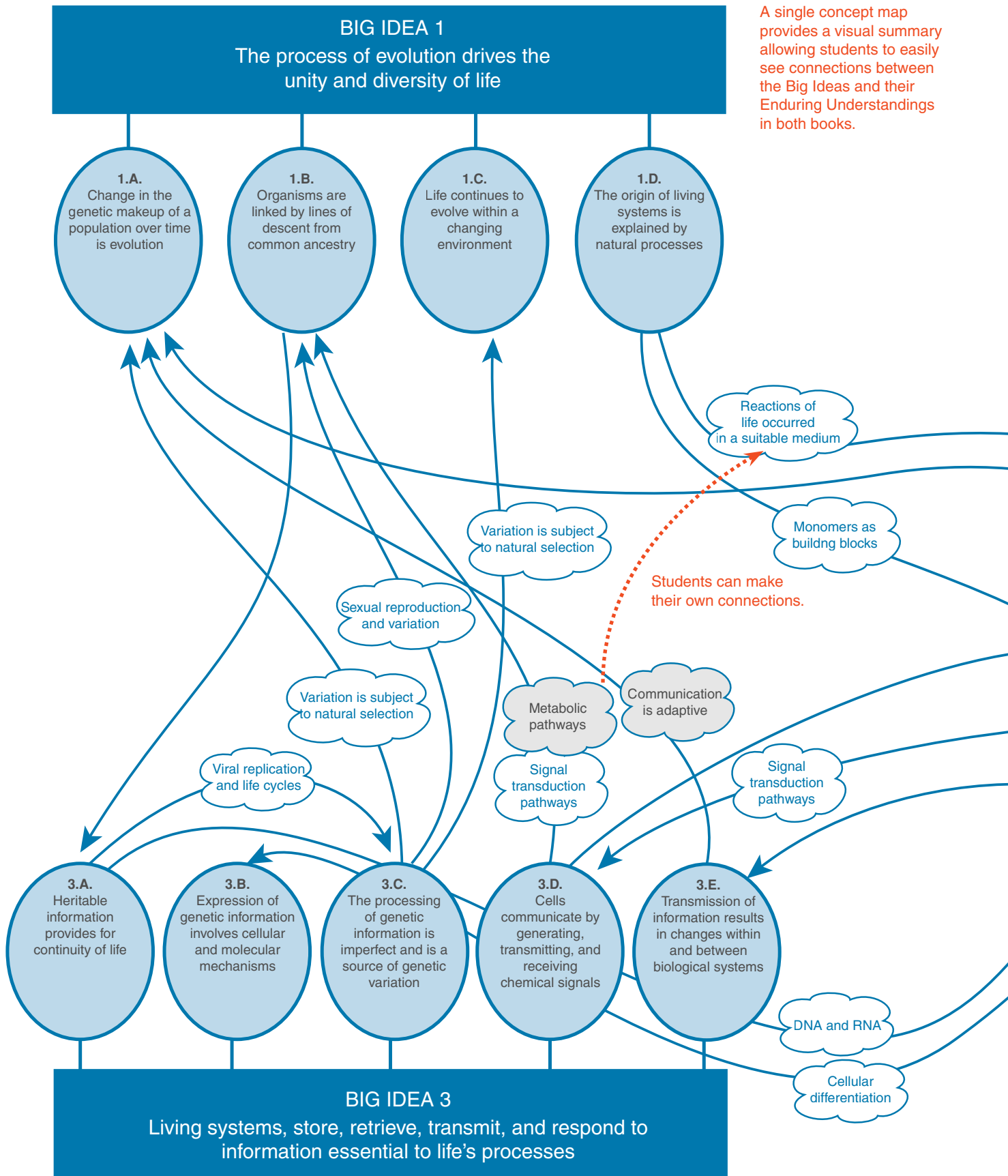
The AP biology program is organized into four underlying big ideas. The guide below lists the enduring understandings

for each big idea, and identifies where the material is located in **AP Biology 1** (blue) or **AP Biology 2** (black).

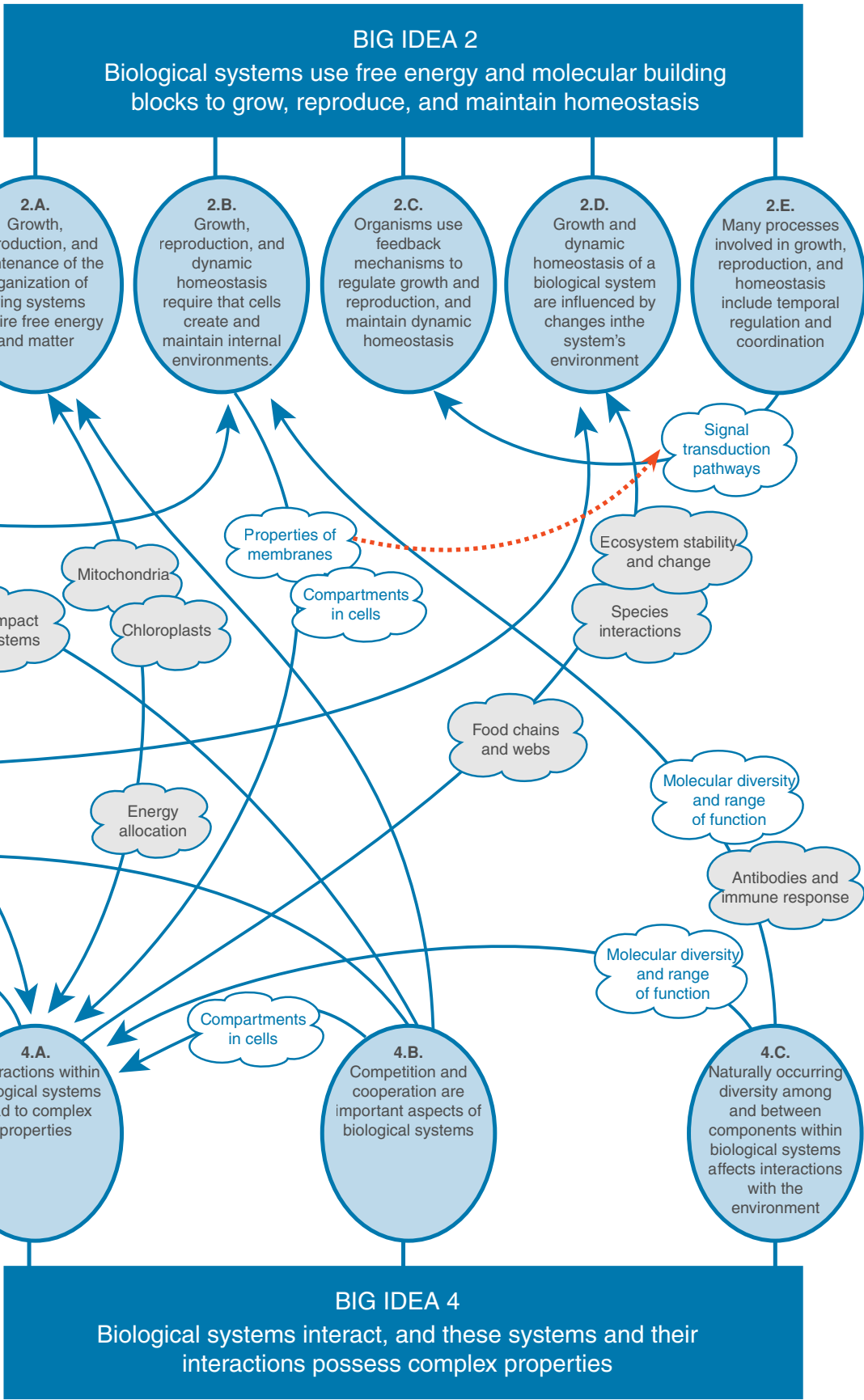
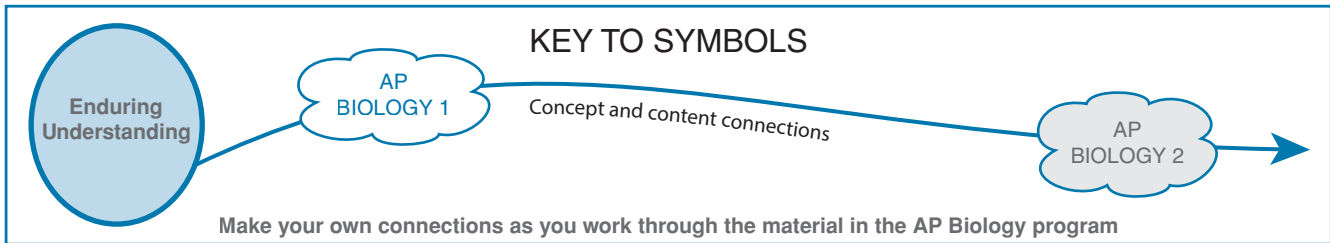
Big Idea 1: The process of evolution drives the diversity and unity of life		
1A: Change in the genetic makeup of a population over time is evolution		
1.A.1	Natural selection is a major mechanism of evolution	Genetic Change in Populations
1.A.2	Natural selection acts on phenotypic variations in populations	
1.A.3	Evolutionary change is also driven by random processes	
1.A.4	Biological evolution is supported by scientific evidence from many disciplines	Evidence for Biological Evolution
1B: Organisms are linked by lines of descent from common ancestry		
1.B.1	Organisms share many conserved core processes and features that have evolved	The Relatedness of Organisms
1.B.2	Phylogenetic trees and cladograms are graphical models of evolutionary history	
1C: Life continues to evolve within a changing environment		
1.C.1	Speciation and extinction have occurred throughout the Earth's history	Speciation and Extinction
1.C.2	Speciation may occur when populations become reproductively isolated	
1.C.3	Populations continue to evolve	
1D: The origin of living systems is explained by natural processes		
1.D.1	Hypotheses about the natural origin of life	The Origin of Living Systems
1.D.2	Scientific evidence from different disciplines supports models of life's origin	
Big Idea 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis		
2A: Growth, reproduction and maintenance of the organization of living systems require free energy and matter		
2.A.1	All living systems require energy	Energy in Living Systems, Homeostasis & Energy Allocation
2.A.2	Organisms capture and store free energy for use in biological processes	Energy in Living Systems, Energy Flow & Nutrient Cycles
2.A.3	Energy exchange maintains life processes	The Biochemistry of Life
2B: Growth, reproduction and dynamic homeostasis require that cells create and maintain internal environments that are different from their external environments		
2.B.1	Cell membranes are selectively permeable	Cell Structure and Processes
2.B.2	Movement of molecules across membranes maintains growth and homeostasis	
2.B.3	Internal membranes in eukaryotic cells partition the cell into specialized regions	
2C: Organisms use feedback mechanisms to regulate growth and reproduction, and to maintain dynamic homeostasis		
2.C.1	Organisms used feedback mechanisms to maintain internal environments	Homeostasis & Energy Allocation
2.C.2	Organisms respond to change in their external environments	Homeostasis & Energy Allocation, Timing & Coordination
2D: Growth & dynamic homeostasis are influenced by changes in the environment		
2.D.1	Biotic and abiotic factors affect biological systems	Populations & Communities
2.D.2	Homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments	Homeostasis & Energy Allocation, Plant Structure & Adaptation, Comparing Animal Systems, Interactions in Physiological Systems
2.D.3	Biological systems are affected by disruptions to their dynamic homeostasis*	The Diversity & Stability of Ecosystems (2.D.3 only)
2.D.4	Plants and animals have chemical defenses against infections	Internal Defense, Plant Structure & Adaptation
2E: Many biological processes involved in growth, reproduction & dynamic homeostasis include temporal regulation & coordination		
2.E.1	Timing and coordination of events are regulated and necessary for development	Regulation of Gene Expression
2.E.2	Multiple mechanisms regulate timing & coordination of physiological events	Timing & Coordination
2.E.3	Timing and coordination are regulated and are important in natural selection	
Big Idea 3: Living systems store, retrieve, transmit & respond to information essential to life processes		
3A: Heritable information provides for continuity of life		
3.A.1	DNA, and in some cases RNA, is the primary source of heritable information	DNA and RNA
3.A.2	In eukaryotes, heritable information is passed on via the cell cycle and mitosis or meiosis plus fertilization	Chromosomes & Cell Division
3.A.3	The chromosomal basis of inheritance gives an understanding of transmission of genes from parent to offspring	Chromosomes & Cell Division, The Chromosomal Basis of Inheritance
3.A.4	The inheritance pattern of many traits is not explained by Mendelian genetics	The Chromosomal Basis of Inheritance
3B: Expression of genetic information involves cellular and molecular mechanisms		
3.B.1	Gene regulation results in differential gene expression and cell specialization	Regulation of Gene Expression
3.B.2	Signals mediate gene expression	
3C: Processing of genetic information is imperfect and a source of genetic variation		
3.C.1	Genotype changes can alter phenotype	Sources of Variation
3.C.2	Processes that increase genetic variation	
3.C.3	Viral replication and genetic variation	
3D: Cells communicate by generating, transmitting and receiving chemical signals		
3.D.1	Commonalities in cell communication	Cellular Communication
3.D.2	Signaling by direct contact or chemicals	
3.D.3	Signal transduction pathways	
3.D.4	Changes to signal transduction pathways	
3E: Transmission of information results in changes within and between systems		
3.E.1	Communicating information with others	Communicating & Responding
3.E.2	Nervous systems and responses	
Big Idea 4: Biological systems interact, and these systems and their interactions possess complex properties		
4A: Interactions within biological systems lead to complex properties		
4.A.1	Properties of a molecule are determined by its molecular construction	The Biochemistry of Life, DNA and RNA
4.A.2	The structure and function of subcellular components, and their interactions, provide essential cellular processes	Cell Structure and Processes Energy in Living Systems
4.A.3	Gene expression results in specialization of cells, tissues and organs	Regulation of Gene Expression
4.A.4	Organisms exhibit complex properties due to interactions between their parts	Plant Structure & Adaptation, Comparing Animal Systems, Interactions in Physiological Systems
4.A.5	Communities are composed of populations that interact in complex ways	Populations and Communities
4.A.6	Movement of matter and energy	Populations & Communities, Energy Flow & Nutrient Cycles, The Diversity and Stability of Ecosystems
4B: Competition and cooperation are important aspects of biological systems		
4.B.1	Interactions between molecules affect their structure and function	Enzymes & Metabolism
4.B.2	Cooperative interactions within organisms promote efficiency	Plant Structure & Adaptation, Comparing Animal Systems, Interactions in Physiological Systems
4.B.3	Population interactions influence species distribution and abundance	Populations & Communities, The Diversity & Stability of Ecosystems
4.B.4	Ecosystem distribution changes over time	The Diversity & Stability of Ecosystems
4C: Naturally occurring diversity among and between components within biological systems affects interactions with the environment		
4.C.1*	Variation in molecular units provides cells with a wider range of functions	Internal Defense
4.C.2*	Environmental factors influence the expression of the genotype	The Chromosomal Basis of Inheritance
4.C.3	Variation in populations affects dynamics	Populations & Communities, The Diversity & Stability of Ecosystems
4.C.4	Diversity may influence ecosystem stability	
* 4.C.1 and 4.C.2 also see Sources of Variation		

The Concept Maps

- ▶ The concept map in the introductory section of BIOZONE's **AP Biology** books provides an overview of the program content.
- ▶ The map provides an overall structure and the "big picture" approach helps students to make the conceptual connections between different parts of the program.
- ▶ Students can make their own connections between ideas on the concept maps as they work through the topics. This helps to reinforce the connectedness of the program content.



A single concept map provides a visual summary allowing students to easily see connections between the Big Ideas and their Enduring Understandings in both books.



The Contents: A Plan of Action

The contents pages are not merely a list of the activities in the student edition. Encourage your students to use them as a planning tool for their program of work. Students can identify the activities they are to complete and then tick them off when completed. The teacher can also see at a glance how quickly the student is progressing through the assigned material.

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CODES: Activity is marked: to be done

The teacher can see at a glance how this student is progressing through this unit of work. Any concerns with progress can be addressed early.

Students can mark the check boxes to indicate the activities they should complete. This helps them to quantify the work to be done and plan their work.

Ticking off the activities as they are completed gives students a sense of progression and helps them to be more personally organized in their work.

Introducing the AP Biology Content

Each chapter in AP Biology is prefaced with an introduction, providing students with an overview of the chapter content and organization. Each of the numbered learning outcomes pertains to a point of essential knowledge, skill, or practical investigation, and is matched to one or more activities. A list of key terms for the chapter is also included. The comprehensive, but accessible, list of learning outcomes encourages students to approach each topic confidently. Familiarity with the scientific terms used in each topic is implicit in this.

This identifies the Enduring Understanding code or codes to which this chapter applies.

The list of key terms can be used to create a glossary for revision and encourages appropriate use of the correct terms when answering questions.

Activities to support the 13 required AP investigations are identified by a blue flag.

Enduring Understanding

4.B

Enzymes and Metabolism

4.8.1 Interactions between molecules affect their structure and function

Essential knowledge

(a) **Change in the structure of a molecular system may result in a change of function**

1 Use examples to illustrate how changes in a molecule's structure can change its function. [also 3.D.3.a]

(b) **An enzyme's essential function is determined by its structure**

1 Explain how an enzyme's structure is related to its function.

2 Explain how an enzyme's structure is related to its function.


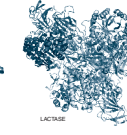

Activity number

24 25

20 21 22

24

Mark the check boxes to complete and tick off when finished.

4.8.2 Cooperative interactions within organisms promote efficiency in the use of energy and matter

Essential knowledge

(a) **Organisms have areas or compartments that perform a subset of functions related to energy and matter and these parts contribute to the whole**

1 Explain how compartmentalization within the cell contributes to overall specialization and functioning of the cell.

2 Using examples, explain how specialization of organs within multicellular organisms contributes to overall functioning. Examples include specialization for exchange of gases, digestion, circulation of fluids, and excretion of wastes.

3 Describe how interactions among cells of a population of unicellular organisms can be similar to those of multicellular organisms and can lead to increases in efficiency and use of energy and matter.

Activity number

28 29

27

30

A summary of essential knowledge and skills are drawn from the study design. They are purposefully brief, with enough information to provide a framework, but not so much that students are overwhelmed.

The activities in the book with the activities pertaining to these key knowledge outcomes

Introduce the concept with a grounding activity

Follow with an activity expanding on that concept

28 Achieving Metabolic Efficiency

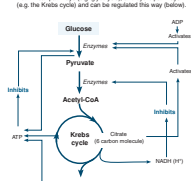
Key Idea: Cells and organelles have compartments. These compartments help achieve metabolic efficiency. Metabolic reactions often occur as a linked series in which each step in the pathway relies on the completion of a previous step and each step is controlled by specific enzymes. The end product of one enzyme-controlled step provides the substrate for the next step, so failure of one step causes failure of all later steps. Metabolic pathways are tightly controlled to prevent energy being wasted. This energy conservation is termed metabolic efficiency. Metabolic reactions are often localized within specific organelles so that all the components of the pathway are kept together.

Achieving efficiency by compartmentalization
To increase metabolic efficiency, regions within a cell or an organelle are compartmentalized (separated) by membranes. Particular metabolic reactions are restricted to certain regions where all the necessary metabolic components are located. Compartmentalization prevents interference between different reaction pathways and enables mutually different reaction environments to be accommodated within different organelles.

Example: Cellular respiration in the mitochondrion. The reactions involving the mitochondrial divide 8 into several regions. Glycolysis takes place outside the mitochondrion, in the cell's cytoplasm, but the remaining steps take place in different compartments of the mitochondrion. This helps to regulate movement of substrates and end products and therefore reaction rates, increasing efficiency of the process (balow).

Achieving efficiency by inhibition
Many metabolic pathways are controlled by feedback inhibition (negative feedback loop). The pathway is stopped when there is a build-up of end product (or certain intermediate products). The build-up stops the enzymes in the pathway from working and allows the cell to shut down a pathway when it is not needed. This conserves the cell's energy, so it is not manufacturing products it does not need.

Both linear pathways (e.g. glycolysis), and cyclic pathways (e.g. the Krebs cycle) can be regulated this way (balow).



1. What does metabolic efficiency mean?
2. Describe how cells achieve metabolic efficiency through:
 - (a) Compartmentalization.
 - (b) Feedback inhibition.
3. What would happen if cells could not regulate their metabolic pathways?

29 Regional Specialization and Functional Efficiency

Key Idea: The specialization of organs to carry out specific roles and regional specialization within an organ system allow for functional efficiency in multicellular organisms. Functional efficiency is the ability to carry out a process in the most efficient manner, with minimal energy or resource cost. In multicellular organisms, functional efficiency is enhanced by having specialized organs and organ systems that perform a specific function. Examples include the digestive system and the immune system. Organs that perform a specialized role can work more efficiently than if they were required to carry out a number of different, unrelated tasks. Within an organ system, further specialization occurs. Specific organs or regions perform certain tasks and this increases the functional efficiency of the system as a whole.

Functional efficiency in the mammalian digestive system
Efficiency of digestion in mammals is enhanced by the one-way movement of food through the digestive system. It allows the gut to become regionally specialized for processing food. Each region of the digestive system has a different role.

The liver produces an alkaline (pH 7.5–8.5) bile to neutralize the contents of the stomach as it enters the small intestine. The bile also emulsifies fats to help their digestion and assist their absorption across the intestinal wall.

The small intestine is the primary site of digestion and absorption. It is very long and has a high surface area to maximize nutrient absorption.

The caecum is located at the beginning of the large intestine. It is very large and has a high surface area to help with fermentation by bacteria for the digestion of cellulose.

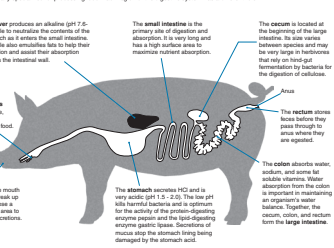
The colon absorbs water, sodium, and some fat-soluble vitamins. Water absorption from the caecum is important in maintaining an organism's water balance. Together, the caecum, colon, and rectum form the large intestine.

