HQIM Bid Package: AP® Science

Created for Mississippi Department of Education
August 2025

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brady.svec@pearson.com

Subjects & Titles Included

MS Course Code	Grade Level/Subject	Suggested Pearson Title	Format	Digital Platform
260143	**AP® Biology**	Campbell Biology In Focus, ©2025 AP® Edition	print + digital	Mastering®
400523	**AP® Chemistry**	Chemistry: The Central Science, ©2023 AP® Edition	print + digital	Mastering®
260609	**AP® Environmental Science**	Environment: The Science Behind the Stories, ©2021 AP® Edition	print + digital	Mastering®
AP® Physics C 400841 400861 AP® Physics 2 400827	**AP® Physics**	Physics for Scientists and Engineers: A Strategic Approach with Modern Physics, ©2022 AP® Edition (AP Physics C) College Physics: A Strategic Approach, ©2023 AP® Edition (AP Physics 2)	print + digital	Mastering®

Presentation Video

Secondary & AP® Science: Biology

https://youtu.be/aifI_FWDImA

Secondary & AP® Science: Chemistry & Physics

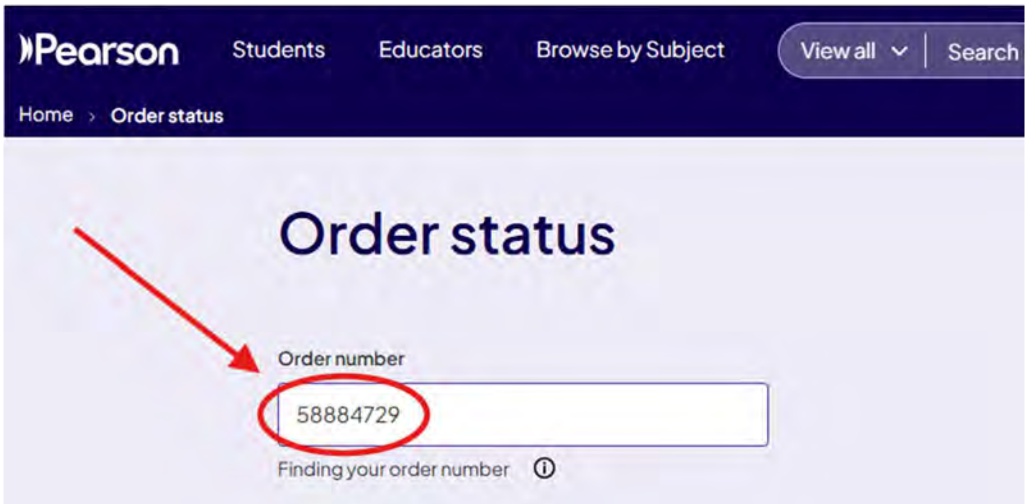
https://youtu.be/Aen0aPdxyZ0

Physical Science & AP® Environmental Science

https://youtu.be/w9iN1wBslXk

Physical Sample Information

Pearson has provided physical samples of the textbooks in this section (pupil edition and teacher edition, if printed teacher edition is available). The Pearson order number for the shipment is: **58884729**. Details and tracking numbers can be found on our Order Status Page after entering the order number.



Pearson Order Status Page

At the time of submission, the items below are backordered. However, they are scheduled for shipment/delivery before the state textbook committees meet in mid-September.

Ordered Item	Item Description	Status	Schedule Ship Date
9780138255213	Campbell Biology In Focus, ©2025 AP® Edition	Awaiting Shipping	8/21/2025
9780137574728	College Physics: A Strategic Approach, ©2023 AP® Edition	Awaiting Shipping	9/3/2025

Campbell Biology in Focus, 4th Edition, AP® Edition

By: Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky

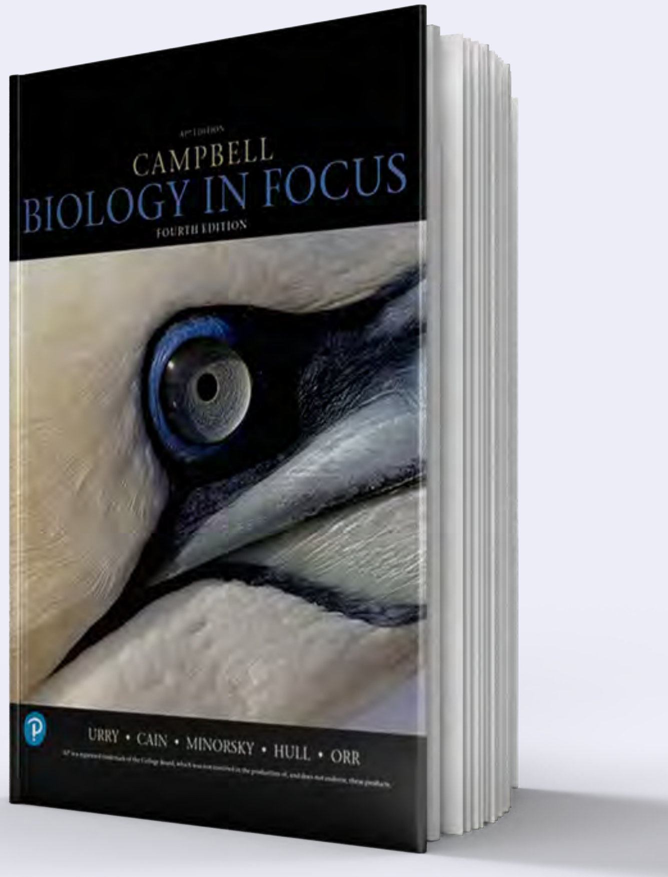
Sharpening Scientific Skills. Centering On Key Concepts.

Campbell Biology in Focus, AP® Edition delivers a streamlined approach to biology—helping high school students master essential concepts while building real-world scientific thinking skills. The 4th Edition emphasizes conceptual understanding over memorization, supporting students with structured content, relevant context, and a wide array of engaging visuals and practice tools.

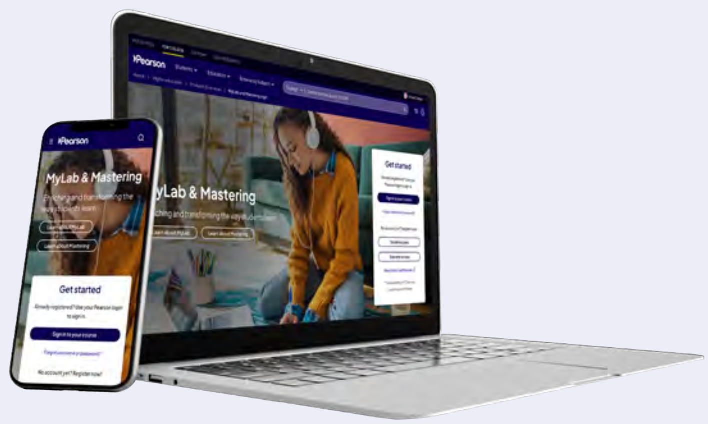
Updated to reflect new developments and aligned with the College Board's AP® Biology Curriculum Framework (Effective Fall 2025), this edition includes timely topics such as climate modeling, global change, and stem cell research—preparing students for the AP® exam and the world beyond it.

Features of the program:

- **Scientific Skills Exercises** use real data to strengthen data analysis, experimental design, and graphing skills.
- **Problem-Solving Exercises** provide opportunities to apply knowledge and interpret scientific data.
- **Visual Overviews and Visualizing Figures** support conceptual understanding through diagrams, models, and illustrations.
- **Active Reading Guides** help teachers differentiate instruction and provide scaffolding.
- **Chapter Review Questions** are aligned to the AP® Big Ideas and Science Practices.
- **AP® Test Prep Workbook** offers targeted review, skill-building, and two full practice exams.
- **Assignable Labs** align to AP® Learning Objectives and Science Practices.
- **Mastering® Biology** delivers interactive tutorials, personalized learning paths, and robust analytics for students and teachers.
- **eTextbook Resources** include CheckPoint interactive questions with real-time feedback and answer-specific guidance.



Pearson Mastering



An immersive and adaptable online learning platform that empowers students to learn through active and engaging experiences. With personalized tutorials, analytics, and feedback, Mastering® helps high school students develop a strong foundation in science and engineering programs.

College Board alignment:

Campbell Biology in Focus, 4th Edition, AP® Edition is fully aligned to the College Board's AP® Biology Curriculum Framework, Effective Fall 2025.

Pearson

Table of Contents:

ISBN List

9780135448144	AP® Edition + Modified Mastering with Pearson eText -- 1 Year
9780138255213	AP® Edition + Modified Mastering with Pearson eText -- 6 Year
9780138238865	AP® Edition HS Digital Modified Mastering with Pearson eText -- 1 Year
9780138238889	AP® Edition HS Digital Modified Mastering with Pearson eText -- 6 Year

Pearson

Chemistry: The Central Science, 15th Edition, AP® Edition

By: Theodore E. Brown, H. Eugene LeMay, Bruce E. Bursten, Catherine Murphy, Patrick Woodward, Matthew E. Stoltzfus

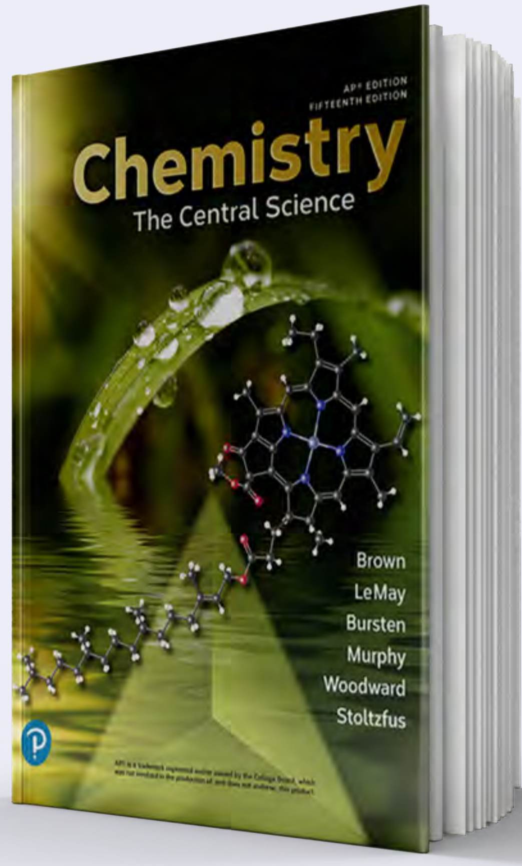
Built on Accuracy. Designed for Real-World Thinking.

Chemistry: The Central Science, 15th Edition, AP® Edition blends scientific accuracy with clarity and relevance to help students develop a deep, lasting understanding of chemistry. Known for its strong pedagogical foundation, this trusted program connects conceptual understanding to real-world applications—preparing students for AP® Chemistry and beyond.

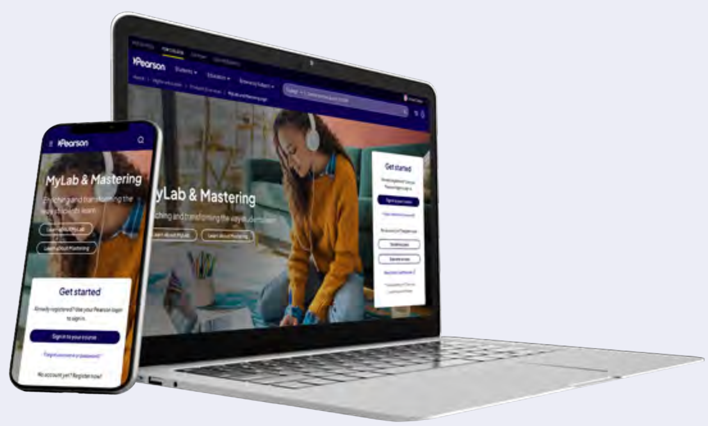
This edition is updated with modern data, self-assessment exercises, media, and resources to help students think like scientists while building problem-solving skills. This text is also aligned with the AP® Chemistry Course and Exam Description (Fall 2024).

Features of the program:

- **Visualizing Concepts Exercises** and **Molecular Illustrations** support conceptual understanding with models, graphs, and visual aids.
- **Analyze/Plan/Solve/Check Framework** models structured problem-solving and is featured in narrated SmartFigures.
- **Design an Experiment** exercises encourage students to apply conceptual understanding and think like scientists.
- **Chemistry & Sustainability Boxes** connect content to current events, environmental issues, and medical discoveries.
- **Exam Prep Questions** and **Self-Assessment Exercises** reinforce core concepts and build test-taking skills.
- **End-of-Chapter Problem Sets** include new questions with real data and modern applications.
- **Mastering® Chemistry** offers narrated worked examples, self-assessments, Dynamic Study Modules, Interactive Sample Exercises, and Exam Prep Videos designed to engage learners and support their academic success. The accompanying eText features valuable study aids, including highlighting, note-taking, flashcards, and an AI-powered study tool.



Mastering Chemistry



An immersive and adaptable online learning platform that empowers students to learn through active and engaging experiences. With personalized tutorials, analytics, and feedback, Mastering® Chemistry helps high school students develop a strong foundation in science and engineering programs.

College Board alignment:

Chemistry: The Central Science, 15th Edition, AP® Edition is fully aligned to the College Board's AP® Chemistry Course and Exam Description (Fall 2024).

Table of Contents:

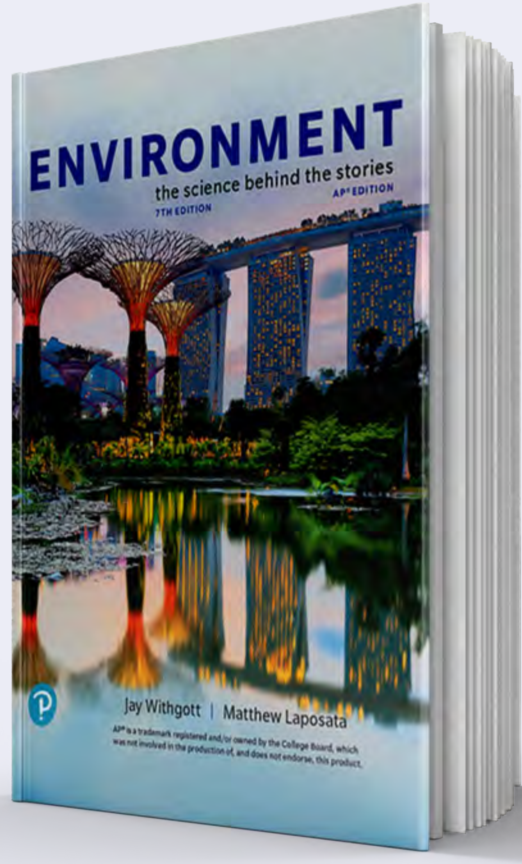
ISBN List

9780135447963	AP® Edition + Modified Mastering with Pearson eText - - 1 Year
9780137606801	AP® Edition + Modified Mastering with Pearson eText - - 6 Year
9780137606764	AP® Edition + Modified Mastering with Pearson eText - - 6 Year + AP® Chemistry Test Prep Workbook
9780137606719	AP® Edition HS Digital Modified Mastering with Pearson eText-- 1 Year
9780137606702	AP® Edition HS Digital Modified Mastering with Pearson eText -- 6 Year
9780137606818	AP® Chemistry Test Prep Workbook

Pearson

Environment: The Science Behind the Stories, 7th Edition, AP® Edition

By: Jay H. Withgott, Matthew Laposata



Real Stories. Real Science. Real Solutions.

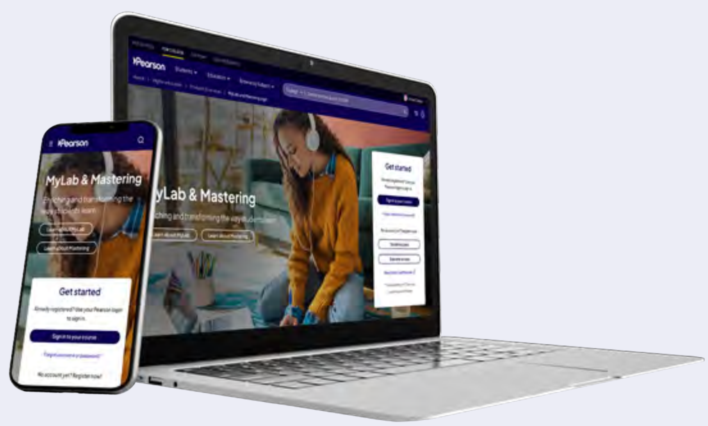
Environment: The Science Behind the Stories, AP® Edition invites students to explore environmental science through real-world research, case studies, and practical solutions. This engaging program combines storytelling and scientific literacy to empower students to think critically, analyze data, and see the relevance of environmental science in their lives.

With a strong focus on inquiry, systems thinking, and sustainability, this edition builds both knowledge and problem-solving confidence while preparing students for the AP® Environmental Science Exam.

Features of the program:

- **Success Story** features highlight discrete stories (one per chapter) of successful efforts to address environmental problems, ranging from local examples (such as prairie restoration in Chicago) to national and global achievements (such as halting ozone depletion by treaty or removing lead from gasoline). Students can explore data behind these solutions with new *Success Story Coaching Activities in Mastering Environmental Science.*
- **Data Graphic** features provide new and visually striking features that bring to life key questions in environmental science. The five *DataGraphics* seek to strengthen student skills in analytical thinking by fostering the ability to draw reasonable conclusions when provided with relevant data. Each *DataGraphic* poses a question, assembles an array of datasets, and leads to a unifying conclusion, guiding students through a synthesis of quantitative information in an inviting and appealing manner.
- **Central Case Studies** anchor each chapter with real people, real places, and real problems—then circle back in **Connect and Continue** reflections.
- **Mastering® Environmental Science** features Video Field Trips, GraphIt! activities, Everyday Environmental Science videos, Dynamic Study Modules, MapMaster™ 3 activities, and Process of Science activities.

Pearson Mastering



An immersive and adaptable online learning platform that empowers students to learn through active and engaging experiences. With personalized tutorials, analytics, and feedback, Mastering® helps high school students develop a strong foundation in science and engineering programs.

College Board alignment:

Environment: The Science Behind the Stories, 7th Edition, AP® Edition is aligned with the AP® Environmental Science Course and Exam Description (Fall 2020) and prepares students for both the exam and environmental citizenship.

Pearson

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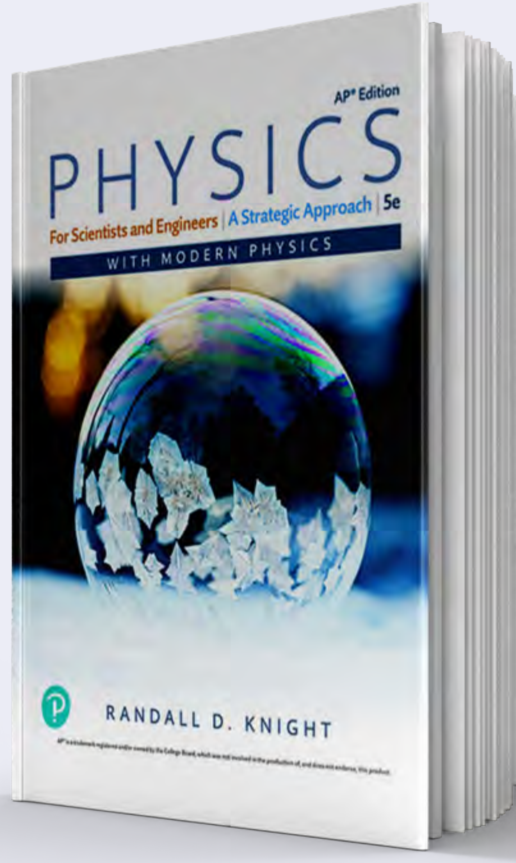
9780135447697	AP® Edition + Modified Mastering with Pearson eText- - 1 Year
9780136451471	*AP® Edition + Modified Mastering with Pearson eText - - 6 Year*
9780136738503	AP® Edition + Modified Mastering with Pearson eText- - 6 Year + AP® Environmental Science Test Prep Workbook
9780137451890	AP® Edition Modified Mastering with Pearson eText-- 1 Year
9780137451944	AP® Edition Modified Mastering with Pearson eText -- 6 Year
9780136451457	AP® Environmental Science Test Prep Workbook

Physics for Scientists and Engineers: A Strategic Approach with Modern Physics, 5th Edition, AP® Edition

By: Randall D. Knight



A Proven Program for Thinking Like a Physicist.

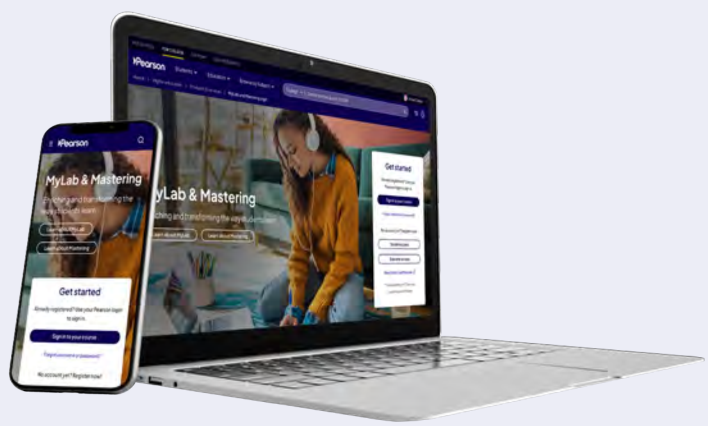
Physics for Scientists and Engineers, AP® Edition equips students to learn physics deeply, think critically, and solve problems with confidence. Based on insights from Physics Education Research (PER) and cognitive science, this program by Randall Knight emphasizes conceptual understanding, real-world applications, and structured problem-solving.

The 5th Edition includes updated content and optional topics that enrich the curriculum—from entropy and viscosity to Carnot efficiency—while staying tightly aligned to the AP® Physics C: Mechanics and AP® Physics C: Electricity and Magnetism Course Frameworks (Fall 2024).

Features of the program:

- **Model Boxes** connect concepts to real-world scenarios and guide model-based reasoning.
- **4-Step Problem-Solving Framework (Model/Visualize/Solve/Review)** helps students systematically approach physics challenges.
- **Tactics Boxes** provide clear, step-by-step methods to develop critical physics skills.
- **Looking Back Pointers** reinforce continuity and conceptual understanding across chapters.
- **Chapter Overviews** answer key questions and prepare students for upcoming material.
- **Pre-Lecture Videos and Reading Questions** identify misconceptions and support self-paced learning.
- **Video Tutor Solutions (VTS)** walk students through quantitative problem-solving steps, linking to related content.
- **Mastering® Physics** offers interactive tutorials, coaching activities, targeted feedback, real-time analytics, and assignable tutorials authored by Randall Knight.

Pearson Mastering



An immersive and adaptable online learning platform that empowers students to learn through active and engaging experiences. With personalized tutorials, analytics, and feedback, Mastering® helps high school students develop a strong foundation in science and engineering programs.

College Board alignment:

Physics for Scientists and Engineers: A Strategic Approach with Modern Physics, 5th Edition, AP® Edition aligns with the College Board's AP® Physics C: Mechanics and AP® Physics C: Electricity and Magnetism frameworks (Fall 2024).

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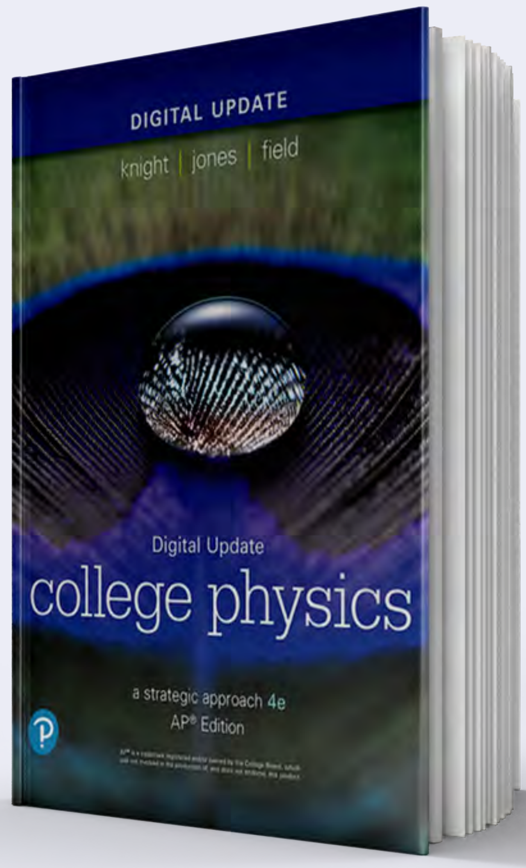
9780137452910	AP® Edition Digital Mastering with Pearson eText -- 1 Year
9780137452927	AP® Edition Digital Mastering with Pearson eText -- 6 Year

College Physics: A Strategic Approach, 4th Edition, AP® Edition

By: Randall D. Knight, Brian Jones, Stuart Field



Connecting Physics to Life—and Every Field of Study.

College Physics: A Strategic Approach, 4th Edition, AP® Edition makes physics relevant, engaging, and approachable for high school students. With a focus on real-world problem solving, this edition helps students understand why physics matters—and how to think like a physicist.

Clear, step-by-step problem-solving strategies, practical applications, and scaffolded skill-building resources prepare students for the AP® Physics 1 and AP® Physics 2 exams, while fostering long-term scientific literacy.

Features of the program:

- **Real-World Examples** and **Critical Thinking Problems** help students apply physics to everyday scenarios.
- **Tactics Boxes** guide students in skills like free-body diagrams and ray tracing, reinforcing core techniques.
- **Chapter Overviews and Learning Objectives** help students see the big picture and connect new ideas to prior knowledge.
- **STOP TO THINK Questions** combine complex visuals with self-check questions to deepen conceptual understanding.
- **Mastering® Physics** provides adaptive tutorials, interactive simulations, and personalized feedback. Mastering also provides over 600 videos, such as Pre-Lecture Videos, Video Tutor Solutions, Dynamic Figure Videos, and pause-and-predict videos recorded by author Brian Jones.

Mastering Physics

An immersive and adaptable online learning platform that empowers students to learn through active and engaging experiences. With personalized tutorials, analytics, and feedback, Mastering® Physics helps high school students develop a strong foundation in science and engineering programs.

College Board alignment:

College Physics: A Strategic Approach, 4th Edition, AP® Edition aligns to both the AP® Physics 1 and AP® Physics 2 Course Frameworks (Fall 2024).

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ISBN List

9780135447932	AP® Edition + Modified Mastering with Pearson eText - - 1 Year
9780137574728	AP® Edition + Modified Mastering with Pearson eText - - 6 Year
9780137451722	AP® Edition Digital Modified Mastering with Pearson eText-- 1 Year
9780137452033	AP® Edition Digital Modified Mastering with Pearson eText -- 6 Year

Curriculum Scope & Sequence

Dear AP Biology Teacher,

I am delighted to introduce to you a pacing guide designed specifically for high school AP Biology courses using Campbell Biology in Focus. As an experienced teacher, I understand the challenges of designing a comprehensive curriculum that aligns with the rigorous standards of the AP program while also accommodating the unique needs and pace of each classroom. With this in mind, I have developed this pacing guide as a starting point to support your instructional journey throughout the academic year.

It is important to note that this pacing guide is not a one-size-fits-all solution. Every classroom is different, with diverse student populations, teaching styles, and learning environments. Therefore, I encourage you to adapt and customize this guide to best suit the needs of your students and the dynamics of your classroom. Consider it a framework that you can modify, expand, or condense as necessary to ensure a meaningful and enriching learning experience for your AP Biology students.

I hope that this pacing guide serves as a valuable resource and contributes to the success of your AP Biology program. Thank you for your dedication to providing high-quality education, and I wish you and your students a rewarding and successful academic year ahead.

Sincerely, Robin Bulleri

<table>
<tr><th>AP Biology</th><th>Week 1</th><th>Matter & Water</th></tr>
<tr><td colspan="2">Overview & Notes
The focus for Week 1 is a review of basic chemistry and the structure and properties of water.
If your students have a strong background in chemistry, you might move through this material more quickly.
It might be helpful to give a pretest of the material in Unit 1 to gauge your students’ prior knowledge.
Properties of water are important because these concepts relate to future topics, such as protein structure, cellular transport, and transpiration.</td><td>Science Practices
1 - Concept Explanation
2 - Visual Representations
4 - Representing and Describing Data</td></tr>
<tr><td colspan="2">Important Terms
Matter
Element
Compound
Atom
Energy
Valence electron
Covalent bond
Ionic bond
Hydrogen bond
Molecule
Electronegativity
Polarity
Adhesion
Cohesion
Surface tension
Specific heat
Evaporative cooling
Calorie
Solute
Solvent
Solution
Hydrophobic
Hydrophilic
Acid
Base
pH
Buffer</td><td>Topics
2.1 Elements & Compounds
2.2 Atomic structure
2.3 Chemical bonding
2.4 Chemical reactions
2.5 Hydrogen bonding and properties of water</td></tr>
<tr><td colspan="2">Alignment to CED Frameworks
Explain how the properties of water that result from its polarity and hydrogen bonding affect its biological function. SYI-1.A</td><td>Biology in Focus Reading
Concept 2.1-2.5
Textbook Practice
Concept Check 2.2, question #2
Concept Check 2.5, questions #1-5
Test Your Understanding questions #1-14</td></tr>
</table>

AP Biology	Week 2	Biological Macromolecules

Overview & Notes

- The focus for Week 2 is the structure and function of biological macromolecules.
- Understanding of the relationship of monomers and polymers, as well as molecule-building and molecule-breaking reactions is important.
- Protein structure is a recurring topic that needs some attention. Protein structure and functions are discussed later with cellular energetics, protein synthesis, and cellular communication.
- Consider activities where students create models of relevant molecules.

Science Practices

- 1 - Concept Explanation
- 2 - Visual Representations
- 4 - Representing and Describing Data

Important Terms

- Hydrocarbons
- Isomers
- Functional groups
- Polymer
- Monomer
- Dehydration synthesis
- Hydrolysis
- Enzymes
- Carbohydrates
- Monosaccharides
- Disaccharides
- Polysaccharides
- Glycosidic linkage
- Lipid
- Fatty acid
- Glycerol
- Fat
- Phospholipid
- Steroid
- Cholesterol
- Protein
- Peptide bond
- Polypeptide
- Amino acid
- Denaturation
- Nucleic acids
- Nucleotide
- Double helix
- Antiparallel

Topics

- 3.1 Carbon Chemistry
- 3.2 Macromolecules
- 3.3 Carbohydrates
- 3.4 Lipids
- 3.5 Proteins
- 3.6 Nucleic Acids
- 3.7 Proteomics and Genomics

Alignment to CED Frameworks

- Describe the composition of macromolecules required by living organisms. *ENE-1.A*
- Describe the properties of the monomers and the type of bonds that connect the monomers in biological macromolecules. *SYI-1.B*
- Describe the properties of the monomers and the type of bonds that connect the monomers in biological macromolecules. *SYI-1.AB*
- Explain how a change in the subunits of a polymer may lead to changes in structure or function of the macromolecule. *SYI-1.C*
- Describe the structural similarities and differences between DNA and RNA. *IST-1.A*

Biology in Focus Reading

- Concept 3.1-3.7

Textbook Practice

- Concept check 3.1, questions #1-4
- Concept check 3.2, questions #1-2
- Concept check 3.3, questions #1-3
- Concept check 3.4, questions #1-3
- Concept check 3.5, questions #1-2

AP Biology	Week 3	Cell Structure & Function

Overview & Notes

- The focus for Week 3 is the structure and function of cells.
- Unit 2 can be taught in two parts, cell structure and function, and the cell membrane and transport.
- Focus on the relationships of structure to function. Some organelles, such as the mitochondria and chloroplasts are revisited later in the course. This unit should provide an overview of their structure and function.

Science Practices

- 1 - Concept Explanation
- 2 - Visual Representations
- 6 - Argumentation

Important Terms

- Organelles
- Cytosol
- Prokaryotic cell
- Eukaryotic cell
- Nucleoid
- Cytoplasm
- Plasma membrane
- Nucleus
- Nuclear envelope
- chromosomes/chromatin
- Nucleolus
- Ribosomes
- Endomembrane systems
- Vesicles
- Smooth and rough endoplasmic reticulum
- Golgi apparatus
- Lysosome
- Phagocytosis
- Vacuoles
- Mitochondria
- Chloroplasts
- Endosymbiont theory
- Peroxisome
- Cytoskeleton
- Centrioles
- Cilia & flagella
- Cell wall
- plasmodesmata

Topics

- 4.1 Microscopes
- 4.2 Cell Compartmentalization
- 4.3 The Nucleus
- 4.4 Endomembrane System
- 4.5 Mitochondria & Chloroplasts
- 4.6 Cytoskeleton
- 4.7 Extracellular Components
- 4.8 Cell Size

Alignment to CED Frameworks

- Describe the structure and/or function of subcellular components and organelles. *SYI-1.D*
- Explain how subcellular components and organelles contribute to the function of the cell. *SYI-1.E*
- Explain the effect of surface area-to-volume ratios on the exchange of materials between cells or organisms and the environment. *ENE-1.B*
- Describe the membrane-bound structures of the eukaryotic cell. *ENE-2.K*
- Explain how internal membranes and membrane-bound organelles contribute to compartmentalization of eukaryotic cell functions. *ENE-2.L*
- Describe similarities and/or differences and compartmentalization between prokaryotic and eukaryotic cells. *EVO-1.A*
- Describe the relationship between the functions of endosymbiotic organelles and their free-living ancestral counterparts. *EVO-1.B*

Biology in Focus Reading

- Concept 4.1-4.8

Textbook Practice

- Concept check 4.2, questions #1-2
- Concept check 4.3, questions #1-3
- Concept check 4.4, questions #1-3
- Concept check 4.5, questions #1-3
- Concept check 4.7, questions #1-2

AP Biology	Week 4	Cell Structure & Function

Overview & Notes

- The focus for Week 4 is the structure and function of the cell membrane and cell transport.
- Consider conducting a lab related to diffusion or osmosis.
- Creating models of the cell membrane can be a powerful learning tool for understanding the dynamic nature of cells.

Science Practices

- 2 - Visual Representations
- 4 - Representing or Describing Data
- 5 - Statistical Tests and Data Analysis

Important Terms

- Amphipathic
- Fluid mosaic model
- Integral proteins
- Peripheral proteins
- Transmembrane proteins
- Selective permeability
- Transport proteins
- Aquaporins
- Diffusion
- Concentration gradient
- Passive transport
- Osmosis
- Tonicity
- Isotonic
- Hypotonic
- Hypertonic
- Plasmolysis
- Facilitate diffusion
- Active transport
- Exocytosis
- Endocytosis

Topics

- 5.1 Cellular Membranes
- 5.2 Membrane Structure
- 5.3 Passive Transport
- 5.4 Active Transport
- 5.5 Bulk Transport

Alignment to CED Frameworks

- Explain how specialized structures and strategies are used for the efficient exchange of molecules to the environment. *ENE-1.C*
- Describe the roles of each of the components of the cell membrane in maintaining the internal environment of the cell. *ENE-2.A*
- Explain how the structure of biological membranes influences selective permeability. *ENE-2.C*
- Describe the role of the cell wall in maintaining cell structure and function. *ENE-2.D*
- Describe the mechanisms that organisms use to maintain solute and water balance. *ENE-2.E*
- Describe the mechanisms that organisms use to transport large molecules across the plasma membrane. *ENE-2.F*
- Explain how the structure of a molecule affects its ability to pass through the plasma membrane. *ENE-2.G*
- Explain how concentration gradients affect the movement of molecules across membranes. *ENE-2.H*
- Explain how osmoregulatory mechanisms contribute to the health and survival of organisms. *ENE-2.I*
- Describe the processes that allow ions and other molecules to move across membranes. *ENE-2.J*

Biology in Focus Reading

- Concept 5.1-5.5

Textbook Practice

- Concept check 5.1, questions #1-2
- Concept check 5.2, questions #1-3
- Concept check 5.3, questions #1-2
- Concept check 5.4, questions #1-3
- Concept check 5.5, questions #1-3

AP Biology	Week 5	Cellular Energetics

Overview & Notes

- The focus for Week 5 is Unit 3: Cellular Energetics, particularly enzymes.
- This unit is conceptually difficult. Chunk the material, and use or have students create graphic organizers to help them visualize the content.
- Consider including a lab or hands-on activity related to enzymes during this week.
- Concepts 6.1 and 6.2 provide helpful background information, but are not specifically included in the Frameworks.

Science Practices

- 2 - Visual Representations
- 4 - Representing or Describing Data
- 5 - Statistical Tests and Data Analysis

Important Terms

- Catabolic pathways
- Anabolic pathways
- Energy
- Thermodynamics
- Exergonic reaction
- Endergonic reaction
- Energy Coupling
- ATP
- Catalyst
- Enzyme
- Activation energy
- Substrate
- Enzyme-substrate complex
- Active site
- Induced fit
- Cofactors
- Coenzyme
- Competitive inhibitors
- Noncompetitive inhibitors
- Allosteric regulation
- cooperativity
- Feedback inhibition

Topics

- 6.1 Metabolism
- 6.2 Free-energy
- 6.3 ATP
- 6.4 Enzymes
- 6.5 Regulation of Enzyme Activity

Alignment to CED Frameworks

- Describe the properties of enzymes. *ENE-1.D*
- Explain how enzymes affect the rate of biological reactions. *ENE-1.E*
- Explain how changes to the structure of an enzyme may affect its function. *ENE-1.F*
- Explain how the cellular environment affects enzyme activity. *ENE-1.G*
- Describe the role of energy in living organisms. *ENE-1.H*

Biology in Focus Reading

- Concept 6.1-6.5

Textbook Practice

- Concept check 6.3, questions #1-3
- Scientific Skills Exercise, page 139
- Concept check 6.4, questions #1-4
- Concept check 6.5, questions #1-2

AP Biology	Week 6	Cellular Energetics

Overview & Notes

- The focus for Week 6 is Unit 3: Cellular Energetics, particularly cellular respiration.
- Students do not need to memorize the intermediate compounds produced during these processes.
- Focus on where in the cell each process occurs, and the products of those processes.
- Consider including a lab or hands-on activity related to cellular respiration during this week.
- This unit is conceptually difficult. Chunk the material, and use or have students create graphic organizers to help them visualize the content.

Science Practices

- 1 - Concept Explanation
- 3 - Questions and Methods
- 5 - Statistical Tests and Data Analysis

Important Terms

- Fermentation
- Aerobic cellular respiration
- Redox reactions
- NAD+/NADH
- Electron transport chain
- Glycolysis
- Citric acid cycle
- Oxidative phosphorylation
- Substrate-level phosphorylation
- Acetyl CoA
- ATP Synthase
- Chemiosmosis
- Alcohol fermentation
- Lactic acid fermentation

Topics

- 7.1 Catabolic Pathways
- 7.2 Glycolysis
- 7.3 Citric Acid Cycle
- 7.4 Oxidative Phosphorylation
- 7.5 Fermentation
- 7.6 Metabolic Pathways

Alignment to CED Frameworks

- Describe the processes that allow organisms to use energy stored and biological macromolecules. *ENE-1.K*
- Explain how cells obtain energy from biological macromolecules in order to power cellular functions. *ENE-1.L*
- Explain the connection between variation and the number and the types of molecules within cells to the ability of the organism to survive and/or reproduce in different environments. *SYI-3.A*

Biology in Focus Reading

- Concept 7.1-7.6

Textbook Practice

- Concept check 7.1, questions #1-3
- Concept check 7.2, questions #1
- Concept check 7.3, questions #1-2
- Concept check 7.4,

	questions #1-3 • Concept check 7.5, questions #1-2 • Concept check 7.6, questions #1-2

AP Biology	Week 7	Cellular Energetics

Overview & Notes

- The focus for Week 7 is Unit 3: Cellular Energetics, particularly photosynthesis.
- Students do not need to memorize the intermediate compounds produced during these processes.
- Focus on where in the cell each process occurs, and the products of those processes.
- Consider including a lab or hands-on activity related to photosynthesis during this week.
- Information about C_4 and CAM plants are not included in the Frameworks, but are nice examples of adaptations and natural selection.