The teeth in the mouth mechanically break up the food to expose a greater surface area to enzymes and emulsions.

The stomach secretes HCl and is very acidic (pH 1.5–2.0). The low pH kills harmful bacteria and is optimum for the activity of the protein-digesting enzyme pepsin and the fat-digesting enzyme gastric lipase. Secretions of mucus into the stomach lining being damaged by the stomach acid.

Regional specialization and functional efficiency
The chemical environment within each region of the mammalian digestive tract (gut) varies. For example, the stomach is a very acidic environment, whereas the small intestine has a more neutral pH. Each region provides the optimal chemical environment for the enzymes operating there. This increases digestive efficiency, reducing the time it takes for food to pass through the gut and enabling the animal to maximize food intake.

For example, the protein-digesting enzymes pepsin and trypsin both require acidic conditions to function. However, each enzyme operates at a different hydrolysis site, so the protein is digested at different places. Pepsin is found in the stomach, operating at pH 2.0, and is inactive in the neutral pH of the small intestine. Trypsin works optimally in the more neutral pH of the small intestine. Having several different enzymes performing a similar task maximizes the digestion of food.

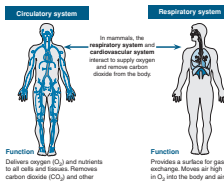


1. What is the advantage of specialization of organs within organ systems?

28 29

Organ systems work together
Although multicellular organisms have specialized organ systems that perform specific roles, the various organ systems must interact and work together to contribute to the overall functioning of the organism. For example:

- The skeletal and muscular systems protect the heart and lungs from damage and enable ventilation of the lungs.
- The gas exchange system provides the environment for the exchange of respiratory gases, O₂ and CO₂, between the blood and the air.
- The circulatory system transports O₂ from the gas exchange surfaces to the tissues and transports CO₂ in the opposite direction (right).



Function
In mammals, the respiratory system and cardiovascular system interact to supply oxygen and remove carbon dioxide from the body.

Function
Provides a surface for gas exchange. Moves air high in O₂ into the body and air high in CO₂ out of the body.

2. How do multicellular organisms achieve functional efficiency?
3. (a) Describe the movement of food through the mammalian digestive system.
(b) How does this flow through the digestive system help to achieve functional efficiency?
4. Several different digestive enzymes are present in the mammalian digestive system.
(a) Predict what would happen to trypsin if it was subjected to the acidic pH of the stomach.
(b) What is the functional advantage of pepsin and trypsin hydrolyzing (breaking down) proteins at different sites?
5. Briefly outline the nature of the interaction between the circulatory and respiratory systems.

Using the Activities

The content of AP Biology is organized into 26 chapters, over two companion volumes. Each chapter begins with an introduction and all except *Essential Skills for AP Biology* conclude with a student's self-test of understanding and vocabulary. Inviting, concept-based activities make up the bulk of each chapter, with each activity focusing on the student developing understanding of a concept, applying that understanding to another scenario, and/or developing an essential skill, such as graphing, data analysis, or biological drawing.

An important feature of each activity is the key idea, which encapsulates the main focus of the activity's content. Clear annotated diagrams and photographs are a major part of most activities and the student's understanding of the information is evaluated through questions and/or tasks involving data handling and interpretation.

The task code for each activity identifies the nature of the activity, the connect tabs identify connections across Big Ideas and Enduring Understandings, the practices icon indicates a particular Science Practice that is emphasized within the activity. Gray weblink tabs indicate if the activity is supported by an external weblink.

The **key idea** provides a focus for each activity. It summarizes the focus of the activity and provides a clear take-home message for the student.

Annotated diagrams, photographs, and graphs explain the content of the page, providing the information necessary to complete the activity.

Understanding of content is tested through questions, data handling, analysis, prediction, or summary. Students are often required to apply their understanding to a new scenario or draw on knowledge acquired through completing earlier, related material. Students must interact with the information on the page in order to complete the activity. It is this interaction that provides the valuable learning experience and reinforcement and explanation of the key idea.

Related content is identified through the tab system. This activity also has a **weblink** assigned to it (see below).

168 **118 Cooperating Systems: Generating Movement**

Key Idea: The nervous and muscular systems interact to bring about movement through muscle contraction. Movement is an essential activity requiring coordination between nervous and muscular systems to bring about muscle contraction. Nerve impulses originating at the central nervous system are carried by neurons, which terminate in a specialized junction (synapse) at the muscle fiber called the neuromuscular junction. The arrival of a nerve impulse at the neuromuscular junction results in release of the neurotransmitter acetylcholine and contraction of the fiber. A motor neuron and all the muscle fibers it innervates is called a motor unit. The response of a single muscle fiber is all-or-none, meaning it contracts maximally or not at all. However, the strength of the contraction in the entire muscle can be varied (below). This way, muscles can produce contractions of varying force, suitable for different tasks.

Muscles have graded responses
Muscle fibers respond to an action potential by contracting maximally or not at all. This response is called the **all or none law** of muscle contraction. However, skeletal muscles as a whole can produce contractions of varying force. This is achieved by changing the frequency of stimulation (more rapid arrival of action potentials) and by changing the number of fibers active at any one time (recruiting more motor units). A stronger muscle contraction is produced when a large number of muscle fibers are recruited (e.g. lifting weights), whereas less strenuous movements, such as picking up a pen, require fewer active fibers.

1. How do the nervous system and muscular system work together to bring about movement?

2. The release of acetylcholine to cause muscle contraction is an example of what type of signaling (circle correct answer):
Autocrine signaling / cell-to-cell communication / local regulation / endocrine signaling

3. (a) What is meant by an all-or-none response of a muscle fiber?

(b) How can a muscle produce contractions of varying force (e.g. effort required to pick up a pen versus the effort required to lift a heavy object)?

KNOW **118** **182** **80** **PRACTICES**
WEB CONNECT CONNECT

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TASK CODES

These identify the nature of the activity

- COMP** = comprehension of text
- DATA** = data handling and interpretation
- KNOW** = content you need to know
- PRAC** = supports one of the 13 AP Biology investigations
- REFER** = reference - use for information
- SKILL** = supporting a mathematical or practical skill
- TEST** = test your understanding

KNOW

WEB

118

CONNECT

182

AP2

CONNECT

80

AP1

PRACTICES

PRACTICES

CONNECT

Concept and content connections are made to other activities within AP1 or in AP2.

PRACTICES

Picture codes indicate where one of the 7 science practices is emphasized.

Weblinks

For AP Biology 1: www.thebiozone.com/weblink/AP1-9629

For AP Biology 2: www.thebiozone.com/weblink/AP2-9650

Bookmark these sites to access the external URLs provided.

Engage, Explore, Explain, Elaborate, and Evaluate

In developing AP Biology, we have used the four big ideas to provide a thematic framework for the books. The activities in AP Biology have been specifically written to address the content and skills requirements for the AP Biology program. Our focus is student engagement through the use of a concept-based, highly visual content coupled with the opportunity to demonstrate skills and understanding.

Enduring Understanding 3.A DNA and RNA

3.A.1 DNA and RNA are the sources of heritable information

Essential knowledge

(a) Genetic information is transmitted from one generation to the next

- 1 Explain how genetic information is stored in and passed to subsequent generations through DNA, or sometimes RNA. 92-96
- 2 Contrast chromosome structure in eukaryotes and non-eukaryotes. 93-95
- 3 Describe the nature of plasmid DNA in prokaryotes, eukaryotes, and viruses. 94
- 4 Describe the historical investigations that showed that DNA is the carrier of genetic information. 96

(b) DNA and RNA have similarities and differences that define function

- 1 Describe the structure of a nucleotide and explain how nucleotides are joined to form linear DNA and RNA molecules with specific properties. 98-100
- 2 Identify differences and similarities between DNA and RNA. 98-100
- 3 Describe the base pairing rule and its universal and conserved nature. Distinguish between purines and pyrimidines and explain the significance of the differences. 98-100
- 4 Relate RNA structure to function. Describe the structure and role of mRNA, tRNA, rRNA, and rRNA. 98-99

(c) Genetic information flows from gene to protein

- 1 Describe transcription of DNA by RNA polymerase to produce mRNA. 104-106
- 2 Describe modifications to the primary mRNA transcript in eukaryotes, including addition of caps and tails and removal of introns. 104-107
- 3 Know that translation of mRNA occurs on ribosomes in the cytoplasm. 104-108
- 4 Know that transcription and translation are coupled processes in prokaryotes. Describe steps in translation (initiation, elongation, termination). Describe how the mRNA is read by ribosomes and the role of tRNA and start and stop codons. 108-109

The introduction to each chapter provides a summary of the learning outcomes and appropriate investigations, presented as a series of short student learning outcomes. The students use the activities indicated to demonstrate that they have met the knowledge and skills requirements outlined in each numbered point.

Activities are written and presented so that students progressively extend and deepen their understanding, using what they have learned in earlier activities to complete later related activities and to solve new problems.

104 What is Gene Expression?

Key Idea: Genes are sections of DNA that code for proteins. Genes are transcribed when they are transcribed into messenger RNA (mRNA) and then translated into a protein. Gene expression is the process by which the information in a gene is used to synthesize a protein. It involves transcription of the DNA into mRNA and translation of the mRNA into protein. Eukaryotic genes include non-protein coding regions called introns. These regions of intron DNA must be edited out before the mRNA is translated by the ribosomes. Transcription of the genes and editing that primary transcript to form the mature mRNA occurs in the nucleus. Translation of the protein by the ribosomes occurs in the cytoplasm.

A summary of eukaryotic gene expression

PRO YOU KNOW?

Students are actively involved by interacting with the material, answering the questions and completing the set tasks. Many activities are suitable for assessment.

- (b) DNA and RNA have similarities and differences that define function**
- 1 Describe the structure of a nucleotide and explain how nucleotides are joined to form linear DNA and RNA molecules with specific properties. 98-100
 - 2 Identify differences and similarities between DNA and RNA. 98-100
 - 3 Describe the base pairing rule and its universal and conserved nature. Distinguish between purines and pyrimidines and explain the significance of the differences. 98-100
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Engage and explore → Explain → Elaborate and evaluate

70 Active Transport

Key Idea: Active transport uses energy to transport molecules against their concentration gradient across a partially permeable membrane.

Active transport: the movement of molecules from an area of low concentration to regions of high concentration requires energy. Active transport needs energy to proceed because molecules are being moved against their concentration gradient.

Active transport

- 1 ATP binds to a transport protein.
- 2 A molecule or ion to be transported binds to the transport protein.
- 3 ATP is hydrolyzed and the energy released is used to transport the molecule or ion across the membrane.
- 4 The molecule or ion is released and the transport protein returns to its previous state.

71 Ion Pumps

Key Idea: Ion pumps are transmembrane proteins that use energy to move ions and molecules across a membrane against their concentration gradient.

Proton pumps

Sodium-potassium pump

Cotransporter

Protein pumps

Sodium-potassium pump

72 Disturbances to Ion Transport

Key Idea: Disturbing the regulation of the movement of ions in and out of cells also has the effect of changing the amount of water entering and leaving a cell.

Mechanism of channel-linked dehydration

Mechanism of oral rehydration salts

Engage, explain, elaborate, and evaluate: Activities are nested, with later activities in a sequence building on understanding so that students can confidently apply a scientific approach to new situations and information.

The KEY IDEA: Provides a focus for each activity. The key ideas through a chapter provide a concise summary of the chapter content.

132 Mitosis

Key Idea: Mitosis is an important part of the eukaryotic cell cycle in which the replicated chromosomes are separated and the cell divides producing two new cells.

Mitosis is part of the cell cycle in which an eukaryotic cell divides to produce two new cells.

Mitosis is a stage in the cell cycle

- Mitosis (cell division) is the part of the cell cycle in which the parent cell divides to form two genetically identical daughter cells.
- Mitosis results in the separation of the nuclear material and division of the cell. It does not result in a change of chromosome number.
- Mitosis is one of the shortest stages of the cell cycle. When a cell is in mitosis, it is not responding to any one of the many signals that a cell must respond to in order to divide.
- In animals, mitosis takes place in the somatic (body) cells. Somatic cells are any cell of the body except sperm and egg cells.
- In plants, mitosis takes place in the meristems. The meristems are regions of growth where new cells are produced, such as the tips of roots and shoots.

Mitosis produces identical daughter cells

The cell divides forming two identical daughter cells.

The mitotic index (number of cells in mitosis) is often used to measure the rate of cell division.

The mitotic index is a measure of the number of cells in mitosis in a high-magnification micrograph.

1. Contrast the location of mitosis in plants and animals.

2. When a slide of plant meristematic tissue is viewed under a microscope, what do you see?

3. A cell with 10 chromosomes undergoes:

(a) How many daughter cells are created?

(b) How many chromosomes does each daughter cell have?

(c) The genetic material of the daughter cells is the same as / different to the parent cell (state one).

4. What feature of mitosis is central to its role in repairing and replacing damaged tissues in an adult organism?

134 Modeling Mitosis

Key Idea: Using chemical slimes to model the stages of mitosis allows students to visualize and understand the process.

Students used chemical slimes (play dough) and yarn to model mitosis in an animal cell.

Four chromosomes were used to simplify (2n = 4). Images of their work are displayed below.

1. (a) Photo 1 represents the stage before mitosis begins. The circular structures are the centrosomes. Name the labeled structures:

A. _____
B. _____
C. _____

(b) Name the stages shown in the photo.

(c) Why are there two copies of the centrosome?

2. Study photos 2-6 below. Identify the mitosis stage shown and briefly describe what is occurring:

Photo 2: _____
Photo 3: _____
Photo 4: _____
Photo 5: _____
Photo 6: _____

3. Draw the final stage of mitosis, in the box.

4. What happens next?

5. How many cells are there?

6. How many cells are there?

7. How many cells are there?

135 Environmental Factors Influence Mitosis

Key Idea: The effect of factors on mitosis rates in onion plants can be tested for significance using the chi-squared test.

Some environmental factors that affect the rate of mitosis in onion plants are temperature, light, and the concentration of carbon dioxide in the atmosphere.

Students wanted to determine if PhA1 (a herbicide) would increase the level of mitosis in the roots of onion plants. They prepared the roots of some onion plants to a 50 mg/L solution of PhA1 and others to a control solution (water). After an incubation period of 2 days, they prepared and stained the samples so they could count the number of cells in mitosis and interphase.

1. Generate a null hypothesis and an alternative hypothesis for this experiment:

(a) Null hypothesis (H₀): _____

(b) Hypothesis (H₁): _____

Procedure

The control class data is given in table 1. The percentage of cells in interphase or mitosis for the control and treated samples are presented in table 2.

A chi-squared test was used to determine if the null hypothesis should be accepted or rejected at P=0.05 (see table 3). Expected values (E) were calculated by applying the control percentages in table 2 (E = observed for the treated total x (20/3) x 100 = 1386). At the end of the calculation, a chi-squared value (Σ(O-E)²/E) is generated.

The P value is compared to a critical value (P) for the appropriate degree of freedom (number of groups - 1). For this test it is (2 - 1) = 1. For this test, the critical value is 3.84 at 5% probability and 1 degree of freedom. If P > 3.84, the result is not significant and H₀ cannot be rejected. If P < 3.84, it can be rejected in favor of H₁.

Table 1: Class data

Class date	Number of cells	Total
Control	252	522
Treated	1405	712

Table 2: Percentage of cells in interphase or mitosis

	Control	Treated
Interphase cells	85	82
Mitotic cells	15	18

Table 3: Calculation of chi-squared value

Interphase cells	Mitotic cells
Observed (O)	Expected (E)
(O-E)	(O-E)
(O-E) ²	(O-E) ²
(O-E) ² /E	(O-E) ² /E

2. Calculate the chi-squared value.

3. (a) Should the null hypothesis be accepted?

(b) If the result you obtained supports your hypothesis, produce a graph of your results.

4. Suggest further investigations to verify the results presented here. Use more paper and attach here if you wish:

207 Factors Determining Population Growth

Key Idea: Population size increases through births and immigration and decreases through deaths and emigration.

Population size is dynamic and the number of individuals in a population may fluctuate considerably over time. Populations grow, individuals through births or immigration, and lose individuals through deaths and emigration. This is measured as:

Population growth = Births + Immigration - Emigration - Deaths

The difference between immigration and emigration (net migration) usually measures the rate of change in the population abundance. When losses exceed gains, the population declines. When gains exceed losses, the population increases.

1. Define the following terms used to describe changes in population numbers:

(a) Death rate (mortality): _____

(b) Birth rate (natality): _____

2. Explain:

(a) A population that is increasing is said to have a positive growth rate.

(b) A population that is decreasing is said to have a negative growth rate.

(c) An increasing population: _____

3. Using the data below, calculate the population growth rate for the following years:

(a) 1975: _____

(b) 1985: _____

(c) 1995: _____

4. A population started with a total number of 100 individuals. Over the following year, population data were collected. Calculate both rates, death rate, net migration rate, and rate of population change for the data below (all percentages):

(a) Births = 14; Birth rate = _____

(b) Deaths = 20; Death rate = _____

(c) Net migration = +2; Net migration rate = _____

(d) Rate of population change = _____

5. State whether the population is increasing or declining.

6. The human population is now more than 7.5 billion. Describe two limiting factors for population growth in humans:

208 Patterns of Population Growth

Key Idea: Populations typically show either exponential or logistic growth. Both can be defined mathematically.

In these mathematical models, the per capita (or intrinsic) growth rate is denoted by a lower case 'r'. Exponential growth occurs when resources are essentially unlimited. Logistic growth begins exponentially but slows as the population approaches environmental carrying capacity.

Exponential growth, dN/dt = rN

Have the number being added to the population per unit time increase as the population increases?

Exponential (2) curve

Substituted only when there is no environmental resistance.

Have the number being added to the population per unit time increase as the population increases?

1. Produce a line graph of the gray wolf population on the grid above.

2. Account which year(s) did not represent exponential growth of the wolf population?

3. Use the data to calculate the approximate doubling time of the wolf population.

4. Why did the human population only begin its rapid increase after the Renaissance?

210 Modeling Population Growth

Key Idea: Computer programs can be used to model population growth. This activity uses Populus 5.5.

Populus 5.5 is a simulation program that uses spreadsheets or computer programs. This activity uses Populus 5.5, a simulation program, which will run on Mac or Windows platforms. It models continuous and discrete population growth as well as the effects of competition. In this activity you will model continuous density-independent (exponential) and density-dependent (logistic) growth. Using Populus, you can also model discrete growth, which uses a method of where it is the discrete time per capita growth rate. Discrete models are used for organisms with a discrete breeding season (as annual plants and insects that breed once a year) because population growth occurs in 'lumps' only in a discrete time period (not continuously) and there is no population growth outside those times.

1. What is the value of r if the population doubles over one time period?

2. What is the value of r if the population doubles over one time period?

3. What is the value of r if the population doubles over one time period?

4. What is the value of r if the population doubles over one time period?

SAVE AND PRINT ALL YOUR SIMULATIONS AND ATTACH THEM TO THIS PAGE

This activity engages the student with a visual representation of the factors affecting change in population size.

Students explore their understanding of population growth by representing it mathematically using second hand data.

Students can explore further by running a population growth simulation, manipulating variables and then explaining their results.

Groups of activities build knowledge and understanding by giving students the chance to learn and apply their knowledge in a series of linked activities.

- Engage:** visualize the concept of hierarchical organization
- Explore:** relate structure to function
- Explain:** present supporting evidence
- Elaborate:** apply understanding to a new scenario
- Evaluate:** the student's record of work can be assessed formally or informally

53 The Plant Body

54 Xylem

62 Uptake at the root

63 Transpiration

64 Investigating Plant Transpiration

Engage

Explore and explain

Elaborate and evaluate

1. (a) What other cells are present and what are their shape?

2. How does water pass between cells?

3. How does water pass between cells?

4. What cell type is the most rapid transport of water?

5. Why do you think the tracheids have a tapered end?

6. How can xylem vessels and tracheids be described?

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100. How can xylem vessels and tracheids be described?

CONNECT Tabs - Making Connections

The **CONNECT** tabs help students to make concept and content connections across the entire AP biology program. Use these tabs, identified by AP1 or AP2 subscripts, to reinforce connections between Big Ideas and their Enduring Understandings across all topics. Connections may be made to activities that build on or develop an idea, utilize the same core principles in another biological context, or examine the evidence for a biological process. The connections help students to appreciate that the same core principles underlie many biological phenomena and there is evidence to support them. Understanding these core principles brings understanding to a wide range of contexts and situations, even if they are unfamiliar.

51 Prokaryotic Cells

Key Idea: Prokaryotic cells lack many of the features of eukaryotic cells, including membrane-bound organelles. Bacterial prokaryotes and archaea are the most abundant cells and each have distinctive features, such as a distinct nucleus and membrane-bound cellular organelles. The cell wall is a structural feature that is unique to prokaryotes and has a role in the regulation of water balance and protection from osmotic lysis.

E. coli structure

220 **51** **93** **197** **KNOW**

93 Prokaryotic Chromosomes

Key Idea: Prokaryotic DNA is packaged as one single chromosome that is not associated with proteins. DNA is a universal carrier of genetic information and it is packaged into chromosomes to ensure that genetic information is transferred accurately during cell division.

The prokaryotic genome

220 **51** **93** **197** **KNOW**

220 The Evolution of Antibiotic Resistance

Key Idea: Current widespread use of antibiotics has created selective pressure for the proliferation of antibiotic-resistant bacteria. Antibiotic resistance arises when a genetic change allows a bacterium to survive in the presence of an antibiotic. The resistance may arise spontaneously through mutation or may be transferred from one bacterium to another by horizontal transmission.

The evolution of drug resistance in bacteria

220 **197** **KNOW**

EXAMPLE 1

Prokaryotic cells

The structure and features of prokaryotic cells are presented in an introductory activity. The nature of the prokaryotic genetic material is explored further in the context of the heritability of information, and connections made to the mechanisms involved in the evolution of antibiotic resistance in bacterial populations.