Science Practices

- 2 - Visual Representations
- 4 - Representing or Describing Data
- 5 - Statistical Tests and Data Analysis

Important Terms

- Photosynthesis
- Autotroph
- Heterotroph
- Chloroplast
- Mesophyll
- Stomata
- Stroma
- Thylakoids
- Chlorophyll
- Light reactions
- Calvin cycle
- NADP+/NADPH
- Photophosphorylation
- Carbon fixation
- Wavelength
- Electromagnetic spectrum
- Photons
- Absorption spectrum
- Photosystems I and II
- Glyceraldehyde 3-phosphate (G3P)
- Carbon fixation
- Rubisco

Topics

- 8.1 Photosynthesis & the Biosphere
- 8.2 Photosynthesis
- 8.3 Light Reactions
- 8.4 Calvin Cycle
- 8.5 Importance of Photosynthesis

Alignment to CED Frameworks

- Describe the photosynthetic processes that allow organisms to capture and store energy. *ENE-1.I*
- Explain how cells capture energy from light and transfer it to biological molecules for storage and use. *ENE-1.J*
- Explain the connection between variation and the number and the types of molecules within cells to the ability of the organism to survive and/or reproduce in different environments. *SYI-3.A*

Biology in Focus Reading

- Concept 8.1-8.5

Textbook Practice

- Concept check 8.1, questions #1-2
- Concept check 8.2, questions #1-3
- Concept check 8.3, questions #1-3
- Concept check 8.4, questions #1-4
- Concept check 8.5, question #1

<table>
<tr><th>AP Biology</th><th>Week 8</th><th>Cell Communication</th></tr>
<tr><td colspan="2">Overview & Notes
Week 8 introduces Unit 4: Cell Communication and the Cell Cycle with a focus on cell signaling.
This is a short, but dense textbook section, but cell signaling is an important topic that is revisited in other units.
Consider having students research a disease or condition related to cell communication dysfunction.</td><td>Science Practices
1 - Concept Explanation
2 - Visual Representations</td></tr>
<tr><td colspan="2">Important Terms
Endocrine
Paracrine
Hormones
Reception
Transduction
Signal transduction pathway
Ligand
G protein
G protein-coupled receptor
Ligand-gated ion channel
Protein kinases
Phosphorylation cascade
Protein phosphatases
Second messengers
Cyclic AMP (cAMP)</td><td>Topics
5. 6 Cell Signaling</td></tr>
<tr><td colspan="2">Alignment to CED Frameworks
Describe the ways that cells can communicate with one another. IST-3.A
Describe the components of a signal transduction pathway. IST-3.C
Describe the role of components of a signal transduction pathway in producing a cellular response. IST-3.D
Describe the different types of cellular responses elicited by a signal transduction pathway. IST-3.F
Explain how a change in the structure of any signaling molecule affects the activity of the signaling pathway. IST-3.G</td><td>Biology in Focus Reading
Concept 5.6
Textbook Practice
Concept check 5.6, questions #1-3</td></tr>
</table>

AP Biology	Week 9	Cell Communication

Overview & Notes

- Week 9 continues Unit 4: Cell Communication and the Cell Cycle with a focus on endocrine and nervous signaling.
- Although specific signaling pathways are not mentioned in the Framework, consider including endocrine and nervous signaling pathways as illustrative examples.

Science Practices

- 1 - Concept Explanation
- 2 - Visual Representations

Important Terms

- Endocrine systems
- Hypothalamus
- Negative feedback
- Positive feedback
- Neuron
- Dendrite
- Axon
- Synapse
- Neurotransmitters
- Membrane potential
- Resting potential
- Sodium-potassium pump
- Action potential
- Threshold
- Hyperpolarization
- Depolarization
- Refractory Period
- Saltatory conduction
- Acetylcholine

Topics

- 32.2 Endocrine and Nervous Systems
- 32.3 Feedback Control
- 37.1 Neurons
- 37.2 Ion Pumps
- 37.3 Action Potentials
- 37.4 Synapses

Alignment to CED Frameworks

- Explain how cells communicate with one another over short and long distances. *IST-3.B*
- Describe the role of the environment in eliciting a cellular response. *IST-3.E*
- Describe positive and/or negative feedback mechanisms. *ENE-3.A*
- Explain how negative feedback helps maintain homeostasis. *ENE-3.B*
- Explain how positive feedback affects homeostasis. *ENE-3.C*

Biology in Focus Reading

- Concept 32.2 & 32.3
- Concept 37.1-37.4

Textbook Practice

- Concept check 32.2, questions #1-3
- Concept check 32.3, questions #1-3
- Concept check 37.1, questions #1-3
- Concept check 37.2, questions #1-3
- Concept check 37.3, questions #1-4
- Concept check 37.4, questions #1-3

AP Biology	Week 10	Cell Communication

Overview & Notes

- Week 10 continues Unit 4 with a focus on the cell cycle and cancer.
- Consider having students observe cells undergoing mitosis under a microscope.
- Students can compare data sets of time spent in each phase of mitosis in healthy and cancerous cells.

Science Practices

- 2 - Visual Representations
- 4 - Representing or Describing Data
- 5 - Statistical Tests and Data Analysis

Important Terms

- Cell division
- Chromosomes
- Chromatin
- Somatic cells
- Gametes
- Sister chromatids
- Centromere
- Mitosis
- Cytokinesis
- Cell Cycles
- Interphase
- G_1, S, and G_2 phases
- Prophase
- Prometaphase
- Metaphase
- Anaphase
- Telophase
- Mitotic spindle
- Centrosomes
- Kinetochore
- Metaphase plate
- Cleavage
- Cleavage furrow
- Cell plate
- Binary fission
- Cell Cycle control
- Checkpoint
- G_0 Phase
- Growth factor
- Density-dependent inhibition
- Anchorage dependence
- Tumor
- Oncogenes
- Proto-oncogenes
- Tumor suppressor genes
- P53 gene

Topics

- 9.1 Cell Division
- 9.2 Phases of Mitosis
- 9.3 Cell Cycle
- 16.3 Cancer

Alignment to CED Frameworks

- Explain how mitosis results in the transmission of chromosomes from one generation to the next. *IST-1.C*
- Describe the role of checkpoints in regulating the cell cycle. *IST-1.D*
- Describe the effects of disruptions to the cell cycle on the cell or organism. *IST-1.E*

Biology in Focus Reading

- Concept 9.1-9.3
- Concept 16.3

Textbook Practice

- Concept check 9.1 questions #1-2
- Concept check 9.2 questions #1-4
- Concept check 9.3 questions #1-4
- Concept check 16.3 questions #1-3

AP Biology	Week 11	Heredity

Overview & Notes

- Week 11 introduces Unit 5: Heredity with a focus on meiosis and Mendelian inheritance.
- Emphasize the differences between mitosis and meiosis, as well as the sources of genetic variation in organisms.

Science Practices

- 1 - Concept Explanation
- 2 - Visual Representations
- 3 - Questions and Methods

Important Terms

- Heredity
- Variation
- Genes
- Locus
- Asexual reproduction
- Clone
- Sexual reproduction
- Karyotype
- Homologous chromosomes/pairs
- Sex chromosomes
- Autosomes
- Diploid
- Haploid
- Fertilization
- Zygote
- Meiosis
- Meiosis I and II
- Synapsis
- Crossing over
- Chiasmata
- Tetrad
- Trait
- True-breeding
- Hybridization
- P generation
- F1 generation
- F2 generation
- Law of Segregation
- Alleles
- Dominant alleles
- Recessive alleles
- Punnett Square
- Homozygous
- Heterozygous
- Phenotype
- Genotype
- Testcross
- Monohybrid cross
- Dihybrid cross
- Law of Independent Assortment
- Multiplication rule
- Addition rule

Topics

- 10.1 Inheritance
- 10.2 Sexual Reproduction
- 10.3 Meiosis
- 10.4 Genetic Variation
- 11.1 Mendel
- 11.2 Probability

Alignment to CED Frameworks

- Explain how meiosis results in the transmission of chromosomes from one generation to the next. *IST-1.F*
- Describe similarities and/or differences between the phases and outcomes of mitosis and meiosis. *IST-1.G*
- Explain how the process of meiosis generates genetic diversity. *IST-1.H*
- Explain how shared, conserved, fundamental processes and features support the concept of common ancestry for all organisms. *EVO-2.A*

Biology in Focus Reading

- Concept 10.1-10.4
- Concept 11.1-11.2

Textbook Practice

- Concept check 10.1 questions #1-3
- Concept check 10.2 questions #1-4
- Concept check 10.3

• Explain the inheritance of genes and traits as described by Mendel's laws. *IST-1.I*	questions #1-2 • Concept check 10.4 questions #1-4 • Concept check 11.1 questions #1-3 • Concept check 11.2 questions #1-3

AP Biology	Week 12	Heredity

Overview & Notes

- Week 12 continues Unit 5 with a focus on Mendelian and complex inheritance.
- This is a good place in the course to teach the Chi-Square test using the exercise on page 254.
- Sickle-cell anemia, cystic fibrosis, Tay-Sachs disease, and Huntington's disease are illustrative examples for these topics.

Science Practices

- 4 - Representing or Describing Data
- 5 - Statistical Tests and Data Analysis
- 6 - Argumentation

Important Terms

- Complete dominance
- Incomplete dominance
- Codominance
- Pleiotropy
- Polygenic inheritance
- Pedigree
- Carriers
- Chromosome theory of inheritance
- Wild type
- Sex-linked genes
- X-linked genes
- Barr body
- Linked genes
- Genetic recombination
- Chi-square test
- Nondisjunction
- Monosomy
- Trisomy
- Polyploidy
- Deletion
- Duplication
- Inversion

Topics

- 11.3 Complex inheritance
- 11.4 Human Traits
- 12.1 Chromosomes
- 12.2 Sex-Linked Genes
- 12.3 Linked Genes
- 12.4 Chromosomal Alterations

Alignment to CED Frameworks

- Explain the inheritance of genes and traits as described by Mendel's laws. *IST-1.I*
- Explain deviations from Mendel's model of the inheritance of traits. *IST-1.J*
- Explain how the same genotype can result in multiple phenotypes under different environmental conditions. *SYI-3.B*
- Explain how chromosomal inheritance generates genetic variation in sexual reproduction. *SYI-3.C*

Biology in Focus Reading

- Concept 11.3-11.4
- Concept 12.1-12.4

Textbook Practice

- Concept check 11.3 questions #1-3
- Concept check 11.4 questions #1-2
- Concept check 12.1 questions #1-3
- Concept check 12.2 questions #1-3
- Concept check 12.3 questions #1-3
- Scientific Skills Exercise - Using the Chi-Square Test
- Concept check 12.4 questions #1-4

AP Biology	Week 13	Gene Expression & Regulation

Overview & Notes

- Week 13 begins Unit 6 with a focus on the structure and function of DNA.
- Consider using models to represent DNA and DNA replication, including base-pairing, direction of the molecule, and the semiconservative nature of replication.
- This unit is long, and should take at least four weeks to cover all the content.
- Emphasize the connections between DNA, protein, and traits. If a change occurs at the molecular level, there can be a change at the phenotype.

Science Practices

- 1 - Concept Explanation
- 2 - Visual Representations
- 3 - Questions and Methods

Important Terms

- Transformation
- Double helix
- Antiparallel
- Semiconservative model
- Replication fork
- Helicase
- Primer
- Primase
- DNA polymerases
- Leading strand
- Lagging strand
- Okazaki fragments
- DNA ligase
- Telomeres
- Chromatin

Topics

- 13.1 DNA
- 13.2 Proteins
- 13.3 Chromosomes

Alignment to CED Frameworks

- Describe the structures involved in passing hereditary information from one generation to the next. *IST-1.K*
- Describe the characteristics of DNA that allow it to be used at the hereditary material. *IST-1.L*
- Describe the mechanisms by which genetic information is copied for transmission between generations. *IST-1.M*

Biology in Focus Reading

- Concept 13.1-13.3

Textbook Practice

- Concept check 13.1 questions #1-2
- Concept check 13.2 questions #1-3
- Concept check 13.3 questions #1-2

<table>
<tr><th>AP Biology</th><th>Week 14</th><th>Gene Expression & Regulation</th></tr>
<tr><td colspan="2">

Overview & Notes

- Week 14 continues Unit 6 with a focus on the Central Dogma, particularly transcription.
- It is worth the time to discuss various mechanisms of RNA processing, as these topics will relate to gene expression later on.

</td><td>

Science Practices

- 1 - Concept Explanation
- 2 - Visual Representations
- 3 - Questions and Methods

</td></tr>
<tr><td colspan="2">

Important Terms

- Gene expression
- Transcription
- Messenger RNA (mRNA)
- Translation
- Ribosomes
- Primary transcript
- Triplet code
- Template strand
- Codons
- RNA polymerase
- Promoter
- Terminator
- Transcription initiation complex
- TATA box
- RNA processing
- 5’ cap
- Poly-A tail
- RNA splicing
- Introns
- Exons
- Spliceosome

</td><td>

Topics

- 14.1 Genes and Proteins
- 14.2 Transcription
- 14.3 RNA Processing

</td></tr>
<tr><td colspan="2">

Alignment to CED Frameworks

- Describe the mechanisms by which genetic information flows from DNA to RNA to protein. *IST-1.N*
- Describe how the phenotype of an organism is determined by its genotype. *IST-1.O*
- Describe the various mutations. *IST-2.E*
- Explain how changes in genotype may result in changes in phenotype. *IST-4.A*
- Explain how alterations in DNA sequences contribute to variation that can be subject to natural selection. *IST-4.B*

</td><td>

Biology in Focus Reading

- Concept 14.1-14.3

Textbook Practice

- Concept check 14.1 questions #1-3
- Concept check 14.2 questions #1-3
- Concept check 14.3 questions #1-3

</td></tr>
</table>

AP Biology	Week 15	Gene Expression & Regulation

Overview & Notes

- Week 15 continues Unit 6 with a focus on the Central Dogma, especially translation and mutations.
- Consider having students create models of transcription and translation, such as storyboards or stop-motion videos.
- Allow time to practice interpreting the genetic code with a codon chart. The Problem-Solving Exercise on page 310 is a good activity for students to examine the effects of mutations on the phenotype.

Science Practices

- 1 - Concept Explanation
- 2 - Visual Representations
- 3 - Questions and Methods

Important Terms

- Translation
- Ribosomes
- Transfer RNA (tRNA)
- Anticodon
- Ribosomal RNA (rRNA)
- P site
- A site
- E site
- Mutations
- Point mutation
- Silent mutation
- Missense mutation
- Nonsense mutation
- Frameshift mutation
- Mutagens

Topics

- 14.4 Translation
- 14.5 Mutations

Alignment to CED Frameworks

- Describe the mechanisms by which genetic information flows from DNA to RNA to protein. *IST-1.N*
- Describe how the phenotype of an organism is determined by its genotype. *IST-1.O*
- Describe the various mutations. *IST-2.E*
- Explain how changes in genotype may result in changes in phenotype. *IST-4.A*
- Explain how alterations in DNA sequences contribute to variation that can be subject to natural selection. *IST-4.B*

Biology in Focus Reading

- Concept 14.4-14.5

Textbook Practice

- Concept check 14.4 questions #1-4
- Concept check 14.5 questions #1-3

AP Biology	Week 16	Gene Expression & Regulation

Overview & Notes

- Week 16 continues Unit 6 with a focus on gene expression mechanisms.

Science Practices

- 1 - Concept Explanation
- 2 - Visual Representations
- 6 - Argumentation

Important Terms

- Operons
- Operator
- Repressor
- Regulatory gene
- Corepressor
- Inducer
- Activator
- Differential gene expression
- Histone acetylation
- DNA methylation
- Epigenetics
- Enhancers
- Alternative RNA splicing
- MicroRNAs (miRNAs)
- Small interfering RNAs (siRNAs)
- RNA Interferences (RNAi)

Topics

- 15.1 Prokaryotic Gene Expression
- 15.2 Eukaryotic Gene Expression
- 15.3 RNA Control of Gene Expression

Alignment to CED Frameworks

- Describe the types of interactions that regulate gene expression. *IST-2.A*
- Explain how the location of regulatory sequences relates to their function. *IST-2.B*
- Explain how the binding of transcription factors to promoter regions affects gene expression and/or the phenotype of the organism. *IST-2.C*
- Explain the connection between the regulation of gene expression and phenotypic differences in cells and organisms. *IST-2.D*

Biology in Focus Reading

- Concept 15.1-15.3

Textbook Practice

- Concept check 15.1 questions #1-3
- Concept check 15.2 questions #1-3
- Concept check 15.3 questions #1-2

<table>
<tr><th>AP Biology</th><th>Week 17</th><th>Gene Expression & Regulation</th></tr>
<tr><td colspan="2">

Overview & Notes

- Week 17 concludes Unit 6 with a focus on biotechnology topics and applications.
- Consider conducting a DNA fingerprinting, PCR, or DNA transformation lab if you have access to the materials.

</td><td>

Science Practices

- 3 - Questions and Methods
- 4 - Representing or Describing Data
- 6 - Argumentation

</td></tr>
<tr><td colspan="2">

Important Terms

- Genetic engineering
- DNA cloning
- Plasmids
- Recombinant DNA
- Gene cloning
- Cloning vector
- Restriction enzymes
- Restriction fragments
- Sticky ends
- Gel electrophoresis
- PCR
- DNA sequencing
- CRISPR- Cas9 system
- Gene drive

</td><td>

Topics

- 13.4 Genetic Engineering
- 16.1Differential Gene Expression
- 16.2 Cloning

</td></tr>
<tr><td colspan="2">

Alignment to CED Frameworks

- Explain the connection between the regulation of gene expression and phenotypic differences in cells and organisms. *IST-2.D*
- Explain the use of genetic engineering techniques in analyzing or manipulating DNA. *IST-1.P*

</td><td>

Biology in Focus Reading

- Concept 13.4
- Concept 16.1-16.2

Textbook Practice

- Concept check 13.4 questions #1-3
- Concept check 16.1 questions #1-3
- Concept check 16.2 questions #1-3

</td></tr>
</table>

AP Biology	Week 18	Natural Selection

Overview & Notes

- Week 18 begins Unit 7: Natural Selection with a focus on the mechanism of natural selection.
- This unit is the most robust, and covers 13-20% of the AP Biology exam. It can take up to five weeks to address all of the topics.
- Beginning with a historical perspective of evolution can provide context for how scientific ideas may change over time.

Science Practices

- 1 - Concept Explanation
- 2 - Visual Representations
- 4 - Representing or Describing Data

Important Terms

- Evolution
- Fossils
- Jean Baptiste de Lamarck
- Charles Darwin
- Adaptations
- Natural selection
- Artificial selection
- Homology
- Homologous structures
- Vestigial structures
- Convergent evolution
- Analogous structures
- Biogeography
- Endemic

Topics

- 19.1 Darwinian Evolution
- 19.2 Descent with Modification
- 19.3 Evidence for Evolution

Alignment to CED Frameworks

- Describe the causes of natural selection. *EVO-1.C*
- Explain how natural selection affects populations. *EVO-1.D*
- Describe the types of data that provide evidence for evolution. *EVO-1.M*
- Explain how morphological, biochemical, and geological data provide evidence that organisms have changed over time. *EVO-1.N*
- Describe the importance of phenotypic variation in a population. *EVO-1.E*
- Explain how humans can affect diversity within a population. *EVO-1.F*
- Explain the relationship between changes in the environment and evolutionary changes in the population. *EVO-1.G*

Biology in Focus Reading

- Concept 19.1-19.3

Textbook Practice

- Concept check 19.1 questions #1-2
- Concept check 19.2 questions #1-3
- Concept check 19.3 questions #1-3

AP Biology	Week 19	Natural Selection

Overview & Notes

- Week 19 continues Unit 7 with a focus on the evolution of populations.
- Students need ample time to understand how to calculate and interpret the Hardy-Weinberg equation. The Scientific Skills Exercise on page 439 is a good problem set for students to work through.

Science Practices

- 4 - Representing or Describing Data
- 5 - Statistical Tests and Data Analysis
- 6 - Argumentation

Important Terms

- Microevolution
- Genetic variation
- Phenotypic plasticity
- Neutral variation
- Population
- Gene pool
- Hardy-Weinberg equilibrium
- Adaptive evolution
- Genetic drift
- Founder effect
- Bottleneck effect
- Gene flow
- Relative fitness
- Directional selection
- Disruptive selection
- Stabilizing selection
- Balancing selection
- Heterozygote advantage
- Frequency-dependent selection
- Sexual selection
- Sexual dimorphism

Topics

- 21.1 Genetic Variation
- 21.2 Hardy-Weinberg Equation
- 21.3 Changes in Allele Frequencies
- 21.4 Natural Selection in Population

Alignment to CED Frameworks

- Explain how random occurrences affect the genetic makeup of a population. *EVO-1.H*
- Describe the role of random processes in the evolution of specific populations. *EVO-1.I*
- Describe the change in the genetic makeup of a population over time. *EVO-1.J*
- Describe the conditions under which allele and genotype frequencies will change in populations. *EVO-1.K*
- Explain the impacts on the population if any of the conditions of Hardy-Weinberg are not met. *EVO-1.L*
- Explain how the genetic diversity of a species or population affects its ability to withstand environmental pressures. *SYI-3.D*

Biology in Focus Reading

- Concept 21.1-21.4

Textbook Practice

- Concept check 21.1 questions #1-4
- Concept check 21.2 questions #1-3
- Concept check 21.3 questions #1-3
- Concept check 21.4 questions #1-3

AP Biology	Week 20	Natural Selection

Overview & Notes

- Week 20 continues with Unit 7 and focuses on speciation.
- Emphasize the different causes of speciation using examples provided in the text.

Science Practices

- 1 - Concept Explanation
- 2 - Visual Representations
- 4 - Representing or Describing Data

Important Terms

- Speciation
- Macroevolution
- Biological species concepts
- Reproductive isolation
- Hybrids
- Prezygotic barriers
- Postzygotic barriers
- Allopatric speciation
- Sympatric speciation
- Polyploidy
- Autopolyploidy
- Allopolyploidy
- Hybrid zone
- Reinforcement
- Fusion
- Stability
- Punctuated equilibrium

Topics

- 22.1 Reproductive Isolation
- 22.2 Mechanisms of Speciation
- 22.3 Hybrid Zones
- 22.4 Rate of Speciation

Alignment to CED Frameworks

- Describe the conditions under which new species may arise. *EVO-3.D*
- Describe the rate of evolution and speciation under different ecological conditions. *EVO-3.E*
- Explain the processes and mechanisms that drive speciation. *EVO-3.F*
- Describe factors that lead to the extinction of a population. *EVO-3.G*

Biology in Focus Reading

- Concept 22.1-22.4

Textbook Practice

- Concept check 22.1 questions #1-2
- Concept check 22.2 questions #1-3
- Concept check 22.3 questions #1-2
- Concept check 22.4 questions #1-3

AP Biology	Week 21	Natural Selection

Overview & Notes

- Week 21 continues Unit 7, and focuses on patterns in evolution.
- Highly conserved genes, such as homeotic genes are strong pieces of evidence that supports a common ancestor.

Science Practices

- 1 - Concept Explanation
- 3 - Questions and Methods
- 4 - Representing or Describing Data

Important Terms

- Radiometric dating
- Half-life
- Stromatolites
- Plate tectonics
- Pangaea
- Mass extinction
- Adaptive radiations
- Heterochrony
- Paedomorphosis
- Homeotic genes

Topics

- 23.1 Fossil Record
- 23.2 Speciation & Extinction Rates
- 23.3 Genetic Changes
- 23.4 Evolution is Not Goal Oriented

Alignment to CED Frameworks

- Explain species diversity in an ecosystem as a function of speciation and extinction rates. *EVO-3.I*
- Explain how extinction can make new environments available for adaptive radiation. *EVO-3.J*
- Describe structural and functional evidence on cellular and molecular levels that provides evidence for the common ancestry of all eukaryotes. *EVO-2.C*
- Explain how evolution is an ongoing process in all living organisms. *EVO-3.A*
- Describe the fundamental molecular and cellular features shared across all domains of life, which provide evidence of common ancestry. *EVO-2.B*

Biology in Focus Reading

- Concept 23.1-23.4

Textbook Practice

- Concept check 23.1 questions #1-3
- Concept check 23.2 questions #1-4
- Concept check 23.3 questions #1-3
- Concept check 23.4 questions #1-2

AP Biology	Week 22	Natural Selection

Overview & Notes

- Week 22 continues Unit 7 with a focus on phylogeny.
- Phylogenetic trees often appear on the AP Biology Exam. Give students ample opportunities to construct, interpret, and critique a variety of phylogenetic trees.
- It is important to emphasize that multiple lines of evidence are used to construct phylogenetic trees.

Science Practices

- 1 - Concept Explanation
- 2 - Visual Representations
- 6 - Argumentation

Important Terms

- Phylogeny
- Systematics
- Binomial
- Genus
- Family
- Order
- Class
- Phylum
- Kingdom
- Domain
- Taxon
- Phylogenetic tree
- Branch point
- Evolutionary lineage
- Rooted
- Basal taxon
- Cladistics
- Clades
- Monophyletic
- Paraphyletic
- Polyphyletic
- Shared ancestral character
- Shared derived character
- Outgroup
- Ingroup
- Maximum parsimony
- Molecular clock
- Horizontal gene transfer

Topics

- 20.1 Phylogeny
- 20.2 Shared Characteristics
- 20.3 Morphological and Molecular Data
- 20.4 Molecular Clocks
- 20.5 Evolutionary History

Alignment to CED Frameworks

- Describe the types of evidence that can be used to infer an evolutionary relationship. *EVO-3.B*
- Explain how a phylogenetic tree and/or cladogram can be used to infer evolutionary relatedness. *EVO-3.C*

Biology in Focus Reading

- Concept 20.1-20.5

Textbook Practice

- Concept check 20.1 questions #1-3
- Concept check 20.2 questions #1-3
- Concept check 20.3 questions #1-4
- Concept check 20.4 questions #1-3
- Concept check 20.5 questions #1-3

AP Biology	Week 23	Natural Selection

Overview & Notes

- Week 23 finishes Unit 7 with a focus on the origin of life.
- This week reviews several concepts from earlier in the course, such as cellular structure and respiration. As the end of course is near, you may spend more than one week with this material.
- This week also introduces material that can segue into Unit 8: Ecology, such as the role of prokaryotes in ecosystems.

Science Practices

- 4 - Representing or Describing Data
- 5 - Statistical Tests and Data Analysis
- 6 - Argumentation

Important Terms

- Prokaryotes
- Protocells
- Ribozymes
- Peptidoglycan
- Gram-positive
- Gram-negative
- Capsule
- Endospores
- Fimbriae
- Pili
- Taxis
- nucleoid
- Plasmids
- Photoautotroph
- Chemoautotroph
- Photoheterotroph
- Chemoheterotroph
- Anaerobic respiration
- Nitrogen fixation
- Heterocysts
- Biofilms
- Transformation
- Transduction
- Conjugation
- F factor
- F plasmid
- R plasmids
- Extremophiles
- Extreme halophiles
- Extreme thermophiles
- Methanogens
- Decomposers
- Symbiosis
- Host
- Symbiont
- Mutualism
- Commensalism
- Exotoxins
- Endotoxins
- Bioremediation

Topics

- 24.1 Early Earth
- 24.2 Metabolic Diversity in Prokaryotes
- 24.3 Genetic Diversity in Prokaryotes
- 24.4 Prokaryote Radiation
- 24.5 Prokaryotes in the Biosphere

Alignment to CED Frameworks

- Describe the scientific evidence that provides support for models of the origin of life on Earth. *SYI-3.E*

Biology in Focus Reading

- Concept 24.1-24.5

Textbook Practice

- Concept check 24.1 questions #1-4
- Concept check 24.2 questions #1-4
- Concept check 24.3 questions #1-4

	• Concept check 24.4 questions #1-2 • Concept check 24.5 questions #1-3

AP Biology	Week 24	Ecology

Overview & Notes

- Week 24 begins Unit 8: Ecology.
- The learning objectives for this week do not focus on any specific animal or plant systems. Rather, focus on adaptations that enable plants and animals to survive in their environments.

Science Practices

- 1 - Concept Explanation
- 2 - Visual Representations
- 3 - Questions and Methods

Important Terms

- Behavioral ecology
- Fixed action patterns
- Sign stimulus
- Migration
- Signal
- Communication
- Pheromones
- Learning
- Imprinting
- Sensitive period
- Spatial learning
- Cognitive map
- Associate learning
- Cognition
- Social learning
- Foraging
- Altruism
- Inclusive fitness
- Kin selection
- Hormone
- Tropism
- Phototropism
- Auxin
- Cytokinins
- Gibberellin
- Abscisic acid
- Ethylene

Topics

- 39.3 Behaviors
- 39.4 Learning
- 39.5 Selection
- 39.6 Genetic Basis for Behavior
- 31.1 Plant Behaviors
- 31.2 Plant Hormones

Alignment to CED Frameworks

- Explain how the behavioral and/or physiological response of an organism is related to changes in internal or external environment. *ENE-3.D*
- Explain how the behavioral responses of organisms affect their overall fitness and may contribute to the success of the population. *IST-5.A*

Biology in Focus Reading

- Concept 39.3-39.6
- Concept 31.1-31.2

Textbook Practice

- Concept check 39.3 questions #1-2
- Concept check 39.4 questions #1-3
- Concept check 39.5 questions #1-2
- Concept check 39.6 questions #1-2
- Concept check 31.1 questions #1-2
- Concept check 31.2 questions #1-3

<table>
<tr><th>AP Biology</th><th>Week 25</th><th>Ecology</th></tr>
<tr><td colspan="2">Overview & Notes
Week 24 continues Unit 8 with a focus on ecosystems and the flow of energy and matter.
Emphasize the concepts of matter and energy flow through ecosystems as well as energy as a limiting factor. You can weave this concept through the rest of the unit.</td><td>Science Practices
1 - Concept Explanation
2 - Visual Representations
4 - Representing or Describing Data</td></tr>
<tr><td>Important Terms
Law of conservation of matter
Primary producers
Primary consumers
Secondary consumers
Tertiary consumers
Decomposers
Detritus
Gross primary production (GPP)</td><td>Net primary production (NPP)
Limiting nutrient
Eutrophication
Trophic efficiency
Biogeochemical cycles
Bioremediation
Biological augmentation</td><td>Topics
42.1 Physical Laws of Energy
42.2 Limiting Factors
42.3 Energy Transfer
42.4 Nutrient Cycles
42.5 Ecosystem Restoration</td></tr>
<tr><td colspan="2">Alignment to CED Frameworks
Describe the strategies organisms use to acquire and use energy. ENE-1.M
Explain how changes in energy availability affect populations and ecosystems. ENE-1.N
Explain how the activities of autotrophs and heterotrophs enable the flow of energy within an ecosystem. ENE-1.O</td><td>Biology in Focus Reading
Concept 42.1-42.5
Textbook Practice
Concept check 42.1 questions #1-3
Concept check 42.2 questions #1-4
Concept check 42.3 questions #1-2
Concept check 42.4 questions #1-3
Concept check 42.5 questions #1-3</td></tr>
</table>

AP Biology	Week 26	Ecology

<table>
<tr><td colspan="2">

Overview & Notes

- Week 24 continues Unit 8 with a focus on populations.
- Biomes are not part of the AP Biology curriculum, rather, spend time on population distribution and demographic patterns.

</td><td>

Science Practices

- 1 - Concept Explanation
- 4 - Representing or Describing Data
- 5 - Statistical Tests and Data Analysis

</td></tr>
<tr><td colspan="2">

Important Terms

- Dispersal
- Biotic factors
- Abiotic factors
- Density
- Dispersion
- Immigration
- Emigration
- Territoriality
- Demography
- Life table
- Cohort
- Survivorship curve

</td><td>

Topics

- 40.3 Interactions Between Organisms
- 40.4 Biotic and Abiotic Factors

</td></tr>
<tr><td colspan="2">

Alignment to CED Frameworks

- Describe the structure of a community according to its species composition and diversity. *ENE-4.A*
- Explain how interactions within and among populations influence community structure. *ENE-4.B*

</td><td>

Biology in Focus Reading

- Concept 40.3-40.4

Textbook Practice

- Concept check 40.3 questions #1-2
- Concept check 40.4 questions #1-3

</td></tr>
</table>

<table>
<tr><th>AP Biology</th><th>Week 27</th><th>Ecology</th></tr>
<tr><td colspan="2">Overview & Notes
Week 24 continues Unit 8 with a focus on population growth models.
This week includes different types of population calculations. Students will need to understand how to use the population growth formulas. There are good practice problems in this chapter, especially the Scientific Skills Exercise on page 893.</td><td>Science Practices
4 - Representing or Describing Data
5 - Statistical Tests and Data Analysis
6 - Argumentation</td></tr>
<tr><td colspan="2">Important Terms
Exponential population growth
Intrinsic rate of increase
Carrying capacity
Logistic population growth
K-selection
r-selection
Density independent
Density dependent
Population dynamics
metapopulation</td><td>Topics
40.5 Exponential and Logistic Models
40.6 Population Dynamics</td></tr>
<tr><td colspan="2">Alignment to CED Frameworks
Describe factors that influence growth dynamics of populations. SYI-1.G
Explain how the density of a population affects and is determined by resource availability in the environment. SYI-1.H</td><td>Biology in Focus Reading
Concept 40.5-40.6
Textbook Practice
Concept check 40.5 questions #1-3
Concept check 40.6 questions #1-3</td></tr>
</table>

AP Biology	Week 28	Ecology

Overview & Notes

- Week 24 continues Unit 8 with a focus on community structure and organism interactions.
- Modeling food chains and food webs is a good way to represent the impact different organisms have on each other.
- When creating and using models, have students make predictions about how disturbances or changes would impact their model.

Science Practices

- 1 - Concept Explanation
- 2 - Visual Representations
- 4 - Representing or Describing Data

Important Terms

- Interspecific interactions
- Interspecific competition
- Competitive exclusion
- Ecological niches
- Resource partitioning
- Predation
- Cryptic coloration
- Aposematic coloration
- Batesian mimicry
- Herbivory
- Parasitism
- Parasite
- Host
- Mutualism
- Commensalism
- Species diversity
- Species richness
- Relative abundance
- Shannon diversity index
- Biomass
- Introduced species
- Trophic structure
- Food chain
- Food web
- Trophic level
- Foundation species
- Keystone species
- Ecosystem engineers

Topics

- 41.1 Species Interactions
- 41.2 Community Characteristics

Alignment to CED Frameworks

- Explain how community structure is related to energy availability in the environment. *ENE-4.C*
- Describe the relationship between ecosystem diversity and its resilience to changes in the environment. *SYI-3.F*

Biology in Focus Reading

- Concept 41.1-41.2

Textbook Practice

- Concept check 41.1 questions #1-3
- Concept check 41.2 questions #1-4

AP Biology	Week 29	Ecology
Overview & Notes • Week 24 continues Unit 8 with an emphasis on changes in ecosystems. • This is a good opportunity to conduct the transpiration lab or similar to highlight the impact on the environment on ecosystem dynamics.		**Science Practices** • 1 - Concept Explanation • 2 - Visual Representations • 4 - Representing or Describing Data
Important Terms • Disturbance • Nonequilibrium model • Intermediate disturbance hypothesis • Ecological succession • Primary succession • Secondary succession • Evapotranspiration • Species-area curve • Pathogens • Zoonotic pathogens • Vector		**Topics** • 41.3 Disturbances • 41.4 Biogeography • 41.5 Pathogens
Alignment to CED Frameworks • Explain how the addition or removal of any component of an ecosystem will affect its overall short-term and long-term structure. *SYI-3.G* • Explain the interaction between the environment and random or preexisting variations in populations. *EVO-1.O* • Explain how invasive species affect ecosystem dynamics. *SYI-2.A*		**Biology in Focus Reading** • Concept 41.3-41.5 **Textbook Practice** • Concept check 41.3 questions #1-3 • Concept check 41.4 questions #1-3 • Concept check 41.5 questions #1-2

AP Biology	Week 30	Ecology

Overview & Notes

- Week 24 concludes Unit 8 with a focus on human impacts on the ecosystems.
- This week can easily become “doom and gloom”. Provide students some opportunities to develop solutions to environmental challenges.

Science Practices

- 1 - Concept Explanation
- 2 - Visual Representations
- 4 - Representing or Describing Data

Important Terms

- Conservation biology
- Endangered species
- Threatened species
- Ecosystem services
- Introduced species
- Extinction vortex
- Movement corridor
- Urban ecology
- Biodiversity hotspot
- Zoned reserve
- Critical load
- Eutrophication
- Biological magnification
- Microplastics
- Climate change
- Greenhouse effect
- Ecological footprint
- Sustainable development

Topics

- 43.1 Human Activities
- 43.2 Population Conservation
- 43.3 Regional Conservation
- 43.4 Changing Earth
- 43.5 Human Population Growth
- 43.6 Sustainable Development

Alignment to CED Frameworks

- Describe human activities that lead to changes in ecosystem structure and/or dynamics. *SYI-2.B*
- Explain how geological and meteorological activity leads to changes in ecosystem structure and/or dynamics. *SYI-2.C*

Biology in Focus Reading

- Concept 43.1-43.6

Textbook Practice

- Concept check 43.1 questions #1-3
- Concept check 43.2 questions #1-3
- Concept check 43.3 questions #1-3
- Concept check 43.4 questions #1-2
- Concept check 43.5

	questions #1-2 • Concept check 43.6 questions #1-3

Scope & Sequence: Pearson – Chemistry: The Central Science, ©2023 AP® Edition

Course Name: AP® Chemistry (400523) Grades 9-12

Note: This scope and sequence is based on a 180-day calendar and includes instructional time for all units aligned to the College Board's AP® Chemistry Framework.