202 HIV Evolves Rapidly

Key Idea: HIV mutates rapidly and has a short generation time, allowing it to evolve quickly. These factors contribute to HIV's ability to evade the immune system and to develop drug resistance. HIV has the highest mutation rate of any virus, including RNA viruses, and a generation time of only a few hours. A single infected cell can produce 10⁷ new copies of HIV, which are then spread to other cells.

How does HIV evolve?

202 **197** **266** **34** **KNOW**

266 Drug Resistance in HIV

Key Idea: HIV's high mutation rate, combined with its short generation time, allows it to evolve quickly. These factors contribute to HIV's ability to evade the immune system and to develop drug resistance. HIV has the highest mutation rate of any virus, including RNA viruses, and a generation time of only a few hours. A single infected cell can produce 10⁷ new copies of HIV, which are then spread to other cells.

Drug resistance in HIV

266 **202** **34** **KNOW**

134 Failures of Defense: HIV/AIDS

Key Idea: The human immunodeficiency virus (HIV) attacks immune cells, eventually causing AIDS. A weak immune system can no longer defend the body against opportunistic infections and certain cancers. HIV/AIDS is a disease caused by the human immunodeficiency virus (HIV), which attacks and destroys the body's immune system. Over time, a disease called AIDS (acquired immunodeficiency syndrome) develops, which is characterized by a severely weakened immune system.

HIV attacks lymphocytes

134 **202** **KNOW**

EXAMPLE 2

Mutations in HIV

In these activities, concept and content connections are made between mutation as a source of variation, and high mutation rates, rapid evolution, and drug resistance in HIV (AP1). Students can then draw on this understanding when they explore the mechanisms and consequences of HIV infection (AP2).

271 Coevolution

Key Idea: Coevolution involves the reciprocal evolution of two or more species. This can occur between predators and prey, between mutualists, and between parasites and hosts. Coevolution can lead to the development of new species and to the extinction of others.

Predator-prey relationships

270 **202** **160** **161** **218** **KNOW**

83 Cellulose Digestion in a Ruminant

Key Idea: Ruminants rely on bacteria in the rumen of their stomachs to break down cellulose. The bacteria produce volatile fatty acids, which are used by the ruminant for energy. The ruminant provides the bacteria with a stable environment and a constant supply of food.

Cellulose digestion in a ruminant

83 **161** **218** **KNOW**

161 Mutualism Involving Animals

Key Idea: Mutualistic relationships benefit both species. One species may provide a service to another, such as cleaning or protection, while the other provides food or shelter. Mutualism can be obligate or facultative.

Resource-resouce relationship: One resource is traded for another (usually food or a nutrient)

223 **218** **84** **83** **161** **KNOW**

EXAMPLE 3

Relationships between organisms

The complexity of species interactions is addressed through several contexts: evolution, form and function, cooperation, and adaptation. Students explore the mechanisms by which mutualistic relationships arise, how these relationships are maintained through cooperation and efficiency of function, and how adaptation promotes efficiencies in ecosystems (AP2-218 not shown).

Using Weblinks and 3D Models

51 Prokaryotic Cells

Key Idea: Prokaryotic cells lack many of the features of eukaryotic cells, including membrane-bound organelles. Bacterial (prokaryotic) cells are much smaller than eukaryotic cells and lack many eukaryotic features, such as a distinct nucleus and membrane-bound cellular organelles. The cell wall is an important feature. It is a complex, multi-layered structure and has a role in the organism's ability to cause disease. A generalized prokaryote, *E. coli*, is shown below.

***E. coli* structure**

Plasma membrane is similar in composition to eukaryotic membranes, although less rigid.

70S ribosomes are **free in the cytoplasm.**

Cytoplasm

Nucleoid region (nucleus)

The circular chromosome occurs within a region called the nucleoid. It is not enclosed in a membrane. The DNA is "naked" meaning it is not associated with proteins.

Some bacteria, including *E. coli*, have a polysaccharide capsule outside the cell wall. The capsule contributes to its ability to cause disease.

The cell wall lies outside the plasma membrane. It gives the cell shape, prevents rupture, and serves as an anchorage point for flagella. It is composed of a carbohydrate macromolecule called peptidoglycan, with variable amounts of lipopolysaccharides and lipoteichoic acids.

Cytoplasmic inclusions include aggregations of storage compounds, e.g. glycogen, fatty acids, sulfur, or phosphorus.

Fimbriae are hairlike structures. They are shorter, stiffer, and thinner than flagella and used for attachment, not movement.

Prokaryotes may have small accessory chromosomes called **plasmids**. These often carry genes for antibiotic resistance and may be exchanged with other bacterial cells.

Flagella (sing. flagellum) are used for locomotion. They are anchored in the plasma membrane. There may be one or more flagella.

Flagellum

Fimbriae

Dividing cells

Abubacterium

A spiral shape is one of four bacterial shapes (the others being coccus, comma, and sphere). These Campylobacter cells also have flagella.

Escherichia coli is a rod-shaped bacterium, common in the human gut. The fimbriae surrounding the cell are used to adhere to the intestinal wall.

Bacteria usually divide by binary fission. During this process, DNA is copied and the cell splits into two cells, as in these round (coccus) cells.

Prokaryotes include the Archaea and Bacteria. The Archaea were first grouped with Bacteria but are now classified in their own domain on the basis of their unique characteristics.

- Describe three features distinguishing prokaryotic cells from eukaryotic cells:
 - (a) _____
 - (b) _____
 - (c) _____
- (a) Describe the function of flagella in bacteria: _____
- (b) Explain how fimbriae differ structurally and functionally from flagella: _____

3. Describe the location and general composition of the bacterial cell wall: _____

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220 AP1 94 AP1 93 AP1 **51** AP1

Weblinks

The gray WEB tab at the base of an activity shows that there is a weblink available to support the activity's content. Weblinks exist for most of the activities in the book. They are coded with the activity number and are accessed via a specific url (below). Bookmark the address below at the start of your course to have it easily accessible. Weblinks comprise mostly short video clips or animations aimed specifically at the activity content. They offer great support to help understanding of basic concepts, especially for visual learners. Weblinks are external sites from a wide range of reputable sources. We endeavour to keep all links current, so please notify us if you find a broken link and we can fix it!

CELLS alive! Interactive Bacteria Cell

Gram-positive **Gram-negative**

Nucleoid
Genophore
Plasmid

Cytoplasm
Endospore
Ribosomes

Storage Granule
Cell Envelope
Capsule

Pili, Fimbriae
Flagella
Examples

[cellsalive.com](#)

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WEBLINK | AP BIOLOGY 1 (2017)

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These websites (blue links) provide material, generally either animations or video clips, to help you visualise and understand the material presented on the relevant activity page.

Back to Product

ANNOTATED 3D MODEL COLLECTION

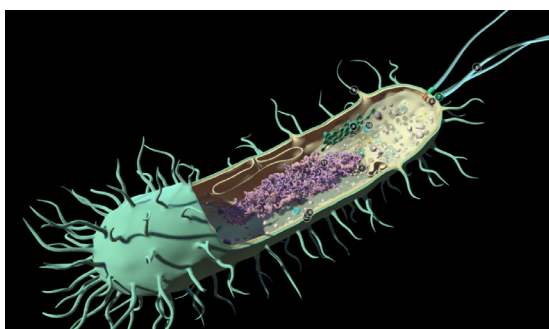
Cell Biology Human Anatomy Prehistoric Life Plant & Animal Adaptations

Chapter 1: **Essential Skills in AP Biology**

Access collections of 3D models here

Access Weblinks for each activity here

Activity #	Title	Weblinks Title
1	How Do We Do Science?	The Real Process of Science
1	How Do We Do Science?	The Structure of DNA: Cooperation and Competition
1	How Do We Do Science?	Hypothesis



3D Models

BIOZONE's extensive collection of annotated 3D models adds another dimension to the student learning experience. Rotate, zoom in, and view annotations describing structure and function.

Models can be accessed from the banner on the Weblinks page and are sorted into broad categories. Choose those relevant to your current area of study or just explore! A good starting point for student discussion of form and function and great for reviewing understanding of content in visual learners.

258 **179 Neurons**

Key Idea: Neurons conduct electrical impulses from sensory receptors along axons to other neurons or to effector cells. **Neurons** (nerve cells) are electrically excitable cells that transmit nerve impulses. Neurons have a recognizable structure with a cell body (soma) and long processes (dendrites and axons). Most neurons in the peripheral nervous system (nerves outside the brain and spinal cord) are also supported by a fatty insulating sheath of myelin, which increases the speed of impulse conduction. Information, in the form of electrochemical impulses, is transmitted along neurons from receptors to a coordination center and then to effectors. The speed of impulse conduction depends primarily on the axon diameter and whether or not the axon is myelinated.

Sensory neuron
Transmit impulses from sensory receptors to the central nervous system (CNS), i.e. brain or spinal cord.

Motor neuron
Transmit impulses from the central nervous system to effectors (muscles or glands).

1. Describe the basic structure of a neuron:

2. (a) Describe the structural differences between a motor and a sensory neuron:

(b) Describe a functional difference between a motor and a sensory neuron:

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A weblink and a 3D model support the activity on neuron structure.

Check the Weblinks regularly!

Corrections and clarifications to editions in print are always posted on the Weblinks page

www.thebiozone.com/weblink/AP2-9650

WEBLINK | AP BIOLOGY 2 (2017)

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ANNOTATED 3D MODEL COLLECTION

- Cell Biology
- Human Anatomy
- Prehistoric Life
- Plant & Animal Adaptations

Chapter 1: Energy in Living Systems

Activity #	Title	Weblink Title
1	Entropy and Order	The Laws of Thermodynamics, Energy, and Gibbs Free Energy
2	Energy Inputs and Outputs	The Ten Percent Rule
3	The Role of ATP in Cells	ATP in Metabolism
4	ATP and Energy	How ATP Supplies Energy
6	ATP Production in Cells	Cellular Respiration Part 1: Introduction & Glycolysis

Access collections of 3D models here

Access weblinks for each activity here

Essential Skills for AP Biology

Essential Skills for AP Biology supports students to become familiar and confident with the basic protocols and skills required to carry out the practical work required by the AP Biology program. Although mathematical and scientific skills are specifically addressed in this chapter, they are also provided in context throughout the book.

Science Practices

Essential Skills for AP Biology

Key terms
accuracy
chi-squared
control
control variable
dependent variable
experiment
graph
hypothesis
independent variable
mean
median
model (scientific)
observation
percentage
precision
prediction
rate
scientific method
statistical test
table
trend
variable

Inquiry is the basis of science
Essential knowledge [points also covered in activities throughout AP1&2]

Inquiry begins with observation

- 1 Describe the role of inquiry-based investigations in science. Show, through your work, your understanding of science as a non-linear process. [SP3]
- 2 Use a variety of methods to answer questions you raise as a result of observation. These include field and laboratory-based investigations, simulations and models, and data analysis. [SP3][SP4]
- 3 Use scientific models to illustrate biological processes and concepts, communicate information, make predictions, and describe systems. [SP1]

Activity number
1
4 5
2

Communication
Essential knowledge [points also covered in activities throughout AP1&2]

The results of investigations must be communicated to peers to have value

- 1 Demonstrate an ability to communicate the findings of your investigations through oral and written presentations, including lab reports, and through graphs and/or contributions to online resources. [SP3][SP4]
- 2 Use a lab notebook or portfolio to organize your work and provide a record of ideas, methods, results, further questions, and references. [SP3][SP4]

Activity number
1 5
5

Quantitative skills
Essential knowledge [points also covered in activities throughout AP1&2]

Quantitative reasoning is an essential part of inquiry in biology

- 1 Demonstrate ability to use basic mathematical skills to collect data. These include making counts and measurements. Distinguish between accuracy and precision and explain their importance when collecting quantitative data. [SP2]
- 2 Demonstrate appropriate application of mathematical routines to data, e.g. determining mean and median, calculating rates and percentages, and chi-square analysis. [SP2]
- 3 Use tables or spreadsheets to organize different types of data, including any calculated values (e.g. means and standard deviation). [SP2][SP5]
- 4 Construct graphs for different types of data, including that collected during your investigations. Indicate error in calculated values as appropriate. [SP2][SP5]
- 5 Use descriptive statistics (e.g. mean and standard deviation) and simple statistical tests (e.g. chi-squared, Student's t test, correlation) to analyze your data and test your hypothesis. [SP2][SP5]
- 6 Develop and use quantitative models (e.g. spreadsheet models) to analyze biological phenomena (e.g. population growth) and predict outcomes. [SP1]

Activity number
3-6 11
6-10
12-17
16-19
2

How Do We Do Science?

1 Key Idea: The scientific method is a rigorous process of gathering evidence in a rigorous, but open-minded way to determine, measure, and analyze that helps us to understand, explain, and predict changes in a system. Scientific knowledge is gained through a non-linear, dynamic process called the scientific method. The scientific method is not a strict set of rules to be followed, but rather a way of approaching problems in a rigorous, but open-minded way to determine, measure, and analyze that helps us to understand, explain, and predict changes in a system. Scientific knowledge is gained through a non-linear, dynamic process called the scientific method. The scientific method is not a strict set of rules to be followed, but rather a way of approaching problems in a rigorous, but open-minded way to determine, measure, and analyze that helps us to understand, explain, and predict changes in a system.

10 Practicing with Data
Key Idea: This activity allows you to practice working with data and applying the skills you have learned in previous activities.

1. Complete the transformations for each of the tables below. The first value is provided in each case.

(a) Photosynthetic rate at different light intensities

Light intensity (%)	Average time for leaf disc to float (min)	Reciprocal of time (min ⁻¹)
100	15	0.067
50	25	
25	50	
11	90	
6	180	

(b) Plant water loss using a bubble potometer

Time (min)	Pipette arm reading (cm ³)	Plant water loss (cm ³ min ⁻¹)
0	0.0	
5	8.0	6.2
10	16.0	
15	24.0	
20	32.0	

12 Using Tables and Graphs
Key Idea: Tables and graphs provide a way to organize and communicate data. Tables and graphs are ways to present data and they help you to see patterns in the data. Tables and graphs are also used to communicate data. Tables and graphs are also used to communicate data. Tables and graphs are also used to communicate data.

16 Mean, Median, and Mode
Key Idea: Mean, median, and mode are measures of central tendency or data. The distribution of the data will determine which measure of central tendency you use. Mean, median, and mode are measures of central tendency or data. The distribution of the data will determine which measure of central tendency you use.

17 Key Idea: The normal distribution is a bell-shaped curve that represents the distribution of data. The normal distribution is a bell-shaped curve that represents the distribution of data. The normal distribution is a bell-shaped curve that represents the distribution of data.

Activities outlining simple practical investigations with second hand data provided for analysis are included in context, as appropriate.

38 Colorimetry

Key Idea: Colorimetry determines the concentration of a colored compound in solution. Colorimetry is a quantitative technique used to determine the concentration of a specific substance in a solution. A specific reagent is added to the test solution where it reacts with the substance of interest.

Method: A calibration curve was prepared using prepared standard solutions containing known concentrations of glucose. The absorbance of the resulting solutions was measured using a colorimeter. The Benedict's test was used to produce a color change in the test solution and the absorbance of the resulting solution measured and compared to the calibration curve.

Produce the calibration curve: Carry out five samples as shown. Using a wet filter, measure the absorbance of 100 µm of each of the known glucose and use these values to produce a calibration curve for glucose.

1. Why is Benedict's reagent added to the samples?

2. Use the calibration curve provided to estimate the glucose content of the urine samples:

(a) Sample 1: _____

(b) Sample 2: _____

(c) Sample 3: _____

3. What is the purpose of the 0 mg/dL 'blank'?

4. What would you do if the absorbance values you obtained for most of your 'unknowns' were outside the range of your calibration curve?

11 Investigating Fermentation in Yeast

Key Idea: The rate of fermentation can be determined by measuring the volume of carbon dioxide produced. The rate of fermentation can be determined by measuring the volume of carbon dioxide produced. The rate of fermentation can be determined by measuring the volume of carbon dioxide produced.

Method: The apparatus was set up as shown. The yeast suspension was added to the glucose solution. The volume of carbon dioxide produced was measured over time.

1. Write the equation for the fermentation of glucose by yeast.

2. The results are presented on the table left. Using the first results, calculate the rate of CO₂ production per minute for each substrate:

(a) Fructose
(b) Glucose
(c) Maltose
(d) Sucrose

3. What assumptions are being made in this experimental design and do you think they are reasonable?

203 Investigating Distribution and Abundance

Key Idea: Sampling populations in a field can reveal patterns of distribution, which can be attributed to habitat preferences. These measurements are common in ecological studies.

The aim: To investigate the effect of light on the distribution of a plant.

Background: Mistletoes are parasitic plants that live on the stems of trees. They are dependent on their hosts for water and nutrients. Mistletoes are parasitic plants that live on the stems of trees. They are dependent on their hosts for water and nutrients.

Experimental method: The distribution of mistletoes in a field was investigated. The field was divided into 100 m² quadrats. The number of mistletoes in each quadrat was counted. The distribution of mistletoes in a field was investigated. The field was divided into 100 m² quadrats. The number of mistletoes in each quadrat was counted.

How do you know the results will be reliable?

1. Why is the field divided into 100 m² quadrats?

2. Why is the field divided into 100 m² quadrats?

3. Why is the field divided into 100 m² quadrats?

Addressing the AP Biology Practical Investigations

Activities supporting the 13 required AP Biology practical investigations are identified in chapter introductions with a blue flag. In some instances, the components of an AP practical investigation are supported over several activities. These activities can be used to provide grounding for students before they attempt the practical themselves or if they are opting to do an approved alternative AP investigation. Some of these alternatives are provided by BIOZONE's supporting partner Carolina® (see later).

BIG IDEA 1: EVOLUTION

Investigation 1: Artificial Selection

This activity outlines a procedure for investigating the effects of artificial selection on trichrome number in Wisconsin Fast Plants®. After carrying out analysis of the second hand data provided, students determine if the trichrome frequencies between the parental and F₁ generation differ (i.e. did their selection process for hairy plants have an effect on hairiness in the next generation).

Applications

- ▶ This activity provides an opportunity to consider experimental design. Students can use it to plan their own investigation of artificial selection.
- ▶ Practice is gained in the mathematical and graphing skills required for this investigation.
- ▶ This activity could be used if there is insufficient time or resources to devote to a practical investigation, if plants fail to grow during the investigation and there are no results, or if an alternative practical investigation has been selected because of the resources available.

Where to next?

- ▶ Students can design further experiments to investigate the effect of artificial selection on the frequency of a trait, or explore the trait's possible adaptive value.
- ▶ The significance of their results could be tested using analysis such as Student's *t* test.

229 Selection in Fast Plants

Key Idea: The effect of artificial selection on the frequency of a selected phenotype between generations can be observed using Wisconsin Fast Plants®.

Artificial selection can be studied using Wisconsin Fast Plants® plants because they complete their cycle in only five weeks. These plants show variation in quantitative traits such as trichrome number and stem color. The students choose hairy (number of trichomes) and selected plants to cross-pollinate the hairy plants with a parental generation to produce a generation of offspring (F₁). The incidence of hairiness in the F₁ generation was studied to quantify the effect of artificial selection on phenotype.

Procedure

Students planted and grew Wisconsin Fast Plants®. Research and notes in the laboratory bring one to cultivate them in the soil. Light and moisture conditions required to optimal growth. At maturity (12-14 days) the students will be required to count the number of trichomes on the edge of the first true leaf of the first true leaf of each plant. The class data for the parental generation (P₁) is available on each page to identify and label the hairy 10% of plants.

At day 14, when several flowers were present on each plant, the students were instructed to harvest 10% of plants using artificial selection. This procedure was repeated for the F₁ generation to produce the F₂ generation. The results are presented in Table 2.

Seeds were harvested from each plant between day 8 and 10. The seeds were planted and grown under the same conditions as described above to produce the F₁ generation of plants. The number of seeds on each plant was counted manually using the same method described above. The results are presented in Table 1.

1. Record the frequency of trichomes for each of the categories listed below in table 2.

Table 2: Frequency of trichomes in parental and first generation plants

Trichomes	Parental generation	F ₁ generation		
Number of trichomes	Working	Frequency	Working	Frequency
0-4				
5-9				
10-14				
15-19				
20-24				
25-29				
30-34				
35-39				
40-44				

Table 1: Trichrome data for parental and F₁ generation fast plants

Number of trichomes	Parental generation	F ₁ generation
Frequency	Total	Mean
0	46	0.1
1	6	0.1
2	3	0.1
3	2	0.1
4	2	0.1
5	4	0.1
6	1	0.1
7	2	0.1
8	2	0.1
9	2	0.1
10	7	0.1
11	1	0.1
12	4	0.1
13	0	0.0
14	1	0.1
15	2	0.1
16	2	0.1
17	1	0.1
18	1	0.1
19	1	0.1
20	1	0.1
21	3	0.1
22	2	0.1
23	2	0.1
24	1	0.1
25	1	0.1
26	1	0.1
27	0	0.0
28	0	0.0
29	1	0.1
30	1	0.1
31	2	0.1
32	1	0.1
33	1	0.1
34	0	0.0
35	0	0.0
36	0	0.0
37	0	0.0
38	0	0.0
39	0	0.0
40	0	0.0
41	0	0.0
42	0	0.0
43	0	0.0
44	1	0.1
45	0	0.0
Totals	120	81

2. (a) Select an appropriate graph type and plot trichrome distribution in the parental and F₁ generation plants above.

(b) Describe the distribution of trichomes between the two sets:

Parental generation mean: _____

Parental generation standard deviation: _____

F₁ generation mean: _____

F₁ generation standard deviation: _____

(c) Are the two generations different? _____

(d) How could you test if any difference was significant? _____

(e) How could you further explore the hairiness of trichome density under selection? _____

Investigation 2: Modeling Hardy-Weinberg

Using a real life data set from Olney, Illinois, students apply their knowledge of the Hardy-Weinberg equation (gained from previous activities) to analyze changes in the allele frequency of a squirrel gene pool.