This is a suggested scope and sequence for the course content.			
Weeks	**Unit/Chapters**	**Periods**	**Referenced Standards**
1–3	**Unit 1: Atomic Structure and Properties** **Textbook Chapters: Chapters 1, 2,3, 6, 7, 8** **Unit Overview:** Students learn about atoms, subatomic particles, and isotopes. The unit introduces mass spectrometry, electron configuration, periodic trends, and the quantum mechanical model of the atom.	Class Periods: 9-10	AP Chemistry Topics 1.1–1.8: Moles, Elemental Composition, Mass Spectrometry, Electron Configuration, and Periodicity
4–6	**Unit 2: Molecular and Ionic Compound Structure and Properties** **Textbook Chapters: Chapters 8, 9, 12** **Unit Overview:** This unit examines bonding models including ionic and covalent compounds, Lewis structures, VSEPR theory, formal charge, and resonance. Students predict molecular geometry and polarity.	Class Periods: 12-13	AP Chemistry Topics 2.1–2.7: Types of Chemical Bonds, Lewis Diagrams, Molecular Geometry, and IMF
7–9	**Unit 3: Intermolecular Forces and Properties** **Textbook Chapters: Chapters 1, 6, 8, 10, 11, 12, 13, 14** **Unit Overview:** Focuses on states of matter and intermolecular forces, including London dispersion, dipole-dipole, hydrogen	Class Periods: 14-15	AP Chemistry Topics 3.1–3.13: IMF, States of Matter, Solutions, and Chromatography

This is a suggested scope and sequence for the course content.			
Weeks	**Unit/Chapters**	**Periods**	**Referenced Standards**
	bonding, and how these affect properties like boiling/melting points and solubility.		
10–12	**Unit 4: Chemical Reactions** **Textbook Chapters: Chapters 1, 3, 4** **Unit Overview:** Students study net ionic equations, redox reactions, titrations, and stoichiometry. The unit includes lab work involving precipitation, acid-base, and redox reactions.	Class Periods: 14-15	AP Chemistry Topics 4.1–4.9: Reactions, Balancing Equations, Redox, and Net Ionic Equations
13–15	**Unit 5: Kinetics** **Textbook Chapters: Chapter 3, 8, 14, 21** **Unit Overview:** Students explore reaction rates, rate laws, reaction mechanisms, and how temperature, concentration, and catalysts influence reaction speed. Lab activities focus on experimental rate laws.	Class Periods: 13-14	AP Chemistry Topics 5.1–5.11: Reaction Rates, Rate Laws, Reaction Mechanisms
16	**Winter Break/Midterm Review**		Practice for AP Exam
17–20	**Unit 6: Thermodynamics** **Textbook Chapters: 5, 11** **Unit Overview:** This unit investigates heat, work, enthalpy, calorimetry, and energy diagrams. Labs include thermochemical equations and enthalpy changes during reactions.	Class Periods: 10-11	AP Chemistry Topics 6.1–6.9: Endothermic/Exothermic Reactions, Enthalpy, Calorimetry
21–23	**Unit 7: Equilibrium** **Textbook Chapters: Chapters 15, 17** **Unit Overview:** Students examine dynamic equilibrium in chemical systems, Le Châtelier's principle, and calculations using	Class Periods: 13-15	AP Chemistry Topics 7.1–7.12: Equilibrium Expressions, ICE Tables, Le Châtelier's Principle

This is a suggested scope and sequence for the course content.			
Weeks	**Unit/Chapters**	**Periods**	**Referenced Standards**
	equilibrium constants. Includes lab modeling of equilibrium shifts.		
24–28	**Unit 8: Acids and Bases** **Textbook Chapters: Chapters 16, 17** **Unit Overview:** This unit covers properties of acids and bases, pH, weak and strong acids, titrations, and buffer systems. Students use pKa and Ka/Kb in equilibrium calculations.	Class Periods: 14-16	AP Chemistry Topics 8.1–8.11: pH, Acid/Base Strength, Buffers, Titrations
29–33	**Unit 9: Applications of Thermodynamics** **Textbook Chapters: Chapters 13, 19, 20** **Unit Overview:** Focus on Gibbs free energy, entropy, spontaneity, and electrochemistry. Students explore voltaic and electrolytic cells and apply thermodynamic principles to redox reactions.	Class Periods: 10-13	AP Chemistry Topics 9.1–9.11: Entropy, Free Energy, Electrochemical Cells, Faraday's Law
34–35	**AP Exam Review**		Practice Exams
36	**AP Exam Week**		Final Exam Prep

Scope & Sequence: Pearson – Environment: The Science Behind the Stories, AP® Edition, © 2021

Course Name: AP® Environmental Science (260609) Grades 9-12

Note: This scope and sequence is based on a 180-day calendar and includes instructional time for all units aligned to the College Board's AP® Environmental Science Framework.

This is a suggested scope and sequence for the course content.			
Weeks	**Unit/Chapters**	**Periods**	**Referenced Standards**
1-3	**Unit 1: The LivingWorld – Ecosystems** **Textbook Chapters: Chapters 4, 5, 12, 15, 16** **Unit Overview:** Introduces ecosystems, biodiversity, and energy flow. Topics include food webs, biogeochemical cycles, and the role of biotic and abiotic factors in shaping ecosystems.	Class Periods: 14-15	APES Topics 1.1–1.11: Ecosystem Structure, Energy Flow, Biogeochemical Cycles, and Ecosystem Dynamics
4–6	**Unit 2: The Living World – Biodiversity** **Textbook Chapters: Chapters 2, 3, 4, 5, 7, 11, 12** **Unit Overview:** Focus on biodiversity types, ecosystem services, natural disruptions, and strategies for conservation. Includes human impacts on biodiversity and endangered species management.	Class Periods: 11-12	APES Topics 2.1–2.7: Biodiversity, Island Biogeography, Ecological Succession, and Conservation Strategies
7–9	**Unit 3: Populations** **Textbook Chapters: Chapters 3, 8, 11, 12** **Unit Overview:** Students analyze population dynamics, growth models, fertility, demographic transition, and human population trends. Concepts of carrying capacity and life history strategies are emphasized.	Class Periods: 12-13	APES Topics 3.1–3.9: Population Ecology, Growth Models, Demographics, and Age Structure

This is a suggested scope and sequence for the course content.			
Weeks	**Unit/Chapters**	**Periods**	**Referenced Standards**
10–12	**Unit 4: Earth Systems and Resources** **Textbook Chapters: Chapters 2, 5, 9, 16, 17, 18** **Unit Overview:** Covers geological processes, soil formation, Earth's atmosphere, and weather patterns. Students examine how these systems interact to shape the environment and impact resource availability.	Class Periods: 11-12	APES Topics 4.1–4.9: Plate Tectonics, Soil, Atmosphere, and Earth-Sun Relationships
13–15	**Unit 5: Land and Water Use** **Textbook Chapters: Chapters 1, 7, 9, 10, 12, 13,18, 23** **Unit Overview:** Explores agriculture, forestry, rangelands, fisheries, mining, and urban development. Focus on sustainability, land management, and ecological consequences of resource exploitation.	Class Periods: 18-19	APES Topics 5.1–5.17: Agriculture, Land Use, Irrigation, Mining, and Urbanization
16	**Winter Break/Midterm Review**		Practice for AP Exam
17–20	**Unit 6: Energy Resources and Consumption** **Textbook Chapters: Chapters 19 20, 21** **Unit Overview:** Students evaluate renewable and nonrenewable energy sources, energy efficiency, and the impacts of energy production. Topics include fossil fuels, solar, wind, geothermal, and nuclear energy.	Class Periods: 16-17	APES Topics 6.1–6.13: Energy Sources, Efficiency, and Environmental Impacts
21–23	**Unit 7: Atmospheric Pollution** **Textbook Chapters: Chapters 13, 14, 16, 17** **Unit Overview:** This unit investigates air pollution, smog, acid rain, noise pollution, and the Clean Air Act. Students examine indoor vs. outdoor pollutants and global climate considerations.	Class Periods: 11-12	APES Topics 7.1–7.8: Air Pollutants, Effects, Legislation, and Environmental Solutions

This is a suggested scope and sequence for the course content.			
Weeks	**Unit/Chapters**	**Periods**	**Referenced Standards**
24–28	**Unit 8: Aquatic and Terrestrial Pollution** **Textbook Chapters: Chapters 5, 6, 13, 14, 15, 16, 17, 18,22** **Unit Overview:** Focus on water pollution, solid waste disposal, hazardous waste, and pollution mitigation. Includes case studies on oil spills, plastic waste, and e-waste solutions.	Class Periods: 19-20	APES Topics 8.1–8.15: Water Quality, Waste Disposal, Pollution Remediation, and Case Studies
29–33	**Unit 9: Global Change** **Textbook Chapters: Chapters 3, 4, 11, 12, 16, 17, 18** **Unit Overview:** Students analyze climate change, invasive species, ozone depletion, and sea level rise. Mitigation and adaptation strategies are explored alongside policy and sustainability.	Class Periods: 19-20	APES Topics 9.1–9.10: Climate Change, Human Impact, and Mitigation Strategies
34–35	**AP Exam Review**		Practice Exams
36	**AP Exam Week**		Final Exam Prep

Pacing Guide: Pearson – Physics for Scientists and Engineers: A Strategic Approach with Modern Physics, ©2022 AP® Edition

AP® Physics C: Electricity & Magnetism (400841) Grades 9–12

AP Physics C: Electricity & Magnetism

Week	AP Unit	Topic	Pearson Chapters	Key Topics & Activities
1-4	8	Electric Charges, Fields, and Gauss's Law	Ch. 22–23	Electric field mapping
4-10	9	Electric Potential	Ch. 24-25	Capacitor charging/discharging
11-15	10	Conductors and Capacitors	Ch. 23, 25, 26	Ohm's Law, Kirchhoff's Rules
16		Winter Break/Midterm Review		Practice for AP Exam
17-21	11	Electric Circuits	Ch. 27-28	Magnetic field sensors
22-27	12	Magnetic Fields and Electromagnetism	Ch. 29, 31	Induction coils, Lenz's Law
28-33	13	Electromagnetic Induction	Ch. 30	EM wave simulation
34–35		AP Exam Review		Practice exams, FRQs
36		AP Exam Week		

Pacing Guide: Pearson – Physics for Scientists and Engineers: A Strategic Approach with Modern Physics, ©2022 AP® Edition

Course Names: AP® Physics C: Mechanics (400861) Grades 9–12

AP Physics C: Mechanics

Week	AP Unit	Topic	Pearson Chapters	Key Topics & Activities
1–3	1	Kinematics	Ch.1-4	Motion sensors, projectile motion
4-8	2	Newton's Laws	Ch. 5-9, 12, 13	Force tables, friction analysis
9-12	3	Work, Energy, Power	Ch. 9-10	Energy conservation, power output
13-15	4	Momentum	Ch. 11	Ballistic pendulum, collisions
16		Winter Break/Midterm Review		Practice for AP Exam
17-21	5	Rotation	Ch. 12	Rotational inertia, torque
22-27	6	Oscillations	Ch. 12-13	Spring-mass systems, pendulums
28-33	7	Gravitation	Ch. 15	Orbital motion simulation
34-35		AP Exam Review		Practice Exams
36		AP Exam Week		Final Exam Prep

Pacing Guide: Pearson – College Physics: A Strategic Approach AP® Edition, ©2023

Course Name: AP® Physics 2 (400827) Grades 9–12

Week(s)	**AP Unit**	**Pearson Ready-To-Go Teaching Modules (Lesson Plans)**	**Key Topics & Activities**
1	Intro & Lab Foundations	Chapter 1: Representing Motion	Measurement, uncertainty, graphing, lab safety
2–6	Unit 9: Thermodynamics	Chapter 11: Using Energy Chapter 12: Thermal Properties of Matter	Heat transfer, PV diagrams, entropy, heat engines
7–10	Unit 10: Electric Force & Field	Chapter 20: Electric Fields and Forces Chapter 21: Electric Potential	Coulomb's law, field mapping, potential energy
11–15	Unit 11: Electric Circuits	Chapter 22: Current and Resistance Chapter 23: Circuits	Ohm's law, Kirchhoff's laws, RC circuits
16	Winter Break / Midterm Review	—	Practice FRQs, concept mapping
17–20	Unit 12: Magnetism & EM	Chapter 24: Magnetic Fields and Forces Chapter 25: EM Induction and EM Waves	Lorentz force, Faraday's law, transformers
21–23	Unit 13: Geometric Optics	Chapter 18: Ray Optics	Reflection, refraction, lenses, ray diagrams

Week(s)	AP Unit	Pearson Ready-To-Go Teaching Modules (Lesson Plans)	Key Topics & Activities
24–28	Unit 14: Waves & Physical Optics	Chapter 15: Traveling Waves and Sound Chapter 16: Superposition and Standing Waves Chapter 17: Wave Optics Chapter 25: EM Induction and EM Waves	Interference, diffraction, Doppler effect
29–33	Unit 15: Modern Physics	Chapter 28: Quantum Physics Chapter 29: Atoms and Molecules Chapter 30: Nuclear Physics	Photoelectric effect, atomic models, decay
34–35	AP Exam Review	Mixed Chapters	Practice exams, FRQ workshops, lab portfolio
36	AP Exam Week	—	Final prep, confidence building

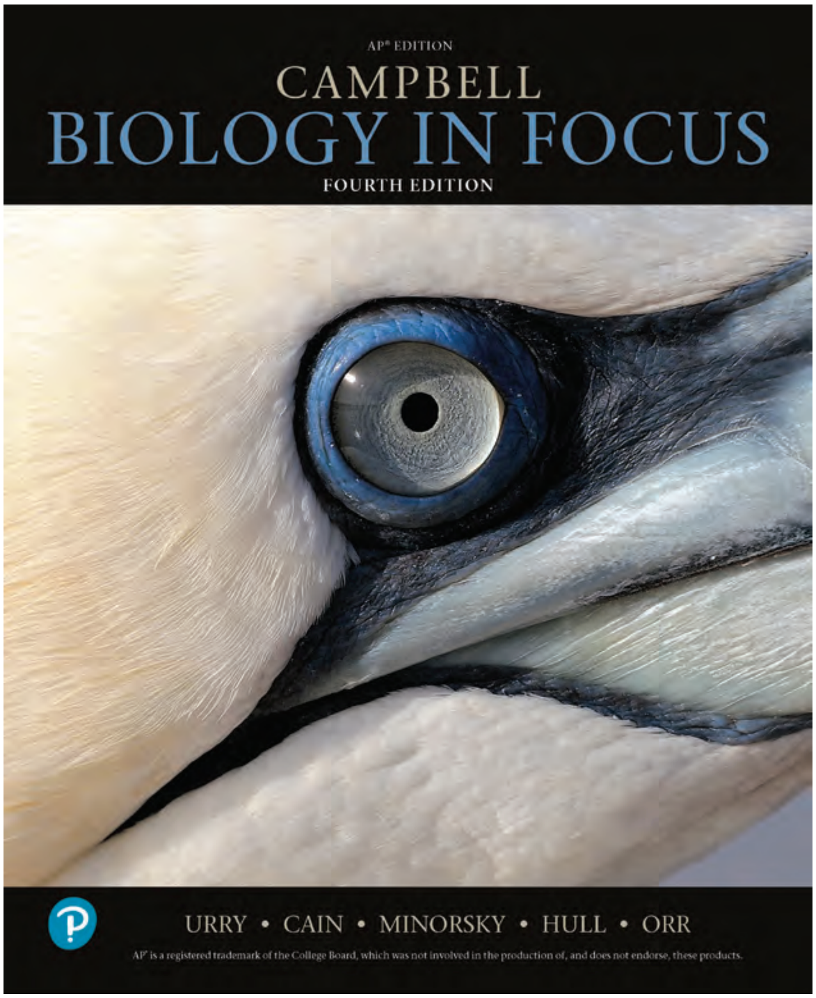
Lab Pairings by Unit

AP Unit	Suggested Pearson Lab Topics
Thermodynamics	Calorimetry, gas law simulations
Electric Force & Field	Field mapping, capacitor plates
Electric Circuits	Circuit building, multimeter use

AP Unit	Suggested Pearson Lab Topics
Magnetism & EM	Induction coil, magnetic field mapping
Geometric Optics	Lens/mirror ray tracing
Waves & Physical Optics	Sound wave analysis, interference patterns
Modern Physics	Photoelectric effect, nuclear decay simulations

Standards Correlations

A Correlation of
Campbell BIOLOGY in Focus
4th Edition, AP® Edition ©2025



To the

AP® Biology Curriculum Framework
Effective Fall 2025

Pearson

A Correlation of Campbell Biology in Focus, 4th Edition, AP® Edition ©2025 to the College Board AP® Biology Curriculum Framework, Fall 2025

Table of Contents

Big Idea Summary

Big Idea 1: Evolution (EVO)
The process of evolution drives the diversity and unity of life.
Evolution is a change in the genetic makeup of a population over time, with natural selection as its major driving mechanism. Darwin's theory, which is supported by evidence from many scientific disciplines, states that inheritable variations occur in individuals in a population. Due to competition for limited resources, individuals with more favorable genetic variations are more likely to survive and produce more offspring, thus passing traits to future generations. A diverse gene pool is vital for the survival of species because environmental conditions change. The process of evolution explains the diversity and unity of life, but an explanation about the origin of life is less clear.

In addition to the process of natural selection, naturally occurring catastrophic and human-induced events, as well as random environmental changes can result in alteration in the gene pools of populations. Scientific evidence supports that speciation and extinction have occurred throughout Earth's history and that life continues to evolve within a changing environment, thus explaining the diversity of life.

Big Idea 2: Energetics (ENE)
Biological systems use energy and molecular building blocks to grow, to reproduce, and maintain dynamic homeostasis.
Cells and organisms must exchange matter with the environment. Organisms respond to changes in their environment at the molecular, cellular, physiological, and behavioral levels. Living systems require energy and matter to maintain order, to grow, and to reproduce. Organisms employ various strategies to capture, use, and store energy and other vital resources. Energy deficiencies are not only detrimental to individual organisms; they also can cause disruptions at the population and ecosystem levels. Homeostatic mechanisms that are conserved or divergent across related organisms reflect either continuity due to common ancestry or evolutionary change in response to distinct selective pressures.

Big Idea 3: Information Storage and Transmission (IST)
Living systems store, retrieve, transmit, and respond to information essential to life processes. Genetic information provides for continuity of life and, in most cases, this information is passed from parent to offspring via DNA. Nonheritable information transmission influences behavior within and between cells, organisms, and populations. These behaviors are directed by underlying genetic information, and responses to information are vital to natural selection and evolution. Genetic information is a repository of instructions necessary for the survival, growth, and reproduction of the organism.
Genetic variation can be advantageous for the long-term survival and evolution of a species.

Big Idea 4: Systems Interactions (SYI)
Biological systems interact, and these systems and their interactions exhibit complex properties. All biological systems comprise parts that interact with one another. These interactions result in characteristics and emergent properties not found in the individual parts alone. All biological systems from the molecular level to the ecosystem level exhibit properties of biocomplexity and diversity. These two properties provide robustness to biological systems, enabling greater resiliency and flexibility to tolerate and respond to changes in the environment.

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AP® Biology Topics	Big Ideas	Learning Objectives	Essential Knowledge	Campbell Biology in Focus 4th Edition
Unit 1: Chemistry of Life (7 Topics)				
1.1 Structure of Water and Hydrogen Bonding	**Big Idea 4** Systems Interactions	**1.1A:** Explain how the properties of water that result from its polarity and hydrogen bonding affect its biological functions	**1.1.A.1:** Living systems depend on the properties of water to sustain life. i. Water had polarity, because of the formation of polar covalent bonds between hydrogen and oxygen within water molecules. This polarity contributes to hydrogen bonding between and within biological molecules. ii. Water has a high specific heat capacity, which allows for the maintenance of homeostatic body temperature within living organisms. iii. Water has a high heat of vaporization, which allows for the evaporative cooling of the surrounding environment. In living organisms, this property allows for body temperature to be maintained.	Figure 2.1: How does water's chemical structure allow its solid form (ice) to float on liquid water? Concept 2.3: The formation and function of molecules depend on chemical bonding between atoms
			1.1.A.2: The hydrogen bonds between adjacent polar water molecules result in cohesion, adhesion, and surface tension.	Concept 2.5: Hydrogen bonding gives water properties that help make life possible on Earth
1.2 Elements of Life	**Big Idea 2** Energetics	**1.2.A:** Describe the composition of macromolecules required by living organisms.	**1.2.A.1:** Atoms and molecules from the environment are necessary to build new molecules. Carbon, hydrogen, and oxygen are the most prevalent elements used to build biological molecules such as carbohydrates, proteins, lipids, and nucleic acids. Additionally i. Sulfur is used in the building of proteins. ii. Phosphorus is used in the building of phospholipids (a type of lipid) and nucleic acids. iii. Nitrogen is used in the building of nucleic acids.	Concept 3.1: Carbon atoms can form diverse molecules by bonding to four other atoms
1.3 Introduction to Macromolecules	**Big Idea 4** Systems Interactions	**1.3.A:** Describe the chemical reactions that build and break biological macromolecules.	**1.3.A.1:** Hydrolysis is a chemical reaction involving the cleaving of covalent bonds. This type of reaction breaks down molecules iinto smaller molecules. When water is added to the bond between monomers in a polymer, the bond is broken. The hydrogen ion from a water molecule is added to one monomer and the hydroxyl	Concept 3.2: Macromolecules are polymers, built from monomers

			group of the water molecule is added to the other monomer completing the reaction. 1.3.A.2 Dehydration synthesis occurs when two smaller molecules are joined together through covalent bonding. A hydrogen ion is removed from one monomer and a hydroxyl group is removed from the other. This causes the loss of the equivalent of a water molecule from the reactants and the connection of the two remaining monomers. The connection of many monomers is known as polymerization.	
1.4 Carbohydrates	**Big Idea 4** Systems Interactions	**1.4.A:** Describe the structure and function of carbohydrates.	**1.4.A.1:** Monosaccharides (simple sugars) are the monomers for poly saccharides (complex carbohydrates). These monomers are connected by covalent bonds to form polymers such as complex carbohydrates, which may be linear or branched.	Concept 3.3: Carbohydrates serve as fuel and building material
1.5 Lipids	**Big Idea 4** Systems Interactions	**1.5.A:** Describe the structure and function of lipids.	**1.5.A.1:** Lipids are typically nonpolar, hydrophobic molecules whose structure and function are derived from the way their subcomponents are assembled. i. Fatty acids contain only single bonds between carbon atoms. ii. Unsaturated fatty acids contain at least one double bond between carbon atoms, which causes the carbon chain to kink. iii. The more double bonds in a fatty acid tail, the more unsaturated the lipid becomes. iv. The more unsaturated a. lipid is, the more liquid it is at room temperature. 1.5.A.2 Lipids provide a variety of functions for living organisms. Some examples of lipids are fats, steroids including cholesterol, and phospholipids. i. Fats provide energy storage and support cell function. In some cases, they can also provide insulation to help keep mammals warm. ii. Steroids are hormones that support physiological functions including growth and development, energy metabolism, and homeostasis.	Concept 3.4: Lipids are a diverse group of hydrophobic molecules.

			iii. Cholesterol provides essential structural stability to animal cell membranes. iv. Phospholipids group together to form the lipid bilayers found in plasma and cell membranes.	
1.6 Nucleic Acids	**Big Idea 3** Information Storage and Transmission	**1.6A:** Describe the structure and function of DNA and RNA.	**1.6.A.1:** In nucleic acids (DNA and RNA) biological information is encoded in sequences of nucleotide monomers. Each nucleotide has the following structural components: a five-carbon sugar (deoxyribose or ribose), a phosphate, and a nitrogenous base (adenine, thymine, guanine, cytosine, or uracil). **1.6.A.2:** Nucleic acids have a linear sequence of nucleotides that have ends, defined by the 3' (three prime) hydroxyl and a 5' (five prime) phosphates of the sugar in the nucleotide. During nucleic acid synthesis, nucleotides are added to the 3' end of the growing strand, resulting in the formation of covalent bonds between nucleotides. **1.6.A.3:** DNA is structured as an antiparallel double helix, with two strands of nucleotides running in opposite 5' to 3' orientation. In DNA, adenine nucleotides pair with thymine nucleotides via hydrogen bonds (A-T), and cytosine nucleotides pair with guanine nucleotides via hydrogen bonds (C-G). In RNA, adenine pairs with uracil (A-U). 1.6.A.4 Structural differences between DNA and RNA include: i. DNA contains the sugar deoxyribose, and RNA contains the sugar ribose. ii. DNA contains the nitrogenous base thymine, and RNA contains the nitrogenous base uracil. iii. DNA is typically double stranded, while RNA is typically single stranded.	Concept 3.6: Nucleic acids store, transmit, and help express hereditary information. Concept 13.1: DNA is the genetic material Figure 13.7 Visualizing DNA
			1.7.A.1: Proteins comprise	.

1.7 Proteins	**Big Idea 4** Systems Interactions	**1.7.A:** Describe the structure and function of proteins.	linear chains of amino acids connected by the formation of covalent (peptide) bonds that form between a carboxyl group (-COOH) of one amino acid and an amine group (-NH_2) of the next amino acid, resulting in a growing peptide chain. **1.7.A.2:** Amino acids are composed of a central carbon atom with a hydrogen atom, a carboxyl group an amine group, and a variable R group covalently bound to it. The R group of an amino acid can be categorized by three possible chemical properties: hydrophobic/nonpolar, hydrophilic/polar, or ionic. The interactions of these R groups determine the structure and function of that region of the protein. **1.7.A.3:** The specific sequence of amino acids in proteins determines the primary structure of a polypeptide as well as the overall shape of the protein. **1.7.A.4:** Secondary structures of proteins are made through the local folding that forms from interactions between atoms of the polypeptide backbone of the amino acid chain. Hydrogen bonding forms shapes such as alpha-helices and beta-pleated sheets. **1.7.A.5:** The three-dimensional shape of the tertiary structure of a protein results from the formation of hydrogen bonds, hydrophobic interactions, ionic interactions, or disulfide bridges. **1.7.A.6:** The quaternary structure arises from interactions between multiple polypeptides. All four levels of a protein structure determine the function of a protein.	Concept 3.5: Proteins include a diversity of structures, resulting in a wide range of functions

AP® Biology Topics	Big Ideas:	Learning Objectives	Essential Knowledge	Campbell Biology in Focus 4th Edition
Unit 2: Cell Structure and Function (10 topics)				
2.1 Cell Structure and Function	**Big Idea 4** Systems Interactions	**2.1.A:** Explain how the structure and function of subcellular components and organelles contribute to the function of cells.	**2.1.A.1:** Ribosomes are comprised of ribosomal RNA (rRNA) and protein. These non-membrane, subcellular structures are found in cells in all forms of life and reflect the common ancestry in all known life. Ribosomes synthesize proteins according to messenger RNA (mRNA) sequences. **2.1.A.2:** The endomembrane system consists of a group of membrane-bound organelles and subcellular components (endoplasmic reticulum (ER), Golgi complex, lysosomes, vacuoles and transport vesicles, the nuclear envelope, and the plasma membrane) that work together to modify, package, and transport polysaccharides, lipids, and proteins intercellularly. **2.1.A.3:** Endoplasmic reticulum provides mechanical support by helping cells maintain shape and plays a role in intracellular transport. i. Rough ER is associated with membrane- bound ribosomes, allows for the compartmentalization of cells, and helps carry out protein synthesis. ii. Smooth ER functions include the detoxification of cells and lipid synthesis. **2.1.A.4:** The Golgi complex is a membrane-bound structure that consists of a series of flattened membrane sacs. Functions of the	Figure 4.1: How does the internal organization of eukaryotic cells allow them to perform the function of life? Concept 4.3: The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes Concept 4.4: The endomembrane system regulates protein traffic and performs metabolic functions Concept 4.5: Mitochondria and chloroplasts change energy from one form to another

			Golgi include: i. Correctly folding and chemically modifying newly synthesized cellular products ii. Packaging proteins for trafficking **2.1.A.5:** Mitochondria have a double membrane that provides compartments for different metabolic reactions involved in aerobic cellular respiration. The outer membrane is smooth, while the inner membrane is highly convoluted, forming folds that enable ATP to be synthesized more efficiently. **2.1.A.6:** Lysosomes are membrane-enclosed sacs that contain hydrolytic enzymes that digest material. Lysosomes also play a role in programmed cell death (apoptosis). **2.1.A.7:** Vacuoles are membrane-bound sacs that play many different roles. i. In plant cells, a specialized large vacuole maintains turgor pressure through nutrient and water storage. ii. In animal cells, vacuoles are smaller in size, are more plentiful than in plant cells, and store cellular materials. **2.1.A.8:** Chloroplasts are specialized organelles that are found in plants and photosynthetic algae. Chloroplasts contain a double membrane and serve as the location for photosynthesis.	Concept 4.4: The endomembrane system regulates protein traffic and performs metabolic functions Concept 4.5: Mitochondria and chloroplasts change energy from one form to another
2.2 Cell Size	**Big Idea 2** Energetics	**2.2A:** Explain the effect of surface area-to-volume rations on the	**2.2.A.1:** Surface area-to-volume ratios affect the ability of a biological system to obtain necessary nutrients, eliminate waste products, acquire or dissipate thermal energy, and otherwise exchange chemicals and energy with the	Concept 4.2: Eukaryotic cells have internal membranes that compartmentalize their functions.

		exchange of materials between cells or organisms and the environment.	environment. **RELEVANT EQUATIONS** Volume of a Sphere: $V = \frac{4}{3} r$ Volume of a Cube: $V = s^3$ Volume of a Rectangular Solid: $V = lwh$ Volume of a Cylinder: $V = r^2 h$ Surface Area of a Sphere: $SA = 4 r^2$ Surface Area of a Cube: $SA = 6s^2$ Surface Area of a Rectangular Solid: $SA = 2lh + 2lw + 2wh$ Surface Area of a Cylinder: $SA = 2 rh + 2 r^2$ r = radius l = length h = height w = width s=length of one side of a cube **2.2.A.2:** The surface area of the plasma membrane must be large enough to adequately exchange materials. i. The surface area-to-volume ratio can restrict cell size and shape. Smaller cells typically have a higher surface area-to-volume ratio as well as a more efficient exchange of materials with the environment than do larger cells. ii. As cells increase in volume, the surface area-to-volume ratio decreases and the demand for internal resources increases. iii. More complex cellular structures (e.g., membrane folds) are necessary to adequately exchange materials with the environment. iv. As organisms increase in size, their surface area-to-	Figure 4.6: Geometric relationships between surface area and volume. Scientific Skills Exercise: Using a Scale Bar to Calculate Volume and Surface Area of a Cell Concept 4.8: A cell is greater than the sum of its parts. Appendix C: The Metric System Figure 26.14: Maximizing surface area

			volume ratio decreases, affecting properties like rate of heat exchange with the environment. Smaller amounts of mass exchange proportionally more heat with the ambient environment than do larger masses. As mass increases, both the surface area- to-volume ratio and the rate of heat exchange decrease. v. There is a relationship between metabolic rate per unit body mass and the size of multicellular organisms; typically, the smaller the organism, the higher the metabolic rate per unit body mass.	Concept 33.5: Feedback circuits regulate digestion, energy allocation and apppetite
2.3 Plasma Membranes	**Big Idea 2** Energetics	**2.3.A:** Describe the roles of each of the components of the cell membrane in maintaining the internal environment of the cell. **2.3.B:** Describe the fluid mosaic model of cell membranes.	**2.3.A.1:** Phospholipids have both hydrophilic and hydrophobic regions. The polar hydrophilic phosphate regions of the phospholipids are oriented toward the aqueous external or internal environment, while the nonpolar hydrophobic fatty acid regions face each other within the interior of the membrane. **2.3.A.2:** Embedded proteins can be hydrophilic (with charged and polar side groups), hydrophobic (with nonpolar side groups), or both. i. Hydrophilic regions of the proteins are either inside the interior of the protein or exposed to the cytosol (cytoplasm). ii. Hydrophobic regions of proteins make up the protein surface that interacts with the fatty acids in the interior membrane. **2.3.B.1:** Plasma membranes consist of a structural framework of phospholipid molecules embedded with proteins, steroids (such as cholesterol in vertebrate	Concept 4.2: Eukaryotic cells have internal membranes that compartmentalize their functions Concept 5.1: Cellular membranes are fluid mosaics of lipids and proteins

			animals), glycoproteins, and glycolipids. All of these can move around the surface of the cell within the membrane, as illustrated by the fluid mosaic model.	
2.4 Membrane Permeability	**Big Idea 2** Energetics	**2.4.A:** Explain how the structure of biological membranes influence selective permeability. **2.4.B:** Describe the role of the cell wall in mainlining cell structure and function.	**2.4.A.1:** Plasma membranes separate the internal environment of the cell from the external environment. Selective permeability is the result of the plasma membrane having a hydrophobic interior. **2.4.A.2:** Small nonpolar molecules including N_2, O_2, and CO_2, free pass across the membrane. Hydrophilic substances, such as large polar molecules and ions, move across the membrane through embedded channels and transport proteins. **2.4.A.3:** The nonpolar hydrocarbon tails of phospholipids prevent the movement of ions and polar molecules across the membrane. Small polar, uncharged molecules, like H_20, or NH_3 (ammonia), pass through the membrane in small amounts. **2.4.B.1:** Cell walls of Bacteria, Archaea, Fungi and plants provide a structural boundary as well las a permeability barrier for some substances to the internal or external cellular environments and protection from osmotic lysis.	Concept 5.2: Membrane structure results in selective permeability Figure 5.1: How does the plasma membrane regulate interactions between the cell and its environment? Concept 4.7: Extracellular components and connections between cells help coordinate cellular activities

AP® Biology Topics	Big Idea	Learning Objectives	Essential Knowledge	Campbell Biology in Focus 4th Edition
2.5 Membrane Transport	**Big Idea 2** Energetics	**2.5.A:** Describe the mechanisms that organisms use to maintain solute and water balance. 2.5.B: Describe the mechanisms that organisms use to transport large molecules across the plasma membrane.	**2.5.A.1:** The selective permeability of membranes allows for the formation of concentration gradients of solutes across the membrane. **2.5.A.2:** Passive transport is the net movement of molecules from regions of high concentration to regions of low concentration without the direct input of metabolic energy. **2.5.A.3:** Active transport requires the direct input of energy to move molecules. In some cases, active transport is utilized to move molecules from regions of low concentration to regions of high concentration. **2.5.B.1:** The processes of endocytosis and exocytosis require energy to move large substances or large amounts of substances into and out of cells. i. In endocytosis, the cell takes in large molecules and particulate matter by folding the plasma membrane in on itself and forming new (small) vesicles that engulf material from the external environment. ii. In exocytosis, internal vesicles release material from cells by fusing with the plasma membrane and secreting large molecules from the cell.	Concept 5.3: Passive transport is diffusion of a substance across a membrane with no energy investment. Concept 5.4: Active transport uses energy to move solutes against their gradients. Concept 5.5: Bulk transport across the plasma membrane occurs by exocytosis and endocytosis
2.6 Facilitated Diffusion	**Big Idea 2** Energetics	**2.6.A:** Explain how the structure of a molecule affects its ability to pass through the plasma membrane.	**2.6.A.1:** Facilitated diffusion requires transport or channel proteins to enable the movement of charged ions across the membrane. i. Membranes may become polarized by the movement of ions across the membrane. ii. Charged ions, including NA^+ (sodium) and K^+ (potassium) require channel proteins to move through the membrane. **2.6.A.2:** Facilitated diffusion enables the movement of large polar molecules through membranes with no energy input. In this type of	Concept 5.3: Passive transport is diffusion of a substance across a membrane with no energy investment.

			diffusion, substances move down the concentration gradient. **2.6.A.3:** Aquaporins transport large quantities of water across membranes.	
2.7 Tonicity and Osmoregulation	**Big Idea 2** Energetics	**2.7.A:** Explain how concentration gradients affect the movement of molecules across membranes.	**2.7.A.1:** External environments can be hypotonic, hypertonic, or isotonic to internal envi Movement of water can also be described as moving from hypotonic to hypertonic region osmosis from regions of high water potential to regions of low water potential. **RELEVANT EQUATION** Water Potential: *ps* where: *p* = pressure potential *s* = solute potential	Concept 5.3: Passive transport is diffusion of a substance across a membrane with no energy investment.
			2.7.B.1: Growth and homeostasis are maintained by the constant movement of molecules across membranes.	
		2.7.B: Explain how osmoregulatory mechanisms contribute to the health and survival of organisms.	**2.7.B.2:** Osmoregulation maintains water balance and allows organisms to control their internal solute composition and water potential. Water moves from regions of low osmolarity or solute concentration to regions of high osmolarity or solute concentration. **RELEVANT EQUATION** Solute Potential of a Solution: *s*=−*iCRT* where: *i* = ionization constant *C* = molar concentration *R* = pressure constant *R* = 0.0831 *L bars* / *mol K* *T* = temperature in Kelvin (°C + 273)	Concept 29.5: Transpiration drives the transport of water and minerals from roots to shoots via the xylem

2.8 Mechanisms of Transport	**Big Idea 2** Energetics	**2.8.A:** Describe the processes that allow ions and other molecules to move across membranes.	**2.8.A.1:** Metabolic energy (such as that from ATP) is required for active transport of molecules and ions across the membrane and to establish and maintain electrochemical gradients i. Membrane proteins are necessary for active transport. ii. the Na^+/K^+ pump and ATPase contribute to the maintenance of the membrane potential.	Concept 5.4: Active transport uses energy to move solutes against their gradients

AP® Biology Topics	Big Ideas	Learning Objectives	Essential Knowledge	Campbell Biology in Focus 4th Edition
2.9 Cell Compartmentalization	**Big Idea 2** Energetics	**2.9.A:** Describe the membrane-bound structures of the eukaryotic cell. **2.9.B:** Explain how internal membranes and membrane-bound organelles contribute to compartmentalization of eukaryotic cell functions.	**2.9.A.1** Membranes and membrane-bound organelles in eukaryotic cells compartmentalize intracellular metabolic processes and specific enzymatic reactions. **2.9.B.1:** Internal membranes facilitate cellular processes by minimizing competing interactions and my increasing surface areas where reactions can occur.	Concept 4.2: Eukaryotic cells have internal membranes that compartmentalize their functions Concept 4.4: The endomembrane system regulates protein traffic and performs metabolic functions Concept 4.5: Mitochondria and chloroplasts change energy from one form to another
2.10 Origins of Cell Compartmentalization	**Big Idea 1** Evolution	**2.10.A:** Describe similarities and/or differences in compartmentalization between prokaryotic and eukaryotic cells.	**2.10.A.1:** Membrane-bound organelles such as mitochondria and chloroplasts evolved from once free-living prokaryotic cells via endosymbiosis. **2.10.A.2:** Prokaryotes typically lack internal membrane-bound organelles but have internal regions with specialized structures and functions. **2.10.A.3:** Eukaryotic cells maintain internal membranes that partition the cell into specialized regions.	Figure 25.1: What ga e rise to the great diversity of eukaryotes, and how have eukaryotic lineages diverged over time? Concept 25.1: Eukaryotes arose by endosymbiosis more than 1.8 billion years ago Concept 24.2: Diverse structural and metabolic adaptations have evolved in prokaryotes Concept 4.2: Eukaryotic cells have internal membranes that compartmentalize their functions
Unit 3: Cellular Energetics (5 Topics)				
3.1 Enzymes	**Big Idea 2** Energetics	**3.1.A:** Explain how enzymes affect the rate of biological reactions.	**3.1.A.1:** The structure and function of enzymes contribute to the regulation of biological processes. Enzymes are proteins that are biological catalysts that facilitate chemical reactions in cells by lowering	Concept 3.5: Proteins include a diversity of structures resulting in a wide range of functions Concept 6.1: An organism's metabolism transforms matter and energy Concept 6.4: Enzymes speed up metabolic reactions by lowering energy barriers

			the activation energy **3.1.A.2:** For an enzyme-mediated chemical reaction to occur, the share and charge of the substrate must be compatible with the active site of the enzyme. This is illustrated by the enzyme-substrate complex model.	
3.2 Environmental Impacts on Enzyme Function	**Big Idea 2** Energetics	**3.2.A:** Explain how changes to the structure of an enzyme may affect its function.	**3.2.A.1:** Change to the molecular structure of a component in an enzymatic system may result in a change to its function or efficiency. i.Denaturation of proteins, such as enzymes, occurs when the protein structure is disrupted by a change in temperature, pH, or chemical environment, eliminating the ability to catalyze reactions. ii.Environmental temperatures and pH outside the optimal range for a given enzyme will cause changes to its structure (by disrupting the hydrogen bonds), altering the efficiency with which it catalyzes reactions. **3.2.A.2**: In some cases, enzyme denaturation is reversible, allowing the enzyme to regain activity.	Concept 6.1: An organism's metabolism transforms matter and energy Concept 6.4: Enzymes speed up metabolic reactions by lowering energy barriers Concept 3.5: Proteins include a diversity of structures, resulting in a wide range of functions
		3.2.B: Explain how the cellular environment affects enzyme activity.	**3.2.B.1:** The relative concentrations of substrates and products determine how efficiently an enzymatic reaction proceeds. **3.2.B.2:** Higher	Concept 6.5: Regulation of enzyme activity helps control metabolism

			environmental temperatures increase the average speed of movement of molecules in a solution, increasing the frequency of collisions between enzyes and substrates and therefore increasing the rate of reaction until the optimal temperature is achieved. **3.2.B.3:** Competitive inhibitor molecules can bind reversibly to the active site of the enzyme. Noncompetitive inhibitors can bind to allosteric sites, changing the activity of the enzyme.	

AP® Biology Topics	Big Ideas	Learning Objectives	Essential Knowledge	Campbell Biology in Focus 4th Edition
3.3 Cellular Energy	**Big Idea 2** Energetics	**3.3.A:** Describe the role of energy in living organisms. **3.3.B:** Explain how shared, conserved, and fundamental processes and features support the concept of common ancestry for all organisms.	**3.3.A.1:** All living systems require an input of energy. **3.3.A.2:** Life requires a highly ordered system and does not violate the first and second laws of thermodynamics. i. Energy input must exceed energy loss to maintain order and to power cellular processes. ii.Cellular processes that release energy may be coupled with cellular processes that require energy. iii. Significant loss of order or energy flow results in death. 3**.3.A.3:** Energy-related pathways in biological systems are sequential to allow for a more controlled transfer of energy. A product of a reaction in a metabolic pathway is typically the reactant for the subsequent step in the pathway. **3.3.B.1:** Core metabolic pathways (e.g., glycolysis, oxidative phosphorylation) are conserved across all currently recognized domains (Archaea, Bacteria, and Eukarya).	Concept 6.1: An organism's metabolism transforms matter and energy Concept 6.2: The free-energy change of a reaction tells us whether or not the reaction occurs spontaneously. Figure 7.1: How is the chemical energy stored in food used to generate ATP, the molecule that drives most cellular work? Concept 6.3: ATP powers cellular work by coupling exergonic reactions to endergonic reactions. Concept 7.1: Catabolic pathways yield energy by oxidizing organic fuels Concept 7.5: Fermentation and anaerobic respiration enable cells to produce ATP without the use of oxygen
3.4 Photosynthesis	**Big Idea 2** Energetics	**3.4.A:** Describe the photosynthetic processes and structural features of the chloroplast that allow organisms to capture and store energy.	**3.4.A.1:** Photosynthesis is the series of reactions that use carbon dioxide (CO_2), water (H_2O), and light energy to make carbohydrates and oxygen (O_2). i. Photosynthetic organisms capture energy from the sun and produce sugars that can be used in biological processes or stored. ii. Photosynthesis first evolved in prokaryotic organisms.	Concept 8.1: Photosynthesis feeds the biosphere Concept 8.2: Photosynthesis converts light energy to the chemical energy of food Concept 24.1: Conditions on early Earth made the

			iii. Scientific evidence supports the claim that prokaryotic (cyanobacterial) photosynthesis was responsible for the production of an oxygenated atmosphere. iv. Prokaryotic photosynthetic pathways were the foundation of eukaryotic photosynthesis.	origin of life possible Concept 24.2: Diverse structural and metabolic adaptations have evolved in prokaryotes
			3.4.A.2: Stroma and thylakoids are found within the chloroplast. i. The stroma is the fluid within the inner chloroplast membrane and outside the thylakoid. The carbon fixation (Calvin cycle) reactions of photosynthesis occur in the stroma. ii. The thylakoid membranes contain chlorophyll pigments organized into two photosystems, as well as electron transport proteins. iii. Thylakoids are organized in stacks called grana. The light reactions of photosynthesis occur in the grana.	Concept 8.3: The light reactions convert solar energy to the Chemical energy of ATP and NADPH
			3.4.A.3: The light reactions of photosynthesis in eukaryotes involve a series of coordinated reaction pathways that capture energy present in light to yield ATP and NADPH, which power the production of organic molecules in the Calvin cycle. This provides energy for metabolic processes.	
		3.4.B: Explain how cells capture energy from light and transfer it to biological molecules for storage and use.	**3.4.B.1:** Electron transport chain (ETC) reactions occur in chloroplasts, in mitochondria, and across prokaryotic plasma membranes. In photosynthesis, electrons that pass through the thylakoid membrane are picked up and ultimately transferred to $NADP^+$ reducing it to NADPH in photosystem I. **3.4.B.2:** During photosynthesis, chlorophylls absorb energy from light, boosting electrons to a higher energy level in photosystems I and II. Water then splits, supplying electrons to replace those lost from photosystem II. **3.4.B.3:** Photosystems I and II are embedded in the thylakoid membranes of chloroplasts and are connected by the transfer of electrons through an ETC. **3.4.B.4:** When electrons are transferred between	figure 8.21: The working cell

			molecules in a series of oxidation/reduction reactions as they pass through the ETC, an electrochemical gradient of protons (hydrogen ions) is established across the thylakoid membrane. The membrane separates a region of low proton concentration outside the thylakoid membrane from a region of high proton concentration inside the thylakoid membrane. **3.4.B.5:** The formation of the proton gradient is linked to the synthesis of ATP from ADP and inorganic phosphate via ATP synthase. The flow of protons back through membrane-bound ATP synthase by chemiosmosis drives the formation of ATP from ADP and inorganic phosphate; this is known as photophosphorylation. **3.4.B.6:** The energy captured in the light reactions and transferred to ATP and NADPH powers the production of carbohydrates from carbon dioxide in the Calvin cycle. This occurs in the stroma of the chloroplast.	Concept 8.4: The Calvin cycle uses the chemical energy of ATP and NADPH to reduce CO_2 to sugar

3.5 Cellular Respiration	**Big Idea 2** Energetics	**3.5.A:** Describe he processes and structural features of mitochondria that allow organisms to use energy stored in biological macromolecules.	**3.5.A.1:** Cellular respiration uses energy from biological macromolecules to synthesize ATP. Respiration and fermentation are characteristic of all forms of life. **3.5.A.2:** Aerobic cellular respiration in eukaryotes involves a series of coordinated enzyme- catalyzed reactions that capture energy from biological macromolecules. **3.5.A.3:** The ETC transfers electrons in a series of oxidation-reduction reactions that establish an electrochemical gradient across membranes. i. In cellular respiration, electrons delivered by NADH and $FADH_2$ are passed to a series of electron acceptors as they move toward the terminal electron acceptor, oxygen. Aerobic prokaryotes use oxygen as a terminal electron acceptor, while anaerobic prokaryotes use other molecules. ii. The transfer of electrons, through the ETC, is accompanied by the formation of a proton gradient across the inner mitochondrial membrane, with the membrane(s) separating a region of high proton concentration outside the membrane from a region of low proton concentration inside the membrane. The folding of the inner membrane increases the surface area, which allows for more ATP to be synthesized. In prokaryotes, the passage of electrons is accompanied by the movement of protons across the plasma membrane. iii. The flow of protons back through membrane-bound ATP synthase by chemiosmosis drives the formation of ATP from ADP and inorganic phosphate. This is known as oxidative phosphorylation in aerobic cellular respiration. iv. In aerobic cellular respiration, decoupling oxidative phosphorylation from electron transport generates heat. This heat can be used by endothermic organisms to regulate body temperature. **3.5.B.1:** Glycolysis is a biochemical pathway that releases the energy in glucose molecules to form ATP (from ADP and inorganic	Concept 7.1: Catabolic pathways yield energy by oxidizing organic fuels Concept 7.4: During oxidative phosphorylation, chemiosmosis couples electron transport to ATP synthesis

			phosphate), NADH (from NAD^+), and pyruvate.	
		3.5.B: Explain how cells obtain energy from biological macromolecules in order to power cellular functions.	**3.5.B.2:** Pyruvate is transported from the cytosol to the mitochondrion where oxidation occurs. This process releases electrons during the Krebs (citric acid) cycle, reducing NAD^+ to NADH and FAD to $FADH_2$, and releasing CO_2 .	Concept 7.2: Glycolysis harvests chemical energy by oxidizing glucose to pyruvate Concept 7.3: After pyruvate is oxidized, the citric acid cycle completes the energy-yielding oxidation of organic molecules
			3.5.B.3: The Krebs cycle takes place in the mitochondrial matrix. During the Krebs cycle, carbon dioxide is released from organic intermediates, ATP is synthesized from ADP and inorganic phosphate, and electrons are transferred by the coenzymes NAD^+ and FAD.	
			3.5.B.4 Electrons extracted in glycolysis and Krebs cycle reactions are transferred by NADH and $FADH_2$ to the ETC in the inner mitochondrial membrane.	
			3.5.B.5 When electrons are transferred between molecules in a sequence of reactions as they pass through the ETC, an electrochemical gradient of protons (hydrogen ions) across the inner mitochondrial membrane is established. The pH inside the mitochondrial matrix is higher than in the intermembrane space.	Concept 7.4: During oxidative phosphorylation, chemiosmosis couples electron transport to ATP synthesis
			3.5.B.6 Fermentation allows glycolysis to proceed in the absence of oxygen and produces organic molecules such as alcohol and lactic acid.	

					Concept 7.5: Fermentation and anaerobic respiration enable cells to produce ATP without the use of oxygen

Unit 4: Cell Communication and Cell Cycle (6 Topics)

AP® Biology Topics	Big Ideas	Learning Objectives	Essential Knowledge	Campbell Biology in Focus 4e
4.1 Cell Communication	**Big Idea 3** Information Storage and Transmission	**4.1.A:** Describe the ways that cells can communicate with one another. **4.1.B:** Explain how cells communicate with one another over short and long distances	**4.1.A.1**: Cells communicate with one another through direct contact with other cell or from a distance via chemical signaling **4.1.B.1:** Cells communicate over short distances by using local regulators that target cells I the vicinity of the signal-emitting cell. **A1.B.2:** Signals released by one cell type can travel long distances to target cells of another type.	Concept 5.6: The plasma membrane plays a key role in most cell signaling
4.2 Introduction to Signal Transduction	**Big Idea 3** Information Storage and Transmission	**4.2.A:** Describe the components of a signal transduction pathway. **4.2.B:** Describe the role of components of a signal transduction pathway in producing a cellular response.	**4.2.A.1:** Signal transduction pathways link signal receptions with cellular responses. **4.2.A.2:** Many signal transduction pathways include protein modifications and involve phosphorylation cascades. **4.2.B.1:** Signaling begins with the recognition of a chemical messenger—a ligand—by a receptor protein in a target cell. i. The ligand-binding domain of a receptor recognizes a specific chemical messenger, which can be a peptide (protein) or a small molecule. ii. G protein-coupled receptors are an example of a receptor protein in eukaryotes. **4.2.B.2:** Signaling cascades relay signals from receptors to cell targets, often amplifying the incoming signals, resulting in the appropriate responses by the cell. Responses could include cell growth, secretion of molecules, or gene expression. i. After the ligand binds, the intracellular domain of a	Concept 5.6: The plasma membrane plays a key role in most cell signaling Concept 32.1: The endocrine and nervous systems act individually and together in regulating animal physiology

			receptor protein changes shape, initiating transduction of the signal. ii. Enzymes and second messengers such as cyclic AMP (cAMP) relay and amplify the intracellular signal. iii. Hormones are an example of a signaling messenger that can travel long distances in the bloodstream. iv. The binding of ligands to ligand-gated channels can cause the channel to open or close,	
4.3 Signal Transduction Pathways	**Big Idea 3** Information Storage and Transmission	**4.3.A:** Describe the different types of cellular responses elicited by a signal transduction pathway. **4.3.A:** Explain how a change in the structure of any signaling molecule affects the activity of the signaling pathway.	**4.3.A.1:** Signal transduction may result in changes in gene expressions and cell function, which may alter phenotype or result in programmed cell death (apoptosis). **4.3.B.2:** Changes in signal transduction pathways can later cellular responses Mutations in any domain of the receptor protein or in any component of the signaling pathway may affect the downstream components by altering the subsequent transduction of the signal. **4.3.B.3:** Chemicals that interact with any component of the signaling pathway may activate or inhibit the pathway.	Concept 5.6: The plasma membrane plays a key role in most cell signaling Concept 9.3: The eukaryotic cell cycle is regulated by a molecular control system Concept 16.1: A program of differential gene expression leads to the different cell types in a multicellular organism Concept 31.2: Plant hormones hep coordinate growth, development, and responses to stimuli
4.4 Feedback	**Big Idea 2** Energetics	**4.4.A:** Explain how positive and negative feedback helps maintain homeostasis.	**4.4.A.1** Organisms use feedback mechanisms to maintain their internal environments in response to internal and external changes. i. Negative feedback mechanisms maintain homeostasis by reducing the initial stimulus to regulate physiological processes. If a system is perturbed or disrupted, negative feedback mechanisms return the system back to its target set point. These processes operate at the molecular cellular, and organismal levels.	Concept 6.5: Regulation of enzyme activity helps control metabolism Concept 32.2: The endocrine and nervous systems act individually and together in regulating animal physiology Concept 32.3: Feedback

			ii. Positive feedback, mechanisms amplify responses and processes in biological organisms. The variable initiating the response is moved further away from the initial set point. Ampfliication occurs when the stimulus is further intensified, which in turn, initiates and additional response that produces system change.	control maintains. the internal environment in many animals Concept 33.5: Feedback circuits regulate. digestion, energy allocation, and appetite

AP® Biology Topics	Big Idea	Big Ideas: Learning Objectives	Essential Knowledge	Campbell Biology in Focus 4e
4.5 Cell Cycle	**Big Idea 3** Information Storage and Transmission	**4.5.A:** Describe the events that occur in the cell cycle.	**4.5.A.1:** The cell cycle is a highly regulated series of events that controls the growth and reproduction of eukaryotic cells. i. The cell cycle consists of sequential stages of interphase (G1, S, G2), mitosis, and cytokinesis. ii. G1 phase: The cell is metabolically active, duplicating organelles and cytosolic components. iii. S phase: DNA is in the form of chromatin and replicates to form two sister chromatids connected at a centromere. iv. G2 phase: Protein synthesis occurs, ATP is produced in large quantities, and centrosomes replicate. v. A cell can enter a stage (G0) in which it no longer divides, but it can reenter the cell cycle in response to appropriate cues. vi. Nondividing cells may exit the cell cycle or be held at a particular cycle	Overview: The Key Roles of Cell Division Concept 9.1 Most cell division results in genetically identical daughter cells Concept 9.2: The mitotic phase alternates with interphase in the cell cycle
		4.5.B: Explain how mitosis results in the transmission of chromosomes from one generation of cells to the next.	**4.5.B.1:** Mitosis is a process that ensures the transfer of a complete genome from a parent cell to two genetically identical daughter cells in eukaryotes. i. Mitosis plays a role in growth, tissue repair, and asexual reproduction. ii. Mitosis occurs in sequential steps (prophase, metaphase, anaphase, telophase) and alternates with interphase in the cell	

			cycle. iii. Prophase: Sister chromatids condense, mitotic spindle begins to form, and centrosomes move to opposite poles of the cell. iv. Metaphase: Spindle fibers align chromosomes along the equator of the cell. v. Anaphase: Paired sister chromatids separate as spindle fibers pull chromatids toward poles. vi. Telophase: Mitotic spindle breaks down, a new nuclear envelope develops, and then the cytoplasm divides. vii. Cytokinesis: A cleavage furrow forms in animal cells or a cell plate forms in plant cells, resulting in two new daughter cells.	
4.6 Regulation of Cell Cycle	**Big Idea 3** Information Storage and Transmission	**4.6.A:** Describe the role of checkpoints in regulating the cell cycle.	**A.6.A.1:** A number of internal controls or checkpoints regulate progression through the cell cycle. **A.6.A.2:** Interactions between cyclins and cylin-dependent kinases control the cell cycle.	Concept 9.3: The eukaryotic cell cycle is regulated by a molecular control system
		4.6.B: Describe the effects of disruptions to the cell cycle on the cell or organism.	**4.6.B.1:** Disruptions to the cell cycle may result in cancer or apoptosis (programmed cell death).	Concept 16.3: Abnormal regulation of genes that affect the cell cycle can lead to cancer

AP® Biology Topics Unit 5: Heredity (5 topics)	**Big Idea**	**Learning Objectives**	**Essential Knowledge**	**Campbell Biology in Focus 4e**
5.1 Meiosis	**Big Idea 3** Information Storage and Transmission	**5.1.A:** Explain how meiosis results in the transmission of chromosomes form one generation to the next.	**5.1.A.1** Meiosis is a process that ensures the formation of haploid gamete cells, sometimes referred to as daughter cells, in sexually reproducing diploid organisms. **5.1.A.2** Meiosis I involves the following steps: i. Prophase I: Homologous chromosomes pair up and condense, synapsis occurs and then chiasmata may form, meiotic spindle begins to form, centrosomes move to opposite poles of the cell, and the nuclear envelope breaks down. ii. Metaphase I: Meiotic spindle fibers align homologous pairs of chromosomes along the equator of the cell at the metaphase plate. iii. Anaphase I: Homologous chromosomes separate, while sister chromatids remain attached, as meiotic spindle fibers pull chromosomes toward poles. iv. Telophase I: Meiotic spindle breaks down, a new nuclear envelope develops, a cleavage furrow (animal cell) or cell plate (plant cell) forms, and cytokinesis occurs. Two haploid daughter cells are formed (at the end of meiosis I). **5.1.A.3:** Meiosis II involves the fo i. Prophase II: Meiotic spin spindle. ii. Metaphase II: Chromoso of each chromatid is attac	Concept 10.1: Offspring acquire genes from parents by inheriting chromosomes Concept 10.2: Fertilization and meiosis alternate in sexual life cycles Concept 10.3: Meiosis reduces the number of chromosomes sets from diploid to haploid

			iii. Anaphase II: Proteins at the centromeres break down, an toward opposite poles in the cell. iv. Telophase II: Meiotic spindle breaks down, a new nucle (animal cell) or a cell plate (plant cell) forms, chromatic occurs. Four haploid daughter cells are formed, each wi	
		5.1.B: Describe similarities and differences between the phases and outcomes of mitosis and meiosis	**5.1.B.1:** Mitosis and meiosis are similar in the use of a spindle a the number of cells produced and the genetic content of the daug	
				Figure 10.10: A comparison of mitosis and meiosis
5.2 Meiosis and Genetic Diversity	**Big Idea 3** Information Storage and Transmission	**5.2.A:** Explain how the process of meiosis generates genetic diversity.	**5.2.A.1:** Correct separation of the homologous chromosomes in meiosis I and sister chromatids in meiosis II ensures that each gamete receives a haploid (1n) set of chromosomes that comprises an assortment of both maternal and paternal chromosomes. When incorrect separation occurs (nondisjunction), gametes are no longer haploid. 5.2.A.2: During prophase I of meiosis, non-sister chromatids exchange genetic material via a process called crossing over (recombination), which increases genetic diversity among the resultant gametes. **5.2.A.3:** Sexual reproduction is eukaryotes increases genetic variation, including crossing over, random assortment of chromosomes during meiosis, and subsequent fertilization of gametes.	Concept 10.3: Meiosis reduces the number of chromosomes sets from diploid to haploid Concept 10.4: Genetic variation produced in sexual life cycles contributes to evolution

5.3 Mendelian Genetics	**Big Idea 1** Evolution	**5.3.A:** Explain the inheritance of genes and traits as described by Mendel's laws.	**5.3.A.1** Mendel's laws of segregation and independent assortment can be applied to genes that are on different chromosomes. **5.3.A.2** In most cases, fertilization involves the fusion of two haploid gametes, restoring the diploid number of chromosomes and increasing genetic variation in populations by creating new combinations of alleles in the zygote. i. Rules of probability can be applied to analyze the passing of single-gene traits from parent to offspring. ii. Monohybrid, dihybrid, and test crosses can be used to determine whether alleles are dominant or recessive. iii. An organism's genotype is the set of alleles inherited for one or more	Concept 11.1: Mendel used the scientific approach to identify tow laws of inheritance. Concept 11.2: Probability laws govern Mendelian inheritance

			genes by an individual organism. An organism's genotype can be homozygous or heterozygous for each gene. iv. An organism's phenotype is the observable expression of the inherited traits. v. Patterns of inheritance (autosomal, genetically linked, sex-linked) and whether an allele is dominant or recessive can often be predicted from data, including pedigrees. Punnett squares can be used to predict the genotypes and phenotypes of parents and offspring. **RELEVANT EQUATIONS** Laws of Probability: If *A* and *B* are mutually exclusive, then: $P(A \text{ or } B) = P(A) + P(B)$ If A and B are independent, then: $P(A \text{ and } B) = P(A) \times P(B)$ v.	Concept 11.3: Inheritance patterns are often more complex than predicted by simple Mendelian genetics Concept 11.4: Many human traits follow Mendelian patterns of inheritnace
5.4 Non-Mendelian Genetics	**Big Idea 3** Information Storage and Transmission	**5.4.A:** Explain deviations from Mendel's model of the inheritance of traits.	**5.4.A.1:** Patterns of inheritance of many traits do not follow the ratios predicted by Mendel's laws and can be identified by quantitative analysis, when the observed phenotypic ratios statistically differ from the predicted ratios. i. Genes located on the same chromosome are referred to as being genetically linked. The probability that these linked genes segregate together during meiosis can be used to calculate the map distance (or map	Concept 12.1: Mendelian inheritance has its physical basis in the behavior of chromosomes Concept 12.3: Linked genes tend to be inherited together because they are located ear each other on

			units) between them on a chromosome. This calculation is called gene or genetic mapping. ii. Codominance occurs when the phenotype from both alleles is expressed such that the heterozygote would have a different phenotype than either homozygote. iii. Incomplete dominance occurs when neither allele of a gene can mask the other, so the phenotype of the heterozygote is a blended version of the dominant and recessive phenotypes.	the same chromosome Concept 11.3: Inheritance patterns are often more complex than predicted by simple Mendelian genetics
			5.4.A.2: Some traits, known as sex-linked traits (X- or Y-linked), are determined by genes on sex chromosomes. The pattern of inheritance of sex-linked traits can often be predicted from data, including pedigrees, indicating the genotypes and phenotypes of both parents and offspring.	Concept 12.2: Sex-linked genes exhibit unique patterns of inheritance
			5.4.A.3: Pleiotropy is a phenomenon in which the expression of a single gene results in multiple traits or effects; these traits therefore do not segregate independently. **5.4.A.4:** Some traits result from non-nuclear inheritance. i. Chloroplasts and mitochondria are randomly assorted to gametes and daughter cells; thus, traits determined by chloroplast and mitochondrial DNA do not follow simple Mendelian rules. ii. In animals, mitochondria are usually transmitted	Concept 11.3: Inheritance patterns are often more complex than predicted by simple Mendelian genetics Concept 30.1:

			by the egg and not by sperm; thus, traits determined by the mitochondrial DNA are typically maternally inherited. iii. In plants, mitochondria and chloroplasts are transmitted in the ovule and not in the pollen; as such, mitochondria-determined and chloroplast-determined traits are typically maternally inherited.	Flower double fertilization, and fruits are unique features of the angiosperm life cycle Figure 36.9: Exploring Human Gametogenesis

AP® Biology Topics	Big Ideas:	Learning Objectives	Essential Knowledge	Campbell Biology in Focus 4e
5.5 Environmental Effects on Phenotype	**Big Idea 4** Systems Interactions	**5.5.A:** Explain how the same genotype can result in multiple phenotypes under different environmental conditions.	**5.5A.1:** Environmental conditions influence can expression and can lead to phenotypic plasticity (e.g., the ability of individual genotypes to produce different phenotypes.	Concept 11.3: Inheritance patterns are often more complex than predicted by simple Mendelian genetics
		Unit 6: Gene Expression and Regulation (8 Topics)		
6.1 DNA and RNA Structure	**Big Idea 3** Information Storage and Transmission	**6.1.A:** Describe the structures involved in passing hereditary information from one generation to the next. **6.1.B:** Describe the characteristics of DNA that allow it to be used as hereditary material.	**6.1.A.1:** Genetic information is stored in and passed to subsequent generations through DNA molecules and, in some cases, RNA molecules. i. Prokaryotic organisms typically have circular chromosomes. ii. Eukaryotic organisms typically have multiple linear chromosomes that are comprised of DNA. These chromosomes are condensed using histones and associated proteins. **6.1.A.2:** Prokaryotes and eukaryotes can contain plasmids, which are extra-chromosomal circular molecules of DNA. 6.1.B. Nucleic acids exhibit specific nucleotide base pairing that is conserved through evolution. i. Purines (guanine and adenine) have a double ring structure. ii. Pyrimidines (cytosine, thymine, and uracil) have a single ring structure. iii. Purines pair with pyrimidines; adenine with thymine (or uracil in RNA) and guanine with cytosine.	Concept 3.6: Nucleic acids store, transmit, and help express hereditary information Concept 24.2: Diverse structural and metabolic adaptations have evolved in prokaryotes Concept 13.2: Many proteins work together in DNA replication and repair Concept 13.3: A chromosome consists of a DNA molecule packed together with proteins. Concept 13.4: Understanding DNA structure and replication makes genetic engineering possible Concept 13.1: DNA is the genetic material

6.2 DNA Replication	**Big Idea 3** Information Storage and Transmission	**6.2.A:** Describe the mechanisms by which genetic information is copied for transmission between generations.	**6.2.A.1:** DNA replication ensures continuity of hereditary information. i. DBA is synthesized in the 5' to 3' direction. ii. Replication is a semiconservative process, meaning one strand of DNA serves as the template for a new strand of complementary DNA. iii. Helicase unwinds the DNA strands. iv. Topoisomerase relaxes supercoiling in front of the replication fork. v. DNA polymerase requires RNA primers to initiate DNA synthesis. vi. DNA polymerase synthesizes new strands of DNA continuously on the leading strand and discontinuously on the lagging strand vii. Ligase joins the fragments on the lagging strand.	Concept 13.2: Many proteins work together in DNA replication and repair
6.3 Transcription and RNA Processing	**Big Idea 3** Information Storage and Transmission	**6.3.A:** Describe the mechanisms by which genetic information flows from DNA to RN to protein.	**6.3.A.1:** The sequence of the RNA bases, together with the structure of the RNA molecule, determines RN function. i. Messenger RNA (mRNA) molecules carry information from DNA in the nucleus to the ribosome in the cytoplasm. ii. Distinct transfer RNA (tRNA) molecules bind specific amino acids and have anticodon sequences that base pair with the codons of mRNA. tRNA is recruited to the ribosome during translation to generate the primary peptide sequence based on the mRNA sequence. iii. Ribosomal RNA (rRNA) molecules are functional building blocks of ribosomes. **6.3.A.2:** RNA polymerases use a single template strand of DNA to direct the inclusion of bases in the newly formed RNA molecule. This process is known as transcription. **6.3.A.3:** The enzyme RNA polymerase synthesizes mRNA molecules in the 5' to 3' direction by reading the template DNA strand in	Concept 14.1: Genes specify proteins via transcription and translation Concept 14.2: Transcription is the DNA-directed synthesis of RNA: A Closer Look

			the 3' to 5' direction. **6.3.A.4:** In eukaryotic cells the mRNA transcript undergoes a series of enzyme-mediated modifications. i. The addition of a poly-A tail makes mRNA more stable. ii. The addition of a GTP cap helps with ribosomal recognition. iii. The excision of introns, along with the splicing and retention of exons, generates different versions of the resulting mature mRNA molecule. This process is known as alternative splicing.	Concept 14.3: Eukaryotic cells modify RNA after transcription
6.4 Translation	**Big Idea 3** Information Storage and Transmission	**6.4.A:** Explain how the phenotype of an organism is determined by its genotype.	**6.A.4.1:** Translation of the mRNA to generate a polypeptide occurs on the ribosomes that are present in the cytoplasm of both prokaryotic and eukaryotic cells, as well as the cytoplasmic surface of the rough ER of eukaryotic cells. **6.A.4.2:** In prokaryotic organisms, translation of the mRNA molecule occurs while it is being transcribed. **6.A.4.3:** Translation involves many sequential steps, including initiation, elongation, and termination. The salient features of translation include: i. The translation is initiated when the rRNA in the ribosome interacts with he mRNA at the start codon (AUG, coding for the amino acid methionine). ii. The sequence of nucleotides on the mRNA is read in triplets, called codons. iii. Each codon encodes a specific amino acid, which can be deduced by using a genetic code chart. Many amino acids are encoded by more than one codon. iv. Nearly a living organisms use the same genetic code, which is evidence for the common ancestry of all living organisms. v. tRNA brings the correct amino acid	Concept 14.4: Translation is the RNA-directed synthesis of a polypeptide: A Closer Look Concept 14.1: Genes specify proteins via transcription and translation

			to the pace specified by the codon on the mRNA. vi. The amino acid is transferred to the growing polypeptide chain. vii. The process continues along the mRNA until a sop codon is reached. viii. Translation terminates with the release of the newly synthesized protein. **6.4.A.4:** Genetic information is retroviruses is a special case and has an alternate flow if information: from RNA to DNA, made possible by reverse transcriptase, an enzyme that copies the viral RNA genome into DNA. This DNA integrates in the host genome and is transcribed and translate for the assembly of new viral progeny.	Concept 17.2: Viruses replicate only in host cells

AP® Biology Topics	Big Ideas:	Learning Objectives	Essential Knowledge	Campbell Biology in Focus 4e
6.5 Regulation of Gene Expression	**Big Idea 3** Information Storage and Transmission	**6.5.A:** Describe the types of interactions that regulate gene expression 6.5.B: Explain how the location of regulatory sequences relates to their function.	**6.5.A.1:** Regulatory sequences are stretches of DNA that interact with regulatory proteins to control transcription. Some genes are constitutively expressed, and others are inducible. **6.5.A.2:** Epigenetic chances can affect gene expression through reversible modifications of DNA or histones. **6.5.A.3:** The phenotype of a cell or an organism is determined by the combination of genes that are expressed and the levels at which they are expressed. i. Observable cell differentiation results from the expression of genes for tissue-specific proteins. ii. induction of transcription factors during development results in sequential gene expression. iii. The function and amount of gene products determine the phenotype of organisms. **6.5.A.4:** Both prokaryotes and eukaryotes have groups of genes that are coordinately regulated. i. Prokaryotes regulate operons in an inducible or repressible system. ii. In eukaryotes, groups of genes may be influenced by the same transcription factors to coordinately regulate expression. **6.5.B.1:** Both prokaryotes and eukaryotes have groups of genes that are coordinately regulated. i. Prokaryotes regulate operons in an inducible or repressible system.	figure 15.1: How can two cells with the same set of genes function differently? Concept 15.2: Eukaryotic gene expression is regulated at many stages Concept 15.3: Noncoding RNAs play multiple roles in controlling gene expression Concept 15.1: Bacteria often respond to environmental change by regulating transcription. Concept 15.2: Eukaryotic gene expression is regulated at many stages Concept 15.4: Researchers can monitor expression of specific genes

			ii. In eukaryotes, groups of genes may be influenced by the same transcription factors to coordinately regulate expression,	
6.6 Gene Expression and Cell Specialization	**Big Idea 3** Information Storage and Transmission	**6.6.A:** Explain how the binding of transcription factors to promoter regions affects gene expression and the phenotype of the organism. **6.6.B:** Explain the connection between the regulation of gene expression and the phenotypic differences in cells and organisms.	**6.6.A.1:** RNA polymerase and transcription factors bind to promoter or enhancer DNA sequences to initiate transcription. These sequences can be upstream or downstream of the transcription start site. **6.6.A.2:** Negative regulatory molecules inhibit gene expression by binding to DNA and blocking transcription. **6.6 B.1:** Gene regulation results in differential gene expression and influences cell products and functions. **6.6.B.2:** Certain small RNA molecules have roles in regulating gene expression.	Concept 15.3: Noncoding RNAs play multiple roles in controlling gene expression Concept 15.4: Researchers can monitor expression of specific genes Figure 15.1: How can two cells with the same set of genes function differently? Concept 15.2: Eukaryotic bene expression is regulated at many stages Concept 15.3: Noncoding RNAs paly multiple roles in controlling gene expression Concept 16.1: A program of differential gene expression leads to the different cell types in a multicelllular organism
6.7 Mutations	**Big Idea 3** Information Storage and Transmission	**6.7.A:** Describe the various types of mutations.	**6.7.A.1:** Alterations in a DNA sequence are mutations that can cause changes in the type or amount of the protein produced and the consequent phenotype. DNA mutations can be beneficial, detrimental, or neutral based on the resulting nucleic acid or protein and the phenotypes that are conferred by the protein. i. Point mutations occur when one nucleotide has been substituted for a different nucleotide. ii. Frameshift mutations	Concept 14.5: Mutations of one or a few nucleotides can affect protein structure and function

		6.7.B: Explain how changes in genotype may result in changes in phenotype. **6.7.C:** Explain how alterations in DNA sequences contribute to variation that can be subject to natural selection.	occur when one or more nucleotides are inserted or deleted, causing the reading frame to be shifted. iii. Nonsense mutations occur when there is a point mutation that causes a premature stop. iv. Silent mutations occur when they change in the nucleotide sequence has not effect on the amino acid sequence. **6.7.B.1:** Errors in DNA replication or DNA repair mechanisms as well as external factors, including radiation and reactive chemicals, can cause random mutations in the DNA. i. Whether a mutation is beneficial, detrimental, or neutral depends on the environmental context. ii. Mutations are a source of genetic variation **6.7.B.2:** Errors in mitosis or meiosis can result in changes in phenotype. i. Changes in chromosome number resulting from nondisjunction often result in new phenotypes caused by triploidy (aneuploidy). ii. Changes in chromosome number often result in disorders with developmental limitations. iii. Alterations in chromosome structure lead to genetic disorders. **6.7.C.1:** Changes in genotype may affect phenotypes that are subject to natural selection. Genetic changes that enhance survival and reproduction can be selected for by environmental conditions. i. The horizontal acquisitions of genetic information in prokaryotes	Concept 12.4: Alterations of chromosome number or structure cause some genetic disorders Concept 20.5: New information continues to improve our understanding of evolutionary history Concept 24.3: Rapid reproduction, mutation, and genetic renominations promote genetic diversity in prokaryotes.

			via transformation (uptake of DNA), transduction (viral transmission of genetic information), conjugation (cell-to-cell transfer of DNA), and transposition (movement of DNA segments within and between DNA molecules) increase genetic variation. ii. Related viruses can recombine genetic information if they infect the same host cell. iii. Reproductive processes that increase genetic variation are evolutionarily conserved and are shared by various organisms.	
6.8 Biotechnology	**Big Idea 3** Information Storage and Transmission	**6.8.A:** Explain the use of genetic engineering techniques in analyzing or manipulating DNA	**6.8.A.1:** Genetic engineering techniques can be used to analyze and manipulate DNA and RNA. i. Gel electrophoresis is a process that separates DNA fragments by size and charge. ii. During polymerase chain reaction (PCR), DNA fragments are amplified by denaturing DNA, annealing primers to the original strand, and extending the new DNA molecule. iii. Bacterial transformation introduces foreign DNA into bacterial cells. iv. DNA sequencing technology determines the order of nucleotides in a DNA molecule. Typically, these techniques result in a DNA fingerprint that allows for the comparison of DNA sequences from various smaples.	Concept 3.7: Genomics and proteomics have transformed biological inquiry and applications Concept 13.4: Understanding DNA structure and replication makes genetic engineering possible Concept 15.4: Researchers can monitor expression of specific genes Concept 16.2: Cloning of organisms showed that differentiated cells could be "reprogrammed" and ultimately led to the production of stem cells Concept 24.5: Prokaryotes play crucial roles in the biosphere Concept 30.3: People modify crops through breeding and genetic engineering

AP® Biology Topics	Big Ideas	Learning Objectives	Essential Knowledge	Campbell Biology in Focus 4e
		Unit 7 Natural Selection (12 Topics)		
7.1 Introduction to Natural Selection	**Big Idea 1** Evolution	**7.1.A:** Describe the causes of natural selection. **7.1.B:** Explain how natural selection affects populations.	**7.1.A.1:** Natural selection is a major mechanism of evolution **7.1.A.2:** According to Darwin's theory of natural selection, competition for limited resources results in differential survival. Individuals with more favorable phenotypes are more likely to survive and produce more offspring, thus passing on those favorable traits to subsequent generations. **7.1.B.1:** Evolutionary fitness is measured by reproductive success. **7.1.B.2:** Biotic and abiotic environments can fluctuate, affecting the rate and direction of evolution. Different genetic variations can be selected in each generation.	Figure 19.1: What causes the similarities and differences among Earth's many different species? Concept 19.1: The Darwinian revolution challenged traditional views of a young Earth inhabited by unchanging species Concept 19.2: Descent with modifications by natural selection explains the adaptations of organisms and the unity and diversity of life Concept 19.3: Evolution is supported by an overwhelming amount of scientific evidence Concept 21.4: Natural selection is the only mechanism that consistently causes adaptive evolution
7.2 Natural Selection	**Big Idea 1** Evolution	**7.2.A:** Describe the importance of phenotypic variation in a population. **7.2.B:** Explain how variation in molecules within cells connects to the fitness of an organism.	**7.2.A.1:** Natural selection acts on phenotypic variations in populations. **7.2.A.2:** Environments change and apply selective pressures to populations. **7.2.A.3:** Some phenotypic variations can increase or decrease the fitness of an organism in particular environments. **7.2.B.1:** Variation in the number and types of molecules within cells can provide populations a greater ability to survive and reproduce in different environments	Figure 21.1: What mechanisms can cause the evolution of populations? Concept 21.1: Genetic variation makes evolution possible Concept 21.4: Natural selection is the only mechanism that consistently causes adaptive evolution Figure 21.15: The Sickle-Cell Allele Concept 21.3: Natural selection, genetic drift, and gene flow can alter allele frequencies in a population