Applications

- ▶ Use this activity to help students become confident with analyses of population allele, genotype, and phenotype frequencies before constructing models or simulations of their own.
- ▶ There is ample opportunity for students to practice graphing and data analysis.

Where to next?

- ▶ Students can design or use spreadsheet models or computer simulations to model hypothetical gene pool changes between generations. Possible examples are provided via Weblinks. Greater complexity can be added to the models and simulations so they become more realistic.
- ▶ Students can attempt to apply the model to a real-world situation (e.g. frequency of supertasters in a population).

213 Analysis of a Squirrel Gene Pool

Key Idea: Allele frequencies for real populations can be calculated using the Hardy-Weinberg equation. Real allele frequencies can show how the population's gene pool changes over time.

In Olney, Illinois, there is a unique population of albino (white) and gray squirrels. Between 1977 and 1990, students at Olney Central College carried out a study of the population. They recorded the frequency of gray and albino squirrels. The albino squirrel is a recessive allele represented as the allele phenotype only in the homozygous recessive condition. The data they collected are presented in the table below. Using the Hardy-Weinberg equation, it was possible to estimate the frequency of the normal wild allele (G) providing gray fur coloring, and the frequency of the mutant allele (g) producing white squirrels when homozygous.

Population of gray and white squirrels in Olney, Illinois (1977-1990)

Year	Gray	White	Total	GG	Gg	gg	Freq. of G	Freq. of g
1977	602	192	794	26.85	48.92	24.21	48.18	51.82
1978	511	172	683	24.89	50.00	25.11	50.18	49.82
1979	482	154	636	23.47	49.77	26.71	48.24	51.76
1980	489	133	622	28.90	48.72	21.38	49.28	50.72
1981	506	143	649	28.74	48.34	22.92	49.28	50.72
1982	618	151	769	31.01	48.36	19.64	48.31	51.69
1983	419	141	560	24.82	50.00	25.18	50.18	49.82
1984	378	102	480	28.75	48.75	21.50	48.60	51.40
1985	448	125	573	28.43	48.18	21.82	48.71	51.29
1986	536	100	637	27.71	48.06	22.43	47.38	52.62
1987								
1988	626	122	748	36.36	47.88	15.76	50.70	49.30
1989	502	146	648	25.45	48.84	25.71	48.74	51.26
1990	603	111	714	28.69	47.76	19.55	48.42	51.58

1. Graph population changes. Use the data in the last 2 columns of the table above to plot a line graph. This will show changes in the phenotypic numbers of gray and white (albino) squirrels, as well as changes in the total population. Plot the number of gray and white squirrels and total for each year.

(a) Determine by how much (as a % of total population) numbers have fluctuated over the sampling period.

(b) Describe the overall trend in total population numbers and any pattern that may exist.

2. Graph allele changes. Use the data in the last two columns of the table on the previous page to plot a line graph. This will show changes in the allele frequencies for each of the normal (G) and recessive (g) alleles. Plot the frequency of G and the frequency of g.

(a) Describe the overall trend in the frequency of the dominant allele (G).

(b) Describe the overall trend in the frequency of the recessive allele (g).

3. Graph allele changes. Use the data in the last two columns of the table on the previous page to plot a line graph. This will show changes in the genotype frequencies for each of the normal (GG) and recessive (gg) alleles. Plot the frequency of GG and the frequency of gg.

(a) Describe the overall trend in the frequency of the dominant allele (GG).

(b) Describe a possible cause of the changes in allele frequencies over the sampling period.

4. State which of the three graphs best indicates that a significant change may be taking place in the gene pool of the population of squirrels.

5. Give a reason for your answer.

6. Yield the simulation resolution based on the website for this activity to model how gene pool changes from one generation to the next when variables such as selection, mutation, and migration are manipulated.

Investigation 3: Comparing DNA Sequences to Understand Evolutionary Relationships

Evolutionary relationships can be expressed visually using phylogenetic trees. Students are shown how a phylogenetic tree can be constructed on the basis of shared derived characteristics. Students apply this knowledge to constructing and interpreting cladograms (phylogenies based on cladistics) themselves.

Applications

- These activities provide grounding and practice in constructing and interpreting cladograms based on synapomorphies. These principles can also be applied to constructing cladograms from DNA sequences.

Where to next?

- Activity 256 (*Constructing a Cladogram*) could be set as a summative test.
- Students can apply the principles learned here to construct cladograms from BLAST gene analysis to determine relatedness.
- Carry out independent BLAST investigations on genes of interest (e.g. DNA polymerase gene).

254 Constructing Phylogenies Using Cladistics

Key Idea Cladograms are phylogenetic trees constructed on the basis of shared derived characteristics.

Cladogram is a phylogenetic tree constructed using a taxonomic tree and shared characteristics. Cladograms represent an evolutionary tree based on shared characteristics. Cladograms are constructed by identifying shared characteristics (synapomorphies) and grouping organisms based on these characteristics. The resulting tree shows the evolutionary relationships between the organisms.

Derived vs. ancestral characters
When constructing cladograms, shared derived characters are used to determine the relationships between organisms. Ancestral characters are shared by all members of a clade and are not used to determine relationships.

Constructing a simple cladogram
A table listing the features for comparison allows us to identify where we should make changes in the tree. An outgroup (one which does not have the trait being investigated) is chosen as a point of comparison. The table lists the features to be investigated. The outgroup (one which does not have the trait being investigated) is chosen as a point of comparison. The table lists the features to be investigated. The outgroup (one which does not have the trait being investigated) is chosen as a point of comparison.

Phylogeny is the study of the evolutionary relationships between organisms. Phylogenetic trees (also called cladograms) are diagrams that show the evolutionary relationships between organisms. They are constructed based on shared derived characteristics (synapomorphies).

256 Constructing a Cladogram

Key Idea A table of selected characters can be organized systematically to create a matrix and used to construct a cladogram.

Character Matrix

Character	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Number of limbs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of eyes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of ears	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of teeth	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of fingers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of toes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of claws	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of scales	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of feathers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of wings	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of tails	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of horns	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of antlers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of hooves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of horns	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of antlers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of hooves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of horns	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of antlers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of hooves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes and working space

1. This activity provides the basis and character matrix for 13 genera of marine fishes in the family of surfperches. The outgroup given is a representative of a sister family of surfperches (Pomacentridae) which are not the bearing group. You look to create the most parsimonious cladogram from the original character matrix provided. It is important that you identify the origin of derived character states with horizontal bars, as shown in the previous activity. CLUSTAL should be used to generate the tree. The derived character states are listed sequentially. Double your effort on the tree.

2. (a) Why is it useful to compare the characters states in a matrix? (b) Why is it useful to compare the characters states in a matrix? (c) Why is it useful to compare the characters states in a matrix?

BIG IDEA 2: CELLULAR PROCESSES: ENERGY AND COMMUNICATION

Investigation 4: Diffusion and Osmosis

It is recommended that students carry out all the activities in this series to cover the three procedures outlined for investigation 4. Students design an experiment using artificial cells to study the relationship between surface area and cell volume and make predictions about how these influence the rate of diffusion. The process and principles of diffusion are investigated across a partially-permeable membrane using dialysis tubing to simulate a plasma membrane. Lastly, students can apply their knowledge to a real life situation when they investigate osmosis in living cells using potato cubes.

Applications

- Ideally each of these activities would be used to provide an introduction to the topic before the student carried out their own investigation. They also provide opportunities to practice the mathematical skills required to successfully complete the investigation.

- In activity 43 students plan their own experiment (with guidance) and consider what factors they must include to ensure valid and meaningful results are obtained.
- These activities could be used in place of carrying out a practical investigation if time is short. In addition, the data provided could be utilized by the students if their own experiment fails.

Where to next?

- Pose the following question to students "do fungal cells have turgor pressure?" The students can generate a hypothesis and then design an experiment to test their hypothesis. This could be carried out in small groups or by individuals. If time permits, they can carry out their experiment.

43 Investigating the Effect of Cell Size

Key Idea Diffusion is less efficient in cells with a small surface area relative to their volume. When an object becomes larger, its surface area compared to its volume increases exponentially.

Background Information
Diffusion is the movement of particles from an area of high concentration to an area of low concentration. The rate of diffusion is affected by the surface area and the volume of the object. As the surface area increases, the rate of diffusion increases. As the volume increases, the rate of diffusion decreases.

Equipment List
Paper towel, Timer, Glass beaker, Agar blocks infused with phenolphthalein, Sodium hydroxide (NaOH) solution, Laboratory tongs, Scalpel, Ruler.

65 Investigating Diffusion

Key Idea Chlorine tubing can be used to model the diffusion of glucose across a partially permeable membrane.

Background Information
Diffusion is the movement of particles from an area of high concentration to an area of low concentration. The rate of diffusion is affected by the surface area and the volume of the object. As the surface area increases, the rate of diffusion increases. As the volume increases, the rate of diffusion decreases.

Method
The dialysis tubing was filled with 5 cm³ of a 1% starch solution and 2% glucose solution. A 10% glucose solution was prepared and poured into the beaker containing distilled water. Lugol's iodine was added to the beaker to detect the presence of starch.

Results

Substance	Initial	Final	Change
Glucose	10%	2%	-8%
Starch	1%	1%	0%

68 Making Dilutions

Key Idea Dilution reduces the concentration of a stock solution to a lower concentration.

Simple dilution
A simple dilution is a process where a known volume of a stock solution is added to a known volume of solvent to create a larger volume of a lower concentration solution.

Serial dilution
A serial dilution is a process where a known volume of a stock solution is added to a known volume of solvent, and the resulting solution is then used as the stock solution for the next dilution.

Method
A 100 mL stock solution of 1.00 mol L⁻¹ NaCl was diluted to 100 mL of a 0.100 mol L⁻¹ solution. This solution was then diluted to 100 mL of a 0.010 mol L⁻¹ solution, and so on.

Results

Concentration	Volume
1.00 mol L ⁻¹	100 mL
0.100 mol L ⁻¹	100 mL
0.010 mol L ⁻¹	100 mL
0.001 mol L ⁻¹	100 mL

69 Estimating Osmolarity of Cells

Key Idea A cell placed in a hypertonic solution will gain water and a cell placed in a hypotonic solution will lose water.

Method
The osmolarity of potato cells was estimated by measuring the change in mass of potato cubes placed in solutions of different sucrose concentrations.

Results

Sucrose Concentration	Initial Mass	Final Mass	% Change
0.0 M	1.00 g	1.20 g	+20%
0.2 M	1.00 g	1.05 g	+5%
0.4 M	1.00 g	1.00 g	0%
0.6 M	1.00 g	0.95 g	-5%
0.8 M	1.00 g	0.80 g	-20%

Investigation 5: Photosynthesis

The effect of light color on photosynthetic rate can be studied in green plants using the leaf disc assay. In this activity students are provided with an outline of the experimental method, background information about the leaf disc assay itself, and some data to analyze.

Applications

- ▶ Students can pose scientific questions regarding the effect of light color on photosynthetic rate.
- ▶ Students can practice the required graphing and data presentation skills.
- ▶ The second hand data provided can be used in the place of student data if their own experiment fails. Alternatively, it could be used as comparative data to see if the student's own work obtained similar results and used as a discussion point if the results differ.

Where to next?

- ▶ If equipment is available, the experiment could be repeated using an oxygen probe interfaced with a data logger to provided more accurate data on the photosynthetic rate.
- ▶ Students could pose questions about environmental conditions that might affect the results (e.g. high CO₂ environment) or physical differences in the leaves themselves that may affect the results (e.g. a hairy leaf compared to a smooth ivy leaf).

18 Investigating Photosynthesis

Key Idea: The rate of photosynthesis varies with different wavelengths of visible light. Photosynthetic pigments absorb specific wavelengths of light and capture the energy within to drive photosynthesis.

Fluorescence: some wavelengths are absorbed more strongly than others. The experiment described below investigates the effect of different wavelengths on the photosynthetic rate of a green plant.

Aim: To investigate the effect of wavelength on the photosynthetic rate of a green plant.

Method:

- Select several green leaves of the same type. Avoiding veins, cut circular leaf discs, use a hole punch to cut out 10 discs of a uniform size. Place the discs into a large syringe containing 0.2% bicarbonate solution. Place a finger lightly over the top of the syringe and slowly pull back on the plunger. Repeat until all the discs sink. Check that only one bubble is trapped in the syringe containing 10 discs in each plunger and repeat.
- Label four 100 mL glass beakers as red, blue, green, and clear. Add each beaker with 100 mL of 0.2% bicarbonate solution and 5 mL of clearest. Color the solutions by adding 10 drops of the appropriate color food coloring to the bicarbonate solution. No food coloring is added to the clear container.
- Place 10 leaf discs into the beaker, and place it 15 cm from a 100 watt light bulb. Start a timer immediately and record the time taken for all 10 leaf discs to float. Repeat with the remaining colors.

Background: Leaf disc assays are commonly used to investigate photosynthesis in the classroom because they are simple to perform and do not require any specialized equipment. The bicarbonate solution allows photosynthesis and any oxygen in the leaf to naturally rise to the leaf and expand and it also serves as a source of CO₂ during the experiment. As photosynthesis occurs, O₂ is produced and the leaf discs become buoyant and eventually float. The rate of flotation is an indirect measure of the rate of photosynthesis. The dye is added to break down the water-repellent cuticle on the leaf surface, allowing carbon bicarbonate to enter the leaf more easily.

Results: The results from the experiment are shown below.

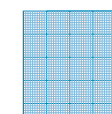
Light color	Time taken for 10 discs to float (s)
Blue	102
Red	203
Green	305
White	404

1. Generate a brief hypothesis for this experiment: _____

2. Why do the leaf discs float? _____

3. (a) Graph the results on the grid provided (right):
 (b) Describe how photosynthesis was affected by light color: _____

4. Did the results support your hypothesis? Explain: _____



Investigation 6: Cellular Respiration

A respirometer is a simple piece of equipment and can be used to measure the rate of cellular respiration in organisms such as germinating seeds or small invertebrates (e.g. maggots). The simple respirometer described here measures oxygen consumption and uses this as a measure of cellular respiration. Students are provided with background information about how to set up use a respirometer and some second hand data to analyze.

Applications

- ▶ Using an example, students gain familiarity with the set up and consider the limitations of measuring cellular respiration with a simple respirometer. The activity provides background to help them design a good experiment of their own to collect valid data.
- ▶ Students can practice mathematical skills (calculation of rates) and graphing skills, both helpful for when they must transform and present their own data.

Where to next?

- ▶ If equipment was available, students could use gas sensor probes to measure oxygen consumption.
- ▶ Students could pose questions about what factors (e.g. temperature) might affect the rate of cellular respiration, and then go on to design and carry out further experiments if time allows.
- ▶ Studying invertebrates, the relationship between the mass of an organism and its rate of cellular respiration could be determined.

9 Measuring Respiration

Key Idea: Oxygen consumption and carbon dioxide production in respiring organisms can be measured with a respirometer. A respirometer measures the amount of oxygen consumed and the amount of carbon dioxide produced during cellular respiration. Respirometers are either simple devices or complex for one-gas accurate results or use gas conductivity.

Measuring respiration with a simple respirometer

The diagram on the left shows a simple respirometer. It measures the change in gases as respiration occurs.

- Respiring organisms, in this case germinating seeds, are placed inside the chamber of the chamber.
- Soda lime or potassium hydroxide is added to absorb any carbon dioxide produced during respiration. Therefore the respirometer measures oxygen consumption.
- Once the experiment has been passed into the chamber the screen clip is closed. The start position of the colored bubble is measured (this is the time zero reading).
- The colored bubble in the capillary tube moves in response to the change in oxygen concentration. Measuring the movement of the bubble (e.g. with a ruler) allows the change in volume of O₂ to be determined.
- Care needs to be taken when using a simple respirometer because changes in temperature or atmospheric pressure may change the height and position of the bubble.
- Differential respirometers (not shown) can help overcome these problems. They consist of two respirometers (one with the organism) connected by a U-tube. Changes in temperature or atmospheric pressure will equally affect both chambers. Observed changes are only due to the activities of the respiring organisms.

1. Why does the bubble in the capillary tube move? _____

2. A student used a simple respirometer (like the one shown) to measure respiration in maggots. Their results are presented in the table (right). The maggots were left to acclimatise for 10 minutes before the experiment was started.

(a) Calculate the rate of respiration and record this in the table. The first two calculations have been done for you.

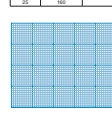
(b) Plot the rate of respiration on the grid, below right.

(c) Describe the results in your plot: _____

(d) Why was there an acclimatization period before the experiment began? _____

3. Why would it have been better to use a differential respirometer? _____

Time (minutes)	Distance bubble moved (mm)	Rate (mm ³ min ⁻¹)
0	0	
5	25	5
10	45	
15	55	
20	65	



BIG IDEA 3: GENETICS AND INFORMATION TRANSFER

Investigation 7: Cell Division, Mitosis, and Meiosis

The activities listed here are designed to cover the first four procedures of investigation 7.

The *Modeling Mitosis* activity provides an alternative way for students to visualize and then summarize the steps of mitosis. Once the process is reinforced, students can investigate how environmental factors (e.g. the presence of lectin proteins) can influence the rate of mitosis in onion cells. Certain forms of leukemia produce abnormal karyograms containing Philadelphia chromosomes. These indicate a loss of normal cell cycle regulation. Students can compare normal and abnormal karyograms in activity 131. The last modeling activity in this series allows students to model the steps of meiosis. It reinforces the key features of meiotic division and helps to differentiate meiosis from mitosis.

Applications

- Students gain experience in reading karyograms by comparing two karyograms to identify the presence of Philadelphia chromosomes. They must apply their knowledge of cell cycle regulation to determine why these abnormalities arise.
- Students can model the steps in *Modeling Mitosis* themselves using pipe cleaners and yarn to learn the phases of mitosis.
- Students are introduced to the Chi-squared test in an easy to use table format to determine if lectin protein influences rate of mitosis. They become familiar with its use for determining significance.
- Modeling Meiosis* provides a chance for collaborative work and is an opportunity to pair students of different abilities together. Better able students will clarify their own understandings through explanation and the less able students improve their understanding through peer-to-peer interaction. Student's can investigate a trait of interest to themselves.

Where to next?

- Pairs of students could video and narrate models depicting mitosis and meiosis and share with the class.
- Students can research how certain cancers (e.g. human papillomavirus) affect the cell cycle and result in their proliferation. Alternatively, they could research the breast cancer genes (BRCA) to see how they affect the cell cycle.
- Ask students to discuss the role of crossing over in increasing genetic variation in individuals and populations. How much variability would there be without it? Students can construct models to visually show the differences.
- Students could work in groups and give short presentations about the how crossing over, independent assortment, segregation, non-disjunction, and random fertilization contribute to genetic diversity.
- Facilitate a discussion about how mutation contributes to genetic variability and how mutations can be caused by specific mutagens.

131 Defective Gene Regulation and Cancer

Key Idea: When cell checkpoints fail, uncontrolled cell division can occur and cancerous tumors can form. Cells that become damaged beyond recovery undergo a controlled process called programmed cell death (apoptosis). However, cancerous cells have managed to evade the control and become immortal, continuing to divide without any checks on their proliferation. Some cells are healthy. Agents capable of causing cancer are called **carcinogens**. Most carcinogens are also mutagens; they damage the DNA. Any one of a number of cancer-causing factors (including genetic changes) may be related to disrupt the cell cycle and result in cancer.

Cancer: cells out of control
Carcinogenesis results from changes in the genes controlling normal cell growth and death. The resulting cells become immortal and no longer carry out their normal role.

Proto-oncogenes and tumor-suppressor genes
The genes of a cell are normally involved in controlling the cell cycle: **proto-oncogenes**, which start cell division and are essential for normal cell development; and **tumor-suppressor genes**, which inhibit cell division. In their normal form, these genes of a cell work together, enabling the body to maintain its bulk such as replacing dead cells. But if a regulatory mutation occurs, such as a missing allele of a tumor-suppressor gene, the normal checks and balances are disrupted. Proto-oncogenes, through mutation, can give rise to **oncogenes**, which cause uncontrolled cell division. Mutations in tumor-suppressor genes inhibit what happens. The best understood tumor-suppressor gene is **p53**, which encodes a protein that halts the cell cycle so that DNA can be repaired before division.

Tumor-suppressor genes
Normal tumor-suppressor gene p53 normally orders genes to bring cell division to a halt.

Proto-oncogenes
Genes that start cell division. When mutated, they lead to uncontrolled cell division.

Did You Know?
A controlling gene encodes a regulatory protein called p53. As the number of controlling genes with functional alleles increases, the more likely the cell is to show the loss of control over the cell cycle. Tumor-suppressor genes are often mutated in cancer.

Know 131 130 132

Karyogram A: Normal individual (male and female sex chromosomes are both shown)

Karyogram B: Individual with chronic myelogenous leukemia (male and female sex chromosomes are both shown)

- How do cancerous cells differ from normal cells?
- Explain how the cell cycle is normally controlled, including reference to the role of tumor-suppressor genes.
- With reference to the role of oncogenes, explain how the normal controls over the cell cycle can be lost.
- Study the two karyograms at the top of the page and answer the following questions:
 - How does karyogram B differ from karyogram A?
 - Suggest what has happened in the karyogram depicting chronic myelogenous leukemia.
 - The result of the changes in karyogram B is an abnormal gene (BCR-ABL). It promotes cell division and blocks apoptosis. Predict the effect of this on the spread of cancerous cells.

Know 131 130 132

134 Modeling Mitosis

Key Idea: Using simple items to model the stages of mitosis will help you to visualize and understand the process. Students used chicken, string, pipe cleaners and yeast.

1. (a) Photo 1 represents the stages before mitosis begins. The circular structures are the centrosomes. Name the labelled structures:
A: _____
B: _____
C: _____
(b) Name the stage shown in the photo: _____
(c) Why are there two copies of the centrosomes?