7.3 Artificial Selection	**Big Idea 1** Evolution	**7.3.A:** Explain how humans can affect diversity within a population	**7.3.A.1:** Through artificial selection, humans affect variation in other species.	Concept 19.2: Descent with modification by natural selection explains the adaptations of organisms and the unity and diversity of life Concept 30.3: People modify crops through breeding and genetic engineering.
7.4 Population Genetics	**Big Idea 1** Evolution	**7.4.A:** Explain how random occurrences affect the genetic makeup of a population. **7.4.B:** Describe the role of random processes in the evolution of specific populations	**7.4.A.1:** Evolution is also driven by random occurrences. i. Mutation is a random process that adds new genetic variation to a population. ii. Genetic drift is a change in allele frequencies attributable to a nonselective process occurring in small populations. iii. The bottleneck effect is a type of genetic drift that occurs when a population size is reduced to a small number of individuals for at least one generation. iv. The founder effect is a type of genetic drift that occurs when a population is separated from other members of the population. The frequency of genes and traits will shift based on the genes in this new founder population. V. Migration can result in gene flow (the addition or removal of alleles from a population). **7.4.B.1:** Random processes can lead to changes in allele frequencies in a	Chapter 21 Overview: The Smallest Unit of Evolution Concept 21.1: Genetic variation makes evolution possible Concept 21.3: Natural selection genetic drift, and gene flow can alter allele ffrequencies in a population

		7.4.C: Describe the change in the genetic makeup of a population over time.	population. i. Mutations result in genetic variation, which provides phenotypes on which natural selection acts. ii. Genetic drift can allow a small population to diverge from other populations of the same species. iii. Gene flow between two populations prevents them from diverging into separate species. **7.4.C.1:** Changes in allele frequencies provide evidence for the occurrence of evolution in a population.	Concept 21.4: Natural selectin is the onlyb mechanism that consistently causes adaptive evoltution
7.5 Hardy-Weinberg Equilibrium	**Big Idea 1** Evolution	**7.5.A:** Describe the conditions under which allele and genotype frequencies will change in populations.	**7.5.A.1:** The Hardy-Weinberg Equilibrium is a model for describing and predicting allele frequencies in a non-evolving population. Conditions for a population or an allele to be in Hardy-Weinberg equilibrium are i. A large population size ii. No migration iii. No new mutations iv. Random mating v. No natural selection These conditions are never met, but they provide a valuable null hypothesis **7.5.A.2:** Allele frequencies in a nonevolving population can be calculated from genotype frequencies.	Concept 21.2: The Hardy-Weinberg equation

			Relevant Equations Hardy-Weinber Equation- P2 + 2pq + q2 = 1 P + q = 1 Where p= frequency of allele 1 in the population q = frequency of allele 2 in the population	

AP® Biology Topics	Big Ideas	Learning Objectives	Essential Knowledge	Campbell Biology in Focus 4e
7.6 Evidence of Evolution	**Big Idea 1** Evolution	**7.6.A:** Describe the types of data that provide evidence for evolution. **7.6.B:** Explain how morphological, biochemical, and geological data provide evidence that organisms have changed over time.	**7.6.A.1:** Evolution is supported by scientific evidence from many disciplines (geographical, geological, physical, biochemical, and mathematical data). **7.6 B.1:** Molecular, morphological, and genetic evidence from extant and extinct organisms adds to our understanding of evolution. i. Fossils an be dated by a variety of methods These include 1) the age of the rocks where a fossil is found; 2) the rate of decay of isotopes including cargon-14; and 3) geographical data. ii. Morphological homologies, including vestigial structures, provide evidence of common ancestry. **7.6.B.2:** A comparison of DNA nucleotide sequences and protein amino acid sequences provides evidence for evolution and common ancestry.	Concept 1.1: The study of life reveals unifying themes Concept 1.2: The Core Theme: Evolution accounts for the unity and diversity of life Concept 3.7: Genomics and proteomics have transformed biological inquiry and applications Concept 19.3: Evolution is supported by an overwhelming amount of scientific evidence Concept 23.1: The fossil record documents life's history Concept 23.2: The rise and fall of groups of organisms reflect differences in speciation and etinction rates Concept 17.3: Viruses and prions are formidable pathogens in animals and plants include: Scientific Skills Exercise: Analyzing a Sequence-Based Phylogenetic Tree to Understand Viral Evolution
7.7 Common Ancestry	**Big Idea 1** Evolution	**EVO: 7.7.A:** Describe structural and functional evidence on cellular and molecular levels that provides evidence for the common ancestry of all eukaryotes.	**7.7.A.1:** Structural and function evidence indicates common ancestry of all eukaryotes. This evidence includes: i. Membrane-bound organelles ii. Linear chromosomes iii. Genes that contain introns	Concept 4.2: Eukaryotic cells have internal membranes that compartmentalize their functions Concept 4.5: Mitochondria and chloroplasts change energy from one form to another Concept 24.2: Diverse structural and metabolic adaptations have evolved in prokaryotes Concept 25.1: Eukaryotes arose by endosymbiosis more than 1.8 billion years ago Concept 14.1: Genes specify proteins via transcription and translation

7.8 Continuing Evolution	**Big Idea 1** Evolution	**EVO: 7.8.A:** Explain how evolution is an ongoing process in all living organisms.	**7.8.A.1:** All species have evolved and continue to evolve. Examples include: i. Genomic changes over time ii. Continuous change in the fossil record iii. Evolution of resistance to antibiotics, pesticides, herbicides or chemotherapy drugs iv. Pathogens evolving and causing emergent diseases.	Concept 19.2: Descent with modification by natural selection explains the adaptations of organisms and the unity and diversity of life Concept 19.3: Evolution is supported by an overwhelming amount of scientific evidence
7.9 Phylogeny	**Big Idea 1** Evolution	**7.9.A:** Describe the types of evidence that can be used to infer an evolutionary relationship. 7.9.B: Explain how phylogenetic trees and cladograms can be used to infer evolutionary relatedness.	**7.9.A.1:** Phylogenetic trees and cladograms show hypothetical evolutionary relationships among lineages that can be tested. **7.9.A.2:** Phylogenetic trees show the amount of change over time calibrated by fossils or a molecular clock, whereas cladograms do not show time scale of the evolutionary difference between groups. **7.9.A.3:** Traits that are either gained or lost during evolution can be used to construct phylogenetic trees and cladograms. The out-group represents the lineage that is east closely related to the remainder of the organisms in the phylogenetic tree or cladogram. i. Shared derived characters can be present in more than one lineage and indicate common ancestry. These are informative for the construction of phylogenetic trees and cladograms. ii. Molecular data typically provide more accurate and reliable evidence than morphological traits in the construction of phylogenetic trees or cladograms. **7.9.B.1:** Phylogenetic trees and cladograms can be used to illustrate speciation that has occurred. The nodes on a tree represent the most recent common ancestor of any two groups or lineages.	Chapter 20 Figure 20.1: How do biologists distinguish and categoriez the millions of species on Earth? Concept 20.1: Phylogenies show evolutionary relationships Concept 20.4: Molecular clocks help track evolutionary time Concept 20.2: Phylogenies can be used to understand shared characters Concept 20.3: Phylogenies are inferred from morphological and molecular data Concept 20.2: Phylogenies can be used to understand shared characters Concept 20.5: New information continues to improve our understanding of evolutionary history

			7.9.B.2: Phylogenetic trees and cladograms can be constructed from morphological similarities of living or fossil species and from DNA and protein sequence similarities. **7.9.B.3:** Phylogenetic trees and cladograms represent hypotheses that are constantly being revised based on evidence.	
7.10 Speciation	**Big Idea 1** Evolution	**7.10.A:** Describe the conditions underwhich new species may arise. **7.10.B:** Describe the rate of evolution and speciation under different ecological conditions **7.10.C:** Explain the processes and mechanisms that drive speciation.	**7.10.A.1:** Speciation occurs when two populations become reproductively isolated from each other. **7.10.A.2:** The biological species concept provides a commonly used definition of a species for sexually reproducing organisms. It states that species can be defined as a group capable of interbreeding and exchanging genetic information to produce viable, fertile offspring. **7.10.B.1:** Punctuated equilibrium is when evolution occurs rapidly after a long period of stasis. Gradualism is when evolution occurs slowly over hundreds of thousands or millions of years. **7.10.B.2:** Divergent evolution occurs when adaptation to new habitats results in phenotypic diversification. Speciation rates can be especially rapid during times of adaptive radiation as new habitats become available. **7.10.B.3:** Convergent evolution occurs when similar selective pressures result in similar phenotypic adaptations in different populations or species. **7.10.C.1:** Sympatric speciation occurs in populations with geographic overlap. Allopatric speciation occurs in populations that are	Chapter 22 Figure 22.1: How do new species originate from existing species? Concept 22.1: The biological species concept emphasizes reproductive isolation Concept 22.4: Speciation can occur rapidly or slowly and can result from changes in few or many genes Concept 19.3: Evolution is supported by overwhelming amount of scientific evidence. Concept. 22.2: Speciation can take place with or without geographic separation Concept 22.3: Hybrid zones reveal factors that cause reproductive isolation Concept 22.1: The biological species concept emphasizes reproductive isolation

			geographically isolated. **7.10.C.2:** Various pre-zygotic and post-zygotic mechanisms can maintain reproductive isolation and prevent gene flow between populations.	

AP® Biology Topics	Big Ideas	Learning Objectives	Essential Knowledge	Campbell Biology in Focus 4e
7.11 Variations in Populations	**Big Idea 4** Systems Interactions	**7.11.A:** Explain how the genetic diversity of a species or population affects its ability to withstand environmental pressures.	**7.11.A.1:** The level of variation in a population affects population dynamics. i. The ability of a population to respond to changes in the environment is influenced by genetic diversity. Species and populations with little genetic diversity are at risk of decline or extinction. ii. Genetically diverse populations are more resilient to environmental perturbation because they are more likely to contain individuals that can withstand the environmental pressure. iii. Alleles that are adaptive in one environmental condition may be deleterious I another because of different selective pressures.	Concept 43.1: Human activities threaten Earth's biodiversity Concept 43.2: Population conservation focuses on population size, genetic diversity, and critical habitat Concept 19.2: Descent with modification by natural selection explains the adaptations of organisms and the unity and diversity of life.

7.12 Origins of Life on Earth	**Big Idea 4** Systems Interactions	**7.12.A**: Describe the scientific evidence that supports models of the origin of life on Earth.	**7.12.A.1:** The origin of life on Earth is supported by scientific evidence. i. Geological evidence reinforces models of the origin of life on Earth. ii. Earth formed approximately 4.6 billion years ago (bya). The environment was too hostile for life until about 3.9 bya, and the earliest fossil evidence for life dates to 3.5 bya. Taken together, this evidence provides a plausible range of dates for the origin of life. **7.12.A.2:** The RNA world hypothesis proposes that RNA could have been the earliest genetic material. There are three assumptions: i. At some point in time, genetic continuity was assured by the replication of RNA. ii. Base-pairing is necessary for replication. iii. Genetically encoded proteins were not involved as catalysts.	Concept 24.1: Conditions on early Earth made the origin of life possible

AP® Biology Topics	Big Ideas	Learning Objectives	Essential Knowledge	Campbell Biology in Focus 4e
		Unit 8: Ecology (7 Topics)		
8.1 Responses to the Environment	**Big Idea 2** Energetics	**8.1.A:** Explain how the behavioral and physiological response of an organism is related to changes in internal or external environment.	**8.1.A.1:** Organisms respond to changes in their environment through behavioral and physiological mechanisms	Concept 31.1: Plants are highly sensitive to environmental stimuli that initiate specific behaviors. Concept 31.2: Plant hormones help coordinate growth, development, and responses to stimuli. Concept 31.3 :Responses to light are critical for plant success Concept 31.4: Plants respond to a wide variety of stimuli other than light
			8.1.A.2: Organisms exchange information with one another in response to internal changes and external cues, which can change behavior.	Concept 31.5: Plants respond to attacks by herbivores and pathogens Chapter 32, Figure 32.1: How do animals regulate their internal state even in changing or harsh environments? Concept 32.2: The endocrine and nervous systems act individually and together in regulating animal physiology Concept 32.3: Feedback control maintains the internal environment in many animals
	Big Idea 3 Information Storage and Transmission	**8.1.B:** Explain how the behavioral responses of organisms affect their overall fitness and may contribute to the success of a population.	**8.1.B.1:** Organisms communicate through various mechanisms (visual, audible, tactile, electrical, and/or chemical signals). i. Organisms have a variety of signaling behviors that produce changes in the behavior of other organisms and can result in differential reproductive success. ii.Animals use sginals to indicate dominance, find food, establish territory, and ensure reproductive success.	Chapter 39, Figure 39.1: What questions do biologists seek to answer in studying animal behavior? Concept 39.3: Discrete sensory inputs can stimulate both simple and complex behaviors Concept 39.4: Learning establishes specific links between experience and behavior Concept 39.5: Selection for individual survival and reproductive success can explain diverse behaviors

			8.1.B.2: Responses to information and communication of information are vital to natural selection and evolution. i. Fitness favors innate and learned behaviors that increase survival and reproductive success. ii. Cooperative behavior tends to increase the fitness of the individual and the survival of the population.	
8.2 Energy Flow Through Ecosystems	**Big Idea 2** Energetics	**8.2.A:** Describe the strategies organisms use to acquire and use energy. **8.2.B:** Explain how energy flows and matter cycles through trophic levels.	**8.2.A.1:** Organisms use energy to organize, grow, reproduce, and maintain homeostasis. i. Organisms use different strategies to regulate body temperature and metabolism. Endotherms use thermal energy generated by metabolism to maintain homeostatic body temperatures. Ectotherms lack efficient internal mechanisms for maintaining body temperature, although they may regulate their temperature behaviorally by moving into the sun or shade or by aggregating with other individuals. ii.A net gain in energy results in energy storage, the growth of an organism, and increased reproductive output. iii. A net loss of energy results in loss of mass, a decrease in reproductive output, and, eventually, the death of an organism. **8.2.A.2:** Different organisms use various reproductive strategies in response to energy availability. Some	Concept 32.3: Feedback control maintains the internal environment in many animals Concept 33.5: Feedback circuits regulate digestion, energy allocation, and appetite Concept 40.4: Biotic and abiotic factors affect population density, dispersion, and demographics Chapter 40, figure 40.2: Exploring the Scope of Ecological Research Concept 40.1: Earth's climate influences the distribution of terrestrial biomes Concept 42.4 :Biological and geochemical processes cycle nutrients and water in ecosystems.

			organisms alternate between asexual and sexual reproduction in response to energy availability.	
			8.2.B.1: Ecological levels of organization include populations, communities, ecosystems, and biomes.	Concept 40.6: Population dynamics are influenced strongly by life history traits and population density
			8.2.B.2: Energy flows through ecosystems, while matter and nutrients cycle between the environment and organisms via biogeochemical cycles. The cycles are essential for life, and each cycle demonstrates the conservation of matter. The cycles are interdependent.	
			8.2.B.3: Biogeochemical cycles include abiotic and biotic reservoirs, as well as processes that cycle matter between reservoirs.	
			8.2.B.4: The hydrologic (water) cycle involves water movement and storage within the hydrosphere. Reservoirs include oceans, surface water, the atmosphere, and living organisms. Processes include evaporation, condensation, precipitation, and transpiration.	
		8.2.C: Explain how changes in energy availability affect populations, communities, and ecosystems.	**8.2.B.5:** The carbon cycle involves recycling carbon atoms t:hrough Earth's biosphere into organisms as carbohydrates and back into the atmosphere as carbon dioxide (CO_2). At the highest levels of organization, the carbon cycle can be simplified	Concept 42.1: Physical laws govern energy flow and chemical cycling in ecosystems Concept 42.2: Energy and other limiting factors control primary production in ecosystems Concept 41.2: Biological communities can be characterized by their diversity

		8.2.D: Explain how the activities of autotrophs and heterotrophs enable the flow of energy within and ecosystem.	into four parts: photosynthesis, cellular respiration, decomposition, and combustion. **8.2.B.6:** The nitrogen cycle involves several steps, including nitrogen fixation, assimilation, ammonification, nitrification, and denitrification. These steps are performed by microorganisms in the soil. The largest reservoir of nitrogen is the atmosphere. In nitrogen fixation, nitrogen gas (N_2) is fixed into ammonia (NH_3), which ionizes to ammonium (NH_4^+) by acquiring hydrogen ions from the soil solution. **8.2.B.7:** The phosphorus cycle involves weathering rocks releasing phosphate (PO_4^{3-})into soil and groundwater. Producers take in phosphate, which is incorporated into biological molecules; consumers eat producers, transferring phosphate to animals. Phosphorus returns to the soil via decomposition of biomass, or excretion. Phosphate can also be incorporated back into the environment via decomposition of decaying organic matter. **8.2.C.1:** Changes in energy availability can result in changes in population size. **8.2.C.2:** Changes in energy availability can result in disruptions to an ecosystem.	and trophic structure Concept 42.3: Energy transfer between trophic levels is typically only 10% efficient Chapter 40 Figure 40.1: What are the dynamics of energy and matter in an ecosystem? Concept 8.1: Photosynthesis feeds the biosphere

			i. A change in energy resources such as sunlight can affect the number and size of the trophic levels. Trophic levels include producers; primary, secondary, tertiary, and quaternary consumers; and decomposers. ii. A change in the biomass or number of producers in a given geographic area can affect the number and size of other trophic levels. **8.2.D.1:** Autotrophs capture energy from physical or chemical sources in the environment. i. Photosynthetic organisms capture energy present in sunlight contributing to primary productivity. ii. Chemosynthetic organisms capture energy from small inorganic molecules present in their environment, which can occur in the absence of oxygen. **8.2.D.2:** Heterotrophs, which include carnivores, herbivores, omnivores, decomposers, and scavengers, metabolize carbohydrates, lipids, and	

			proteins as sources of energy. Heterotrophs capture the energy present in carbon compounds by consuming organic matter derived from autotrophs incorporating matter into their tissues.	

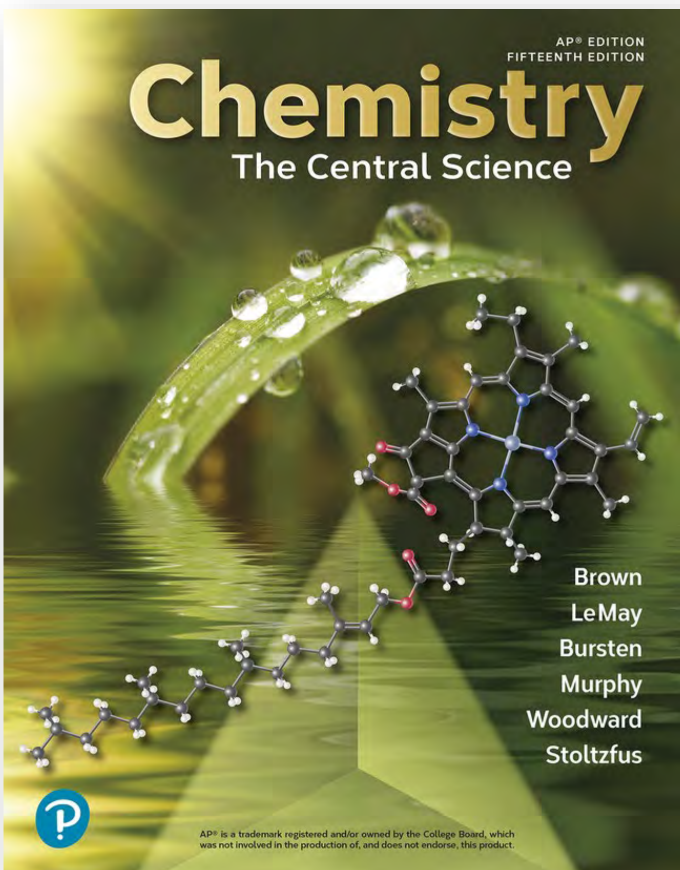
AP® Biology Topics	Big Idea	Learning Objectives	Essential Knowledge	Campbell Biology in Focus 4e
8.3 Population Ecology	**Big Idea 4** Systems Interactions	**8.3.A:** Describe factors that influence growth dynamics of populations.	**8.3.A.1** Populations comprise individual organisms of the same species that interact with one another and with the environment in complex ways. **8.3.A.2** Many adaptations in organisms are related to obtaining and using energy and matter in a particular environment. i. Population growth dynamics depend on birth rate, death rate, and population size. **RELEVANT EQUATION** Population Growth— $\frac{dN}{dt} = B - D$ where dt =chageintime B = birth rate D =deathrate N = population size dN =changeinpopulationsize ii. Reproduction without constraints results in the exponential growth of a population. **RELEVANT EQUATION** Exponential Growth— $\frac{dN}{dt} = r_{max} N$ where dt =changeintime N =populationsize dN = change in population size r_{max} = maximum per capita growth	Concept 40.4: Biotic and abiotic factors affect population density, dispersion, and demographics Concept 40.5: The exponential and logistic models describe the growth of populations

			rate of population	
8.4 Effect of Density of Populations	**Big Idea 4** Systems Interactions	**8.4.A:** Explain how the density of a population affects and is determined by resource availability in the environment.	**8.4.A.1:** Carrying capacity is the sustainable abundance of a species that can be supported by the ecosystem's total available resources. **8.4.A.2:** As limits to growth attributable to density- dependent and density-independent factors are imposed, a logistic growth model typically ensues. **RELEVANT EQUATION** Logistical Growth— $dN_{=r\ N}\ K-N\ dt^{max}\ K$ where dt =changeintime N =populationsize dN =changeinpopulationsize r_{max} = maximum per capita growth rate of population K =carryingcapacity	Concept 40.4: Biotic and abiotic factors affect population density, dispersion, and demographics Concept 40.5: The exponential and logistic models describe the growth of populations Concept 40.6: Population dynamics are influenced strongly by life history traits and population density Concept 43.5: The human population is no longer growing exponentially but is still increasing rapidly
8.5 Community Ecology	**Big Idea 2** Energetics	**8.5.A:** Describe the structure of a community according to its species composition and diversity.	**8.5.A.1:** The structure of a community is measured and described in terms of species composition and species diversity. **RELEVANT EQUATION** Simpson's Diversity Index— 2 Diversity Index = 1 n	Concept 41.4: Interactions between species may help, harm, or have no effect on the individuals involved Conceept 43.2: Population conservation focuses on population size, genetic diversity, and critical habitat

			where N n = total number of organisms of a particular species N =totalnumberoforganismsofall species	
		8.5.B: Explain how interactions within and among populations influence community structure.	**8.5.B.1:** Communities are groups of interacting populations of different specie on the interactions between those populations. **8.5.B.2:** Interactions among populations determine how they access energy and matter within a community. **8.5.B.3:** Relationships among interacting populations can be characterized by can be modeled. Examples include predator/prey interactions, cooperation, tro partitioning. **8.5.B.4:** Competition, predation, and symbioses, including parasitism, mutuali drive population dynamics.	Chapter 41: Figure 41.1: What are some factors that influence the structure of a community? Concept 41.2: Biological communities can be characterized by their diversity and trophic structure Concept 41.1: Interactions between species can help, harm or have no effect on the individuals involved
8.6 Biodiversity	**Big Idea 4** Systems Interactions	**8.6.A:** Describe the relationship between ecosystem diversity and its resilience to changes in the environment. **8.6.B:** Explain how the addition or removal of any component of an ecosystem will affect its overall short-term and long-term structure.	**8.6.A.1:** Natural and artificial ecosystems with fewer component parts, and with little diversity among the parts, are often less resilient to changes in the environment. **8.6.A.2:** Keystone species, producers, and essential abiotic and biotic factors contribute to maintaining the diversity of an ecosystem. **8.6.B.1:** The effects of keystone species on the ecosystem are disproportionate relative to their abundance in the ecosystem. When they are removed from the ecosystem, it often collapses.	Concept 41.3: Disturbance influences species diversity and composition Concept 41.2: Biological communities can be characterized by their diversity and trophic structure
8.7 Disruptions in Ecosystems	**Big Idea 1** Evolution **Big Idea 4** Systems	**8.7.A:** Explain the interaction between the environment and random or preexisting variations in populations.	**8.7.A.1:** An adaptation is a genetic variation that is favored by selection and manifests as a trait that provides an advantage to an organism in a particular environment. **8.7.A.2:** Heterozygote advantage is when the heterozygous genotype has a higher relative fitness than either the homozygous dominant or homozygous recessive genotype. **8.7.A.3:** Mutations are not directed by specific environmental	Concept 21.4: Natural selection is the only mechanism that consistently causes adaptive evolution Concept 21.3: Natural selection, genetic drift, and gene flow can alter allele frequencies in a population Concept 41.3: Disturbance influences species diversity and composition Concept 41.5: Pathogens alter

	Interactions	**8.7.B:** Explain how invasive species affect ecosystem dynamics. **8.7.C:** Describe human activities that lead to changes in ecosystem structure and dynamics. **8.7.D:** Explain how geological and meteorological activity leads to changes in ecosystem structure and dynamics.	pressures. **8.7.B.1:** The intentional or unintentional introduction of an invasive species can allow the species to exploit a new niche free of predators or coopetitors or to outcompete native species for resources. **8.7.C.1:** Human impact accelerates changes at the local and global levels. These activities can drive changes in ecosystems, such as the following that cause extinctions to occur i. Biomagnification ii. Eutrophication **8.7.D.1:** Geological and meteorological events affect habitat change and ecosystem distribution. Biogeographical studies illustrate these changes.	community structure locally and globally Concept 43.4: Earth is changing rapidly as a result of human actions Concept 41.4: Biogeographic factors affect community diversity Chapter 43, Figure 43.1: How can we protect the many species threatened by human activities? Concept 43.1: Human activities threaten Earth's biodiversity Concept.43.3: Landscape and regional conservation help sustain biodiversity Concept 43.4: Earth is changing rapidly as a result of human actions Concept 43.6: Sustainable development can improve human lives while conserving biodiversity

Correlation of AP® Chemistry Standards to *Chemistry the Central Science, AP® Edition Fifteenth Edition*, (Brown, LeMay, Bursten, Murphy, Woodward, and Stoltzfus)



Correlation of AP® Chemistry Standards to *Chemistry the Central Science, AP® Edition Fifteenth Edition,* (Brown, LeMay, Bursten, Murphy, Woodward, and Stoltzfus)

Unit 1: Atomic Structure and Properties

AP Subunit	Learning Objective	Essential Knowledge	Textbook Reference
1.1 Moles and Molar Mass	**1.1.A** Calculate quantities of a substance or its relative number of particles using dimensional analysis and the mole concept	**1.1.A.1** One cannot count particles directly while performing laboratory work. Thus, there must be a connection between the masses of substances reacting and the actual number of particles undergoing chemical changes.	Ch. 3, Sec. 3.3-3.4; Pgs 93-98
		1.1.A.2 Avogadro's number (N = 6.022 × 1023 mol−1) provides the connection bet A ween the number of moles in a pure sample of a substance and the number of constituent particles (or formula units) of that substance.	Ch. 3, Sec. 3.3-3.4; Pgs 93-98
		1.1.A.3 Expressing the mass of an individual atom or molecule in atomic mass units (amu) is useful because the average mass in amu of one particle (atom or molecule) or formula unit of a substance will always be numerically equal to the molar mass of that substance in grams. Thus, there is a quantitative connection between the mass of a substance and the	Ch. 3, Sec. 3.3-3.4; Pgs 93-98

AP Subunit	Learning Objective	Essential Knowledge	Textbook Reference
		number of particles that the substance contains. EQN: n = m/M	
1.2 Mass Spectra of Elements	**1.2.A** Explain the quantitative relationship between the mass spectrum of an element and the masses of the element's isotopes	**1.2.A.1** The mass spectrum of a sample containing a single element can be used to determine the identity of the isotopes of that element and the relative abundance of each isotope in nature.	Ch. 2, Sec. 2.3–2.4; Pgs 48-52
		1.2.A.2 The average atomic mass of an element can be estimated from the weighted average of the isotopic masses using the mass of each isotope and its relative abundance. **Exclusion Statement:** Interpreting mass spectra of samples containing multiple elements or peaks arising from species other than singly charged monatomic ions will not be assessed on the AP Exam.	Ch. 2, Sec. 2.3–2.4; Pgs 48-52
1.3 Elemental Composition of Pure Substances	**1.3.A** Explain the quantitative relationship between the elemental composition by mass and the empirical formula of a pure substance.	**1.3.A.1** Some pure substances are composed of individual molecules, while others consist of atoms or ions held together in fixed proportions as described by a formula unit.	Ch. 2, Sec. 2.6; Pgs 56-58 Ch. 3, Sec. 3.5; Pgs 99-102
		1.3.A.2 According to the law of definite proportions, the ratio of the masses of the constituent elements in any pure sample of that compound is always the same.	Ch. 2, Sec. 2.6; Pgs 56-58 Ch. 3, Sec. 3.5; Pgs 99-102

AP Subunit	Learning Objective	Essential Knowledge	Textbook Reference
		1.3.A.3 The chemical formula that lists the lowest whole number ratio of atoms of the elements in a compound is the empirical formula.	Ch. 2, Sec. 2.6; Pgs 56-58 Ch. 3, Sec. 3.5; Pgs 99-102
1.4 Composition of Mixtures	**1.4.A** Explain the quantitative relationship between the elemental composition by mass and the composition of substances in a mixture.	**1.4.A.1** Pure substances contain atoms, molecules, or formula units of a single type. Mixtures contain atoms, molecules, or formula units of two or more types, whose relative proportions can vary.	Ch. 1, Sec. 1.2-1.3; Pgs 4-12
		1.4.A.2 Elemental analysis can be used to determine the relative numbers of atoms in a substance and to determine its purity.	Ch. 1, Sec. 1.2-1.3; Pgs 4-12

1.5 Atomic Structure and Electron Configuration	**1.5.A** Represent the ground-state electron configuration of an atom of an element or its ions using the Aufbau principle.	**1.5.A.1** The atom is composed of negatively charged electrons and a positively charged nucleus that is made of protons and neutrons.	Ch. 6, Sec. 6.3–6.8; Pgs 217-239
		1.5.A.2 Coulomb's law is used to calculate the force between two charged particles. EQN: F coulombic $\propto q^1 q^2 / r^2$ **1.5.A.3** In atoms and ions, the electrons can be thought of as being in "shells (energy levels)" and "subshells (sublevels)," as described by the ground-state electron configuration. Inner electrons are called core electrons, and outer electrons are called valence electrons. The electron configuration is explained by quantum mechanics, as delineated in the Aufbau principle and exemplified in the periodic table of the elements. **Exclusion Statement:** The assignment of quantum numbers to electrons in subshells of an atom will not be assessed on the AP Exam.	Ch. 6, Sec. 6.3–6.8; Pgs 217-239
		1.5.A.4 The relative energy required to remove an electron from different subshells of an atom or ion or from the same subshell in different atoms or ions (ionization energy) can be estimated through a qualitative application of Coulomb's law. This energy is related to the distance from the nucleus and the effective (shield) charge of the	Ch. 6, Sec. 6.3–6.8; Pgs 217-239

		nucleus.	
1.6 Photoelectron Spectroscopy (PES)	**1.6.A** Explain the relationship between the photoelectron spectrum of an atom or ion and: i. The ground-state electron configuration of the species. ii. The interactions between the electrons and the nucleus.	**1.6.A.1** The energies of the electrons in a given shell can be measured experimentally with photoelectron spectroscopy (PES). The position of each peak in the PES spectrum is related to the energy required to remove an electron from the corresponding subshell, and the relative height of each peak is (ideally) proportional to the number of electrons in that subshell.	Not represented thoroughly in the text. .

1.7 Periodic Trends	**1.7.A** Explain the relationship between trends in atomic properties of elements and electronic structure and periodicity.	**1.7.A.1** The organization of the periodic table is based on patterns of recurring properties of the elements, which are explained by patterns of ground-state electron configurations and the presence of completely or partially filled shells (and subshells) of electrons in atoms. **Exclusion Statement:** Writing the electron configuration of elements that are exceptions to the aufbau principle will not be assessed on the AP Exam.	Ch. 7, Sec. 7.2–7.4; Pgs 257-271
		1.7.A.2 Trends in atomic properties within the periodic table (periodicity) can be predicted by the position of the element on the periodic table and qualitatively understood using Coulomb's law, the shell model, and the concepts of shielding and effective nuclear charge. These properties include: i. Ionization energy ii. Atomic and ionic radii iii. Electron affinity iv. Electronegativity.	Ch. 7, Sec. 7.2–7.4; Pgs 257-271

		1.7.A.3 The periodicity (in 1.7.A.2) is useful to predict/ estimate values of properties in the absence of data.	Ch. 7, Sec. 7.2–7.4; Pgs 257-271
1.8 Valence Electrons and Ionic Compounds	**1.8.A** Explain the relationship between trends in the reactivity of elements and periodicity.	**1.8.A.1** The likelihood that two elements will form a chemical bond is determined by the interactions between the valence electrons and nuclei of elements.	Ch. 8, Sec. 8.1–8.4; Pgs 298-311
		1.8.A.2 Elements in the same column of the periodic table tend to form analogous compounds.	Not represented thoroughly in the text.
		1.8.A.3 Typical charges of atoms in ionic compounds are governed by the number of valence electrons and predicted by their location on the periodic table	Ch. 8, Sec. 8.1–8.4; Pgs 298-311, Ch. 2; Sec 2.7, Pg 59-68

Unit 2: Compound Structure and Properties

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
2.1 Types of Chemical Bonds	**2.1.A** Explain the relationship between the type of bonding and the properties of the elements participating in the bond.	**2.1.A.1** Electronegativity values for the representative elements increase going from left to right across a period and decrease going down a group. These trends can be understood qualitatively through the electronic structure of the atoms, the shell model, and Coulomb's law.	Ch. 8, Sec. 8.2–8.4; Pgs 299-311 Ch. 12, Sec. 12.3; Pgs 482-485
		2.1.A.2 Valence electrons shared between atoms of similar electronegativity constitute a nonpolar covalent bond. For example, bonds between carbon and hydrogen are effectively nonpolar even though carbon is slightly more electronegative than hydrogen.	Ch. 8, Sec. 8.2–8.4; Pgs 299-311 Ch. 12, Sec. 12.3; Pgs 482-485
		2.1.A.3 Valence electrons shared between atoms of unequal electronegativity constitute a polar covalent bond. i. The atom with a higher electronegativity will develop a partial negative charge relative to the other atom in the bond. ii. In single bonds, greater differences in electronegativity lead to greater bond dipoles. iii. All polar bonds have some ionic character, and the difference between ionic and covalent bonding is not distinct but rather a continuum.	Ch. 8, Sec. 8.2–8.4; Pgs 299-311 Ch. 12, Sec. 12.3; Pgs 482-485

		2.1.A.4 The difference in electronegativity is not the only factor in determining if a bond should be designated as ionic or covalent. Generally, bonds between a metal and nonmetal are ionic, and bonds between two nonmetals are covalent. Examination of the properties of a compound is the best way to characterize the type of bonding.	Ch. 8, Sec. 8.2–8.4; Pgs 299-311 Ch. 12, Sec. 12.3; Pgs 482-485
		2.1.A.5 In a metallic solid, the valence electrons from the metal atoms are considered to be delocalized and not associated with any individual atom.	Ch. 8, Sec. 8.2–8.4; Pgs 299-311 Ch. 12, Sec. 12.3; Pgs 482-485

2.2 Intramolecular Force and Potential Energy	**2.2.A** Represent the relationship between potential energy and distance between atoms, based on factors that influence the interaction strength.	**2.2.A.1** A graph of potential energy versus the distance between atoms (internuclear distance) is a useful representation for describing the interactions between atoms. Such graphs illustrate both the equilibrium bond length (the separation between atoms at which the potential energy is lowest) and the bond energy (the energy required to separate the atoms).	Ch. 8, Sec. 8.3, 8.8; Pgs 304-305, 323-325
		2.2.A.2 In a covalent bond, the bond length is influenced by both the size of the atom's core and the bond order (i.e., single, double, triple). Bonds with a higher order are shorter and have larger bond energies.	Ch. 8, Sec. 8.3, 8.8; Pgs 304-305, 323-325
		2.2.A.3 Coulomb's law can be used to understand the strength of interactions between cations and anions. i. Because the interaction strength is proportional to the charge on each ion, larger charges lead to stronger interactions. ii. Because the interaction strength increases as the distance between the centers of the ions (nuclei) decreases, smaller ions lead to stronger interactions.	Ch. 8, Sec. 8.3, 8.8; Pgs 304-305, 323-325
2.3 Structure of Ionic Solids	**2.3.A** Represent an ionic solid with a particulate model that is consistent with Coulomb's law and the properties of the constituent ions.	**2.3.A.1** The cations and anions in an ionic crystal are arranged in a systematic, periodic 3-D array that maximizes the attractive forces among cations and anions while minimizing	Ch. 12, Sec. 12.4; Pgs 486-489

		the repulsive forces. **Exclusion Statement:** Knowledge of specific crystal structures is not essential to an understanding of the learning objective and will not be assessed on the AP Exam.	
2.4 Structure of Metals and Alloys	**2.4.A** Represent a metallic solid and/or alloy using a model to show essential characteristics of the structure and interactions present in the substance.	**2.4.A.1** Metallic bonding can be represented as an array of positive metal ions surrounded by delocalized valence electrons (i.e.,a "sea of electrons”).	Ch. 12, Sec. 12.2; Pgs 475-481
		2.4.A.2 Interstitial alloys form between atoms of significantly different radii, where the smaller atoms fill the interstitial spaces between the larger atoms (e.g., with steel in which carbon occupies the interstices in iron).	Ch. 12, Sec. 12.2; Pgs 475-481
		2.4.A.3 Substitutional alloys form between atoms of comparable radius, where one atom substitutes for the other in the lattice. (e.g., in certain brass alloys, other elements, usually zinc,substitute for copper.)	Ch. 12, Sec. 12.2; Pgs 475-481
2.5 Lewis Diagrams	**2.5.A** Represent a molecule with a Lewis diagram	**2.5.A.1** Lewis diagrams can be constructed according to an established set of principles.	Ch. 8, Sec. 8.5, 8.7; Pgs 312-316; 320-322
2.6 Resonance and Formal Charge	**2.6.A** Represent a molecule with a Lewis diagram that accounts for resonance between equivalent structures or that uses formal charge to select between nonequivalent structures.	**2.6.A.1** In cases where more than one equivalent Lewis structure can be constructed, resonance	Ch. 8, Sec. 8.5-8.6; Pgs 312-319

		must be included as a refinement to the Lewis structure. In many such cases, this refinement is needed to provide qualitatively accurate predictions of molecular structure and properties.	
		2.6.A.2 The octet rule and formal charge can be used as criteria for determining which of several possible valid Lewis diagrams provides the best model for predicting molecular structure and properties.	Ch 8, Sec 8.1, 8.5 8.7, Pg 298, 304, 312-314, 320-321
		2.6.A.3 As with any model, there are limitations to the use of the Lewis structure model, particularly in cases with an odd number of valence electrons.	Ch 8, Sec 8.1, 8.5 8.7, Pg 298, 304, 312-314, 320-321 .
2.7 VSEPR and Hybridization	**2.7.A** Based on the relationship between Lewis diagrams, VSEPR theory, bond orders, and bond polarities: i. Explain structural properties of molecules. ii. Explain electron properties of molecules.	**2.7.A.1** VSEPR theory uses the Coulombic repulsion between electrons as a basis for predicting the arrangement of electron pairs around a central atom.	Ch. 9, Sec. 9.1–9.3; Pgs 336-349
		2.7.A.2 Both Lewis diagrams and VSEPR theory must be used for predicting electronic and structural properties of many covalently bonded molecules and polyatomic ions, including the following: i. Molecular geometry (linear, trigonal planar, tetrahedral, trigonal pyramidal, bent, trigonal bipyramidal, seesaw, T-shaped, octahedral, square	Ch 8, Sec 8.1, 8.5 8.7, Pg 298, 304, 312-314, 320-321

		pyramidal, square planar) ii. Bond angles iii. Relative bond energies based on bond order iv. Relative bond lengths (multiple bonds, effects of atomic radius) v. Presence of a dipole moment vi.Hybridization of valence orbitals for atoms within a molecule or polyatomic ion.	
		2.7.A.3 The terms "hybridization" and "hybrid atomic orbital" are used to describe the arrangement of electrons around a central atom. When the central atom is sp hybridized, its ideal bond angles are 180°; for sp2 hybridized atoms the bond angles are 120°; and for sp3 hybridized atoms the bond angles are 109.5°. **Exclusion Statement:** An understanding of the derivation and depiction of hybrid orbitals will not be assessed on the AP Exam. The course includes the distinction between sigma and pi bonding, the use of VSEPR to explain the shapes of molecules, and the sp, sp2, and sp3 nomenclature. **Exclusion Statement:** Hybridization involving d orbitals will not be assessed on the AP Exam. When an atom has more than four pairs of electrons surrounding the central atom, students are only responsible for the shape of the resulting molecule.	Ch 8, Sec 8.1, 8.5 8.7, Pg 298, 304, 312-314, 320-321
		2.7.A.4 Bond formation is associated with overlap	Ch 8, Sec 8.2, Pg 300

		between atomic orbitals. In multiple bonds, such overlap leads to the formation of both sigma and pi bonds. The overlap is stronger in sigma than pi bonds, which is reflected in sigma bonds having greater bond energy than pi bonds. The presence of a pi bond also prevents the rotation of the bond and leads to geometric isomers. **Exclusion Statement:** Molecular orbital theory is recommended as a way to provide deeper insight into bonding. However, the AP Exam will neither explicitly assess molecular orbital diagrams, filling of molecular orbitals, nor the distinction between bonding, nonbonding, and antibonding orbitals.	

Unit 3: Properties of Substances and Mixtures

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
3.1 Intermolecular and Interparticle Forces	3.1.A Explain the relationship between the chemical structures of molecules and the relative strength of their intermolecular forces when: i. The molecules are of the same chemical species. ii. The molecules are of two different chemical species.	**3.1.A.1** London dispersion forces are a result of the Coulombic interactions between temporary, fluctuating dipoles. London dispersion forces are often the strongest net intermolecular force between large molecules. i. Dispersion forces increase with increasing contact area between molecules and with increasing polarizability of the molecules. ii. The polarizability of a molecule increases with an increasing number of electrons in the molecule and the size of the electron cloud. It is enhanced by the presence of pi bonding. iii. The term “London dispersion forces” should not be used synonymously with the term “van der Waals forces”.	Ch. 11, Sec. 11.2; Pgs 433-441
		3.1.A.2 The dipole moment of a polar molecule leads to additional interactions with other chemical species. i. Dipole-induced dipole interactions are present between a polar and nonpolar molecule. These forces are always attractive. The strength of these forces increases with the magnitude of the dipole of the polar molecule and with the polarizability of the nonpolar molecule ii. Dipole-dipole	Ch. 11, Sec. 11.2; Pgs 433-441

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		interactions are present between polar molecules. The interaction strength depends on the magnitude of the dipoles and their relative orientation. Interactions between polar molecules are typically greater than those between nonpolar molecules of comparable size because these interactions act in addition to London dispersion forces. iii. Ion-dipole forces of attraction are present between ions and polar molecules. These tend to be stronger than dipole-dipole forces.	
		3.1.A.3 The relative strength and orientation dependence of dipole-dipole and ion-dipole forces can be understood qualitatively by considering the sign of the partial charges responsible for the molecular dipole moment, and how these partial charges interact with an ion or with an adjacent dipole.	Ch. 11, Sec. 11.2; Pgs 433-441
		3.1.A.4 Hydrogen bonding is a strong type of intermolecular interaction that exists when hydrogen atoms covalently bonded to the highly electronegative atoms (N, O, and F) are attracted to the negative end of a dipole formed by the electronegative atom (N, O, and F) in a different molecule, or a different part of the same molecule.	Ch. 11, Sec. 11.2; Pgs 433-441

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		3.1.A.5 In large biomolecules, noncovalent interactions may occur between different molecules or between different regions of the same large biomolecule.	Ch. 11, Sec. 11.2; Pgs 433-441
3.2 Properties of Solids	**3.2.A** Explain the relationship among the macroscopic properties of a substance, the particulate-level structure of the substance, and the interactions between these particles.	**3.2.A.1** Many properties of liquids and solids are determined by the strengths and types of intermolecular forces present. Because intermolecular interactions are overcome completely when a substance vaporizes, the vapor pressure and boiling point are directly related to the strength of those interactions. Melting points also tend to correlate with interaction strength, but because the interactions are only rearranged, in melting, the relations can be more subtle.	Ch. 11, Sec. 11.1; Pgs 432-433
		3.2.A.2 Particulate-level representations, showing multiple interacting chemical species, are a useful means to communicate or understand how intermolecular interactions help to establish macroscopic properties.	Ch. 11, Sec. 11.1; Pgs 432-433
		3.2.A.3 Due to strong interactions between ions, ionic solids tend to have low vapor pressures, high melting points, and high boiling points. They tend to be brittle due to the repulsion of like charges caused	Ch. 11, Sec. 11.1; Pgs 432-433, Ch. 12, Sec 12.4, Pgs 486

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		when one layer slides across another layer. They conduct electricity only when the ions are mobile, as when the ionic solid is melted (i.e., in a molten state) or dissolved in water or another solvent.	
		3.2.A.4 In covalent network solids, the atoms are covalently bonded together into a three-dimensional network (e.g., diamond) or layers of two-dimensional networks (e.g., graphite). These are only formed from nonmetals and metalloids: elementals (e.g., diamond, graphite) or binary compounds (e.g., silicon dioxide and silicon carbide). Due to the strong covalent interactions, covalent solids have high melting points. Three-dimensional network solids are also rigid and hard, because the covalent bond angles are fixed. However, graphite is soft because adjacent layers can slide past each other relatively easily.	Ch 12, Sec 12.5, Pg 490-496
		3.2.A.5 Molecular solids are composed of distinct, individual units of covalently-bonded molecules attracted to each other through relatively weak intermolecular forces. Molecular solids generally have a low melting point because of the relatively weak intermolecular forces present between the molecules. They do not conduct electricity because	Ch 8, Sec 8.3, Pg 304-311, Ch 9, Sec 9.4, Pg 350,

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		their valence electrons are tightly held within the covalent bonds and the lone pairs of each constituent molecule. Molecular solids are sometimes composed of very large molecules or polymers.	
		3.2.A.6 Metallic solids are good conductors of electricity and heat, due to the presence of free valence electrons. They also tend to be malleable and ductile, due to the ease with which the metal cores can rearrange their structure. In an interstitial alloy, interstitial atoms tend to make the lattice more rigid, decreasing malleability and ductility. Alloys typically retain a sea of mobile electrons and so remain conducting.	Ch 12, Sec 12.2, Pg 480.
		3.2.A.7 In large biomolecules or polymers, noncovalent interactions may occur between different molecules or between different regions of the same large biomolecule. The functionality and properties of such molecules depend strongly on the shape of the molecule, which is largely dictated by noncovalent interactions.	Ch 8, Sec 8.3, Pg 304-311, Ch 9, Sec 9.4, Pg 350,
3.3 Solids, Liquids, and Gases	**3.3.A** Represent the differences between solid, liquid, and gas phases using a particulate level model.	**3.3.A.1** Solids can be crystalline, where the particles are arranged in a regular three-dimensional structure, or they can be amorphous, where the particles do not have a	Ch. 11, Sec. 11.1–11.6; Pgs 432-454

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		regular, orderly arrangement. In both cases, the motion of the individual particles is limited, and the particles do not undergo overall translation with respect to each other. The structure of the solid is influenced by interparticle interactions and the ability of the particles to pack together.	

		3.3.A.2 The constituent particles in liquids are in close contact with each other, and they are continually moving and colliding. The arrangement and movement of particles are influenced by the nature and strength of the forces (e.g., polarity, hydrogen bonding, and temperature) between the particles.	Ch. 11, Sec. 11.1–11.6; Pgs 432-454
		3.3.A.3 The solid and liquid phases for a particular substance typically have similar molar volume because, in both phases, the constituent particles are in close contact at all times.	Ch. 11, Sec. 11.1–11.6; Pgs 432-454
		3.3.A.4 In the gas phase, the particles are in constant motion. Their frequencies of collision and the average spacing between them are dependent on temperature, pressure, and volume. Because of this constant motion, and minimal effects of forces between particles, a gas has neither a definite volume nor a definite shape. **Exclusion Statement:** Understanding/ interpreting phase diagrams will not be assessed on the AP Exam.	Ch. 11, Sec. 11.1–11.6; Pgs 432-454
3.4 Ideal Gas Law	**3.4.A** Explain the relationship between the macroscopic properties of a sample of gas or mixture of gases using the ideal gas law.	**3.4.A.1** The macroscopic properties of ideal gases are related through the ideal gas law: EQN: $PV = nRT$.	Ch. 10, Sec. 10.1–10.4; Pgs 392-407
		3.4.A.2 In a sample containing a	Ch. 10, Sec. 10.1–10.4; Pgs 392-407

		mixture of ideal gases, the pressure exerted by each component (the partial pressure) is independent of the other components. Therefore, the partial pressure of a gas within the mixture is proportional to its mole fraction (X), and the total pressure of the sample is the sum of the partial pressures. EQN: $P_A = P_{total} \times X_A$, where X_A = moles A/total moles; EQN: $P_{total} = P_A + P_B + P_C + \ldots$	
		3.4.A.3 Graphical representations of the relationships between P, V, T, and *n* are useful to describe gas behavior.	Ch. 10, Sec. 10.1–10.4; Pgs 392-407
3.5 Kinetic Molecular Theory	**3.5.A** Explain the relationship between the motion of particles and the macroscopic properties of gases with: i. The kinetic molecular theory (KMT). ii. A particulate model. iii. A graphical representation.	**3.5.A.1** The kinetic molecular theory (KMT) relates the macroscopic properties of gases to motions of the particles in the gas. The Maxwell-Boltzmann distribution describes the distribution of the kinetic energies of particles at a given temperature.	Ch. 10, Sec. 10.5-10.6; Pgs 408-414
		3.5.A.2 All the particles in a sample of matter are in continuous, random motion. The average kinetic energy of a particle is related to its average velocity by the equation: EQN: $KE = \frac{1}{2} mv^2$.	Ch. 10, Sec. 10.5-10.6; Pgs 408-414
		3.5.A.3 The Kelvin temperature of a sample of matter is proportional to the average kinetic energy of the particles in the sample.	Ch. 10, Sec. 10.5-10.6; Pgs 408-414
		3.5.A.4 The Maxwell-Boltzmann	Ch. 10, Sec. 10.5-10.6;

		distribution provides a graphical representation of the energies/ velocities of particles at a given temperature.	Pgs 408-414
3.6 Deviation from Ideal Gas Law	**3.6.A** Explain the relationship among non-ideal behaviors of gases, interparticle forces, and/or volumes.	**3.6.A.1** The ideal gas law does not explain the actual behavior of real gases. Deviations from the ideal gas law may result from interparticle attractions among gas molecules, particularly at conditions that are close to those resulting in condensation. Deviations may also arise from particle volumes, particularly at extremely high pressures.	Ch. 10, Sec. 10.7; Pgs 415-419
3.7 Solutions and Mixtures	**3.7.A** Calculate the number of solute particles, volume, or molarity of solutions.	**3.7.A.1** Solutions, also sometimes called homogeneous mixtures, can be solids, liquids, or gases. In a solution, the macroscopic properties do not vary throughout the sample. In a heterogeneous mixture, the macroscopic properties depend on location in the mixture.	Ch. 13, Sec. 13.1–13.4; Pgs 522-538
		3.7.A.2 Solution composition can be expressed in a variety of ways; molarity is the most common method used in the laboratory. EQN: $M = n_{solute} / L_{solution}$	Ch. 13, Sec. 13.1–13.4; Pgs 522-538
3.8 Representations of Solutions	**3.8.A** Using particulate models for mixtures: i. Represent interactions between components. ii. Represent concentrations of components.	**3.8.A.1** Particulate representations of solutions communicate the structure and properties of solutions, by illustration of the relative concentrations of the components in the solution and/or drawings that show interactions among the components. **Exclusion**	Ch. 13, Sec. 13.1-13.4; Pgs 522-538

		Statement: Colligative properties will not be assessed on the AP Exam. **Exclusion Statement:** Calculations of molality, percent by mass, and percent by volume for solutions will not be assessed on the AP Exam.	
3.9 Separation of Solutions and Mixtures	**3.9.A** Explain the results of a separation experiment based on intermolecular interactions.	**3.9.A.1** The components of a liquid solution cannot be separated by filtration. They can, however, be separated using processes that take advantage of differences in the intermolecular interactions of the components. i.Chromatography (paper, thin-layer, and column) separates chemical species by taking advantage of the differential strength of intermolecular interactions between and among the components of the solution (the mobile phase) and with the surface components of the stationary phase. The resulting chromatogram can be used to infer the relative polarities of components in a mixture. ii. Distillation separates chemical species by taking advantage of the differential strength of intermolecular interactions between and among the components and the effects these interactions have on the vapor pressures of the components in the mixture.	Ch. 1, Sec. 1.3; Pgs 10-12
3.10 Solubility	**3.10.A** Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents, and the intermolecular interactions between	**3.10.A.1** Substances with similar intermolecular interactions tend to be miscible or soluble in one another.	Ch. 13, Sec. 13.3; Pgs 528-534

	particles.		
3.11 Spectroscopy and the Electromagnetic Spectrum	**3.11.A** Explain the relationship between a region of the electromagnetic spectrum and the types of molecular or electronic transitions associated with that region.	**3.11.A.1** Differences in absorption or emission of photons in different spectral regions are related to the different types of molecular motion or electronic transition: i. Microwave radiation is associated with transitions in molecular rotational levels. ii. Infrared radiation is associated with transitions in molecular vibrational levels. iii. Ultraviolet/visible radiation is associated with transitions in electronic energy levels.	Ch. 6, Sec. 6.1–6.4; Pgs 212-224
3.12 Properties of Photons	**3.12.A** Explain the properties of an absorbed or emitted photon in relationship to an electronic transition in an atom or molecule.	**3.12.A.1** When a photon is absorbed (or emitted) by an atom or molecule, the energy of the species is increased (or decreased) by an amount equal to the energy of the photon.	Ch. 6, Sec. 6.2; Pgs 214-216
		3.12.A.2 The wavelength of the electromagnetic wave is related to its frequency and the speed of light by the equation: EQN: $c = \lambda\nu$. The energy of a photon is related to the frequency of the electromagnetic wave through Planck's equation: EQN: $E = h\nu$.	Not represented thoroughly in the text.
3.13 Beer–Lambert Law	**3.13.A** Explain the amount of light absorbed by a solution of molecules or ions in relationship to the concentration, path length, and molar absorptivity.	**3.13.A.1** The Beer-Lambert law relates the absorption of light by a solution to three variables according to the equation: EQN: $A = \varepsilon bc$. The molar absorptivity, ε,	Ch. 14, Sec. 14.2; Pgs 571-576

		describes how intensely a chemical species absorbs light of a specific wavelength. The path length, b, and concentration, c, are proportional to the number of light-absorbing particles in the light path.	
		3.13.A.2 In most experiments the path length and wavelength of light are held constant. In such cases, the absorbance is proportional only to the concentration of absorbing molecules or ions. The spectrophotometer is typically set to the wavelength of maximum absorbance (optimum wavelength) for the species being analyzed to ensure the maximum sensitivity of measurement.	Ch. 14, Sec. 14.2; Pgs 571-576

Unit 4: Chemical Reactions

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
4.1 Introduction for Reactions	**4.1.A** Identify evidence of chemical and physical changes in matter.	**4.1.A.1** A physical change occurs when a substance undergoes a change in properties but not a change in composition. Changes in the phase of a substance (solid, liquid, gas) or formation/separation of mixtures of substances are common physical changes.	Ch. 3, Sec. 3.1–3.2; Pgs 86-92
		4.1.A.2 A chemical change occurs when substances are transformed into new substances, typically	Ch. 3, Sec. 3.1–3.2; Pgs 86-92

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		with different compositions. Production of heat or light, formation of a gas, formation of a precipitate, and/or color change provide possible evidence that a chemical change has occurred.	
4.2 Net Ionic Equations	**4.2.A** Represent changes in matter with a balanced chemical or net ionic equation: i. For physical changes. ii. For given information about the identity of the reactants and/or product. iii. For ions in a given chemical reaction.	**4.2.A.1** All physical and chemical processes can be represented symbolically by balanced equations.	Ch. 4, Sec. 4.1–4.2; Pgs 120-127
		4.2.A.2 Chemical equations represent chemical changes. These changes are the result of a rearrangement of atoms into new combinations; thus, any representation of a chemical change must contain equal numbers of atoms of every element before and after the change occurred. Equations thus demonstrate that mass and charge are conserved in chemical reactions.	Ch. 4, Sec. 4.1–4.2; Pgs 120-127
		4.2.A.3 Balanced molecular, complete ionic, and net ionic equations are differing symbolic forms used to represent a chemical reaction. The form used to represent the reaction depends on the context in which it is to be used.	Ch. 4, Sec. 4.1–4.2; Pgs 120-127
4.3 Representations of Reactions	**4.3.A** Represent a given chemical reaction or physical process with a consistent	**4.3.A.1** Balanced chemical equations in their	Ch. 4, Sec. 4.1–4.2; Pgs 120-127

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
	particulate model.	various forms can be translated into symbolic particulate representations.	
4.4 Physical and Chemical Changes	**4.4.A** Explain the relationship between macroscopic characteristics and bond interactions for: i. Chemical processes. ii. Physical processes.	**4.4.A.1** Processes that involve the breaking and/or formation of chemical bonds are typically classified as chemical processes. Processes that involve only changes in intermolecular interactions, such as phase changes, are typically classified as physical processes.	Ch. 1, Sec. 1.3; Pgs 10-12
		4.4.A.2 Sometimes physical processes involve the breaking of chemical bonds. For example, plausible arguments could be made for the dissolution of a salt in water, as either a physical or chemical process, involves breaking of ionic bonds, and the formation of ion-dipole interactions between ions and solvent.	Ch. 1, Sec. 1.3; Pgs 10-12
4.5 Stoichiometry	**4.5.A** Explain changes in the amounts of reactants and products based on the balanced reaction equation for a chemical process.	**4.5.A.1** Because atoms must be conserved during a chemical process, it is possible to calculate product amounts by using known reactant amounts, or to calculate reactant amounts given known product amounts.	Ch. 3, Sec. 3.6–3.7; Pgs 103-108
		4.5.A.2 Coefficients of balanced chemical equations contain information	Ch. 3, Sec. 3.6–3.7; Pgs 103-108

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		regarding the proportionality of the amounts of substances involved in the reaction. These values can be used in chemical calculations involving the mole concept. **4.5.A.3** Stoichiometric calculations can be combined with the ideal gas law and calculations involving molarity to quantitatively study gases and solutions	
4.6 Introduction to Titration	**4.6.A** Identify the equivalence point in a titration based on the amounts of the titrant and analyte, assuming the titration reaction goes to completion.	**4.6.A.1** Titrations may be used to determine the amount of an analyte in solution. The titrant has a known concentration of a species that reacts specifically and quantitatively with the analyte. The equivalence point of the titration occurs when the analyte is totally consumed by the reacting species in the titrant. The equivalence point is often indicated by a change in a property (such as color) that occurs when the equivalence point is reached. This observable event is called the endpoint of the titration.	Ch. 4, Sec. 4.6; Pgs 147-151
4.7 Types of Chemical Reactions	**4.7.A** Identify a reaction as acid base, oxidation-reduction, or precipitation.	**4.7.A.1** Acid-base reactions involve transfer of one or more protons (H+	Ch. 4, Sec. 4.2–4.4; Pgs 123-141

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		ions) between chemical species. **4.7.A.2** Oxidation-reduction (redox) reactions involve transfer of one or more electrons between chemical species, as indicated by changes in oxidation numbers of the involved species. Combustion is an important subclass of oxidation-reduction reactions, in which a species reacts with oxygen gas. In the case of hydrocarbons, carbon dioxide and water are products of complete combustion. **4.7.A.3** In a redox reaction, electrons are transferred from the species that is oxidized to the species that is reduced. **Exclusion Statement**: The meaning of the terms "reducing agent" and "oxidizing agent" will not be assessed on the AP Exam. **4.7.A.4** Oxidation numbers may be assigned to each of the atoms in the reactants and products; this is often an effective way to identify the oxidized and reduced species in a redox reaction. 4.7.A.5 Precipitation reactions frequently involve mixing ions in aqueous	

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		solution to produce an insoluble or sparingly soluble ionic compound. All sodium, potassium, ammonium, and nitrate salts are soluble in water. **Exclusion Statement:** Rote memorization of "solubility rules" other than those implied in 4.7.A.5 will not be assessed on the AP Exam.	
4.8 Introduction to Acid–Base Reactions	**4.8.A** Identify species as Brønsted-Lowry acids, bases, and/or conjugate acid-base pairs, based on proton-transfer involving those species.	4.8.A.1 By definition, a Brønsted-Lowry acid is a proton donor and a Brønsted-Lowry base is a proton acceptor. 4.8.A.2 Only in aqueous solutions, water plays an important role in many acid-base reactions, as its molecular structure allows it to accept protons from and donate protons to dissolved species. 4.8.A.3 When an acid or base ionizes in water, the conjugate acid-base pairs can be identified and their relative strengths compared. **Exclusion Statement:** Lewis acid-base concepts will not be assessed on the AP Exam. The emphasis in AP Chemistry is on reactions in aqueous solution	Ch. 4, Sec. 4.3; Pgs 128-134
4.9 Oxidation-Reduction (Redox) . Reactions	4**.9.A** Represent a balanced redox	**4.9.A.1** Balanced chemical equations for redox reactions can be	Ch. 4, Sec. 4.4; Pgs 135-141

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
	reaction equation using half-reactions.	constructed from half-reactions.	

Unit 5: Kinetics

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
5.1 Reaction Rates	5.1.A Explain the relationship between the rate of a chemical reaction and experimental parameters	5.1.A.1 The kinetics of a chemical reaction is defined as the rate at which an amount of reactants is converted to products per unit of time.	Ch. 14, Sec. 14.1; Pgs 566-570
		5.1.A.2 The rates of change of reactant and product concentrations are determined by the stoichiometry in the balanced chemical equation. 5.1.A.3 The rate of a reaction is influenced by reactant concentrations, temperature, surface area, catalysts, and other environmental factors.	Ch. 14, Sec. 14.1; Pgs 566-570
5.2 Introduction to Rate Law	5.2.A Represent experimental data with a consistent rate law expression.	5.2.A.1 Experimental methods can be used to monitor the amounts of reactants and/or products of a reaction over time and to determine the rate of the reaction.	Ch. 14, Sec. 14.2; Pgs 571-576
		5.2.A.2 The rate law expresses the rate of a reaction as proportional to the concentration of each	Ch. 14, Sec. 14.2; Pgs 571-576

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		reactant raised to a power.	
		5.2.A.3 The power of each reactant in the rate law is the order of the reaction with respect to that reactant. The sum of the powers of the reactant concentrations in the rate law is the overall order of the reaction.	Ch. 14, Sec. 14.2; Pgs 571-576
		5.2.A.4 The proportionality constant in the rate law is called the rate constant. The value of this constant is temperature dependent and the units reflect the overall reaction order.	Ch. 14, Sec. 14.2-5; Pgs 571-592
		5.2.A.5 Comparing initial rates of a reaction is a method to determine the order with respect to each reactant.	Ch. 14, Sec. 14.2; Pgs 571-576
5.3 Concentration Changes Over Time	5.3.A Identify the rate law expression of a chemical reaction using data that show how the concentrations of reaction species change over time	5.3.A.1 The order of a reaction can be inferred from a graph of concentration of reactant versus time.	Ch. 14, Sec. 14.3; Pgs 577-582
		5.3.A.2 If a reaction is first order with respect to a reactant being monitored, a plot of the natural log (ln) of the reactant concentration as a function of time will be linear.	Ch. 14, Sec. 14.3; Pgs 577-582
		5.3.A.3 If a reaction is second order with respect to a reactant being monitored, a plot of the	Ch. 14, Sec. 14.3; Pgs 577-582

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		reciprocal of the concentration of that reactant versus time will be linear.	
		5.3.A.4 The slopes of the concentration versus time data for zeroth, first, and second order reactions can be used to determine the rate constant for the reaction. Zeroth order: EQN: $[A]_t - [A]_0 = -kt$ First order: EQN: $\ln[A]_t - \ln[A]_0 = -kt$ Second order: EQN: $1/[A]_t - 1/[A]_0 = kt$	Ch. 14, Sec. 14.3; Pgs 577-582
		5.3.A.5 Half-life is a critical parameter for first order reactions because the half-life is constant and related to the rate constant for the reaction by the equation: EQN: $t_{1/2} = 0.693/k$.	Ch. 14, Sec. 14.3; Pgs 577-582
		5.3.A.6 Radioactive decay processes provide an important illustration of first order kinetics.	Ch 21, Sec 21.1-21.4, Pg 892-94
5.4 Elementary Reactions	5.4.A Represent an elementary reaction as a rate law expression using stoichiometry	5.4.A.1 The rate law of an elementary reaction can be inferred from the stoichiometry of the particles participating in a	Ch. 14, Sec. 14.5; Pgs 590-598

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		collision.	
		5.4.A.2 Elementary reactions involving the simultaneous collision of three or more particles are rare.	Ch. 14, Sec. 14.5; Pgs 590-598
5.5 Collision Model	5.5.A Explain the relationship between the rate of an elementary reaction and the frequency, energy, and orientation of particle collisions.	5.5.A.1 For an elementary reaction to successfully produce products, reactants must successfully collide to initiate bond-breaking and bond-making events	Ch. 14, Sec. 14.4; Pgs 583-589
		5.5.A.2 In most reactions, only a small fraction of the collisions leads to a reaction. Successful collisions have both sufficient energy to overcome the activation energy requirements and orientations that allow the bonds to rearrange in the required manner.	Ch. 14, Sec. 14.4; Pgs 583-589
		5.5.A.3 The Maxwell-Boltzmann distribution curve describes the distribution of particle energies; this distribution can be used to gain a qualitative estimate of the fraction of collisions with sufficient energy to lead to a reaction, and also how that fraction depends on temperature.	Ch. 14, Sec. 14.4; Pgs 583-589
5.6 Reaction Energy Profile	5.6.A Represent the activation energy and overall energy change in an elementary reaction using a reaction energy profile	5.6.A.1 Elementary reactions typically involve the breaking of some bonds and the forming of new	Ch. 14, Sec. 14.4; Pgs 583-589

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		ones.	
		5.6.A.2 The reaction coordinate is the axis along which the complex set of motions involved in rearranging reactants to form products can be plotted.	Ch. 3, Sec 3.1, 86-58, Sec.3.7, pg 106
		5.6.A.3 The energy profile gives the energy along the reaction coordinate, which typically proceeds from reactants, through a transition state, to products. The energy difference between the reactants and the transition state is the activation energy for the forward reaction.	Ch. 3, Sec 3.1, 86-58, Sec.3.7, pg 106
		5.6.A.4 The rate of an elementary reaction is temperature dependent because the proportion of particle collisions that are energetic enough to reach the transition state varies with temperature. The Arrhenius equation relates the temperature dependence of the rate of an elementary reaction to the activation energy needed by molecular collisions to reach the transition state. Exclusion Statement: Calculations involving the Arrhenius equation will not be assessed on the AP Exam.	Ch. 14, Sec. 14.4; Pgs 583-589
5.7 Introduction to Reaction Mechanisms	5.7.A Identify the components of a reaction mechanism	5.7.A.1 A reaction mechanism consists of a series of elementary	Ch. 14, Sec. 14.5; Pgs 590-598

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		reactions, or steps, that occur in sequence. The components may include reactants, intermediates, products, and catalysts	
		5.7.A.2 The elementary steps when combined should align with the overall balanced equation of a chemical reaction.	Ch. 14, Sec. 14.5; Pgs 590-598
		5.7.A.3 A reaction intermediate is produced by some elementary steps and consumed by others, such that it is present only while a reaction is occurring.	Ch. 3, Sec 3.1, 86-58, Sec.3.7, pg 106
		5.7.A.4 Experimental detection of a reaction intermediate is a common way to build evidence in support of one reaction mechanism over an alternative mechanism. Exclusion Statement: Collection of data pertaining to detection of a reaction intermediate will not be assessed on the AP Exam	Ch. 3, Sec 3.1, 86-58, Sec.3.7, pg 106
5.8 Reaction Mechanism and Rate Law	5.8.A Identify the rate law for a reaction from a mechanism in which the first step is rate limiting	5.8.A.1 For reaction mechanisms in which each elementary step is irreversible, or in which the first step is rate limiting, the rate law of the reaction is set by the molecularity of the slowest elementary step (i.e., the rate-limiting step). Exclusion Statement: Collection of data pertaining to detection of a reaction intermediate will	Ch. 14, Sec. 14.5; Pgs 590-598

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		not be assessed on the AP Exam	
5.9 Pre-Equilibrium Approximation	5.9.A Identify the rate law for a reaction from a mechanism in which the first step is not rate limiting	5.9.A.1 If the first elementary reaction is not rate limiting, approximations (such as pre-equilibrium) must be made to determine a rate law expression	Ch. 14, Sec. 14.5; Pgs 590-598
5.10 Multistep Reaction Energy Profile	5.10.A Represent the activation energy and overall energy change in a multistep reaction with a reaction energy profile	5.10.A.1 Knowledge of the energetics of each elementary reaction in a mechanism allows for the construction of an energy profile for a multistep reaction	Ch. 14, Sec. 14.5; Pgs 590-598
5.11 Catalysis	5.11.A Explain the relationship between the effect of a catalyst on a reaction and changes in the reaction mechanism	5.11.A.1 In order for a catalyst to increase the rate of a reaction, the addition of the catalyst must increase the number of effective collisions and/ or provide a reaction path with a lower activation energy relative to the original reaction coordinate.	Ch. 14, Sec. 14.6; Pgs 599-605
		5.11.A.2 In a reaction mechanism containing a catalyst, the net concentration of the catalyst is constant. However, the catalyst will frequently be consumed in the rate-determining step of the reaction, only to be regenerated in a subsequent step in the mechanism.	Ch. 14, Sec. 14.6; Pgs 599-605
		5.11.A.3 Some catalysts accelerate a reaction by binding to the reactant(s).	Ch 8, Sec 8.3, Pg 304-311, Ch 9, Sec 9.4, Pg

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		The reactants are either oriented more favorably or react with lower activation energy. There is often a new reaction intermediate in which the catalyst is bound to the reactant(s). Many enzymes function in this manner	350,
		5.11.A.4 Some catalysts involve covalent bonding between the catalyst and the reactant(s). An example is acid-base catalysis, in which a reactant or intermediate either gains or loses a proton. This introduces a new reaction intermediate and new elementary reactions involving that intermediate	Ch 8, Sec 8.3, Pg 304-311, Ch 9, Sec 9.4, Pg 350,
		5.11.A.5 In surface catalysis, a reactant or intermediate binds to, or forms a covalent bond with, the surface. This introduces elementary reactions involving these new bound reaction intermediate(s).	Ch 8, Sec 8.3, Pg 304-311, Ch 9, Sec 9.4, Pg 350,

Unit 6: Thermochemistry

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
6.1 Endothermic and Exothermic Processes	6.1.A Explain the relationship between experimental observations and energy changes associated with a chemical or physical transformation.	6.1.A.1 Temperature changes in a system indicate energy changes.	Ch. 5, Sec. 5.1–5.3; Pgs 162-173
		6.1.A.2 Energy changes in a system can be described as endothermic and exothermic processes such as the	Ch. 5, Sec. 5.1–5.3; Pgs

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		heating or cooling of a substance, phase changes, or chemical transformations.	162-173
		6.1.A.3 When a chemical reaction occurs, the energy of the system either decreases (exothermic reaction), increases (endothermic reaction), or remains the same. For exothermic reactions, the energy lost by the reacting species (system) is gained by the surroundings, as heat transfer from or work done by the system. Likewise, for endothermic reactions, the system gains energy from the surroundings by heat transfer to or work done on the system.	Ch. 5, Sec. 5.1–5.3; Pgs 162-173
		6.1.A.4 The formation of a solution may be an exothermic or endothermic process, depending on the relative strengths of intermolecular/interparticle interactions before and after the dissolution process.	Ch. 5, Sec. 5.1–5.3; Pgs 162-173
6.2 Energy Diagrams	6.2.A Represent a chemical or physical transformation with an energy diagram.	6.2.A.1 A physical or chemical process can be described with an energy diagram that shows the endothermic or exothermic nature of that process.	Ch. 5, Sec. 5.1–5.4; Pgs 162-176
6.3 Heat Transfer and Thermal Equilibrium	6.3.A Explain the relationship between the transfer of thermal energy and molecular collisions.	6.3.A.1 The particles in a warmer body have a greater average kinetic energy than those in a cooler body.	Ch. 5, Sec. 5.2; Pgs 164-169
		6.3.A.2 Collisions between particles in thermal contact can result in the transfer of energy. This process is called "heat transfer," "heat exchange," or "transfer of energy as heat."	Ch. 5, Sec. 5.2; Pgs 164-169
		6.3.A.3 Eventually, thermal equilibrium is reached as the particles continue to collide. At thermal equilibrium, the average kinetic energy of both bodies is the same, and hence, their temperatures are the same	Ch. 5, Sec. 5.2; Pgs 164-169
6.4 Heat Capacity and Calorimetry	6.4.A Calculate the heat q absorbed or released by a system undergoing heating/cooling based on the amount of the substance, the heat capacity, and the change in	6.4.A.1 The heating of a cool body by a warmer body is an important form of energy transfer between two systems. The amount of heat transferred between two bodies may be quantified by the heat transfer equation: EQN: $q = mc\Delta T$. Calorimetry experiments are used to	Ch. 5, Sec. 5.5; Pgs 177-181

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
	temperature.	measure the transfer of heat.	
		6.4.A.2 The first law of thermodynamics states that energy is conserved in chemical and physical processes	Ch. 5, Sec. 5.5; Pgs 177-18
		6.4.A.3 The transfer of a given amount of thermal energy will not produce the same temperature change in equal masses of matter with differing specific heat capacities.	Ch. 5, Sec. 5.5; Pgs 177-18
		6.4.A.4 Heating a system increases the energy of the system, while cooling a system decreases the energy of the system.	Ch. 5, Sec. 5.5; Pgs 177-18
		6.4.A.5 The specific heat capacity of a substance and the molar heat capacity are both used in energy calculations.	Ch. 5, Sec. 5.5; Pgs 177-18
		6.4.A.6 Chemical systems change their energy through three main processes: heating/cooling, phase transitions, and chemical reactions	Ch. 5, Sec. 5.5; Pgs 177-18
		6.4.A.7 In calorimetry experiments involving dissolution, temperature changes of the mixture within the calorimeter can be used to determine the direction of energy flow. If the temperature of the mixture increases, thermal energy is released by the dissolution process (exothermic). If the temperature of the mixture decreases, thermal energy is absorbed by the dissolution process (endothermic).	Ch. 5, Sec. 5.5; Pgs 177-18
6.5 Energy of Phase Changes	6.5.A Explain changes in the heat q absorbed or released by a system undergoing a phase transition based on the amount of the substance in moles and the molar enthalpy of the phase transition	6.5.A.1 Energy must be transferred to a system to cause a substance to melt (or boil). The energy of the system therefore increases as the system undergoes a solid-to-liquid (or liquid -to-gas) phase transition. Likewise, a system releases energy when it freezes (or condenses). The energy of the system decreases as the system undergoes a liquid-to-solid (or gas-to-liquid) phase transition. The temperature of a pure substance remains constant during a phase change.	Ch. 11, Sec. 11.4; Pgs 445-448

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		6.5.A.2 The energy absorbed during a phase change is equal to the energy released during a complementary phase change in the opposite direction. For example, the molar enthalpy of condensation of a substance is equal to the negative of its molar enthalpy of vaporization. Similarly, the molar enthalpy of fusion can be used to calculate the energy absorbed when melting a substance and the energy released when freezing a substance	Ch. 11, Sec. 11.4; Pgs 445-448
6.6 Introduction to Enthalpy of Reaction	6.6.A Calculate the heat q absorbed or released by a system undergoing a chemical reaction in relationship to the amount of the reacting substance in moles and the molar enthalpy of reaction.	6.6.A.1 The enthalpy change of a reaction gives the amount of heat energy released (for negative values) or absorbed (for positive values) by a chemical reaction at constant pressure.	Ch. 5, Sec. 5.4; Pgs 174-176
		6.6.A.2 When the products of a reaction are at a different temperature than their surroundings, they exchange energy with the surroundings to reach thermal equilibrium. Thermal energy is transferred to the surroundings as the reactants convert to products in an exothermic reaction. Thermal energy is transferred from the surroundings as the reactants convert to products in an endothermic reaction.	Ch. 11, Sec. 11.4; Pgs 445-448
		6.6.A.3 The chemical potential energy of the products of a reaction is different from that of the reactants because of the breaking and forming of bonds. The energy difference results in a change in the kinetic energy of the particles, which manifests as a temperature change. Exclusion Statement: The technical distinctions between enthalpy and internal energy will not be assessed on the AP Exam. Most reactions studied at the AP level are carried out at constant pressure, where the enthalpy change of the process is equal to the heat (and by extension, the energy) of reaction.	Ch. 11, Sec. 11.4; Pgs 445-448
6.7 Bond Enthalpies	6.7.A Calculate the enthalpy change of a reaction based on the average bond energies of bonds broken and formed in	6.7.A.1 During a chemical reaction, bonds are broken and/or formed, and these events change the potential energy of the system.	Ch. 5, Sec. 5.8; Pgs 188-191

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
	the reaction.		
		6.7.A.2 The average energy required to break all of the bonds in the reactant molecules can be estimated by adding up the average bond energies of all the bonds in the reactant molecules. Likewise, the average energy released in forming the bonds in the product molecules can be estimated. If the energy released is greater than the energy required, the reaction is exothermic. If the energy required is greater than the energy released, the reaction is endothermic.	Ch. 5, Sec. 5.8; Pgs 188-191
6.8 Enthalpy of Formation	6.8.A Calculate the enthalpy change for a chemical or physical process based on the standard enthalpies of formation.	6.8.A.1 Tables of standard enthalpies of formation can be used to calculate the standard enthalpies of reactions. EQN: $\Delta H°_{reaction} =$ $\Sigma \Delta H_f{}°_{products} - \Sigma \Delta H_f{}°_{reactants}$	Ch. 5, Sec. 5.7; Pgs 184-187
6.9 Hess's Law	6.9.A Represent a chemical or physical process as a sequence of steps.	6.9.A.1 Many processes can be broken down into a series of steps. Each step in the series has its own energy change.	Ch. 5, Sec. 5.6; Pgs 182-183
	6.9.B Explain the relationship between the enthalpy of a chemical or physical process and the sum of the enthalpies of the individual steps.	6.9.B.1 Because total energy is conserved (first law of thermodynamics), and each individual reaction in a sequence transfers thermal energy to or from the surroundings, the net thermal energy transferred in the sequence will be equal to the sum of the thermal energy transfers in each of the steps. These thermal energy transfers are the result of potential energy changes among the species in the reaction sequence; thus, at constant pressure, the enthalpy change of the overall process is equal to the sum of the enthalpy changes of the individual steps	Ch. 5, Sec. 5.5; Pgs 177-18
		6.9.B.2 The following are essential principles of Hess's law: i. When a reaction is reversed, the enthalpy change stays constant in magnitude but becomes reversed in mathematical sign. ii. When a reaction is multiplied by a factor c, the enthalpy change is multiplied by the same factor c. iii. When two (or more) reactions are added to obtain	Ch. 5, Sec. 5.6; Pgs 182-183