2. Study photos 2-6 below. Identify the mitosis stage shown and briefly describe what is occurring:

Photo 2: _____
Photo 3: _____
Photo 4: _____
Photo 5: _____
Photo 6: _____

3. Draw the final stage of mitosis, in the bin.
4. What happens next?
5. How many cells are there?

Know 131 130 132

135 Environmental Factors Influence Mitosis

Key Idea: The effect of lectin on mitosis rates in onion plants can be tested by experiment using the chi-squared test. Some environmental factors, such as presence of the carcinogen/lectin protein lectin, may even be known to increase the rate of mitosis in onion cells. They represent the work of some cancer genes to a 50 right: lectin of PVX is an agent to a certain disease. After an incubation period of 2 days, they prepared and stained the samples so they could count the number of cells in mitosis and compare.

1. Generate a null hypothesis and an alternative hypothesis for the experiment:
(a) Null hypothesis (H₀): _____
(b) Hypothesis (H_a): _____

Procedure

A. The combined class data is given in table 1. The percentage of cells in interphase or mitosis for the control and treated samples are presented in table 2.

B. A chi-squared test (χ²) was used to determine if the null hypothesis should be accepted or rejected at P=0.05 (see table 3). Expected values (E) were calculated by applying the control percentages in table 2 (the column for the treated total) to the total (n = 171) x (171) = 29241. At the end of the calculation, a chi-squared test (χ²) = 12.1. The result is not significant and H₀ cannot be rejected. If χ² is > 3.84, it can be rejected in favor of H_a.

Table 1: Class Data

Class Data	Number of cells
Interphase	1522
Mitosis	502
Total	2024

Table 2: Percentage of cells in interphase or mitosis

	Control	Treated
Interphase cells	81	82
Mitotic cells	9	9

Table 3: Calculation of chi-squared value

	Observed (O)	Expected (E)	(O - E)	(O - E) ² / E
Interphase cells	1522	29241 * 81 / 2024		
Mitotic cells	502	29241 * 9 / 2024		

2. Calculate the chi-squared value by completing table 3. χ² = _____
(a) Should the null hypothesis be accepted or rejected?
(b) In the result you would have expected? Explain: _____

4. Suggest further investigations to verify the results presented here. Use more paper and attach here if you wish: _____

Know 131 130 132

138 Modeling Meiosis

Key Idea: You can simulate crossing over, gene/protein production, and the inheritance of alleles during meiosis using sock-like items to represent chromosomes.

Background: Each of your somatic cells contains 46 chromosomes. You inherit 23 chromosomes from your mother (maternal chromosomes), and 23 chromosomes from your father (paternal chromosomes). Therefore, you have 22 homologous pairs. The members of each pair of chromosomes are called sister chromatids. The members of a pair of homologous pairs. To study the effect of crossing over on genetic variability, you will act as the researcher or you to your own cells, the only to target cell and homologous.

Procedure: Record your phenotype and genotype for each trait in the table (right).

Genotype: You have a dominant trait, you will not have it. You are heterozygous for dominant trait, you will not have it. You are heterozygous for dominant trait, you will not have it. You are heterozygous for dominant trait, you will not have it.

Genotype you start the simulation: Partner up with a classmate that genetic cell division with you (individuals at the end of the activity to produce a child. Decide who will be the female, and who will be the male. You will need to work with the same genetic trait.

1. Color four sock-like items. These represent four chromosomes. Color two socks red or blue with 17. These are the maternal chromosomes. The pair socks are the maternal chromosomes. With your classmate, color the socks. Color each chromosome with the same color (red).

2. Simulate crossing over by using the colored chromosomes pair with their homologous pair (red). For each chromosome pair, you will have four socks (two red and two blue). Use the color changing over cards (similes) by wrapping socks from non-homologous pairs.

3. Simulate anaphase I by using the colored chromosomes pair with their homologous pair (red). For each chromosome pair, you will have four socks (two red and two blue). Use the color changing over cards (similes) by wrapping socks from non-homologous pairs.

Know 131 130 132

BIG IDEA 4: INTERACTIONS

Investigation 10: Energy Dynamics

A simplified ecosystem model is presented for students to study energy dynamics in ecosystems. In the first part of this activity students calculate net primary productivity in fast growing *Brassica rapa* plants. The focus of the second part of the activity is on calculating the efficiency of energy transfer from producers to consumers.

Applications

- ▶ The simplified ecosystem model provides students with ample opportunity to practice the mathematical calculations and data analysis required to complete their own investigation.
 - ▶ If time is short, the data provided can be used in place of the student's own investigation, or if their own investigation fails (e.g. caterpillars or plants die).
- ### Where to next?
- ▶ Students struggling with the concept could use an analogy, such as a simple financial budget, to help consolidate the principles. Money, like energy, is a limited commodity and must be budgeted to meet all our needs (e.g. what proportion is allocated to food, heating, etc).
 - ▶ Students could manipulate the model system to determine how changes in the environment (e.g. increased temperature) affect energy flow.


243 Investigating Trophic Efficiencies

Key Idea: The efficiency of energy transfer in ecosystems can be quantified if we know the amount of energy entering and leaving the different trophic levels. The gross primary production of any ecosystem will be determined by the efficiency with which solar energy is captured by photosynthesis. The efficiency of subsequent energy transfers will determine the amount of energy available to consumers. These energy transfers can be quantified using measurements of dry mass in the activity. You will calculate energy and biomass transfers in real and experimental systems. This activity will help you to more easily plan and carry out your own investigation (NPP #10).

Production vs productivity: What's the difference?

Production: the primary production of an ecosystem is defined as the production of biomass in a given area over a period of time. However, because values for production are calculated from dry mass, they are not a direct measure of energy. Instead, they are a measure of biomass that is usually given for a certain period of time in order to be meaningful. The two terms are often used interchangeably.

Productivity: the amount of energy stored as biomass per unit area per unit time. It is measured in terms of energy per unit area per unit time.



1. The energy budgets of two agricultural systems (1000 or smaller) were measured over a growing season of 100 days. The results are tabulated right.

System	Gross plant production (GPP)	Plant respiration (R _p)	Net primary production (NPP)
Incubated in a pot	105.8	20.7	85.1
Field	32.2	3.7	28.5

2. For each system, calculate the percentage efficiency of energy utilization. How much incident solar radiation is captured by photosynthesis?

3. For each system, calculate the percentage efficiency of energy transfer to consumers.

4. For each system, calculate the percentage efficiency of NPP.

5. Which system has the greatest efficiency of energy transfer to biomass?

Estimating NPP in *Brassica rapa*

Background: *Brassica rapa* (fast) is a fast growing brassica species, which can complete its life cycle in 40 days or less. It is a good model organism for studying energy dynamics in ecosystems. It is a fast growing plant that can be grown in a pot or in a field. It is a good model organism for studying energy dynamics in ecosystems. It is a fast growing plant that can be grown in a pot or in a field. It is a good model organism for studying energy dynamics in ecosystems.

The method:

- Sever groups of three students each grow 10 *B. rapa* plants in plant trays under controlled conditions. On day 7, each group makes a random selection of 10 plants and weighs them. The 10 plants are washed, blotted dry, and weighed (collected) (giving wet mass).
- The 10 plants were placed in a desiccating oven (not placed in drying oven at 60°C for 24 hours, then weighed (giving dry mass).
- On day 14 and again on day 21, the procedure was repeated with a further 10 plants (randomly selected).
- The full results for group 1 are presented in Table 1 on the next page. You will complete the calculations yourself.

6. What would you need to know to determine the gross primary productivity of *B. rapa*?

7. Net production (consumers (N)) or secondary production, can be expressed as $N = (P - R_p)$. Net mass contains approximately 100 kJ per 100 grams. If N = 20% of the energy gain (G), how much energy is lost as P and R?

8. To this value roughly what you would expect? Explain.

9. Write the equation to calculate respiratory losses per larva (use the relation provided).

10. Calculate the respiratory losses per larva (have).

11. Why can't we measure the actual dry biomass of *Drosophila* larvae and larvae on day 17?

12. Write the equation to calculate respiratory losses per larva (use the relation provided).

13. Calculate the respiratory losses per larva (have).

14. Why can't we measure the actual dry biomass of *Drosophila* larvae and larvae on day 17?

Investigation 11: Transpiration

This activity prepares students to carry out their own investigation into plant transpiration. Introductory information is followed by two investigations. The first looks at the effect of stomatal density on transpiration rate. The second investigation looks at how environmental factors can effect transpiration rate in one species of plant.

Applications

- ▶ Completing this activity will help students plan their own transpiration investigation; what questions do they need to ask, what equipment is needed, how will data be measured and recorded?
- ▶ Background information includes how to set up a potometer and calculation of stomatal density.
- ▶ Practice is gained over a range of skills including microscopy, measurement, mathematics, graphing, and data analysis.
- ▶ The data provided can be used in place of the student's own investigation, or if their own investigation fails to produce valid data.

Where to next?

- ▶ Students can revise their method and suggest how it could be improved.
- ▶ Students can make predictions about the transpiration rates of two different types of plant (e.g. xerophyte vs mesophyte) and design an experiment to test their hypothesis.
- ▶ Students can investigate how the opening and closing of stomata is controlled (e.g. role of potassium and abscisic acid).

64 Investigating Plant Transpiration

Key Idea: Factors affecting the rate of transpiration from leaves, including physical factors and features of the leaves themselves, can be investigated using a potometer. Different kinds of plants have different shapes and sizes.

The potometer

A potometer is a simple instrument for investigating transpiration rate (water loss per unit time). The experiment is simple to use and easy to adapt. A basic potometer, such as the one shown right, can easily be moved around so that transpiration rate can be measured under different environmental conditions.

Physical factors that can affect transpiration rate include:

- Humidity or vapor pressure (high or low)
- Temperature (high or low)
- An increase (still or windy)
- Light level (high or low)
- Water supply

It is also possible to compare transpiration rates in plants with different adaptations. E.g. compare transpiration rates in plants with rolled leaves or waxy or glaucous leaf surfaces. If possible, experiments like these should be conducted simultaneously using replicate equipment. If conducted sequentially, care should be taken to keep the environmental conditions the same for all groups.

Measuring leaf area

Leaf area can be measured by tracing the leaves onto grid paper and counting the squares, or by tracing or photographing the leaves onto a paper of known mass per area, then cutting out the shapes and weighing them. For each square, multiply by 2 for top and bottom surfaces.

Calculating SA by mass:

Photograph three small plants with known green masses (masses may differ) onto a grid paper. Calculate the surface area from the mass of the leaves.

Calculating SA by leaf area method:

Count the squares covered by the leaf. Calculate the area of the paper squares by counting those that are not fully covered by the leaf and multiplying them by 2 for top and bottom surfaces.

1. (a) Determine the area of the leaf traced onto the blue grid paper.

(b) Twenty leaves from plant A were placed on paper and photographed on to 80 grid paper. The shapes were cut out and weighed on a digital balance. The total weight of shapes was 3.21 grams. Calculate the surface area of the leaves.

2. Calculate the number of stomata per square millimeter on the microscope view of the leaf above.

3. (a) Which plant has the highest transpiration rate?

(b) Which plant has the lowest transpiration rate?

(c) Which plant has the highest stomatal density?

(d) Which plant has the lowest stomatal density?

(e) Is there a relationship between the number of stomata per mm² and the transpiration rate?

(f) Explain your answer.

4. (a) Where was the majority of stomata located in a typical dicot leaf?

(b) Suggest why this might be the case.

5. (a) Plot the potometer data from Table 2 on the grid provided.

(b) Identify the independent variable.

(c) Identify the control.

(d) Explain the purpose of including a control in an experiment.

(e) Which factors increased water loss?

(f) How does each environmental factor influence water loss?

(g) Explain why the plant lost less water in humid conditions.

Investigation 12: Fruit Fly Behavior

The background information in this activity introduces students to the concept of a choice chamber and how they can be used to test an organism's preference for certain environmental conditions. In the second part of the activity, a series of questions prompts students to think about how they would design their own choice chamber experiment to test fruit fly preference for banana at various stages of ripeness.

Applications

- ▶ Ideally this activity should be completed before students attempt their own investigation. It provides valuable insight into the design, set-up, and use of choice chambers, and prompts the students to consider possible challenges and how these can be overcome.
- ▶ The data provided allows students to practice analyzing results and understand their meaning.
- ▶ Students can use this activity to plan their own choice chamber investigation. The design can be peer reviewed and then approved by a teacher before it is carried out.

Where to next?

- ▶ Students can extend their skills by designing an investigation to test the behavior in another organism (e.g. mealworm, ladybug, or housefly). They can carry it out if time permits.

153 Choice Chamber Investigations

Key Idea: Choice chambers are a simple way to investigate animal behavior, including simple learned behavior. Choice chambers are a simple way to investigate behavior in animals. A simple choice chamber consists of two distinct environments.

Background: Students conduct two investigations on woodlice. The first was to determine woodlice preference for light or dark. The second was to test preference for warm or cool environments.

Aim: Investigation 1
To investigate if woodlice prefer a light or dark environment.

The method:
A choice chamber was set up using two food pellets, one in each dish. One dish had light and the other had dark. The woodlice were placed in the middle of the chamber and left for ten minutes to acclimatise. The number of woodlice in each chamber were then recorded. The experiment was carried out a total of four times.

Results:

Time	Dark	Light
1	3	1
2	3	1
3	2	2
4	2	2

Aim: Investigation 2
To investigate if woodlice prefer a warm or cool environment.

The method:
A choice chamber was set up painted entirely black. One side was heated to 20°C by placing a heat pad underneath. The other side was kept cool at 10°C by placing a metal rod in cool water around the chamber. Ten woodlice were placed in the middle of the chamber and left for ten minutes to acclimatise. The number of woodlice in each chamber were then recorded. The experiment was carried out a total of four times.

Results:

Time	Warm (20°C)	Cool (10°C)
1	3	1
2	3	1
3	2	2
4	2	2

1. (a) Write a hypothesis for investigation 1.
(b) Write a hypothesis for investigation 2.

2. For each investigation, what would you expect if there was no difference in choice of environment by the woodlice?

3. How would you determine if the results for each investigation were significant?

4. Describe one way to improve investigation 1.

200 Designing an investigation: fruit flies

Students wanted to investigate at which stage of ripeness bananas were the most attractive to fruit flies. Designate investigations.

This needs a choice chamber made of two clear bottles and to use bananas of known age used to determine the age of the banana for one trial. Bananas were purchased green and designated day 0. The age of the banana was determined from the date as they ripened.

5. Where will the bananas be placed in the choice chamber?

6. What range of ages of bananas would be suitable to investigate?

7. What number of bananas (separate investigations) should be carried out?

8. Write a method that would allow you to determine the age of the banana that is most attractive to fruit flies.

9. The results for a trial between 0 and 10 day old bananas are shown below.

Time (minutes)	Position in chamber (number of fruit flies)			
	End with 10 day old banana	Middle	End with 0 day old banana	
1	21	18	21	
10	45	3	12	

(a) Which banana appeared the most attractive to the fruit flies?
(b) A student suggested that the sex of the flies might make a difference to their choice of banana ripeness. How could you test this?

10. As a group discuss how the method and the design of the choice chamber could be improved. Draw and label your design and attach it to the page 199C. Think about the accuracy of counting.

Investigation 13: Enzyme Activity

In this activity, students explore the influence of biotic and abiotic factors on the activity of turnip peroxidase. In the first section, students are provided with a guided example exploring the effect of pH on enzyme activity. They apply the knowledge gained from this (and their own understanding of enzyme activity) to design their own investigation.

Applications

- ▶ The guided example (effect of pH on turnip peroxidase activity) is intended as a guide for students planning their own investigation.
- ▶ The second hand data provides an opportunity to practice graphing and analytical skills.
- ▶ By analyzing the example, students are encouraged to think about how the method can be improved to obtain better results, and include the refinements in their own design.
- ▶ Students plan their own investigation to test the effect of enzyme concentration on reaction rate. This can be used as the basis for planning their own investigation. The experiment could be designed for other factors such as temperature and substrate concentration if desired.

Where to next?

- ▶ Students might want to research the literature about the optimal conditions for turnip peroxidase and compare these with their own results. Can they account for any differences?
- ▶ How do abiotic factors influence structural integrity? How does this affect functionality?
- ▶ How do biotic factors (e.g. inhibitors) influence peroxidase activity? How do these affect functionality?

26 Investigating Enzyme Activity

Key Idea: This lesson exploring peroxidase activity can be measured using an indicator substance. Enzymes control all the metabolic activities required to sustain life. Changes to environmental conditions (e.g. pH or temperature) may alter an enzyme's shape and functionality.

Background: Peroxidase breaks down hydrogen peroxide (H₂O₂) a toxic substance to produce dihydroxyacetone and oxygen. Hydrogen peroxide → Water + Oxygen. Like all enzymes, peroxidase activity is highest within specific ranges of pH and temperature, and activity drops off or is inhibited altogether when the conditions are outside of the optimal range. The rate of H₂O₂ use is measured by color changes such as the levels of substrate and enzyme.

The effect of temperature on H₂O₂ breakdown can be studied using the indicator substance. Oxidation of a high affinity of oxygen is reduced, resulting in a color change from brown to yellow, which is a brown color. The greater the amount of oxygen produced, the darker brown the solution becomes (right). The color palette provides a standard way to measure relative oxygen production (and therefore peroxidase activity).

Determining the effect of pH on peroxidase activity

Students explored the effect of pH on peroxidase activity using the following procedure:

1. Substrate tubes were prepared by adding 2 ml of distilled water, 0.2 ml of 0.1% H₂O₂ solution, and 0.1 ml of prepared guaiacol solution into 6 clean test tubes. The tubes were covered with parafilm and mixed.

2. Enzyme tubes were prepared by adding 0.5 ml of prepared buffered pH solution (pH 5, 6, 7, 8, 9, 10) and 0.1 ml of prepared turnip peroxidase solution into 6 clean test tubes. The tubes were covered with parafilm and mixed.

3. The substrate and enzyme tubes were combined, covered to parafilm, mixed and placed into the hot water bath at room temperature. Timing began immediately. Students color palette with their phones to record the color change relative to the reference color palette every minute from 0-6 minutes. Results are provided in Table 1.

4. Graph the student's results on the grid (right).

5. (a) Describe the effect of pH on peroxidase activity.

Table 1: Effect of pH on peroxidase activity

pH	Color reference number					
	Start	1 min	2 min	3 min	4 min	5 min
pH 5	0	2	4	5	5	5
pH 6	0	2	4	5	6	6
pH 7	0	2	2	2	2	2
pH 8	0	3	4	4	4	4
pH 9	0	0	0	0	0	0
pH 10	0	0	0	0	0	0

(b) No color change was recorded at pH 10. Explain why and relate this finding to the enzyme's structure and the way it interacts with the substrate.

3. The color palette (opposite) shows the relative amounts of tetraoxygen formed when oxygen binds to guaiacol. How can this be used to determine enzyme activity?

4. In the pH experiment, the students measured the rate of enzyme activity by comparing their results against a color palette. How could they have measured the results quantitatively?

5. How might the results be affected if the students did not begin timing immediately after mixing the enzyme and substrate tubes together?

6. Why is peroxidase written above the arrow in the equation for enzymatic breakdown of H₂O₂?

7. Using the information provided, design an experiment to test the effect of concentration of turnip peroxidase on oxygen production. In the space below, compare your method as step by step instructions. Note how you will record and display the data as well as any limitations or sources of error with your design.

Supporting Resources: Carolina Investigations® Series

- ▶ BIOZONE's student books for AP® Biology contain many activities designed to support the 13 practical investigations outlined in the 'AP® Biology Investigative Labs'. Their intention is to prepare students to design and carry out their own investigations, but they are not wet labs. However, BIOZONE's supporting partner, Carolina Biological Supply (www.carolina.com), provides a variety of tools and equipment to support the practical requirements of AP® Biology.
- ▶ The current AP® Biology program does not limit students to a specific set of investigations, so teachers can address the practical components of the course using labs that fit their classroom and their students' interests. Carolina offers unique kits and activities exclusively designed for the AP® curriculum. The Carolina Investigations® series is specifically aligned to the Big Ideas and Science Practices, and was built from the ground up with the help of expert AP® teachers. The kits are designed to meet the requirements of the new AP® Biology curriculum and focus on making inquiry in the classroom easier for students and teachers.
- ▶ Each kit features activities that allow students to take a guided approach to inquiry while building their science practices and connecting the Big Ideas. Each kit offers an initial skill-building activity that features a more traditional classroom approach, followed by a secondary investigation that utilizes a unique experimental design template to help guide invaluable student-driven, inquiry-based learning opportunities. For information, type the product code into the website's search function.

BIG IDEA 1: EVOLUTION

Carolina Investigations® for AP® Biology: Origin of Life

Students learn about various scientific models concerning the origin of life and then extend their knowledge through hands-on inquiry and exploration. This lab challenges students to explore the origin of life by creating coacervate-phospholipid vesicles similar to those created in the laboratory of Alexander Oparin in the 1920s. Students then design an additional experiment to investigate the impact of various environmental factors on coacervate formation and movement.



Item number: 747500



Carolina Investigations® for AP® Biology: Population Genetics and Evolution

Using direct counting, students calculate the allele frequency of traits such as stem and leaf type in a population of Wisconsin Fast Plants®. They compare the results with the calculated allele frequency determined by applying the Hardy-Weinberg equilibrium model. Students then design their own experiment to prove the model.



Item number: 747510



Carolina Investigations® for AP® Biology: Natural Selection

Students investigate natural selection using brine shrimp. After quantifying brine shrimp hatch rates in environments of different salinity to determine viability, students investigate other environmental changes that might affect viability and change the population.