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		an overall reaction, the individual enthalpy changes of each reaction are added to obtain the net enthalpy change of the overall reaction. Exclusion Statement: The concept of state functions will not be assessed on the AP Exam	

Unit 7: Equilibrium

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
7.1 Introduction to Equilibrium	7.1.A Explain the relationship between the occurrence of a reversible chemical or physical process, and the establishment of equilibrium, to experimental observations	7.1.A.1 Many observable processes are reversible. Examples include evaporation and condensation of water, absorption and desorption of a gas, or dissolution and precipitation of a salt. Some important reversible chemical processes include the transfer of protons in acid-base reactions and the transfer of electrons in redox reactions.	Ch. 15, Sec. 15.1; Pgs 622-623
		7.1.A.2 When equilibrium is reached, no observable changes occur in the system. Reactants and products are simultaneously present, and the concentrations or partial pressures of all species remain constant.	Ch. 15, Sec. 15.1; Pgs 622-623

		7.1.A.3 The equilibrium state is dynamic. The forward and reverse processes continue to occur at equal rates, resulting in no net observable change.	Ch. 15, Sec. 15.1; Pgs 622-623
		7.1.A.4 Graphs of concentration, partial pressure, or rate of reaction versus time for simple chemical reactions can be used to understand the establishment of chemical equilibrium	Ch. 15, Sec. 15.1; Pgs 622-623
7.2 Direction of Reversible Reactions	7.2.A Explain the relationship between the direction in which a reversible reaction proceeds and the relative rates of the forward and reverse reactions	7.2.A.1 If the rate of the forward reaction is greater than the reverse reaction, then there is a net conversion of reactants to products. If the rate of the reverse reaction is greater than that of the forward reaction, then there is a net conversion of products to reactants. An equilibrium state is reached when these rates are equal	Ch. 15, Sec. 15.1-15.3; Pgs 622-632

7.3 Reaction Quotient and Equilibrium Constant	7.3.A Represent the reaction quotient Q_c or Q_p , for a reversible reaction, and the corresponding equilibrium expressions $K_c = Q_c$ or $K_p = Q_p$	7.3.A.1 The reaction quotient Q_c describes the relative concentrations of reaction species at any time. For gas phase reactions, the reaction quotient may instead be written in terms of partial pressures as Q_p . The reaction quotient tends toward the equilibrium constant such that at equilibrium $K_c = Q_c$ and $K_p = Q_p$. As examples, for the reaction a A + b B ⇄ C + d D the law of mass action indicates that the equilibrium expression for (Kc , Qc) is EQN: $K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$ and that for (Kp , Qp) is EQN: $K_p = \frac{(P_C)^c(P_D)^d}{(P_A)^a(P_B)^b}$ Exclusion Statement: Conversion between Kc and Kp will not be assessed on the AP Exam. Students should be aware of the conceptual differences and pay attention to whether Kc or Kp is used in an exam question. Exclusion Statement: Equilibrium calculations on systems where a dissolved species is in equilibrium with that species in the gas phase will not be assessed on the AP Exam.	Ch. 15, Sec. 15.6; Pgs 638-640

		7.3.A.2 The reaction quotient does not include substances whose concentrations (or partial pressures) are independent of the amount, such as for solids and pure liquids	
7.4 Calculating the Equilibrium Constant	7.4.A Calculate K_c or K_p based on experimental observations of concentrations or pressures at equilibrium	7.4.A.1 Equilibrium constants can be determined from experimental measurements of the concentrations or partial pressures of the reactants and products at equilibrium	Ch. 15, Sec. 15.5; Pgs 635-637
7.5 Magnitude of the Equilibrium Constant	7.5.A Explain the relationship between very large or very small values of K and the relative concentrations of chemical species at equilibrium	7.5.A.1 Some equilibrium reactions have very large K values and proceed essentially to completion. Others have very small K values and barely proceed at all.	Ch. 15, Sec. 15.1-15.6; Pgs 622-640
7.6 Properties of the Equilibrium Constant	7.6.A Represent a multistep process with an overall equilibrium expression, using the constituent K expressions for each individual reaction.	7.6.A.1 When a reaction is reversed, K is inverted	Ch. 15, Sec. 15.1-15.6; Pgs 622-640
		7.6.A.2 When the stoichiometric coefficients of a reaction are multiplied by a factor c, K is raised to the power c.	Ch. 15, Sec. 15.1-15.6; Pgs 622-640
		7.6.A.3 When reactions are added together, the K of the resulting overall reaction is the product of the K's for the reactions that were	Ch. 15, Sec. 15.1-15.6; Pgs 622-640

		summed.	
		7.6.A.4 Since the expressions for K and Q have identical mathematical forms, all valid algebraic manipulations of K also apply to Q.	Ch. 15, Sec. 15.1-15.6; Pgs 622-640
7.7 Calculating Equilibrium Concentrations	7.7.A Identify the concentrations or partial pressures of chemical species at equilibrium based on the initial conditions an	7.7.A.1 The concentrations or partial pressures of species at equilibrium can be predicted given the balanced reaction, initial concentrations, and the appropriate K.	Ch. 15, Sec. 15.1-15.6; Pgs 622-640
		7.7.A.2 When $Q < K$, the reaction will proceed with a net consumption of reactants and generation of products. When $Q > K$, the reaction will proceed with a net consumption of products and generation of reactants. When $Q = K$, the system is at dynamic equilibrium; both forward and reverse reactions proceed at the same rate, and the proportion of reactants and products remains constant	Ch. 15, Sec. 15.1-15.6; Pgs 622-640
7.8 Representations of Equilibrium	7.8.A Represent a system undergoing a reversible reaction with a particulate model.	7.8.A.1 Particulate representations can be used to describe the relative numbers of reactant and product particles present prior to and at equilibrium, and the value of the	Ch. 15, Sec. 15.1-15.6; Pgs 622-640

		equilibrium constant.	
7.9 Introduction to Le Châtelier’s Principle	7.9.A Identify the response of a system at equilibrium to an external stress, using Le Châtelier's principle.	7.9.A.1 Le Châtelier’s principle can be used to predict the response of a system to stresses such as addition or removal of a chemical species, change in temperature, change in volume/ pressure of a gas-phase system, or dilution of a reaction system	Ch. 15, Sec. 15.7; Pgs 641-650
		7.9.A.2 Le Châtelier’s principle can be used to predict the effect that a stress will have on experimentally measurable properties such as pH, temperature, and color of a solution	Ch. 15, Sec. 15.7; Pgs 641-650
7.10 Reaction Quotient and Le Châtelier’s Principle	7.10.A Explain the relationships between Q, K, and the direction in which a reversible reaction will proceed to reach equilibrium.	7.10.A.1 A disturbance to a system at equilibrium causes Q to differ from K, thereby taking the system out of equilibrium. The system responds by bringing Q back into agreement with K, thereby establishing a new equilibrium state	Ch. 15, Sec. 15.7; Pgs 641-650
		7.10.A.2 Some stresses, such as changes in concentration, cause a change in Q only. A change in temperature causes a change in K. In either case, the concentrations or partial pressures of species redistribute to bring Q and K back	Ch. 15, Sec. 15.7; Pgs 641-650

		into equality.	
7.11 Introduction to Solubility Equilibria	7.11.A Calculate the solubility of a salt based on the value of K sp for the salt.	7.11.A.1 The dissolution of a salt is a reversible process whose extent can be described by K sp, the solubility-product constant	Ch. 17, Sec. 17.4; Pgs 737-740
		7.11.A.2 The solubility of a substance can be calculated from the K sp for the dissolution process. This relationship can also be used to predict the relative solubility of different substances.	Ch. 17, Sec. 17.4; Pgs 737-740
		7.11.A.3 The solubility rules (see 4.7.A.5) can be quantitatively related to K_{sp}, in which K values >1 $_{sp}$	Ch. 17, Sec. 17.4; Pgs 737-740
		7.11.A.4 The molar solubility of one or more species in a saturated solution can be used to calculate the K_{sp} of a substance.	Ch. 17, Sec. 17.4; Pgs 737-740
7.12 Common–Ion Effect	7.12.A Identify the solubility of a salt, and/or the value of K sp for the salt, based on the concentration of a common ion already present in solution.	7.12.A.1 The solubility of a salt is reduced when it is dissolved into a solution that already contains one of the ions present in the salt. The impact of this “common-ion effect” on solubility can be understood qualitatively using Le Châtelier’s principle or calculated from the K sp for the dissolution process	Ch. 17, Sec. 17.1; Pgs 714-716

Unit 8: Acids and Bases

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
8.1 Introduction to Acids and Bases	8.1.A Calculate the values of pH and pOH, based on K_w and the concentration of all species present in a neutral solution of water	8.1.A.1 The concentrations of hydronium ion and hydroxide ion are often reported as pH and pOH, respectively. EQN: $pH = -\log[H_3O^+]$ EQN: $pOH = -\log[OH^-]$ The terms “hydrogen ion” and “hydronium ion” and the symbols $H^+(aq)$ and $H_3O^+(aq)$ are often used interchangeably for the aqueous ion of hydrogen. Hydronium ion and $H_3O^+(aq)$ are preferred, but $H^+(aq)$ is also accepted on the AP Exam	Ch. 16, Sec. 16.1–16.2; Pgs 662-668
		8.1.A.2 Water autoionizes with an equilibrium constant Kw. EQN: $K_w = [H_3O^+][OH^-] = 1.0 \times 10^{-14}$ at 25°C	Not enough information avaliable for this topic.
		8.1.A.3 In pure water, pH = pOH is called a neutral solution. At 25°C, $pK_w = 14.0$ and thus pH = pOH = 7.0. EQN: $pK_w = 14 = pH + pOH$ at 25°C	Ch. 16, Sec. 16.1–16.2; Pgs 662-668
		8.1.A.4 The value of Kw is temperature dependent, so the pH of pure, neutral water will deviate from 7.0 at temperatures other than 25°C.	Ch. 16, Sec. 16.1–16.2; Pgs 662-668
8.2 pH and pOH of Strong Acids and Bases	8.2.A Calculate pH and pOH based on concentrations of all species in a solution of a strong acid or a strong base.	8.2.A.1 Molecules of a strong acid (e.g., HCl, HBr, HI, $HClO_4$, H_2SO_4, and HNO_3) will completely ionize in aqueous solution to produce hydronium ions and the conjugate base of the acid. As	Ch. 16, Sec. 16.3–16.5; Pgs 669-676

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		such, the concentration of H_3O^+ in a strong acid solution is equal to the initial concentration of the strong acid, and thus the pH of the strong acid solution is easily calculated.	
		8.2.A.2 When dissolved in solution, strong bases (e.g., group I and II hydroxides) completely dissociate to produce hydroxide ions. As such, the concentration of OH^- in a strong base solution is equal to the initial concentration of a group I hydroxide and double the initial concentration of a group II hydroxide, and thus the pOH (and pH) of the strong base solution is easily calculated	Ch. 16, Sec. 16.3–16.5; Pgs 669-676
8.3 Weak Acid and Base Equilibria	8.3.A Explain the relationship among pH, pOH, and concentrations of all species in a solution of a monoprotic weak acid or weak base.	8.3.A.1 Weak acids react with water to produce hydronium ions. However, only a small percentage of molecules of a weak acid will ionize in this way. Thus, the concentration of H_3O^+ is much less than the initial concentration of the molecular acid, and the vast majority of the acid molecules remain un-ionized	Ch. 16, Sec. 16.6–16.8; Pgs 677-692
		8.3.A.2 A solution of a weak acid involves equilibrium between an un-ionized acid and its conjugate base. The equilibrium constant for this reaction is K_a , often reported as pK_a . The pH of a weak acid solution can be determined from the initial acid concentration and the pK_a	Ch. 16, Sec. 16.6–16.8; Pgs 677-692

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		EQN: $K_a = \frac{[H_3O^+][A^-]}{[HA]}$ EQN: pK_a= -log K_a	
		8.3.A.3 Weak bases react with water to produce hydroxide ions in solution. However, ordinarily just a small percentage of the molecules of a weak base in solution will ionize in this way. Thus, the concentration of OH- in the solution does not equal the initial concentration of the base, and the vast majority of the base molecules remain un-ionized	Ch. 16, Sec. 16.6–16.8; Pgs 677-692
		8.3.A.4 A solution of a weak base involves equilibrium between an un-ionized base and its conjugate acid. The equilibrium constant for this reaction is K_b , often reported as pK_b . The pH of a weak base solution can be determined from the initial base concentration and the pK_b . EQN: $K_b = \frac{[OH^-][HB^+]}{[B]}$ EQN: pK_b = -log K_b	Ch. 16, Sec. 16.6–16.8; Pgs 677-692
		8.3.A.5 The percent ionization of a weak acid (or base) can be calculated from its pK_a (pK_b) and the initial concentration of the acid (base). The percent ionization can also be calculated from the initial concentration of the acid (base) and the equilibrium concentration of any of the species in the equilibrium expression.	Ch. 16, Sec. 16.6–16.8; Pgs 677-692

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		8.3.A.6 For any conjugate acid-base pair, the acid ionization constant and base ionization constant are related by Kw: EQN: $K_w = K_a \times K_b$ EQN: $pK_w = pK_a + pK_b$	Ch. 16, Sec. 16.6–16.8; Pgs 677-692
8.4 Acid–Base Reactions and Buffers	8.4.A Explain the relationship among the concentrations of major species in a mixture of weak and strong acids and bases.	8.4.A.1 When a strong acid and a strong base are mixed, they react quantitatively in a reaction represented by the equation: $H^+ (aq) + OH^- (aq) \rightarrow H_2O(l)$. The pH of the resulting solution may be determined from the concentration of excess reagent.	Ch. 17, Sec. 17.2; Pgs 717-724
		8.4.A.2 When a weak acid and a strong base are mixed, they react quantitatively in a reaction represented by the equation: $HA(aq) + OH^- (aq) \rightleftarrows A^- (aq) H_2O(l)$. If the weak acid is in excess, then a buffer solution is formed, and the pH can be determined from the Henderson-Hasselbalch (H−H) equation (see 8.9.A.1). If the strong base is in excess, then the pH can be determined from the moles of excess hydroxide ion and the total volume of solution. If they are equimolar, then the (slightly basic) pH can be determined from the equilibrium represented by the equation: $A^- (aq) + H_2O(l) \rightleftarrows HA(aq) + OH^- (aq)$.	Ch. 17, Sec. 17.2; Pgs 717-724

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		8.4.A.3 When a weak base and a strong acid are mixed, they will react quantitatively in a reaction represented by the equation: $B(aq) + H_3O^+(aq) \rightleftarrows HB^+(aq) + H_2O(l)$. If the weak base is in excess, then a buffer solution is formed, and the pH can be determined from the H−H equation. If the strong acid is in excess, then the pH can be determined from the moles of excess hydronium ion and the total volume of solution. If they are equimolar, then the (slightly acidic) pH can be determined from the equilibrium represented by the equation: $HB^+(aq) + H_2O(l) \rightleftarrows B(aq) + H_3O^+(aq)$.	Ch. 17, Sec. 17.2; Pgs 717-724
		8.4.A.4 When a weak acid and a weak base are mixed, they will react to an equilibrium state whose reaction may be represented by the equation: $HA(aq) + B(aq) \rightleftarrows A^-(aq) + HB^+(aq)$.	Ch. 17, Sec. 17.2; Pgs 717-724
8.5 Acid–Base Titrations	8.5.A Explain results from the titration of a mono- or polyprotic acid or base solution, in relation to the properties of the solution and its components.	8.5.A.1 An acid-base reaction can be carried out under controlled conditions in a titration. A titration curve, plotting pH against the volume of titrant added, is useful for summarizing results from a titration.	Ch. 17, Sec. 17.3; Pgs 725-736
		8.5.A.2 At the equivalence point for titrations of monoprotic acids or bases, the number of moles of titrant added is equal to the number of moles of analyte originally present. This relationship can	Ch. 17, Sec. 17.3; Pgs 725-736

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		be used to obtain the concentration of the analyte. This is the case for titrations of strong acids/bases and weak acids/bases.	
		8.5.A.3 For titrations of weak acids/bases, it is useful to consider the point halfway to the equivalence point, that is, the half-equivalence point. At this point, there are equal concentrations of each species in the conjugate acid-base pair, for example, for a weak acid [HA] = [A^-]. Because pH = pK_a when the conjugate acid and base have equal concentrations, the pK_a can be determined from the pH at the half-equivalence point in a titration.	Ch. 17, Sec. 17.3; Pgs 725-736
		8.5.A.4 At the equivalence point, pH is determined by the major species in solution. Strong acid and strong base titrations result in neutral pH at the equivalence point. However, in titrations of weak acids (weak bases), the conjugate base of the weak acid (conjugate acid of the weak base) is present at the equivalence point and can undergo proton-transfer reactions with the surrounding water, producing basic (acidic) solutions.	Ch. 17, Sec. 17.3; Pgs 725-736. Ch. 16, Sec 16.6, Pg 684.
		8.5.A.5 For polyprotic acids, titration curves can be used to determine the number of acidic protons. In doing so, the major species present at any point along the curve can be identified, along with the pK_a	Ch. 17, Sec. 17.3; Pgs 725-736

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		associated with each proton in a weak polyprotic acid. Exclusion Statement: Computation of the concentration of each species present in the titration curve for polyprotic acids will not be assessed on the AP Exam. Such computations for titration of monoprotic acids are within the scope of the course (see 8.4.A.2 and 8.4.A.3), as is qualitative reasoning regarding what species are present in large versus small concentrations at any point in a titration of a polyprotic acid.	
8.6 Molecular Structure and Acids/Bases	8.6.A Explain the relationship between the strength of an acid or base and the structure of the molecule or ion.	8.6.A.1 The protons on a molecule that will participate in acid-base reactions, and the relative strength of these protons, can be inferred from the molecular structure. i. Strong acids (such as HCl, HBr, HI, $HClO_4$, $H_2 SO_4$ and HNO_3) have very weak conjugate bases that are stabilized by electronegativity, inductive effects, resonance, or some combination thereof. ii. Carboxylic acids are one common class of weak acid. iii. Strong bases (such as group I and II hydroxides) have very weak conjugate acids. iv. Common weak bases include nitrogenous bases such as ammonia as well as carboxylate ions. v. Electronegative elements tend to stabilize the conjugate base relative to the conjugate acid, and so increase acid	Ch. 16, Sec. 16.10; Pgs 697-702

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		strength.	
8.7 pH and pKa	8.7.A Explain the relationship between the predominant form of a weak acid or base in solution at a given pH and the pKa of the conjugate acid or the pKb of the conjugate base.	8.7.A.1 The protonation state of an acid or base (i.e., the relative concentrations of HA and A−) can be predicted by comparing the pH of a solution to the pKa of the acid in that solution. When solution pH < acid pKa , the acid form has a higher concentration than the base form. When solution pH > acid pKa , the base form has a higher concentration than the acid form.	Ch. 16; Sec. 16.8; Pgs 691-692
		8.7.A.2 Acid-base indicators are substances that exhibit different properties (such as color) in their protonated versus deprotonated state, making that property respond to the pH of a solution.	Ch. 16; Sec. 16.8; Pgs 691-692
		8.7.A.3 To ensure accurate results in a titration experiment, acid-base indicators should be selected that have a pKa close to the pH at the equivalence point	Ch. 16; Sec. 16.8; Pgs 691-692
8.8 Properties of Buffers	8.8.A Explain the relationship between the ability of a buffer to stabilize pH and the reactions that occur when an acid or a base is added to a buffered solution.	8.8.A.1 A buffer solution contains a large concentration of both members in a conjugate acid-base pair. The conjugate acid reacts with added base and the conjugate base reacts with added acid. These reactions are responsible for the ability of a buffer to stabilize pH	Ch. 17, Sec. 17.2; Pgs 717-724
8.9 Henderson–Hasselbalch Equation	8.9.A Identify the pH of a buffer solution based on the identity and concentrations of the conjugate	8.9.A.1 The pH of the buffer is related to the pKa of the acid and the concentration ratio of	Ch. 17, Sec. 17.2; Pgs 717-724

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
	acid-base pair used to create the buffer.	the conjugate acid-base pair. This relation is a consequence of the equilibrium expression associated with the dissociation of a weak acid, and is described by the Henderson-Hasselbalch equation. Adding small amounts of acid or base to a buffered solution does not significantly change the ratio of [A−]/[HA] and thus does not significantly change the solution pH. The change in pH on addition of acid or base to a buffered solution is therefore much less than it would have been in the absence of the buffer EQN: $pH = pKa + \log \frac{[A-]}{[HA]}$ Exclusion Statement: Computation of the change in pH resulting from the addition of an acid or a base to a buffer will not be assessed on the AP Exam. Exclusion Statement: Derivation of the Henderson-Hasselbalch equation will not be assessed on the AP Exam.	
8.10 Buffer Capacity	8.10.A Explain the relationship between the buffer capacity of a solution and the relative concentrations of the conjugate acid and conjugate base components of the solution.	8.10.A.1 Increasing the concentration of the buffer components (while keeping the ratio of these concentrations constant) keeps the pH of the buffer the same but increases the capacity of the buffer to neutralize added acid or base.	Ch. 17, Sec. 17.2; Pgs 717-724
		8.10.A.2 When a buffer has more conjugate acid than base, it has a greater buffer capacity for addition of added base than acid. When a buffer has more	Ch. 16, Sec. 16.2 666-667

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		conjugate base than acid, it has a greater buffer capacity for addition of added acid than base.	
8.11 pH and Solubility	8.11.A Identify the qualitative effect of changes in pH on the solubility of a salt.	8.11.A.1 The solubility of a salt is pH sensitive when one of the constituent ions is a weak acid, a weak base, or the hydroxide ion. These effects can be understood qualitatively using Le Châtelier's principle. Exclusion Statement: Computations of solubility as a function of pH will not be assessed on the AP Exam.	Ch. 17, Sec. 17.5; Pgs 741-747

Unit 9: Thermodynamics and Electrochemistry

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
9.1 Introduction to Entropy	9.1.A Identify the sign and relative magnitudeof the entropychange associated with chemical or physicalprocesses	9.1.A.1 Entropy increases when matter becomes more dispersed. For example, the phase change from solid to liquid or from liquid to gas results in a dispersal of matter as the individual particles become freer to move and generally occupy a larger volume. Similarly, for a gas, the entropy increases when there is an increase in volume (at constant temperature), and the gas molecules are able to move within a larger space.Forreactionsinvolvinggas-phase reactants or products, the entropy generally increases when the total number of moles of gas-phaseproductsisgreaterthanthetotal numberofmolesofgas-phasereactants.	Ch. 19, Sec. 19.1-19.2; Pgs 800-807
		9.1.A.2 Entropy increases when energy is dispersed. According to kinetic molecular theory (KMT), the distribution of kinetic energy among the particles of a gas broadens as the temperature increases. As a result, the entropy of the system increases with an increase in temperature.	Ch. 19, Sec. 19.1-19.2; Pgs 800-807
9.2 Absolute Entropy and Entropy Change	9.2.A Calculate the standard entropy change for a chemical or physical process based on the absolute entropies (standard molar entropies) of the species.	9.2.A.1 The entropy change for a process can be calculated from the absolute entropies of the species involved before and after the process occurs. EQN: $\Delta S^{o}_{reaction} = \Sigma S^{o}_{products} - \Sigma S^{o}_{reactants}$	Ch. 19, Sec. 19.3-19.4; Pgs 808-816
9.3 Gibbs Free Energy and Thermodynamic Favorability	9.3.A Explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ΔG^{o}.	9.3.A.1 The Gibbs free energy change for a chemical process in which all the reactants and products are present in a standard state (as pure substances, as solutions of 1.0 M concentration, or as gases at a pressure of 1.0 atm (or 1.0 bar)) is given the	Ch. 19, Sec. 19.5-19.6; Pgs 817-821

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		symbol ΔG^o.	
		9.3.A.2 The standard Gibbs free energy change for a chemical or physical process is a measure of thermodynamic favorability. Historically, the term “spontaneous” has been used to describe processes for which $\Delta G^o < 0$. The phrase “thermodynamically favored” is preferred instead so that common misunderstandings (equating “spontaneous” with “suddenly” or “without cause”) can be avoided. When $\Delta G^o < 0$ for the process, it is said to be thermodynamically favored.	Ch. 19, Sec. 19.5-19.6; Pgs 817-821
		9.3.A.3 The standard Gibbs free energy change for a physical or chemical process may also be determined from the standard Gibbs free energy of formation of the reactants and products. EQN: $\Delta G^\circ_{reaction} = \Sigma \Delta G^\circ_{f\ products} - \Sigma \Delta G^\circ_{f\ reactants}$	Ch. 19, Sec. 19.5-19.6; Pgs 817-821
		9.3.A.4 In some cases, it is necessary to consider both enthalpy and entropy to determine if a process will be thermodynamically favored. The freezing of water and the dissolution of sodium nitrate are examples of such phenomena.	Ch. 19, Sec. 19.1-19.2; Pgs 800-807
		9.3.A.5 Knowing the values of $\Delta H°$ and $\Delta S°$ for a process at a given temperature allows $\Delta G°$ to be calculated directly. EQN: $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$	Ch. 19, Sec. 19.5-19.6; Pgs 817-821
		In general, the temperature conditions for a process to be thermodynamically favored ($\Delta G° < 0$) can be predicted from the signs of $\Delta H°$ and $\Delta S°$ as shown in the table below: $\Delta H°$ / $\Delta S°$ / Symbols / $\Delta G° < 0$, favored at: < 0 / > 0 / < > / all T > 0 / < 0 / > < / no T > 0 / > 0 / > > / high T < 0 / < 0 / < < / low T	Ch. 19, Sec. 19.5-19.6; Pgs 817-821

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		In cases where $\Delta H° < 0$ and $\Delta S° >$, no 0 calculation of $\Delta G°$ is necessary to determine that the process is thermodynamically favored ($\Delta G° < 0$). In cases where $\Delta H° > 0$ and $\Delta S° < 0$, no calculation of ΔG° is necessary to determine that the process is thermodynamically unfavored ($\Delta G° > 0$).	
9.4 Thermodynamics and Kinetic Control	9.4.A Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate.	9.4.A.1 Many processes that are thermodynamically favored do not occur to any measurable extent, or they occur at extremely slow rates.	The text does not explicitly cover this topic.
		9.4.A.2 Processes that are thermodynamically favored, but do not proceed at a measurable rate, are under "kinetic control." High activation energy is a common reason for a process to be under kinetic control. The fact that a process does not proceed at a noticeable rate does not mean that the chemical system is at equilibrium. If a process is known to be thermodynamically favored, and yet does not occur at a measurable rate, it is reasonable to conclude that the process is under kinetic control.	The text does not explicitly cover this topic.
9.5 Free Energy and Equilibrium	9.5.A Explain whether a process is thermodynamically favored using the relationships between K, $\Delta G°$, and T.	9.5.A.1 The phrase "thermodynamically favored" ($\Delta G° < 0$) means that the products are favored at equilibrium ($K > 1$) under standard conditions.	Ch. 19, Sec. 19.7; Pgs 824-827 Ch. 20, Sec 20.5, Pg 857-859
		9.5.A.2 The equilibrium constant is related to free energy by the equations EQN: $K = e^{-\Delta G°/RT}$ and EQN: $\Delta G° = -RT \ln K$.	Ch. 19, Sec. 19.7; Pgs 824-827 Ch. 20, Sec 20.5, Pg 857-859
		9.5.A.3 Connections between K	Ch. 19, Sec.

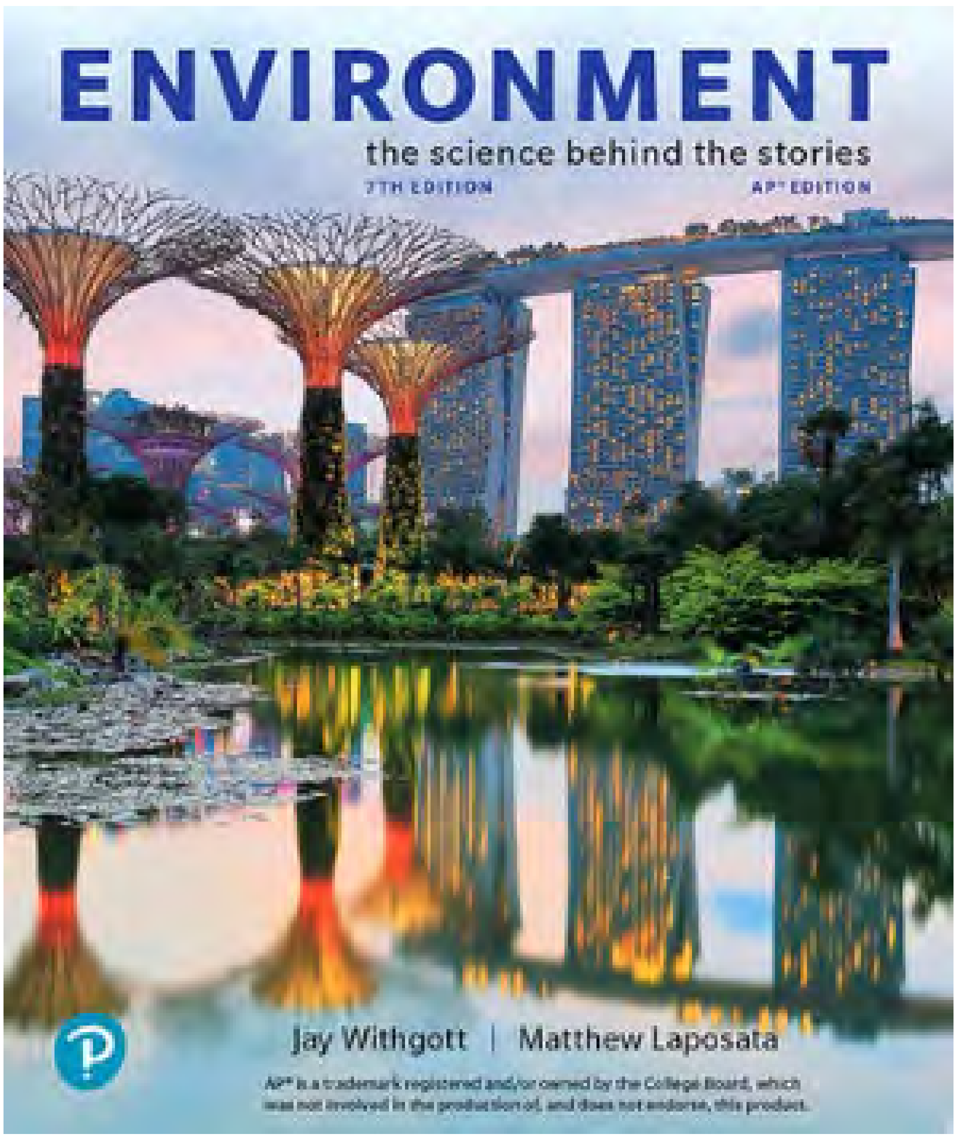
AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		and Δ*G*° can be made qualitatively through estimation. When Δ*G*° is near zero, the equilibrium constant will be close to 1. When Δ*G*° is much larger or much smaller than *RT*, the value of *K* deviates strongly from 1.	19.7; Pgs 824-827 Ch. 20, Sec 20.5, Pg 857-859
		9.5.A.4 Processes with $\Delta G° < 0$ favor products (i.e., $K > 1$) and those with $\Delta G° > 0$ favor reactants (i.e., $K < 1$).	The text does not explicitly cover this topic.
9.6 Free Energy of Dissolution	9.6.A Explain the relationship between the solubility of a salt and changes in the enthalpy and entropy that occur in the dissolution process.	9.6.A.1 The free energy change (ΔG°)for dissolution of a substance reflects a number of factors: the breaking of the intermolecular interactions that hold the solid together, the reorganization of the solvent around the dissolved species, and the interaction of the dissolved species with the solvent. It is possible to estimate the sign and relative magnitude of the enthalpic and entropic contributions to each of these factors. However, making predictions for the total change in free energy of dissolution can be challenging due to the cancellations among the free energies associated with the three factors cited.	Ch. 13, Sec. 13.1; Pgs 522-526
9.7 Coupled Reactions	9.7.A Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes.	9.7.A.1 An external source of energy can be used to make a thermodynamically unfavorable process occur. Examples include: i. Electrical energy to drive an electrolytic cell or charge a battery. ii. Light to drive the overall conversion of carbon dioxide to glucose in photosynthesis.	The text does not explicitly cover this topic
		9.7.A. 2. A desired product can be formed by coupling a thermodynamically unfavorable	Ch. 13, Sec. 13.1; Pgs 522-526

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		reaction that produces that product to a favorable reaction (e.g., the conversion of *ATP* to *ADP* in biological systems). In the coupled system, the individual reactions share one or more common intermediates. The sum of the individual reactions produces an overall reaction that achieves the desired outcome and has $\Delta G° < 0$	
9.8 Galvanic (Voltaic) and Electrolytic Cells	9.8.A Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell.	9.8.A.1 Each component of an electrochemical cell (electrodes,solutions in the half-cells,salt bridge, voltage/current measuring device) plays a specific role in the overall functioning of the cell. The operational characteristics of the cell (galvanic vs.electrolytic,direction of electron flow, reactions occurring in each half-cell, change in electrode mass, evolution of a gas at an electrode, ion flow through the salt bridge) can be described at both the macroscopic and particulate levels.	Ch. 20, Sec. 20.1–20.3, 20.9; Pgs 840-849, 876-889
		9.8.A.2 Galvanic, sometimes called voltaic, cells involve a thermodynamically favored reaction, whereas electrolytic cells involve a thermodynamically unfavored reaction. Visual representations of galvanic and electrolytic cells are tools of analysis to identify where half-reactions occur and in what direction current flows.	Ch. 20, Sec. 20.1–20.3, 20.9; Pgs 840-849, 876-889
		9.8.A.3 For all electrochemical cells, oxidation occurs at the anode and reduction occurs at the cathode.	Ch. 20, Sec. 20.1–20.3, 20.9; Pgs 840-849, 876-889
9.9 Cell Potential and Free Energy	9.9.A Explain whether an electrochemical cell is thermodynamically favored,	9.9.A.1 Electrochemistry encompasses the study of redox reactions that occur within	Ch. 20, Sec. 20.4–20.5; Pgs 850-

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
	based on its standard cell potential and the constituent half-reactions within the cell.	electrochemical cells. The reactions are either thermodynamically favored (resulting in a positive voltage) or thermodynamically unfavored (resulting in a negative voltage and requiring an externally applied potential for the reaction to proceed).	860
		9.9.A.2 The standard cell potential of electrochemical cells can be calculated by identifying the oxidation and reduction half-reactions and their respective standard reduction potentials.	Ch. 20, Sec. 20.4–20.5; Pgs 850-860
		9.9.A.3 ΔG^o (standard Gibbs free energy change) is proportional to the negative of the cell potential for the redox reaction from which it is constructed. Thus, a cell with a positive Eo involves a thermodynamically favored reaction, and a cell with a negative E^o involves a thermodynamically unfavored reaction. EQN: $\Delta G^o = -nFE^o$	Ch. 19, Sec. 19.5-19.6; Pgs 817-821
9.10 Cell Potential Under Nonstandard Conditions	9.10.A Explain the relationship between deviations from standard cell conditions and changes in the cell potential.	9.10.A.1 In a real system under nonstandard conditions, the cell potential will vary depending on the concentrations of the active species. The cell potential is a driving force toward equilibrium; the farther the reaction is from equilibrium, the greater the magnitude of the cell potential.	Ch. 20, Sec. 20.6; Pgs 861-867
		9.10.A.2 Equilibrium arguments such as Le Châtelier's principle do not apply to electrochemical systems, because the systems are not in equilibrium.	Ch. 20, Sec. 20.6; Pgs 861-867
		9.10.A.3 The standard cell potential E^o corresponds to the standard conditions of $Q = 1$. As the system approaches equilibrium, the magnitude (i.e., absolute value) of the cell	Ch. 20, Sec. 20.6; Pgs 861-867

AP Subunit	Enduring Understanding & Learning Objective	Essential Knowledge	Textbook Reference
		potential decreases, reaching zero at equilibrium (when $Q = K$). Deviations from standard conditions that take the cell further from equilibrium than $Q = 1$ will increase the magnitude of the cell potential relative to E^o . Deviations from standard conditions that take the cell closer to equilibrium than $Q = 1$ will decrease the magnitude of the cell potential relative to E^o. In concentration cells, the direction of spontaneous electron flow can be determined by considering the direction needed to reach equilibrium.	
		9.10.A.4 Algorithmic calculations using the Nernst equation are insufficient to demonstrate an understanding of electrochemical cells under nonstandard conditions. However, students should qualitatively understand the effects of concentration on cell potential and use conceptual reasoning, including the qualitative use of the Nernst equation: EQN: $E = E^o - (RT/nF) \ln Q$ to solve problems.	Ch. 20, Sec. 20.6; Pgs 861-867
9.11 Electrolysis and Faraday's Law	9.11.A Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.	9.11.A.1 Faraday's laws can be used to determine the stoichiometry of the redox reaction occurring in an electrochemical cell with respect to the following: i. Number of electrons transferred ii. Mass of material deposited on or removed from an electrode (as in electroplating) iii. Current iv. Time elapsed v. Charge of ionic species EQN: $I = q/t$	Ch. 20, Sec. 20.9; Pgs 876-879

Correlation of AP® Environmental Science Standards to *Environment: The Science Behind the Stories 7e,* AP Edition (Withgott)



Correlation of
College Board's AP® Environmental Science
Environment*: The Science Behind the Stories,*
Seventh Edition, AP® Edition, (Jay Withgott, Matthew Laposata)

AP® Environmental Science Topic Title	Learning Objective	Essential Knowledge	Withgott/ Laposata Module Title
Unit 1: The Living World: Ecosystems			
1.1 Introduction to Ecosystems	ERT-1.A Explain how the availability of resources influences species interactions.	ERT-1.A.1 In a predator-prey relationship, the predator is an organism that eats another organism (the prey).	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 111)
		ERT-1.A.2 Symbiosis is a close and long-term interaction between two species in an ecosystem. Types of symbiosis include mutualism, commensalism, and parasitism.	Ch. 4 Species Interactions and Community Ecology (pg. 80)
		ERT-1.A.3 Competition can occur within or between species in an ecosystem where there are limited resources. Resource partitioning— using the resources in different ways, places, or at different times— can reduce the negative impact of competition on survival.	Ch. 4 Species Interactions and Community Ecology (pg. 82)
1.2 Terrestrial Biomes	ERT-1.B Describe the global distribution and principal environmental aspects of terrestrial biomes.	ERT-1.B.1 A biome contains characteristic communities of plants and animals that result from, and are adapted to, its climate.	Ch. 4 Species Interactions and Community Ecology (pg. 94)