Item number: 747520



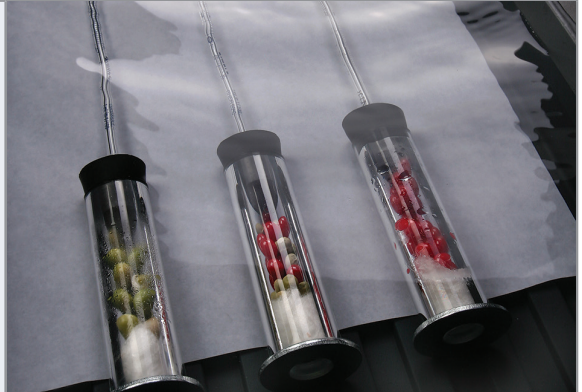
BIG IDEA 2: CELLULAR PROCESSES: ENERGY AND COMMUNICATION

Carolina Investigations® for AP® Biology: Cell Respiration

Students construct respirometers to create closed systems for measuring relative oxygen consumption. They extend this learning into their own investigations, during which they can manipulate environmental variables and compare the respiration rates of various seeds.



Item number: 747600



Carolina Investigations® for AP® Biology: Transpiration

Students explore transpiration by using a potometer to measure water loss in bush bean seedlings. Then, to extend their new knowledge of transpiration, students design an investigation into the various environmental factors that affect plant transpiration rate.



Item number: 747610



Carolina Investigations® for AP® Biology: Plant Pigments and Photosynthesis

Understanding the process of photosynthesis and the pigments involved has never been easier. Using chromatography, students separate plant pigments from their own samples and then identify them based on R_f values. Continuing their exploration, students then study the impact of various environmental factors on the photosynthesis reaction rates in different plants using DPIP indicator solution and a spectrophotometer.



Item number: 747800

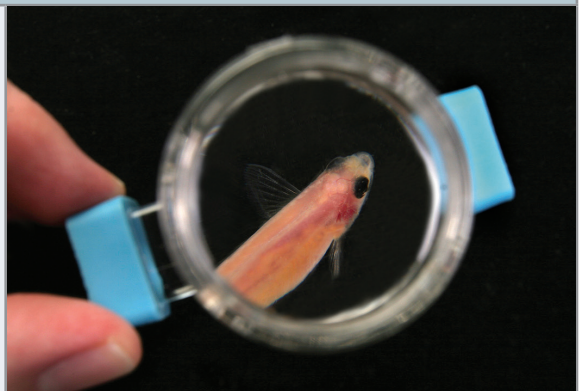


Carolina Investigations® for AP® Biology: Physiology of the Circulatory System

Students use *Daphnia* and Casper Fish™ to observe the differences between open and closed circulatory systems. In the inquiry activity, students monitor *Daphnia*'s heart rate to investigate the organism's response to various environmental changes.



Item number: 747620



BIG IDEA 3: GENETICS AND INFORMATION TRANSFER

Carolina Investigations® for AP® Biology: Transformation

Students discover and explore the process of transformation, a key technique in genetic engineering. They perform a classic transformation activity, to build background knowledge regarding plasmid function, genotype/phenotype connection, and antibiotic resistance. Using proper sterile technique and inquiry, students then design a new experiment to distinguish between 3 different plasmids and determine their gene function.



Item number: 747730



Carolina Investigations® for AP® Biology: Electrophoresis and Simulated Genetic Screen

Students learn how to perform gel electrophoresis as they begin to understand the roles of restriction enzymes, genetic inheritance, and polymerase chain reaction (PCR) in this key genetic engineering process. Following their initial experimentation, students dive deeper into the activity by working to optimize the technique and completing a simulated genetic screen.



Item number: 747710



Carolina Investigations® for AP® Biology: Exploring Mendelian Genetics

Students uncover and experience the mechanism of Mendelian genetics hands on with Wisconsin Fast Plants®. Using Fast Plants® seedlings, students germinate F₁ and F₂ generations of a population to learn about the inheritance of traits, including stem color and length. After drawing conclusions about inheritance in the population, students are tasked with using inquiry to determine the genotype of an unknown sample of Fast Plants® seed.



Item number: 747720



Carolina Investigations® for AP® Biology: Cell Communication

Students put their microscopy skills to the test as they use sterile technique to investigate the life cycle of yeast cells. As they build an understanding of the yeast life cycle, they delve deeper into the process of yeast reproduction. Students then culture and mix 2 strains of yeast and observe the role pheromones play in the cell communication. Students further investigate mating pheromone communication by designing individual experiments using both a-factor and alpha-factor yeast cells.



Item number: 747740



Carolina Investigations® for AP® Biology: Quantitative Analysis and Statistics

This advanced kit, which reinforces data analysis, visualization, and statistical evaluation skills, is a great opener or end-of-year review for your AP® Biology class. The optional pre-lab inquiry, when students test a hypothesis during a demonstrated magic trick, emphasizes to students the value of statistics when applied to hypothesis testing. Next, students complete any or all of 3 guided-inquiry-based activities, using genetic corn to reinforce Mendelian genetics and chi-square test for fit.



Item number: 747805



BIG IDEA 4: INTERACTIONS

Carolina Investigations® for AP® Biology: Animal Behavior

Students set up a choice experiment to determine the food preferences of *Brassica* larvae. Results are collected and quantified, and their significance is determined using chi-square analysis. Applying these techniques, students pose proximate and ultimate questions about other *Brassica* larvae behaviors and design an experiment to answer the questions.



Item number: 747700



Carolina Investigations® for AP® Biology: Species Interactions

Help your students make a big picture connection across communities and populations by characterizing food webs and other factors, such as predation and abiotic factors. Students master the Winkler titration method for measuring dissolved oxygen concentrations. Using this tool, they measure dissolved oxygen fluctuations to assess the relationships between species in an aquatic food chain (*Daphnia*, *Chlorella*, and *Hydra*). After understanding the dynamics of the aquatic food chain, students introduce new variables to design their own experiment using the producers and consumers



Item number: 747810



Carolina Investigations® for AP® Biology: Evolving Enzymes

Students explore in-depth the interactions of enzymes and substrates through this hands-on activity that helps them understand enzyme kinetics. After investigating the relationship between enzymes and substrates, students conduct a bioinformatics analysis to explore the evolutionary relationship of catalase in 4 different species. Combining their earlier lab experiences, students then design their own investigations focused on exploring the impacts of environmental conditions on catalase and/or the activity of catalase from various enzyme sources.



Item number: 747820



Carolina Investigations® for AP® Biology: Primary Consumer Energy Flow

As an alternative to measuring energy flow through primary productivity, students measure the transfer of energy at a higher trophic level and modify environmental conditions to explore their effects on energy consumption. In this lab, *Vanessa cardui* (painted lady butterfly) larvae, representing a primary consumer, feed on a growth medium that represents a primary producer. Students investigate how efficiently developing butterflies convert food into body mass. They then analyze results, calculate efficiency, and build food chains by constructing ecological pyramids.



Item number: 181079



Addressing the Science Practices

The AP Biology Science Practices are addressed in context throughout AP Biology 1 & 2. As students progress through their program of work, they can identify the Science Practices associated with each activity by the picture tab system at the bottom of the activity page. Activities relating to the specific Science Practices are identified in the tables on the following pages.

PRACTICES



SCIENCE PRACTICE 1

Use representations and models to communicate scientific phenomena and solve scientific problems. Includes creating, describing, refining, and using representations and models of natural or man-made phenomena and systems.

Practice number	Practice description	Activity number in AP1	Activity number in AP2
1.1	The student can <i>create representations</i> and models of natural or man-made phenomena and systems in the domain.	66, 77, 100, 138, 145, 174, 189, 240, 256	125, 126, 132, 178, 180-181, 210, 212, 226
1.2	The student can <i>describe representations</i> and models of natural or man-made phenomena and systems in the domain.	2, 28, 40, 51, 52, 54, 77, 100, 104, 106, 129, 154, 179, 264, 277, 278	21, 125, 126, 132, 166 (bonus content), 178, 185-186, 205, 208, 210, 212, 226, 259
1.3	The student can <i>refine representations</i> and models of natural or man-made phenomena and systems in the domain.	66, 210	21, 23, 104, 190, 210, 226, 241, 259-260
1.4	The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively.	51, 52, 54, 66, 72, 77, 100, 134, 138, 169, 172, 176, 179, 197, 210, 248	5, 6, 107, 205, 208, 210, 212, 226, 241, 259-260
1.5	The student can <i>reexpress key elements</i> of natural phenomena across multiple representations in the domain.	77, 106, 179, 213	93, 135, 157, 213, 236, 237, 248, 249, 266, 274

PRACTICES



SCIENCE PRACTICE 2

Use mathematics appropriately, including justifying the use of mathematical routines, applying mathematical routines, and making numerical estimates.

Practice number	Practice description	Activity number in AP1	Activity number in AP2
2.1	The student can <i>justify the selection</i> of a mathematical routine to solve problems.	8, 16, 20, 49, 211-213, 223	11, 18, 26, 197, 203
2.2	The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena.	3, 6-10, 16-19, 42-43, 48-49, 67, 69, 156-157, 184-185, 211-213, 215, 221, 223, 235	9, 11, 23, 32-33, 64, 105, 114, 194, 197-198, 200-203, 205, 207-208, 212-213, 226, 229, 239, 241, 243, 256-257, 271
2.3	The student can <i>estimate numerically quantities</i> that describe natural phenomena.	6	23, 208

PRACTICES



SCIENCE PRACTICE 3

Engage in scientific questioning to extend thinking or to guide investigations, including posing, refining, and evaluating scientific questions.

Practice number	Practice description	Activity number in AP1	Activity number in AP2
3.1	The student can <i>pose scientific questions</i> .	1, 43, 63, 79, 122, 135, 138, 162, 185, 250, 254	18, 64, 153
3.2	The student can <i>refine scientific questions</i> .	38, 115, 135, 185, 229	26, 153, 225, 229, 259
3.3	The student can <i>evaluate scientific questions</i> .	38, 43, 63, 65, 100, 115, 119, 122-125, 131, 135, 138, 185, 229, 276, 278	18, 26, 64, 153, 201, 241, 243, 258-260

PRACTICES

**SCIENCE PRACTICE 4**

Plan and implement data collection strategies appropriate to a particular scientific question. Includes posing, refining, and evaluating scientific questions as well as drawing conclusions from the experimental results of other scientists.

Practice number	Practice description	Activity number in AP1	Activity number in AP2
4.1	The student can <i>justify the selection of the kind of data</i> needed to answer a particular scientific question.	4, 45, 47, 96-97, 115, 126, 229, 278	139, 140, 201
4.2	The student can <i>design a plan</i> for collecting data to answer a particular scientific question.	4, 11, 38, 43, 46, 63, 115, 126, 229	26, 139, 153, 201
4.3	The student can <i>collect data</i> to answer a particular scientific question.	43, 63, 118, 229	153
4.4	The student can <i>evaluate sources of data</i> to answer a particular scientific question.	5, 38, 60, 63, 65, 68-69, 96-97, 103, 115, 119, 135, 229, 276-278	8, 18, 26, 65, 139-140, 153, 201, 225, 229, 243

PRACTICES

**SCIENCE PRACTICE 5**

Perform data analysis and evaluation of evidence, including analyzing data to identify patterns or relationships and evaluating evidence provided by data in relation to a particular question.

Practice number	Practice description	Activity number in AP1	Activity number in AP2
5.1	The student can <i>analyze data</i> to identify patterns and relationships.	12-20, 63-65, 69, 97, 119, 135, 143, 184-185, 213, 215, 217, 229, 234, 236-237, 240, 242-244, 256-257, 263	9, 11, 25, 26, 32-34, 39-40, 64, 101, 105, 146-147, 151, 153, 160, 171, 177, 188, 203-205, 208, 210-213, 216, 224, 226-227, 229-230, 243, 250, 258, 264-266, 268, 271-272
5.2	The student can <i>refine observations and measurements</i> based on data analysis.	38, 60, 97, 229	9, 26, 153, 210, 226, 229
5.3	The student can evaluate the <i>evidence provided by data sets</i> in relation to a particular scientific question.	18-19, 60, 63-65, 69, 97, 103, 119, 130-131, 135, 143, 184-185, 213, 215, 217, 229, 234, 240, 242-248, 255-257, 263, 267	9, 26, 40, 45, 64, 139-140, 153, 156, 210, 216, 224, 226, 229, 243, 258, 268

PRACTICES

**SCIENCE PRACTICE 6**

Work with scientific explanations and theories, including justifying claims with evidence, constructing explanations and making claims and predictions about natural phenomena.

Practice number	Practice description	Activity number in AP1	Activity number in AP2
6.1	The student can <i>justify claims with evidence</i> .	32, 60, 89, 103, 171, 184, 185, 217, 221, 250-251, 277-278	13, 64, 139-140, 188, 229
6.2	The student can <i>construct explanations of phenomena based on evidence</i> produced through scientific practices.	41-43, 60-61, 64, 79, 97, 103, 111, 112, 129, 135, 144, 173, 183, 190, 191, 193, 197, 199, 201, 203, 217, 278	2, 5, 6, 8, 14, 32, 63, 105, 117, 139-141, 178-183, 188, 229, 258, 260
6.3	The student can <i>articulate the reasons that scientific explanations and theories are refined or replaced</i> .	60, 97, 103, 205, 216, 250, 278	140, 229, 259-260, 262, 268
6.4	The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models.	28, 40, 64, 73, 97, 103, 110, 129, 236, 144, 183, 193, 206, 214, 216, 217, 221-223, 250, 251, 265-267, 272, 277	8, 13, 42-43, 45, 60, 64, 139-141, 180, 182, 188, 229, 250, 252, 254, 257-259
6.5	The student can <i>evaluate alternative scientific explanations</i> .	62, 63, 97, 103, 147-150, 153-155, 159-160, 164, 166, 167, 216, 276	229, 260



SCIENCE PRACTICE 7

Connect and relate knowledge across various scales, concepts, and representations in and across domains.

Includes connecting phenomena and models across scales such as time, size, and complexity, and describing how enduring understandings and/or big ideas are connected.

Table with 4 columns: Practice number, Practice description, Activity number in AP1, Activity number in AP2. Rows 7.1 and 7.2 describe connecting phenomena and models across spatial and temporal scales, and connecting concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

PRACTICES



236 Cave Food Webs. Includes a diagram of a cave ecosystem with various organisms and their interactions, and a list of questions for analysis.

Reexpress the information provided as a diagram.

PRACTICES



23 Enzyme Kinetics. Includes graphs of reaction rate vs. substrate concentration and time, and a list of questions for analysis.

Apply a mathematical routine to determine reaction rate and Q10.

PRACTICES



201 Sampling Techniques and Population Estimates. Includes diagrams of different sampling methods and a list of questions for analysis.

Evaluate scientific questions about sampling techniques.

PRACTICES



96 Does DNA Really Carry the Code? Includes diagrams of DNA and protein synthesis, and a list of questions for analysis.

Evaluate data from experiments investigating scientific questions.

PRACTICES



64 Investigating Transport Across Membranes. Includes diagrams of cell membranes and transport mechanisms, and a list of questions for analysis.

Evaluate the results of an investigation of cellular transport.

PRACTICES



229 Population Cycles. Includes diagrams of population growth and cycles, and a list of questions for analysis.

Using the presented results of several key historical investigations to explain phenomena and understand how explanations are refined.

PRACTICES



182 Chemical Synapses. Includes diagrams of a synapse and neurotransmission, and a list of questions for analysis.

Connect concepts of cell signaling across domains.

Addressing Student Learning Objectives

The Learning Objectives for AP Biology are summarized below together with the activities through which they can be wholly or partly met. In some cases, Learning Objectives are met through an instructional sequence of several related activities. The activities identified support the student's achievement of the learning objective directly (e.g. require the student to evaluate evidence provided by data) or sometimes indirectly (e.g. by providing the background to enable the student to pose a scientific question or design a plan to collect data, which may not be required of them in the activity *per se*). It is BIOZONE's plan to extend this support of Learning Objectives further in our print and online resources.

BIG IDEA 1: The process of evolution drives the diversity and unity of life				
Enduring Understanding 1A: Change in the genetic makeup of a population over time is evolution				
	Learning Objectives	SP	EK	Activities
1.1	The student is able to convert a data set from a table of numbers that reflect a change in the genetic makeup of a population over time and to apply mathematical methods and conceptual understandings to investigate the cause(s) and effect(s) of this change.	1.5 2.2	1A1	213, 215, 229
1.2	The student is able to evaluate evidence provided by data to qualitatively and quantitatively investigate the role of natural selection in evolution.	2.2 5.3	1A1	213-220
1.3	The student is able to apply mathematical methods to data from a real or simulated population to predict what will happen to the population in the future.	2.2	1A1	211, 213, 216, 219-223
1.4	The student is able to evaluate data-based evidence that describes evolutionary changes in the genetic makeup of a population over time.	5.3	1A2	213, 215, 218, 226, 229
1.5	The student is able to connect evolutionary changes in a population over time to a change in the environment.	7.1	1A2	217, 220, 236, 238, 244-247
1.6	The student is able to use data from mathematical models based on the Hardy-Weinberg equilibrium to analyze genetic drift and effects of selection in the evolution of populations.	1.4 2.1	1A3	212-213, 223
1.7	The student is able to 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.	2.1	1A3	212-213, 223
1.8	The student is able to make predictions about the effects of genetic drift, migration and artificial selection on the genetic makeup of a population.	6.4	1A3	221-224, 226-229
1.9	The student is able to evaluate evidence provided by data from many scientific disciplines that support biological evolution.	5.3	1A4	234, 240-248
1.10	The student is able to refine evidence based on data from many scientific disciplines that support biological evolution.	5.2	1A4	231-249
1.11	The student is able to design a plan to answer scientific questions regarding how organisms have changed over time using information from morphology, biochemistry and geology.	4.2	1A4	247, 248
1.12	The student is able to connect scientific evidence from many scientific disciplines to support the modern concept of evolution.	7.1	1A4	231-249
1.13	The student is able to construct and/or justify mathematical models, diagrams or simulations that represent processes of biological evolution.	1.1 2.1	1A4	240
Enduring Understanding 1B: Organisms are linked by lines of descent from common ancestry				
1.14	The student is able to pose scientific questions that correctly identify essential properties of shared, core life processes that provide insights into the history of life on Earth.	3.1	1B1	250
1.15	The student is able to 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.	7.2	1B1	251
1.16	The student is able to justify the scientific claim that organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.	6.1	1B1	250-251
1.17	The student is able to pose scientific questions about a group of organisms whose relatedness is described by a phylogenetic tree or cladogram in order to (1) identify shared (derived) characteristics, (2) make inferences about the evolutionary history of the group, and (3) identify character data that could extend or improve the phylogenetic tree.	3.1	1B2	252-256
1.18	The student is able to evaluate evidence provided by a data set in conjunction with a phylogenetic tree or a simple cladogram to determine evolutionary history and speciation.	5.3	1B2	254-256
1.19	The student is able create a phylogenetic tree or simple cladogram that correctly represents evolutionary history and speciation from a provided data set.	1.1	1B2	256
Enduring Understanding 1C: Life continues to evolve within a changing environment				
1.20	The student is able to analyze data related to questions of speciation and extinction throughout the Earth's history.	5.1	1C1	257
1.21	The student is able to analyze data related to questions of speciation and extinction throughout the Earth's history.	4.2	1C1	257, 263, 265-272, 274

1.22	The student is able to 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.	6.4	1C2	265-267
1.23	The student is able to justify the selection of data that address questions related to reproductive isolation and speciation.	4.1	1C2	258-263
1.24	The student is able to describe speciation in an isolated population and connect it to change in gene frequency, change in environment, natural selection and/or genetic drift.	7.2	1C2	263
1.25	The student is able to describe a model that represents evolution within a population.	1.2	1C3	244, 263-264
1.26	The student is able to evaluate given data sets that illustrate evolution as an ongoing process.	5.3	1C3	244, 263, 265-267
Enduring Understanding 1D: The origin of living systems is explained by natural processes				
1.27	The student is able to describe a scientific hypothesis about the origin of life on Earth.	1.2	1D1	276-278
1.28	The student is able to evaluate scientific questions based on hypotheses about the origin of life on Earth	3.3	1D1	276-278
1.29	The student is able to describe the reasons for revisions of scientific hypotheses of the origin of life on Earth.	6.3	1D1	276-278
1.30	The student is able to evaluate scientific hypotheses about the origin of life on Earth.	6.5	1D1	276
1.31	The student is able to evaluate the accuracy and legitimacy of data to answer scientific questions about the origin of life on Earth.	4.4	1D1	276-278
1.32	The student is able to justify the selection of geological, physical, and chemical data that reveal early Earth conditions.	4.1	1D2	278
BIG IDEA 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce, and to maintain dynamic homeostasis				
Enduring Understanding 2A: Growth, reproduction and maintenance of the organization of living systems require free energy and matter				
2.1	The student is able to 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.	6.2	2A1	1-2, 32
2.2	The student can 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.	6.1	2A1	1-2, 32, 34-36
2.3	The student is able to predict how changes in free energy availability affect organisms, populations and ecosystems.	6.4	2A1	2, 32, 34-39
2.4	The student is able to use representations to pose scientific questions about what mechanisms and structural features allow organisms to capture, store, and use free energy.	1.4 3.1	2A2	2, 5, 10, 14, 32-39
2.5	The student is able to construct explanations of the mechanisms and structural features of cells that allow organisms to capture, store or use free energy.	6.2	2A2	2, 5, 8, 10, 14
2.41	The student is able to evaluate data to show the relationship between photosynthesis and respiration in the flow of free energy through a system.	5.3 7.1	2A2	2, 5
2.6	The student is able to use calculated surface area-to-volume ratios to predict which cell(s) might eliminate wastes or procure nutrients faster by diffusion.	2.2	2A3	41-43
2.7	Students will be able to explain how cell size and shape affect the overall rate of nutrient intake and the rate of waste elimination.	6.2	2A3	41-43
2.8	The student is able to 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.	4.1	2A3	21, 24, 25
2.9	The student is able to 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.	1.1 1.4	2A3	25
Enduring Understanding 2B: Growth, reproduction and dynamic homeostasis require that cells create and maintain internal environments that are different from their external environments.				
2.10	The student is able to use representations and models to pose scientific questions about the properties of cell membranes and selective permeability based on molecular structure.	1.4 3.1	2B1	59-60, 63-66
2.11	The student is able to construct models that connect the movement of molecules across membranes with membrane structure and function.	1.1 7.1 7.2	2B1	63-66
2.12	The student is able to 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.	1.4	2B2	63-66, 71-74
2.13	The student is able to explain how internal membranes and organelles contribute to cell functions.	6.2	2B3	51-58, 61
2.14	The student is able to use representations and models to describe differences in prokaryotic and eukaryotic cells.	1.2 1.4	2B3	51, 52, 54
Enduring Understanding 2C: Organisms use feedback mechanisms to regulate growth and reproduction, and maintain dynamic homeostasis				
2.15	The student can justify a claim made about the effect(s) on a biological system at the molecular, physiological or organismal level when given a scenario in which one or more components within a negative regulatory system is altered.	6.1	2C1	41, 43-49

2.16	The student is able to connect how organisms use negative feedback to maintain their internal environments.	7.2	2C1	41, 43-45, 47-49
2.17	The student is able to evaluate data that show the effect(s) of changes in concentrations of key molecules on negative feedback mechanisms.	5.3	2C1	45
2.18	The student can make predictions about how organisms use negative feedback mechanisms to maintain their internal environments.	6.4	2C1	41, 43-45, 47-49
2.19	The student is able to make predictions about how positive feedback mechanisms amplify activities and processes in organisms based on scientific theories and models.	6.4	2C1	42-43, 50
2.20	The student is able to justify that positive feedback mechanisms amplify responses in organisms.	6.1	2C1	42-43, 50
2.21	The student is able to 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.	4.1	2C2	44-45, 136-148
2.42	The student is able to pose a scientific question concerning the behavioral or physiological response of an organism to a change in its environment.	3.1	2C2	151-153
Enduring Understanding 2D: Growth and dynamic homeostasis of a biological system are influenced by changes in the system's environment				
2.22	The student is able to 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	1.3 3.2	2D1	18, 23, 193, 217, 220-225, 227, 229
2.23	The student is able to 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.	4.2 7.2	2D1	197-203
2.24	The student is able to analyze data to identify possible patterns and relationships between a biotic or abiotic factor and a biological system (cells, organisms, populations, communities or ecosystems).	5.1	2D1	203
2.25	The student can construct explanations based on scientific evidence that homeostatic mechanisms reflect continuity due to common ancestry and/or divergence due to adaptation in different environments.	6.2	2D2	59-63, 68-93, 98, 101-105, 117
2.26	The student is able to analyze data to identify phylogenetic patterns or relationships, showing that homeostatic mechanisms reflect both continuity due to common ancestry and change due to evolution in different environments.	5.1	2D2	61, 68, 70-72, 75-92, 95, 101
2.27	The student is able to connect differences in the environment with the evolution of homeostatic mechanisms.	7.1	2D2	61, 68-92, 101
2.28	The student is able to use representations or models to analyze quantitatively and qualitatively the effects of disruptions to dynamic homeostasis in biological systems.	1.4	2D3	47, 48, 106, 120, 133-134
2.29	The student can create representations and models to describe immune responses.	1.1 1.2	2D4	128, 130-132
2.30	The student can create representations or models to describe nonspecific immune defenses in plants and animals.	1.1 1.2	2D4	124-126
2.43	The student is able to connect the concept of cell communication to the functioning of the immune system.	7.2	2D4	126, 130, 133 also 80-81
Enduring Understanding 2E: Many biological processes involved in growth, reproduction, and dynamic homeostasis include temporal regulation and coordination				
2.31	The student can 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.	7.2	2E1	169-177
2.32	The student is able to 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.	1.4	2E1	170-173, 175-176
2.33	The student is able to 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.	6.1	2E1	170-176
2.34	The student is able to describe the role of programmed cell death in development and differentiation, the reuse of molecules, and the maintenance of dynamic homeostasis.	7.1	2E1	130-131, 177
2.35	The student is able to design a plan for collecting data to support the scientific claim that the timing and coordination of physiological events involve regulation.	4.2	2E2	140, also 173
2.36	The student is able to justify scientific claims with evidence to show how timing and coordination of physiological events involve regulation.	6.1	2E2	136, 139-141, 144-147
2.37	The student is able to connect concepts that describe mechanisms that regulate the timing and coordination of physiological events.	7.2	2E2	136-149, 170-176
2.38	The student is able to analyze data to support the claim that responses to information and communication of information affect natural selection.	5.1	2E3	137, 141, 144, 147-152, 156-164 also 170, 173-177

2.39	The student is able to justify scientific claims, using evidence, to describe how timing and coordination of behavioral events in organisms are regulated by several mechanisms.	6.1	2E3	139-144, 147, 148, 156-159
2.40	The student is able to connect concepts in and across domain(s) to predict how environmental factors affect responses to information and change behavior.	7.2	2E3	151-153, 156-157
BIG IDEA 3: Living systems store, retrieve, transmit, and respond to information essential to life processes				
Enduring Understanding 3A: Heritable information provides for continuity of life				
3.1	The student is able to 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.	6.2 6.5	3A1	96-98, 100, 103
3.2	The student is able to justify the selection of data from historical investigations that support the claim that DNA is the source of heritable information.	4.1	3A1	96-97
3.3	The student is able to describe representations and models that illustrate how genetic information is copied for transmission between generations.	1.2	3A1	100-103
3.4	The student is able to describe representations and models illustrating how genetic information is translated into polypeptides	1.2	3A1	104-109
3.5	The student can justify the claim that humans can manipulate heritable information by identifying at least two commonly used technologies	6.2 6.4	3A1	111-126
3.6	The student can predict how a change in a specific DNA or RNA sequence can result in changes in gene expression.	6.4	3A1	105, 110
3.7	The student can make predictions about natural phenomena occurring during the cell cycle	6.2 6.5	3A2	129
3.8	The student can describe the events that occur in the cell cycle.	1.2	3A2	129
3.9	The student is able to 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.	6.2	3A2	132-139
3.10	The student is able to represent the connection between meiosis and increased genetic diversity necessary for evolution	7.1	3A2	137
3.11	The student is able to 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.	5.3	3A2	143
3.12	The student is able to construct a representation that connects the process of meiosis to the passage of traits from parent to offspring.	1.1 7.2	3A3	144-145
3.13	The student is able to pose questions about ethical, social or medical issues surrounding human genetic disorders.	3.1	3A3	162-163
3.14	The student is able to apply mathematical routines to determine Mendelian patterns of inheritance provided by data sets.	2.2	3A3	156-158
3.15	The student is able to explain deviations from Mendel's model of the inheritance of traits.	6.2 6.5	3A4	147-150, 153-155, 159-160, 164, 166-167
3.16	The student is able to explain how the inheritance patterns of many traits cannot be accounted for by Mendelian genetics.	6.3	3A4	147-150, 153-155, 159-160, 164, 166-167
3.17	The student is able to describe representations of an appropriate example of inheritance patterns that cannot be explained by Mendel's model of the inheritance of traits.	1.2	3A4	153-155, 166-167
Enduring Understanding 3B: Expression of genetic information involves cellular and molecular mechanisms				
3.18	The student is able to describe the connection between the regulation of gene expression and observed differences between different kinds of organisms	7.1	3B1	171-176, also 243
3.19	The student is able to describe the connection between the regulation of gene expression and observed differences between individuals in a population.	7.1	3B1	171-176, also 243
3.20	The student is able to explain how the regulation of gene expression is essential for the processes and structures that support efficient cell function.	6.2	3B1	173
3.21	The student can use representations to describe how gene regulation influences cell products and function.	1.4	3B1	169-173
3.22	The student is able to explain how signal pathways mediate gene expression, including how this process can affect protein production.	6.2	3B2	169, 172-173 also 77, 79, 82-83
3.23	The student can use representations to describe mechanisms of the regulation of gene expression.	1.4	3B2	172-173, 178-180
Enduring Understanding 3C: The processing of genetic information is imperfect and is a source of genetic variation				
3.24	The student is able to predict how a change in genotype, when expressed as a phenotype, provides a variation that can be subject to natural selection.	6.4 7.2	3C1	182-183
3.25	The student can create a visual representation to illustrate how changes in a DNA nucleotide sequence can result in a change in the polypeptide produced.	1.1	3C1	187, 189

3.26	The student is able to explain the connection between genetic variations in organisms and phenotypic variations in populations.	7.2	3C1	187-197
3.27	The student is able to compare and contrast processes by which genetic variation is produced and maintained in organisms from multiple domains.	6.2	3C2	182-183, 187-197, also 242
3.28	The student is able to construct an explanation of the multiple processes that increase variation within a population.	1.4	3C2	182-183, 187-197, also 242
3.29	The student is able to construct an explanation of how viruses introduce genetic variation in host organisms.	6.2	3C3	197-202
3.30	The student is able to use representations and appropriate models to describe how viral replication introduces genetic variation in the viral population	1.4	3C3	197-198, 200-202
Enduring Understanding 3D: Cells communicate by generating, transmitting, and receiving chemical signals				
3.31	The student is able to describe basic chemical processes for cell communication shared across evolutionary lines of descent.	7.2	3D1	77-79
3.32	The student is able to generate scientific questions involving cell communication as it relates to the process of evolution.	3.1	3D1	78-82
3.33	The student is able to use representation(s) and appropriate models to describe features of a cell signaling pathway.	1.4	3D1	77, 85
3.34	The student is able to construct explanations of cell communication through cell-to-cell direct contact or through chemical signaling.	6.2	3D2	77, 79-82, 172
3.35	The student is able to create representation(s) that depict how cell-to-cell communication occurs by direct contact or from a distance through chemical signaling.	1.1	3D2	77
3.36	The student is able to describe a model that expresses the key elements of signal transduction pathways by which a signal is converted to a cellular response.	1.5	3D3	77, 85-87
3.37	The student is able to justify claims based on scientific evidence that changes in signal transduction pathways can alter cellular response.	6.1	3D4	89
3.38	The student is able to describe a model that expresses key elements to show how change in signal transduction can alter cellular response.	1.5	3D4	88, 89
3.39	The student is able to construct an explanation of how certain drugs affect signal reception and, consequently, signal transduction pathways.	6.2	3D4	89
Enduring Understanding 3E: Transmission of information results in changes within and between biological systems				
3.40	The student is able to analyze data that indicate how organisms exchange information in response to internal changes and external cues, and which can change behavior.	5.1	3E1	167, 171, 174-177
3.41	The student is able to 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.	1.1	3E1	167, 171, 174-177
3.42	The student is able to describe how organisms exchange information in response to internal changes or environmental cues.	7.1	3E1	168, 174-175
3.43	The student is able to 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.	6.2 7.1	3E2	178-183
3.44	The student is able to describe how nervous systems detect external and internal signals.	1.2	3E2	166, 178
3.45	The student is able to describe how nervous systems transmit information.	1.2	3E2	178-182
3.46	The student is able to describe how the vertebrate brain integrates information to produce a response.	1.2	3E2	181, 185-186
3.47	The student is able to 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.	1.1	3E2	178
3.48	The student is able to create a visual representation to describe how nervous systems detect external and internal signals.	1.1	3E2	166, 178
3.49	The student is able to create a visual representation to describe how nervous systems transmit information.	1.1	3E2	180-181
3.50	The student is able to create a visual representation to describe how the vertebrate brain integrates information to produce a response.	1.1	3E2	185-186
BIG IDEA 4: Biological systems interact, and these systems and their interactions possess complex properties				
Enduring Understanding 4A: Interactions within biological systems lead to complex properties				
4.1	The student is able to explain the connection between the sequence and the subcomponents of a biological polymer and its properties.	7.1	4A1	27-32, 34-36, 39-40, 91
4.2	The student is able to refine representations and models to explain how the subcomponents of a biological polymer and their sequence determine the properties of that polymer.	1.2	4A1	27-32, 34-36, 39-40, 91, 100
4.3	The student is able to use models to predict and justify that changes in the subcomponents of a biological polymer affect the functionality of the molecule.	6.1 6.4	4A1	31-35, 39-40, 100

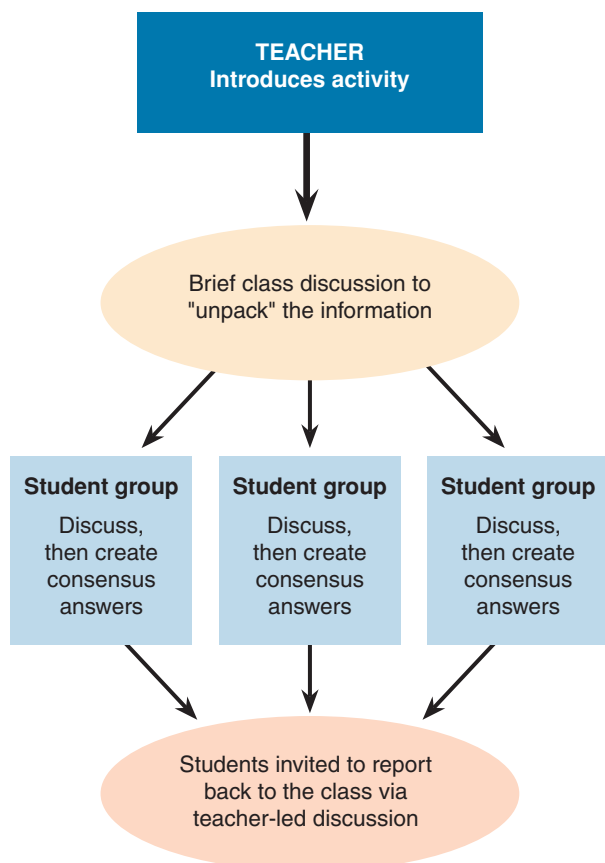
4.4	The student is able to make a prediction about the interactions of subcellular organelles.	6.4	4A2	73
4.5	The student is able to construct explanations based on scientific evidence as to how interactions of subcellular structures provide essential functions.	6.2	4A2	61,73 6-7
4.6	The student is able to use representations and models to analyze situations qualitatively to describe how interactions of subcellular structures, which possess specialized functions, provide essential functions.	1.4	4A2	61,72-73 6-7
4.7	The student is able to refine representations to illustrate how interactions between external stimuli and gene expression result in specialization of cells, tissues and organs.	1.3	4A3	169-170, 173
4.8	The student is able to evaluate scientific questions concerning organisms that exhibit complex properties due to the interaction of their constituent parts.	3.3	4A4	53-63, 64, 65, 72-74, 82, 85, 88, 118, 94, 96- 97, 107-118
4.9	The student is able to predict the effects of a change in a component(s) of a biological system on the functionality of an organism(s).	6.4	4A4	59-61, 64, 66,73-74, 76,101,104- 105, 118
4.10	The student is able to refine representations and models to illustrate biocomplexity due to interactions of the constituent parts.	1.3	4A4	64, 98, 104- 105,190
4.11	The student is able to justify the selection of the kind of data needed to answer scientific questions about the interaction of populations within communities.	1.4 4.1	4A5	193-194, 197-203, 226, 231
4.12	The student is able to apply mathematical routines to quantities that describe communities composed of populations of organisms that interact in complex ways.	2.2	4A5	194, 197- 198, 201- 203, 226
4.13	The student is able to predict the effects of a change in the community's populations on the community.	6.4	4A5	207, 210- 213, 250- 252,
4.14	The student is able to apply mathematical routines to quantities that describe interactions among living systems and their environment, which result in the movement of matter and energy.	2.2	4A6	239, 241, 243, 257, 274
4.15	The student is able to 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.	1.4	4A6	234-237, 240-244, 246-248
4.16	The student is able to predict the effects of a change of matter or energy availability on communities.	6.4	4A6	235, 241, 243, 254, 257
Enduring Understanding 4B: Competition and cooperation are important aspects of biological systems.				
4.17	The student is able to analyze data to identify how molecular interactions affect structure and function.	5.1	4B1	25
4.18	The student is able to use representations and models to analyze how cooperative interactions within organisms promote efficiency in the use of energy and matter.	1.4	4B2	59, 83-84, 107
4.19	The student is able to use data analysis to refine observations and measurements regarding the effect of population interactions on patterns of species distribution and abundance.	2.2 5.2	4B3	226, 229
4.20	The student is able to explain how the distribution of ecosystems changes over time by identifying large-scale events that have resulted in these changes in the past.	6.2 6.3	4B4	262, 268
4.21	The student is able to predict consequences of human actions on both local and global ecosystems.	6.4	4B4	254-267
Enduring Understanding 4C: Naturally occurring diversity among and between components within biological systems affects interaction with the environment.				
4.22	The student is able to construct explanations based on evidence of how variation in molecular units provides cells with a wider range of functions.	6.2	4C1	189, 191-193
4.23	The student is able to construct explanations of the influence of environmental factors on the phenotype of an organism.	6.2	4C2	179, 182-183
4.24	The student is able to predict the effects of a change in an environmental factor on the genotypic expression of the phenotype.	6.4	4C2	179, 182-185
4.25	The student is able to use evidence to justify a claim that a variety of phenotypic responses to a single environmental factor can result from different genotypes within the population.	6.1	4C3	182-183, 188-193
4.26	The student is able to use theories and models to make scientific claims and/ or predictions about the effects of variation within populations on survival and fitness.	6.4	4C3	188-193, also 206-207
4.27	The student is able to make scientific claims and predictions about how species diversity within an ecosystem influences ecosystem stability.	6.4	4C4	249, 253, 263, 270-272

Teaching Strategies for Classroom Use

Achieving effective differential instruction in classes is a teaching challenge. Students naturally have mixed abilities, varying backgrounds in the subject, and different language skills. Used effectively, BIOZONE's student books and supporting resources can make teaching a mixed ability class easier. Here, we suggest some approaches for differential instruction.

MAKING A START

Regardless of which activity you might be attempting in class, a short introduction to the task by the teacher is a useful orientation for all students. For collaborative work, the teacher can then divide the class into appropriate groups, each with a balance of able and less able students. Depending on the activity, the class may regroup at the end of the lesson for discussion.



Using collaboration to maximize learning outcomes

- The structure of the AP Biology books allows for a flexible approach to unpacking the content with your students.
- The content can be delivered in a way to support collaboration, where students work in small groups to share ideas and information to answer and gain a better understanding of a topic, or design a solution to a problem.
- By working together to ask questions and evaluate each other's ideas, students maximize their own and each other's learning opportunities. They are exposed to ideas and perspectives they may not have come up with on their own.
- Use a short, informal collaborative learning session to get students to exchange ideas about the answer to a question. Alternatively, collaboration may take a more formal role that lasts for a longer period of time (e.g. assign groups to work together for a paper practical activity, to research a topic, or design a solution to a problem).



The teacher introduces the topic. They provide structure to the session by providing background information and setting up discussion points and clear objectives. Collaboration is emphasized to encourage participation from the entire group. If necessary, students in a group can be assigned specific tasks.



Students work in small groups so everyone's contribution is heard. They collaborate, share ideas, and engage in discourse. The emphasis is on discussing questions and formulating a consensus answer, not just sharing ideas.



At the end of the session, students report back on their findings. Each student should have enough knowledge to report back on the group's findings. Reporting consists primarily of providing answers to questions, but may involve presenting a report, model, or slide show, or contributing to a debate.



Peer to peer support

- **Peer-to-peer learning** can be used for any activities, but is particularly valuable for more challenging activities in which the content is more complex or the questions require students to draw on several areas of their knowledge to synthesize an answer. Examples of such activities include modeling activities, activities with a design component, or activities involving data analysis, graphing, and evaluation.
- Stronger peers can assist weaker students and both groups benefit from verbalizing their thoughts and presenting them to a group. Students for whom English is a second language can ask their peers to explain unfamiliar terms (both scientific and English) and this benefits both parties.

Paper practicals and simulation activities (e.g. *Modeling Mitosis*, *Modeling Meiosis*, *Modeling Population Growth*, *Creating a DNA Model*, *Modeling Interspecific Competition*, and *Gene Pool Exercise*) are an ideal vehicle for this kind of peer-to-peer learning. They are not only enjoyable, but they prompt students to ask questions and think about how they could use the model to answer those questions.

138 Modeling Meiosis

Key Idea: We can simulate crossing over, gamete production, and the inheritance of alleles during meiosis using ice-block sticks to represent chromosomes. This practical activity simulates the production of gametes (sperm and eggs) by meiosis and shows you how crossing

Background

Each of your somatic cells contain 46 chromosomes. You received 23 chromosomes from your mother (**maternal chromosomes**), and 23 chromosomes from your father (**paternal chromosomes**). Therefore, you have 23 homologous (same) pairs. For simplicity, the number of chromosomes studied in this exercise has been reduced to four (two chromosome pairs). To study the effect of crossing over on genetic variability, you will look at the inheritance of two of your own traits: the ability to tongue roll and handedness.

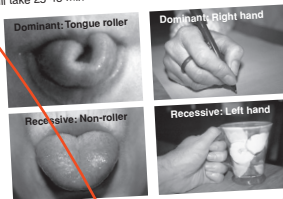
Chromosome #	Phenotype	Genotype
10	Tongue roller	TT, Tt
10	Non-tongue roller	tt
2	Right handed	RR, Rr
2	Left handed	rr

Record your phenotype and genotype for each trait in the table (right). **NOTE:** If you have a dominant trait, you will not know if you are heterozygous or homozygous for that trait, so you can choose either genotype for this activity.

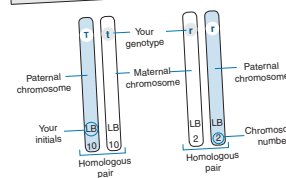
BEFORE YOU START THE SIMULATION: Partner up with a classmate. Your gametes will combine with theirs (fertilization) at the end of the activity to produce a child. Decide who will be the female, and who will be the male. You will need to work with this person again at step 6.

1. Collect four ice-block sticks. These represent four chromosomes. Color two sticks blue or mark them with a P. These are the paternal chromosomes. The plain sticks are the maternal chromosomes. Write your initials on each of the four sticks. Label each chromosome with their chromosome number (10 and 2).
2. Randomly drop the chromosomes onto a table. This represents a cell in either the testes or ovaries. Duplicate your chromosomes (to simulate DNA replication) by adding four more identical ice-block sticks to the table (below). This represents **interphase**.

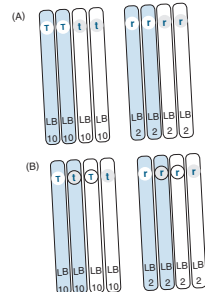
over increases genetic variability. This is demonstrated by studying how two of your own alleles are inherited by the child produced at the completion of the activity. Completing this activity will help you to visualize and understand meiosis. It will take 25-45 minutes.



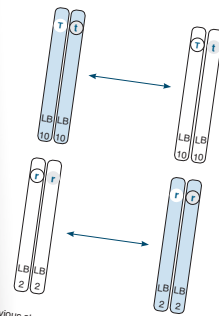
Trait	Phenotype	Genotype
Handedness		
Tongue rolling		



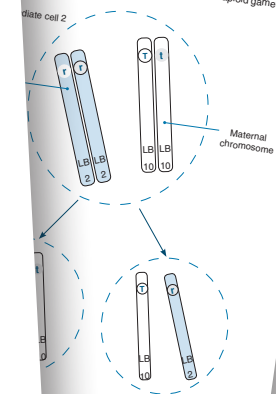
3. Simulate **prophase I** by lining the duplicated chromosome pair with their homologous pair (below). For each chromosome pair, you will have four sticks touching side-by-side (A). At this stage **crossing over** occurs. Simulate this by swapping sticky dots from adjoining homologs (B).



Simulate alignment on the metaphase plate (as occurs in **metaphase I**). Simulate separation of four sticks, two are pulled to each pole.



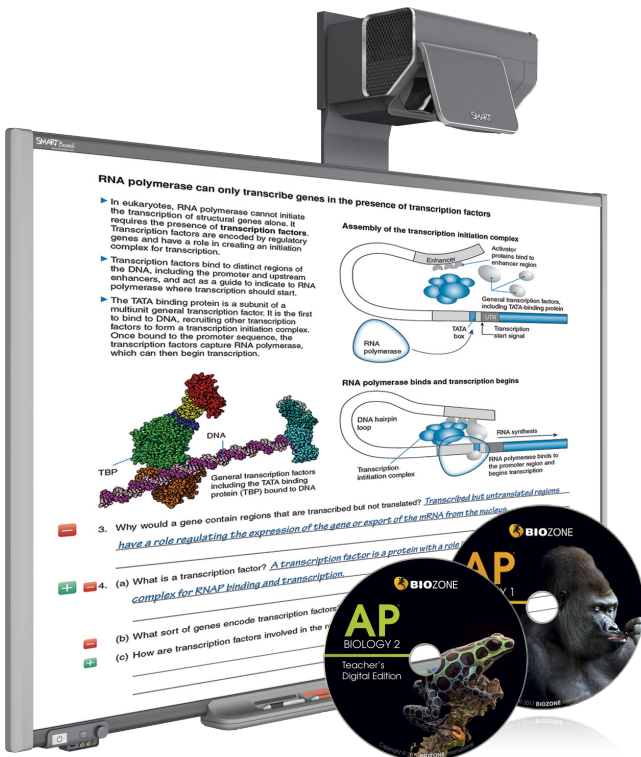
In the previous step, each intermediate cell will contain a mixture of maternal and paternal chromosomes. During **prophase II, metaphase II, anaphase II, and telophase II**, each intermediate cell will have produced two haploid gametes.



Randomly select one sperm and one egg cell, and simulate fertilization. You have created a zygote with two pairs of chromosomes.

In Modeling Meiosis, students can collaborate in pairs to determine the outcome of a mating between two individuals with different traits. This tests and creates understanding by putting theory into practice.

Encourage students to consolidate and extend their knowledge by visiting the **Weblinks** for the activity.



Interactive revision of tasks in class

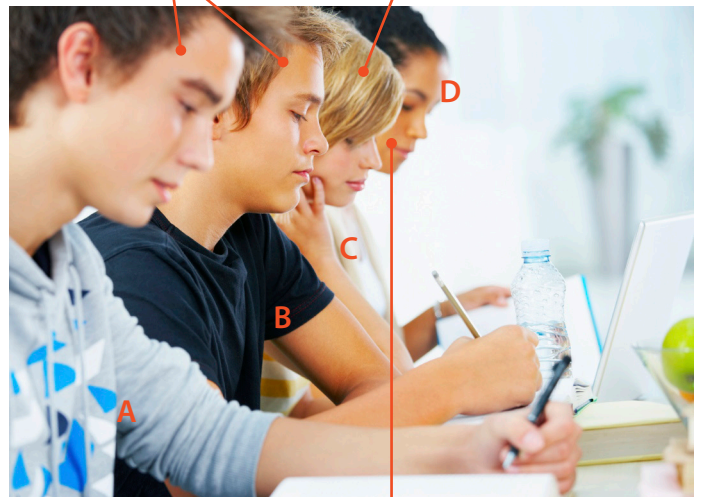
- The **Teacher's Digital Edition** provides a digital rights managed (DRM) version of the student book as PDF files. It features useful HIDE/SHOW answers, which can be used to review activities in class using a data projector or interactive whiteboard.
- Students benefit from the feedback in class, where questions can be addressed, and teachers benefit by having students self-mark their work and receive helpful feedback on their responses.
- This approach is particularly suited to activities with questions requiring a discussion, as students will be able to clarify some aspects of their responses. Stronger students can benefit by contributing to the explanatory feedback and class discussion.

Students **A** and **B** will work through simpler questions themselves but may require assistance with the more challenging questions in this activity.

Student **C** is capable. She completes all of this activity including the more challenging questions.

Gaining confidence

- The questions in the activities have generally been written in a direct questioning style, e.g. "What are the differences between A and B", or "Why are A and B different?". This makes it easier for the students to understand what is required to answer the question.
- Questions are also arranged so that simpler questions (describe, what, identify, name) are generally asked first, followed by questions demanding an explanation (explain, how, why, account for). This allows students to gain confidence from answering the simpler questions first before attempting the questions that require more comprehensive answers.
- This arrangement also allows teachers to direct students appropriately so that some may attempt only the simpler questions themselves and work with peers to attempt the more challenging questions.



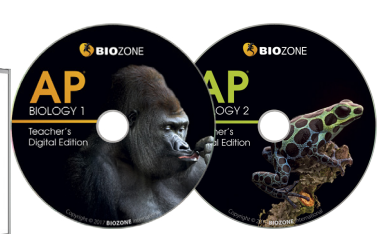
Student **D** is capable and needs extension. She works quickly, completing her set work. She can demonstrate her understanding in the synoptic question.

Moving on to Synoptic Questions

- BIOZONE's AP Biology contains synoptic questions at the end of each major section of work. These require students to draw on the knowledge gained in a range of activities to answer the questions.
- The synoptic questions include multi-choice, short answer, and longer answer questions. Students are given introductory information and asked to discuss certain aspects of the topic relating to the information. The examples used in the questions may not directly relate to examples in the book, but the ideas and concepts required to answer the question will have been covered in the preceding activities.
- Sometimes students will need to interpret the information given in the question's introduction and integrate their interpretation into their answer.

38 The Teacher's Digital Edition

The *Teacher's Digital Edition* is a DRM product, sold separately, and aimed primarily at extending the pedagogical tools at a teacher's disposal. Many of the features of this resource have been developed in response to requests from teachers themselves.



AP BIOLOGY 1

- Model Answers**: The Model Answers booklet provides suggested answers for all activities in the workbook. Model Answers are also provided as 'show/hide' in the PDF of the workbook.
- 3D Models and Weblinks**: An activity provides a range of resources to weblinks (usually animations or short video clips) that have particular relevance to the activity. <http://www.thebiocentre.com/weblink/ap1-3dmodels>
- Classroom Guide**: A comprehensive guide to effective use of BIOZONE's AP Biology 1 and 2. It provides strategies for use with students of different abilities and for a variety of tasks, including assessment.
- Presentation Media**: Sample from Cell Structure Presentation Media provides high quality colour PowerPoint/Keynote slides for your presentations. All slides are fully editable:
 - > Add or delete slides
 - > Change the order of slides
 - > Edit the wording
- Spreadsheets and Statistics**: Microsoft® Excel® Spreadsheets directly support the data handling and graphing activities in the workbook. Click here to view the CT activities available.

Digital copy of the Model Answers (non-printable). Suggested answers are provided to all activities. Some include explanatory detail.

A digital (PDF) version of the student edition (non-printable). Use the interactive buttons to HIDE or SHOW the answers.

Access the Weblinks directly from this link for a range of animations and video clips to support the activities.

A BONUS sample copy of a Presentation Media title is included. In AP1 the title is 'Cell Structure', in AP2 the title is 'Populations and Interactions'. Both are fully editable.

Link to **Excel®** spreadsheets for all activities with a graphing or data analysis component.

This **Classroom Guide** is provided as a printable PDF.

214 Types of Natural Selection

Key Idea: Natural selection is responsible for the differential survival of some phenotypes (and genotypes) over others. It is an important cause of genetic change in populations. Natural selection operates on the phenotypes of individuals produced by their particular combinations of alleles. It results in the differential survival of some genotypes over others. As a result, organisms with phenotypes most suited to the environment at the time are more likely to survive and breed than those with less suited phenotypes. Favorable phenotypes will become relatively more common in the population over time. Natural selection is always in operation. It is a process that favors existing phenotypes over new ones. The population phenotypic bottom row the spread of

215 Stabilizing Selection for Human Birth Weight

Key Idea: Stabilizing selection operates to keep human birth weight within relatively narrow constraints. Selection pressures operate on populations in such a way as to reduce mortality. For humans, selection pressures act to constrain birth weight. For example, a baby that is too large or too small can result in a poor population. Ca

Step 1: For this activity you will need a sample of 100 birth weights. You can search birth weights in the appendix of this book (page 410).

Step 2: Group the weights into each of the 12 weight classes indicated on the graph template provided. Calculate the percentage in each weight class.

Step 3: Graph these in the form of a histogram for the 12 weight classes (use the histogram for grid provided on the left vertical Y) axis. Create a plot of percentage mortality of newborns in relation to their birth weight. Use the scale on the right Y axis and data through the points.

Step 4: Draw a line of best fit

Weight (kg)	Percent mortality
1.0	80
1.5	30
2.0	12
2.5	4
3.0	3
3.5	2
4.0	3
4.5	7
5.0	15

DID YOU KNOW? Evidence indicates that the phenotypic norm is shifting. Researchers estimate that the average birth weight of newborn babies in the UK has increased from 3.4 kg in 1980 to 3.6 kg in 2010. This is due to a trend in the population towards larger babies. Many of these larger babies are now safely delivered by Caesarian section.

1. Define the following, including a statement about the type of selection.

(a) Stabilizing selection: _____

(b) Directional selection: _____

(c) Disruptive selection: _____

2. Fluctuating environments are more likely to favor diversification of phenotypes to exploit a range of niches. This is because in such environments there is a greater chance of a phenotype being suited to the environment at the time. As a result, organisms with phenotypes most suited to the environment at the time are more likely to survive and breed than those with less suited phenotypes. Favorable phenotypes will become relatively more common in the population over time. Natural selection is always in operation. It is a process that favors existing phenotypes over new ones. The population phenotypic bottom row the spread of

Activities with graphing or data handling requirements are supported by working spreadsheets, which include all data and comments on graphical analysis.

Use the interactive buttons to reveal the answers as you work through the activity on-screen.

Formative and Summative Assessments

AP Biology provides ample opportunity for students to demonstrate their understanding and proficiency across all four Big Ideas. Most of the activities in the book can be used for formative assessment to provide feedback to the student during the learning process. Synoptic questions at the end of each section can be used as summative assessment tasks.

Formative assessment

Individual activities, or an instructional sequence, can be used as formative assessments to determine how a student's knowledge is progressing within a selected topic. Teachers can revise their instruction, revisit material, or set further tasks if a student is having difficulty with the material.

KEY TERMS AND IDEAS: Did You Get It? activities at the end of each chapter can be used for formal testing as a class, or set as an informal check point where students use the activity as a opportunity for self assessment.

Summative assessment

Each section of work concludes with synoptic questions. These activities may be administered at the end of a unit of instruction as a formal or semi-formal test. They are designed to test a student's ability to apply their knowledge and understanding of a particular topic.

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135 KEY TERMS AND IDEAS: Did You Get It?

1. Test your vocabulary by matching each term to its correct definition, as identified by its preceding letter code.

<p>antigen antibody cell-mediated response humoral response immunity inflammation pathogen vaccination</p>	<p>A Immune response against antigens involving the activation of macrophages, specific T cells, and cytokines. B A disease-causing organism. C The collective defenses of the body that provide resistance to infection or disease. D A molecule, usually a protein, that is capable of inducing an immune response. E The delivery of antigenic material to produce immunity to a disease (produce an immunized individual). F The protective response of vascular tissues to harmful stimuli, such as irritants, pathogens, or damaged cells. G Immune response that is mediated by secreted antibodies. H Gamma globulin protein in the blood or other bodily fluids, which identifies and neutralizes foreign material, such as bacteria and viruses.</p>
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1. Contrast the innate and the adaptive immune responses with reference to the basic action and the cells involved:

2. The photograph on the right shows the effect of a pathogen infecting a human.

(a) Name the defensive response occurring: _____

(b) What is happening to the blood vessels at this location? _____


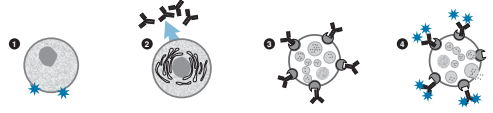
(c) Name the substance responsible for the change in the blood vessels: _____

(d) What type of cell is the substance released from? _____

(e) During this response, the number of white blood cells increases/decreases (delete one).

(f) The process occurring here is an example of innate immunity / adaptive immunity (delete one).

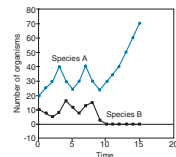
3. The diagram below shows a hypersensitivity sequence. Label the following components on the diagram: mast cell, antibody, histamine, antigen, B cell, plasma B cell. In the space below each drawing, briefly state what is happening.

TEST

274 Synoptic Questions

Questions 1-2 relate to the plot below. Identify the correct answer



1. Species A and B are found in the same ecosystem. What could be inferred from the data presented:

(a) Species B is the prey of species A
(b) Species B is the predator of species A
(c) Species A is a keystone species
(d) Species A is a parasite of species B

2. Which of the following statements would explain why a species would show cyclic population changes:

(a) A keystone species in the ecosystem is removed.
(b) The vegetation on which it depends varies seasonally.
(c) Climate shifts alter the prevalence of parasites that affect the species.
(d) A predator of the species is preyed on by a species that is introduced to the ecosystem.

3. Pumas prey on a species of deer in a region. The deer feed on vegetation. What is the most likely outcome if the puma population declines markedly as a result of hunting by humans:

(a) The deer population will cycle between high and low numbers until the predator returns.
(b) The deer population will increase and strip the region of vegetation.
(c) The deer population will decline and vegetation cover will increase.
(d) The deer population will be stable.

4. Which of the following might be expected if a keystone species is eliminated from an ecosystem:

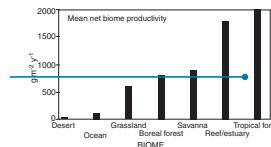
(a) Interspecific competition increases.
(b) There is one less niche available.
(c) The ecosystem diversity declines.
(d) There is no significant change.

5. When two species have a close relationship in which both obtain benefits, the relationship is called:


(a) Symbiosis
(b) Mutualism
(c) Commensalism
(d) Competition

6. The plot below shows the mean net productivity of various biomes. The productivity varies between them because:

(a) Productivity increases from the poles to the equator.
(b) The oceans have fewer photosynthetic organisms than terrestrial biomes.
(c) Productivity is determined largely by available water, light, and nutrients.
(d) Grasses have lower productivity than trees.

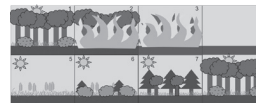


7. The photograph below depicts:



(a) Intraspecific competition and predation
(b) Cooperation
(c) Intra- and interspecific competition and predation
(d) Interspecific competition and predation

8. The cartoon sequence depicted below illustrates?



(a) Primary succession and ecosystem resilience
(b) Secondary succession and ecosystem resilience
(c) Secondary succession and ecosystem resistance
(d) Primary succession and ecosystem resistance

9. Which of the following could accelerate current rates of global warming:

(a) Increased rate of fossil fuel use
(b) Deforestation without replanting
(c) Decrease in ice-albedo
(d) All of the above

TEST

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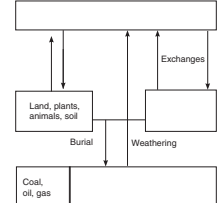
10. (a) Use the following labels to complete the diagram of the carbon cycle shown right: atmosphere, geosphere, oceans, respiration (R), photosynthesis (PS).

(b) Add arrows to show deforestation (D) and combustion (C) of fossil fuels:

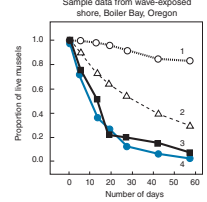
(c) Combustion and deforestation result in another 9 petagrams of carbon being added to the carbon cycle. Add this value to the diagram.

(d) About 3 petagrams is taken up by photosynthesis and 2 petagrams is taken up by the oceans. Add these values to the appropriate labels on the diagram.

(e) How much extra carbon is actually added to the atmosphere by deforestation and combustion?



11. The plot below right shows the results of a 60 day experiment to investigate the interactions between rocky shore organisms, whelks (*Nucella* spp.), the starfish *Pisaster*, and a species of mussel (*Mytilus*) which is preyed on by both *Nucella* and *Pisaster*. The experiment involved replicate groups of mussels in experimental areas of the shore. From some areas, the researchers removed both *Pisaster* and *Nucella*, from some areas only *Pisaster* or only *Nucella*, and from some areas neither predator was removed.



(a) Which line represents the control? _____

(b) What was the effect of removing both predators? _____

(c) What was the effect of removing only *Pisaster*? _____

(d) What was the effect of removing only *Nucella*? _____

(e) Do these results support the statement that *Pisaster* is a keystone species in rocky shore ecosystems in Oregon? Explain your reasoning, using the data above to justify your statement.

TEST

Choosing Activities for Home Study

Many of the book's activities are ideal for homework or as vehicles for a quick self assessment. Review activities are ideal as homework. They provide a way to review a topic that has recently been completed, while at the same time facilitating consolidation by presenting the material in a slightly different way. The information for review activities can be found within the chapter, although stronger students may not need to refer back to source material to complete the set work. Generally, homework activities should revise completed topics or provide a basic entry-level introduction.

244 Nutrient Cycles
Key Idea: Matter cycles through the biotic and abiotic compartments of Earth's ecosystems in nutrient cycles. Nutrient cycles move and transfer chemical elements (e.g. carbon, hydrogen, nitrogen, and oxygen) through the abiotic and biotic components of an ecosystem. Commonly, nutrients are recycled in the form of molecules rather than elemental form in order to be more readily available to them. The supply of nutrients is limited.

Essential nutrients		
Macronutrient	Common form	Function
Carbon (C)	CO ₂	Organic molecules
Oxygen (O)	O ₂	Respiration
Hydrogen (H)	H ₂ O	Cellular hydration
Nitrogen (N)	N ₂ , NO ₃ ⁻ , NH ₄ ⁺	Proteins, nucleic acids
Potassium (K)	K ⁺	Principal ion in cells
Phosphorus (P)	H ₂ PO ₄ ⁻ , HPO ₄ ²⁻	Nucleic acids, lipids
Calcium (Ca)	Ca ²⁺	Membrane permeability
Magnesium (Mg)	Mg ²⁺	Chlorophyll
Sulfur (S)	SO ₄ ²⁻	Proteins
Micronutrient		
Micronutrient	Common form	Function
Iron (Fe)	Fe ²⁺ , Fe ³⁺	Chlorophyll, blood
Manganese (Mn)	Mn ²⁺	Enzyme activation
Molybdenum (Mo)	MoO ₄ ²⁻	Nitrogen metabolism
Copper (Cu)	Cu ²⁺	Enzyme activation
Sodium (Na)	Na ⁺	Ion in cells
Silicon (Si)	Si(OH) ₄	Support tissues

150 Innate Behaviors
Key Idea: Innate behavior is a behavioral response to stimuli and performed without any prior learning. Innate behaviors are inherited without any prior experience and play important roles in survival of young.

107 The Human Digestive Tract
Key Idea: Interactions between the tissues and organs in the different regions of the digestive tract maximize the efficiency of digestion and absorption. The human digestive system (gut) is a tubular tract, which is regionally specialized into a complex series of organs and glands that function in sequence to process food. Specialization of organs, so that each carries out a specific role, maximizes the efficiency with which food is processed.

KNOW 244 (WEB) (CONNECT 21 AP1)

KNOW 150 (WEB) (CONNECT 147 AP2)

KNOW 148 (CONNECT AP2)

KNOW 155 (CONNECT AP2)

KNOW 156 (CONNECT AP2)

KNOW 29 (CONNECT AP2)

KNOW 107 (WEB)

Tailor your program so that simpler activities are most often set as homework exercises, especially for less able students who may be easily discouraged.

Most students will have access to the internet. If they are having trouble understanding a subject or visualizing a process, encourage them to visit the assigned **Weblinks** where these are provided.

Summary activities are ideal as homework because they involve reviewing completed work. This activity provides an opportunity for students to recall and apply knowledge about regional and functional specialization in mammalian digestive tracts.