		ERT-1.B.2 Major terrestrial biomes include taiga, temperate rainforests, temperate seasonal forests, tropical rainforests, shrubland, temperate grassland, savanna, desert, and tundra.	Ch. 4 Species Interactions and Community Ecology (pg. 95)
		ERT-1.B.3 The global distribution of nonmineral terrestrial natural resources, such as water and trees for lumber, varies because of some combination of climate, geography, latitude and altitude, nutrient availability, and soil.	Ch. 4 Species Interactions and Community Ecology (pg. 97)
		ERT-1.B.4 The worldwide distribution of biomes is dynamic; the distribution has changed in the past and may again shift as a result of global climate changes.	Ch. 12 Forests, Forest Management, and Protected Areas (pg. 323)
1.3 Aquatic Biomes	ERT-1.C Describe the global distribution and principal environmental aspects of aquatic biomes.	ERT-1.C.1 Freshwater biomes include streams, rivers, ponds, and lakes. These freshwater biomes are a vital resource for drinking water.	Ch. 4 Species Interactions and Community Ecology (pg. 101)

		ERT-1.C.2 Marine biomes include oceans, coral reefs, marshland, and estuaries. Algae in marine biomes supply a large portion of the Earth's oxygen, and also take in carbon dioxide from the atmosphere.	Ch. 4 Species Interactions and Community Ecology (pg. 101)
		ERT-1.C.3 The global distribution of nonmineral marine natural resources, such as different types of fish, varies because of some combination of salinity, depth, turbidity, nutrient availability, and temperature.	Ch. 16 Marine and Coastal Systems and Resources (pg. 424)
1.4 The Carbon Cycle	ERT-1.D Explain the steps and reservoir interactions in the carbon cycle.	ERT-1.D.1 The carbon cycle is the movement of atoms and molecules containing the element carbon between sources and sinks.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 122)
		ERT-1.D.2 Some of the reservoirs in which carbon compounds occur in the carbon cycle hold those compounds for long periods of time, while some hold them for relatively short periods of time.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 122)
		ERT-1.D.3 Carbon cycles between photosynthesis and cellular respiration in living things.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 123)

		ERT-1.D.4 Plant and animal decomposition have led to the storage of carbon over millions of years. The burning of fossil fuels quickly moves that stored carbon into atmospheric carbon, in the form of carbon dioxide.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 124)
1.5 The Nitrogen Cycle	ERT-1.E Explain the steps and reservoir interactions in the nitrogen cycle.	ERT-1.E.1 The nitrogen cycle is the movement of atoms and molecules containing the element nitrogen between sources and sinks.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 124)
		ERT-1.E.2 Most of the reservoirs in which nitrogen compounds occur in the nitrogen cycle hold those compounds for relatively short periods of time.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 126)
		ERT-1.E.3 Nitrogen fixation is the process in which atmospheric nitrogen is converted into a form of nitrogen (primarily ammonia) that is available for uptake by plants and that can be synthesized into plant tissue.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 125)
		ERT-1.E.4 The atmosphere is the major reservoir of nitrogen.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 126)
1.6 The Phosphorus Cycle	ERT-1.F Explain the steps and reservoir interactions in the phosphorus cycle.	ERT-1.F.1 The phosphorus cycle is the movement of atoms and molecules containing the element phosphorus between sources and sinks.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 127)

		ERT-1.F.2 The major reservoirs of phosphorus in the phosphorus cycle are rock and sediments that contain phosphorus-bearing minerals.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 127)
		ERT-1.F.3 There is no atmospheric component in the phosphorus cycle, and the limitations this imposes on the return of phosphorus from the ocean to land make phosphorus naturally scarce in aquatic and many terrestrial ecosystems. In undisturbed ecosystems, phosphorus is the limiting factor in biological systems.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 127)
1.7 The Hydrologic Cycle	ERT-1.G Explain the steps and reservoir interactions in the hydrologic cycle.	ERT-1.G.1 The hydrologic cycle, which is powered by the sun, is the movement of water in its various solid, liquid, and gaseous phases between sources and sinks.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 121)
		ERT-1.G.2 The oceans are the primary reservoir of water at the Earth's surface, with ice caps and groundwater acting as much smaller reservoirs.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 121)

1.8 Primary Productivity	ENG-1.A Explain how solar energy is acquired and transferred by living organisms.	ENG-1.A.1 Primary productivity is the rate at which solar energy (sunlight) is converted into organic compounds via photosynthesis over a unit of time.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 111)
		ENG-1.A.2 Gross primary productivity is the total rate of photosynthesis in a given area.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 111)
		ENG-1.A.3 Net primary productivity is the rate of energy storage by photosynthesizers in a given area, after subtracting the energy lost to respiration.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 111)
		ENG-1.A.4 Productivity is measured in units of energy per unit area per unit time (e.g., kcal/m2/yr).	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 114)
		ENG-1.A.5 Most red light is absorbed in the upper 1m of water, and blue light only penetrates deeper than 100m in the clearest water. This affects photosynthesis in aquatic ecosystems, whose photosynthesizers have adapted mechanisms to address the lack of visible light.	Ch. 15 Freshwater, Systems and Resources (pg. 398)

1.9 Trophic Levels	ENG-1.B Explain how energy flows and matter cycles through trophic levels.	ENG-1.B.1 All ecosystems depend on a continuous inflow of high-quality energy in order to maintain their structure and function of transferring matter between the environment and organisms via biogeochemical cycles.	Ch. 4 Species Interactions and Community Ecology (pg. 81)
		ENG-1.B.2 Biogeochemical cycles are essential for life and each cycle demonstrates the conservation of matter.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 111)
		ENG-1.B.3 In terrestrial and near-surface marine communities, energy flows from the sun to producers in the lowest trophic levels and then upward to higher trophic levels.	Ch. 4 Species Interactions and Community Ecology (pg. 82)
1.10 Energy Flow and 10% Rule	ENG-1.C Determine how the energy decreases as it flows through ecosystems.	ENG-1.C.1 The 10% rule approximates that in the transfer of energy from one trophic level to the next, only about 10% of the energy is passed on.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 111)
		ENG-1.C.2 The loss of energy that occurs when energy moves from lower to higher trophic levels can be explained through the laws of thermodynamics.	Ch. 4 Species Interactions and Community Ecology (pg. 82)
1.11 Food Chains and	ENG-1.D Describe	ENG-1.D.1 A food web	Ch. 4 Species

Food Webs	food chains and food webs, and their constituent members by trophic level.	is a model of an interlocking pattern of food chains that depicts the flow of energy and nutrients in two or more food chains.	Interactions and Community Ecology (pg. 81)
		ENG-1.D.2 Positive and negative feedback loops can each play a role in food webs. When one species is removed from or added to a specific food web, the rest of the food web can be affected.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 108)
Unit 2: The Living World: Biodiversity			
2.1 Introduction to Biodiversity	ERT-2.A Explain levels of biodiversity and their importance to ecosystems.	ERT-2.A.1 Biodiversity in an ecosystem includes genetic, species, and habitat diversity	Ch. 11 Biodiversity and Its Conservation (pg. 275)
		ERT-2.A.2 The more genetically diverse a population is, the better it can respond to environmental stressors. Additionally, a population bottleneck can lead to a loss of genetic diversity	Ch. 11 Biodiversity and Its Conservation (pg. 275)
		ERT-2.A.3 Ecosystems that have a larger number of species are more likely to recover from disruptions.	Ch. 11 Biodiversity and Its Conservation (pg. 276)
		ERT-2.A.4 Loss of habitat leads to a loss of specialist species, followed by a loss of generalist species. It also leads to reduced numbers of species that have large territorial requirements.	Ch. 11 Biodiversity and Its Conservation (pg. 291)

		ERT-2.A.5 Species richness refers to the number of different species found in an ecosystem.	Ch. 11 Biodiversity and Its Conservation (pg. 277)
2.2 Ecosystem Services	ERT-2.B Describe ecosystem services.	ERT-2.B.1 There are four categories of ecosystem services: provisioning, regulating, cultural, and supporting.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 120)
	ERT-2.C Describe the results of human disruptions to ecosystem services.	ERT-2.C.1 Anthropogenic activities can disrupt ecosystem services, potentially resulting in economic and ecological consequences.	Ch. 7 Environmental Policy; Making Decisions and Solving Problems (pg. 163)
2.3 Island Biography	ERT-2.D Describe island biogeography	ERT-2.D.1 Island biogeography is the study of the ecological relationships and distribution of organisms on islands, and of these organisms' community structures.	Ch. 12 Forests, Forest Management, and Protected Areas (pg. 329)
		ERT-2.D.2 Islands have been colonized in the past by new species arriving from elsewhere.	Ch. 12 Forests, Forest Management, and Protected Areas (pg. 332)

	ERT-2.E Describe the role of island biogeography in evolution.	ERT-2.E.1 Many island species have evolved to be specialists versus generalists because of the limited resources, such as food and territory, on most islands. The long-term survival of specialists may be jeopardized if and when invasive species, typically generalists, are introduced and outcompete the specialists	Ch. 12 Forests, Forest Management, and Protected Areas (pg. 329)
2.4 Ecological Tolerance	ERT-2.F Describe ecological tolerance.	ERT-2.F.1 Ecological tolerance refers to the range of conditions, such as temperature, salinity, flow rate, and sunlight that an organism can endure before injury or death results.	Ch. 11 Biodiversity and Its Conservation (pg. 283)
		ERT-2.F.2 Ecological tolerance can apply to individuals and to species.	Ch. 11 Biodiversity and Its Conservation (pg. 283)
2.5 Natural Disruption to Ecosystems	ERT-2.G Explain how natural disruptions, both shortand long-term, impact an ecosystem.	ERT-2.G.1 Natural disruptions to ecosystems have environmental consequences that may, for a given occurrence, be as great as, or greater than, many human-made disruptions.	Ch. 4 Species Interactions and Community Ecology (pg. 87)
		ERT-2.G.2 Earth system processes operate on a range of scales in terms of time. Processes can be periodic, episodic, or random.	Ch. 4 Species Interactions and Community Ecology (Pg. 87)
		ERT-2.G.3 Earth's climate has changed over geological time for many reasons.	Ch. 2 Earth's Physical Systems: Matter, Energy, and Geology (pg. 39)

		ERT-2.G.4 Sea level has varied significantly as a result of changes in the amount of glacial ice on Earth over geological time.	Ch. Global Climate Change (pg. 502)
		ERT-2.G.5 Major environmental change or upheaval commonly results in large swathes of habitat changes.	Ch. 2 Earth's Physical Systems: Matter, Energy, and Geology (pg. 37)
		ERT-2.G.6 Wildlife engages in both short- and long-term migration for a variety of reasons, including natural disruptions.	Ch. 11 Biodiversity and its Conservation (pg. 274)
2.6 Adaptations	ERT-2.H Describe how organisms adapt to their environment.	ERT-2.H.1 Organisms adapt to their environment over time, both in short- and long-term scales, via incremental changes at the genetic level.	Ch. 3 Evolution and Population Ecology (pg. 52)
		ERT-2.H.2 Environmental changes, either sudden or gradual, may threaten a species' survival, requiring individuals to alter behaviors, move, or perish.	Ch. 4 Species Interactions and Community Ecology (Pg. 87)
2.7 Ecological Succession	ERT-2.I Describe ecological succession.	ERT-2.I.1 There are two main types of ecological succession: primary and secondary succession.	Ch. 4 Species Interactions and Community Ecology (pg. 87)

		ERT-2.I.2 A keystone species in an ecosystem is a species whose activities have a particularly significant role in determining community structure.	Ch. 4 Species Interactions and Community Ecology (Pg. 86)
		ERT-2.I.3 An indicator species is a plant or animal that, by its presence, abundance, scarcity, or chemical composition, demonstrates that some distinctive aspect of the character or quality of an ecosystem is present.	Ch. 4 Species Interactions and Community Ecology (Pg. 87)
	ERT-2.J Describe the effect of ecological succession on ecosystems.	ERT-2.J.1 Pioneer members of an early successional species commonly move into unoccupied habitat and over time adapt to its particular conditions, which may result in the origin of new species.	Ch. 4 Species Interactions and Community Ecology (Pg. 87)
		ERT-2.J.2 Succession in a disturbed ecosystem will affect the total biomass, species richness, and net productivity over time.	Ch. 4 Species Interactions and Community Ecology (Pg. 87)
Unit 3: Populations			
3.1 Generalist and Specialist Species	ERT-3.A Identify differences between generalist and specialist species.	ERT-3.A.1 Specialist species tend to be advantaged in habitats that remain constant, while generalist species tend to be advantaged in habitats that are changing.	Ch. 11 Biodiversity and Its Conservation (pg. 282)

3.2 K-Selected r-selected Species	ERT-3.B Identify differences between K- and r-selected species.	ERT-3.B.1 K-selected species tend to be large, have few offspring per reproduction event, live in stable environments, expend significant energy for each offspring, mature after many years of extended youth and parental care, have long life spans/life expectancy, and reproduce more than once in their lifetime. Competition for resources in K-selected species' habitats is usually relatively high.	Ch. 3 Evolution and Population Ecology (pg. 68)
		ERT-3.B.2 r-selected species tend to be small, have many offspring, expend or invest minimal energy for each offspring, mature early, have short life spans, and may reproduce only once in their lifetime. Competition for resources in r-selected species' habitats is typically relatively low.	Ch. 11 Biodiversity and Its Conservation (pg. 283)
		ERT-3.B.3 Biotic potential refers to the maximum reproductive rate of a population in ideal conditions.	Ch. 3 Evolution and Population Ecology (pg. 63)

		ERT-3.B.4 Many species have reproductive strategies that are not uniquely r-selected or K-selected, or they change in different conditions at different times.	Ch. 3 Evolution and Population Ecology (pg. 68)
		ERT-3.B.5 K-selected species are typically more adversely affected by invasive species than r-selected species, which are minimally affected by invasive species. Most invasive species are r-selected species.	Ch. 3 Evolution and Population Ecology (pg. 69)
3.3 Survivorship Curves	ERT-3.C Explain survivorship curves	ERT-3.C.1 A survivorship curve is a line that displays the relative survival rates of a cohort—a group of individuals of the same age—in a population, from birth to the maximum age reached by any one cohort member. There are Type I, Type II, and Type III curves.	Ch. 3 Evolution and Population Ecology (pg. 68)
		ERT-3.C.2 Survivorship curves differ for K-selected and r-selected species, with K-selected species typically following a Type I or Type II curve and r-selected species following a Type III curve.	Ch. 3 Evolution and Population Ecology (pg. 68)

3.4 Carrying Capacity	ERT-3.D Describe carrying capacity.	ERT-3.D.1 When a population exceeds its carrying capacity (carrying capacity can be denoted as K), overshoot occurs. There are environmental impacts of population overshoot, including resource depletion.	Ch. 3 Evolution and Population Ecology (pg. 67)
	ERT-3.E Describe the impact of carrying capacity on ecosystems.	ERT-3.E.1 A major ecological effect of population overshoot is dieback of the population (often severe to catastrophic) because the lack of available resources leads to famine, disease, and/or conflict.	Ch. 3 Evolution and Population Ecology (pg. 68)
3.5 Population Growth and Resource Availability	ERT-3.F Explain how resource availability affects population growth.	ERT-3.F.1 Population growth is limited by environmental factors, especially by the available resources and space.	Ch. 3 Evolution and Population Ecology (pg. 67)
		ERT-3.F.2 Resource availability and the total resource base are limited and finite over all scales of time.	Ch. 12 (Forests, Forest Management, and Protected Areas (pg. 317)
		ERT-3.F.3 When the resources needed by a population for growth are abundant, population growth usually accelerates.	Ch. 3 Evolution and Population Ecology (pg. 66)
		ERT-3.F.5 When the resource base of a population shrinks, the increased potential for unequal distribution of resources will ultimately result in increased mortality, decreased fecundity,	Ch. 3 Evolution and Population Ecology (pg. 66)

		or both, resulting in population growth declining to, or below, carrying capacity	
3.6 Age Structure Diagram	EIN-1.A Explain age structure diagrams.	EIN-1.A.1 Population growth rates can be interpreted from age structure diagrams by the shape of the structure.	Ch. 8 Human Population (pg. 195)
		EIN-1.A.2 A rapidly growing population will, as a rule, have a higher proportion of younger people compared to stable or declining populations.	Ch. 3 Evolution and Population Ecology (pg. 66)
3.7 Total Fertility Rate	EIN-1.B Explain factors that affect total fertility rate in human populations.	EIN-1.B.1 Total fertility rate (TFR) is affected by the age at which females have their first child, educational opportunities for females, access to family planning, and government acts and policies.	Ch. 8 Human Population (pg. 198)
		EIN-1.B.2 If fertility rate is at replacement levels, a population is considered relatively stable.	Ch. 8 Human Population (pg. 198)
		EIN-1.B.3 Factors associated with infant mortality rates include whether mothers have access to good healthcare and nutrition. Changes in these factors can lead to changes in infant mortality rates over time.	Ch. 8 Human Population (pg. 199)

3.8 Human Population Dynamics	EIN-1.C.1 Explain how human populations experience growth and decline.	EIN-1.C.1 Birth rates, infant mortality rates, and overall death rates, access to family planning, access to good nutrition, access to education, and postponement of marriage all affect whether a human population is growing or declining.	Ch. 8 Human Population (pg. 202)
		EIN-1.C.2 Factors limiting global human population include the Earth's carrying capacity and the basic factors that limit human population growth as set forth by Malthusian theory.	Ch. 8 Human Population (pg. 209)
		EIN-1.C.3 Population growth can be affected by both density-independent factors, such as major storms, fires, heat waves, or droughts, and density-dependent factors, such as access to clean water and air, food availability, disease transmission, or territory size.	Ch. 3 Evolution and Population Ecology (pg. 67)
		EIN-1.C.4 The rule of 70 states that dividing the number 70 by the percentage population growth rate approximates the population's doubling time.	Ch. 8 Human Population (pg. 209)

3.9 Demographic Transition	EIN-1.D Define the demographic transition.	EIN-1.D.1 The demographic transition refers to the transition from high to lower birth and death rates in a country or region as development occurs and that country moves from a preindustrial to an industrialized economic system. This transition is typically demonstrated through a four-stage demographic transition model (DTM).	Ch. 8 Human Population (pg. 199)
		EIN-1.D.2 Characteristics of developing countries include higher infant mortality rates and more children in the workforce than developed countries.	Ch. 8 Human Population (pg. 197)
Unit 4: Earth Systems and Resources			
4.1 Tectonic Plates	ERT-4.A Describe the geological changes and events that occur at convergent, divergent, and transform plate boundaries.	ERT-4.A.1 Convergent boundaries can result in the creation of mountains, island arcs, earthquakes, and volcanoes.	Ch. 2 Earth's Physical Systems: Matter, Energy, and Geology (pg. 35)
		ERT-4.A.2 Divergent boundaries can result in seafloor spreading, rift valleys, volcanoes, and earthquakes.	Ch. 2 Earth's Physical Systems: Matter, Energy, and Geology (pg. 36)
		ERT-4.A.3 Transform boundaries can result in earthquakes.	Ch. 2 Earth's Physical Systems: Matter, Energy, and Geology (pg. 36)

		ERT-4.A.4 Maps that show the global distribution of plate boundaries can be used to determine the location of volcanoes, island arcs, earthquakes, hot spots, and faults.	Ch. 2 Earth's Physical Systems: Matter, Energy, and Geology (pg. 36)
		ERT-4.A.5 An earthquake occurs when stress overcomes a locked fault, releasing stored energy.	Ch. 2 Earth's Physical Systems: Matter, Energy, and Geology (pg. 50)
4.2 Soil Formation and Erosion	ERT-4.B Describe the characteristics and formation of soil.	ERT-4.B.1 Soils are formed when parent material is weathered, transported, and deposited.	Ch. 9 The Understanding of Agriculture (pg. 217)
		ERT-4.B.2 Soils are generally categorized by horizons based on their composition and organic material.	Ch. 9 The Understanding of Agriculture (pg. 217)
		ERT-4.B.3 Soils can be eroded by winds or water. Protecting soils can protect water quality as soils effectively filter and clean water that moves through them.	Ch. 9 The Understanding of Agriculture (pg. 217)
4.3 Soil Composition and Properties	ERT-4.C Describe similarities and differences between properties of different soil types.	ERT-4.C.1 Water holding capacity—the total amount of water soil can hold—varies with different soil types. Water retention contributes to land productivity and fertility of soils.	Ch. 9 The Understanding of Agriculture (pg. 217)
		ERT-4.C.2 The particle size and composition of each soil horizon can affect the porosity, permeability, and fertility of the soil.	Ch. 9 The Understanding of Agriculture (pg. 219)
		ERT-4.C.3 There are a variety of methods to test the chemical,	Ch. 9 The Understanding of Agriculture (pg. 221)

		physical, and biological properties of soil that can aid in a variety of decisions, such as irrigation and fertilizer requirements.	
		ERT-4.C.4 A soil texture triangle is a diagram that allows for the identification and comparison of soil types based on their percentage of clay, silt, and sand.	Ch. 9 The Understanding of Agriculture (pg. 219)

4.4 Earth's Atmosphere	ERT-4.D Describe the structure and composition of the Earth's atmosphere.	ERT-4.D.1 The atmosphere is made up of major gases, each with its own relative abundance.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 452)
		ERT-4.D.2 The layers of the atmosphere are based on temperature gradients and include the troposphere, stratosphere, mesosphere, thermosphere, and exosphere.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 453)
4.5 Global Wind Patterns	ERT-4.E Explain how environmental factors can result in atmospheric circulation.	ERT-4.E.1 Global wind patterns primarily result from the most intense solar radiation arriving at the equator, resulting in density differences and the Coriolis effect.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 455)
4.6 Watersheds	ERT-4.F Describe the characteristics of a watershed.	ERT-4.F.1 Characteristics of a given watershed include its area, length, slope, soil, vegetation types, and divides with adjoining watersheds.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 109)

4.7 Solar Radiation and Earth's Seasons	ENG-2.A Explain how the sun's energy affects the Earth's surface.	ENG-2.A.1 Incoming solar radiation (insolation) is the Earth's main source of energy and is dependent on season and latitude.	Ch. 18 Global Climate Change (pg. 490)
		ENG-2.A.2 The angle of the sun's rays determines the intensity of the solar radiation. Due to the shape of the Earth, the latitude that is directly horizontal to the solar radiation receives the most intensity.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 455)
		ENG-2.A.3 The highest solar radiation per unit area is received at the equator and decreases toward the poles.	Not found
		ENG-2.A.4 The solar radiation received at a location on the Earth's surface varies seasonally, with the most radiation received during the location's longest summer day and the least on the shortest	Not found
		ENG-2.A.5 The tilt of Earth's axis of rotation causes the Earth's seasons and the number of hours of daylight in a particular location on the Earth's surface.	Not found
4.8 Earth's Geography and Climate	ENG-2.B Describe how the Earth's geography affects weather and climate.	ENG-2.B.1 Weather and climate are affected not only by the sun's energy but by geologic and geographic factors, such as mountains and ocean temperature.	Ch. 18 Global Climate Change (pg. 487)

		ENG-2.B.2 A rain shadow is a region of land that has become drier because a higher elevation area blocks precipitation from reaching the land.	Ch. 4 Species Interactions and Community Ecology (pg. 96)
4.9 El Nino and La Nina	ENG-2.C Describe the environmental changes and effects that result from El Niño or La Niña events (El Niño–Southern Oscillation).	ENG-2.C.1 El Niño and La Niña are phenomena associated with changing ocean surface temperatures in the Pacific Ocean. These phenomena can cause global changes to rainfall, wind, and ocean circulation patterns.	Ch. 16 Maine and Coastal Resources (pg. 427)
		ENG-2.C.2 El Niño and La Niña are influenced by geological and geographic factors and can affect different locations in different ways.	Ch. 16 Maine and Coastal Resources (pg. 427)
Unit 5: Land and Water Use			
5.1 The Tragedy of the Commons	EIN-2.A Explain the concept of the tragedy of the commons.	EIN-2.A.1 The tragedy of the commons suggests that individuals will use shared resources in their own self-interest rather than in keeping with the common good, thereby depleting the resources	Ch. 7 Environmental Policy: Making Decisions and Solving Problems (pg. 164)
5.2 Clearcutting	EIN-2.B Describe the effect of clearcutting on forests.	EIN-2.B.1 Clearcutting can be economically advantageous but leads to soil erosion, increased soil and stream temperatures, and flooding.	Ch. 12 Forests, Forest Management, and Protected Areas (pg. 320)

		EIN-2.B.2 Forests contain trees that absorb pollutants and store carbon dioxide. The cutting and burning of trees releases carbon dioxide and contributes to climate change.	Ch. 12 Forests, Forest Management, and Protected Areas (pg. 322)
5.3 The Green Revolution	EIN-2.C Describe changes in agricultural practices.	EIN-2.C.1 The Green Revolution started a shift to new agricultural strategies and practices in order to increase food production, with both positive and negative results. Some of these strategies and methods are mechanization, genetically modified organisms (GMOs), fertilization, irrigation, and the use of pesticides	Ch. 10 Making Agriculture Sustainable (pg. 245)
		EIN-2.C.2 Mechanization of farming can increase profits and efficiency for farms. It can also increase reliance on fossil fuels.	Ch. 10 Making Agriculture Sustainable (pg. 245)
5.4 Impacts of Agricultural Practices	EIN-2.D Describe agricultural practices that cause environmental damage.	LOR-2.D.1 Agricultural practices that can cause environmental damage include tilling, slash and-burn farming, and the use of fertilizers.	Ch. 10 Making Agriculture Sustainable (pg. 246)
5.5 Irrigation Methods	EIN-2.E Describe different methods of irrigation.	EIN-2.E.1 The largest human use of freshwater is for irrigation (70%).	Ch. 9 The Underpinnings of Agriculture (pg. 219)
		EIN-2.E.2 Types of irrigation include drip irrigation, flood irrigation, furrow irrigation, drip irrigation, and spray irrigation.	Ch. 9 The Underpinnings of Agriculture (pg. 220)

	EIN-2.F Describe the benefits and drawbacks of different methods of irrigation.	EIN-2.F.1 Waterlogging occurs when too much water is left to sit in the soil, which raises the water table of groundwater and inhibits plants' ability to absorb oxygen through their roots.	Ch. 9 The Underpinnings of Agriculture (pg. 220)
		EIN-2.F.2 Furrow irrigation involves cutting furrows between crop rows and filling them with water. This system is inexpensive, but about 1/3 of the water is lost to evaporation and runoff.	Ch. 9 The Underpinnings of Agriculture (pg. 220)
		EIN-2.F.3 Flood irrigation involves flooding an agricultural field with water. This system sees about 20% of the water lost to evaporation and runoff. This can also lead to waterlogging of the soil.	Ch. 9 The Underpinnings of Agriculture (pg. 220)
		EIN-2.F.4 Spray irrigation involves pumping ground water into spray nozzles across an agricultural field. This system is more efficient than flood and furrow irrigation, with only 1/4 or less of the water lost to evaporation or runoff. However, spray systems are more expensive than flood and furrow irrigation, and also requires energy to run.	Ch. 9 The Underpinnings of Agriculture (pg. 221)

		EIN-2.F.5 Drip irrigation uses perforated hoses to release small amounts of water to plant roots. This system is the most efficient, with only about 5% of water lost to evaporation and runoff. However, this system is expensive and so is not often used.	Ch. 9 The Underpinnings of Agriculture (pg. 221)
		EIN-2.F.6 Salinization occurs when the salts in groundwater remain in the soil after the water evaporates. Over time, salinization can make soil toxic to plants	Ch. 9 The Underpinnings of Agriculture (pg. 220)
		EIN-2.F.7 Aquifers can be severely depleted if overused for agricultural irrigation, as has happened to the Ogallala Aquifer in the central United States.	Ch. 9 The Underpinnings of Agriculture (pg. 220)
5.7 Pest Control Methods	EIN-2.G Describe the benefits and drawbacks of different methods of pest control.	EIN-2.G.1 One consequence of using common pest-control methods such as pesticides, herbicides, fungicides, rodenticides, and insecticides is that organisms can become resistant to them through artificial selection. Pest control decreases crop damage by pest and increases crop yields.	Ch. 10 Making Agriculture Sustainable (pg. 251)

		EIN-2.G.2 Crops can be genetically engineered to increase their resistance to pests and diseases. However, using genetically engineered crops in planting or other ways can lead to loss of genetic diversity of that particular crop.	Ch. 10 Making Agriculture Sustainable (pg. 255)
5.7 Meat Production Methods	EIN-2.H Identify different methods of meat production.	EIN-2.H.1 Methods of meat production include concentrated animal feeding operations (CAFOs), also called feedlots, and free-range grazing.	Ch. 10 Making Agriculture Sustainable (pg. 247)
	EIN-2.I Describe the benefits and drawbacks of different methods of meat production.	EIN-2.I.1 Meat production is less efficient than agriculture; it takes approximately 20 times more land to produce the same amount of calories from meat as from plants.	Ch. 10 Making Agriculture Sustainable (pg. 248)
		EIN-2.1.2 Concentrated animal feeding operation (CAFOs) are used as a way to quickly get livestock ready for slaughter. They tend to be crowded, and animals are fed grains or feed that are not as suitable as grass. Additionally, feedlots generate a large amount of organic waste, which can contaminate ground and surface water. The use of feedlots are less expensive than other methods, which can keep costs to consumers down.	Ch. 10 Making Agriculture Sustainable (pg. 248)
		EIN-2.1.3 Free range grazing allows animals to graze on grass	Ch. 10 Making Agriculture Sustainable (pg. 250)

		during their entire lifecycle. Meat from free range animals tends to be free from antibiotics and other chemicals used in feedlots. Organic waste from these animals acts as fertilizer. Free range grazing requires large areas of land and the meat produced is more expensive for consumers.	
		EIN-2.I.4 Overgrazing occurs when too many animals feed on a particular area of land. Overgrazing causes loss of vegetation, which leads to soil erosion.	Ch. 9 The Understanding of Agriculture (pg. 234)
		EIN-2.I.5 Overgrazing can cause desertification. Desertification is the degradation of low precipitation regions toward being increasingly arid until they become deserts.	Ch. 9 The Understanding of Agriculture (pg. 234)
		EIN-2.I.6 Less consumption of meat could reduce CO2, methane, and N2O emissions; conserve water; reduce the use of antibiotics and growth hormones; and improve topsoil.	Ch. 10 Making Agriculture Sustainable (pg. 249)

5.8 Impacts of Overfishing	EIN-2.J Describe causes of and problems related to overfishing.	EIN-2.J.1 Overfishing has led to the extreme scarcity of some fish species, which can lessen biodiversity in aquatic systems and harm people who depend on fishing for food and commerce.	Ch. 9 The Understanding of Agriculture (pg. 219)
5.9 Impacts of Mining	EIN-2.K Describe natural resource extraction through mining.	EIN-2.K.1 As the more accessible ores are mined to depletion, mining operations are forced to access lower grade ores. Accessing these ores requires increased use of resources that can cause increased waste and pollution.	Ch. 23 Minerals and Mining (pg. 649)
		EIN-2.K.2 Surface mining is the removal of large portions of soil and rock, called overburden, in order to access the ore underneath. An example is strip mining, which removes the vegetation from an area, making the area more susceptible to erosion.	Ch. 23 Minerals and Mining (pg. 649)

	EIN-2.L Describe ecological and economic impacts of natural resource extraction through mining.	EIN-2.L.1 Mining wastes include the soil and rocks that are moved to gain access to the ore and the waste, called slag and tailings that remain when the minerals have been removed from the ore. Mining helps to provide low cost energy and material necessary to make products. The mining of coal can destroy habitats, contaminate ground water, and release dust particles and methane.	Ch. 23 Minerals and Mining (pg. 649)
		EIN-2.L.2 As coal reserves get smaller, due to a lack of easily accessible reserves, it becomes necessary to access coal through subsurface mining, which is very expensive.	Ch. 23 Minerals and Mining (pg. 650)
5.10 Impacts of Urbanization	EIN-2.M Describe the effects of urbanization on the environment.	EIN-2.M.1 Urbanization can lead to depletion of resources and saltwater intrusion in the hydrologic cycle.	Ch. 13 The Urban Environment: Creating sustainable Cities (pg. 338)
		EIN-2.M.2 Urbanization, through the burning of fossil fuels and landfills, affects the carbon cycle by increasing the amount of carbon dioxide in the atmosphere.	Ch. 18 Global Climate Change (pg. 488)
		EIN-2.M.3 Impervious surfaces are human-made structures—such as roads, buildings, sidewalks, and parking lots—that do not allow water to reach the soil, leading to flooding.	Ch. 13 The Urban Environment: Creating sustainable Cities (pg. 353)
		EIN-2.M.4 Urban sprawl is the change in population	Ch. 13 The Urban Environment: Creating sustainable

		distribution from high population density areas to low density suburbs that spread into rural lands, leading to potential environmental problems.	Cities (pg. 341)
5.11 Ecological Footprints	EIN-2.N Explain the variables measured in an ecological footprint.	EIN-2.N.1 Ecological footprints compare resource demands and waste production required for an individual or a society.	Ch. 1 Science and Sustainability: An introduction to Environmental Science (pg. 5)
5.12 Intro to Sustainability	STB-1.A Explain the concept of sustainability.	STB-1.A.1 Sustainability refers to humans living on Earth and their use of resources without depletion of the resources for future generations. Environmental indicators that can guide humans to sustainability include biological diversity, food production, average global surface temperatures and CO2 concentrations, human population, and resource depletion.	Ch. 1 Science and Sustainability: An introduction to Environmental Science (pg. 16)
		STB-1.A.2 Sustainable yield is the amount of a renewable resource that can be taken without reducing the available supply	Ch. 12 Forests, Forest Management, and Protected Areas (pg. 318)

5.13 Methods to Reduce Urban Runoff	STB-1.B Describe methods for mitigating problems related to urban runoff.	STB-1.B.1 Methods to increase water infiltration include replacing traditional pavement with permeable pavement, planting trees, increased use of public transportation, and building up, not out.	Ch. 13 The Urban Environment: Creating sustainable Cities (pg. 342)
5.14 Integrated Pest Management	STB-1.C Describe integrated pest management.	STB-1.C.1 Integrated pest management (IPM) is a combination of methods used to effectively control pest species while minimizing the disruption to the environment. These methods include biological, physical, and limited chemical methods such as biocontrol, intercropping, crop rotation, and natural predators of the pests.	Ch. 10 Making Agriculture Sustainable (pg. 254)
	STB-1.D Describe the benefits and drawbacks of integrated pest management (IPM).	STB-1.D.1 The use of integrated pest management (IPM) reduces the risk that pesticides pose to wildlife, water supplies, and human health.	Ch. 10 Making Agriculture Sustainable (pg. 254)
		STB-1.D.2 Integrated pest management (IPM) minimizes disruptions to the environment and threats to human health but can be complex and expensive.	Ch. 10 Making Agriculture Sustainable (pg. 254)

5.15 Sustainable Agriculture	STB-1.E Describe sustainable agricultural and food production practices.	STB-1.E.1 The goal of soil conservation is to prevent soil erosion. Different methods of soil conservation include contour plowing, windbreaks, perennial crops, terracing, no-till agriculture, and strip cropping.	Ch. 9 The Understanding of Agriculture (pg. 215)
		STB-1.E.2 Strategies to improve soil fertility include crop rotation and the addition of green manure and limestone.	Ch. 9 The Understanding of Agriculture (pg. 215)
		STB-1.E.3 Rotational grazing is the regular rotation of livestock between different pastures in order to avoid overgrazing in a particular area.	Ch. 9 The Understanding of Agriculture (pg. 234)
5.16 Aquaculture	STB-1.F Describe the benefits and drawbacks of aquaculture.	STB-1.F.1 Aquaculture has expanded because it is highly efficient, requires only small areas of water, and requires little fuel.	Ch. 10 Making Agriculture Sustainable (pg. 250)
		STB-1.F.2 Aquaculture can contaminate wastewater, and fish that escape may compete or breed with wild fish. The density of fish in aquaculture can lead to increases in disease incidences, which can be transmitted to wild fish.	Ch. 10 Making Agriculture Sustainable (pg. 250)

5.17 Sustainable Forestry	STB-1.G Describe methods for mitigating human impact on forests.	STB-1.G.1 Some of the methods for mitigating deforestation include reforestation, using and buying wood harvested by ecologically sustainable forestry techniques, and reusing wood.	Ch. 12 Forests, Forest Management, and Protected Areas (pg. 324)
		STB-1.G.2 Methods to protect forests from pathogens and insects include integrated pest management (IPM) and the removal of affected trees.	Ch. 10 Making Agriculture Sustainable (pg. 254)
		STB-1.G.3 Prescribed burn is a method by which forests are set on fire under controlled conditions in order to reduce the occurrence of natural fires.	Ch. 12 Forests, Forest Management, and Protected Areas (pg. 324)
Unit 6: Energy Resources and Consumption			
6.1 Renewable and Nonrenewable Resources	ENG-3.A Identify differences between nonrenewable and renewable energy sources.	ENG-3.A.1 Nonrenewable energy sources are those that exist in a fixed amount and involve energy transformation that cannot be easily replaced.	Ch. 21 New Renewable Energy Sources (pg. 591)
		ENG-3.A.2 Renewable energy sources are those that can be replenished naturally, at or near the rate of consumption, and reused.	Ch. 21 New Renewable Energy Sources (pg. 591)
6.2 Global Energy Consumption	ENG-3.B Describe trends in energy consumption.	ENG-3.B.1 The use of energy resources is not evenly distributed between developed and developing countries.	Ch. 20 Conventional Energy Alternatives (pg. 564)

		ENG-3.B.2 The most widely used sources of energy globally are fossil fuels.	Ch. 20 Conventional Energy Alternatives (pg. 563)
		ENG-3.B.3 As developing countries become more developed, their reliance on fossil fuels for energy increases.	Ch. 478 The Atmosphere, Air Quality, and Air Pollution Control (pg. 478
		ENG-3.B.4 As the world becomes more industrialized, the demand for energy increases.	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 527)
		ENG-3.B.5 Availability, price, and governmental regulations influence which energy sources people use and how they use them.	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 528)
6.3 Fuel Types and Uses	ENG-3.C Identify types of fuels and their uses.	ENG-3.C.1 Wood is commonly used as fuel in the forms of firewood and charcoal. It is often used in developing countries because it is easily accessible.	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 525)
		ENG-3.C.2 Peat is partially decomposed organic material that can be burned for fuel.	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 530)
		ENG-3.C.3 Three types of coal used for fuel are lignite, bituminous, and anthracite. Heat, pressure, and depth of burial contribute to the development of various coal types and their qualities.	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 529)
		ENG-3.C.4 Natural gas, the cleanest of the fossil fuels, is mostly methane.	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 535)

		ENG-3.C.5 Crude oil can be recovered from tar sands, which are a combination of clay, sand, water, and bitumen.	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 523)
		ENG-3.C.6 Fossil fuels can be made into specific fuel types for specialized uses (e.g., in motor vehicles).	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 526)
		ENG-3.C.7 Cogeneration occurs when a fuel source is used to generate both useful heat and electricity	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 526)
6.4 Distribution of Natural Resources	ENG-3.D Identify where natural energy resources occur.	ENG-3.D.1 The global distribution of natural energy resources, such as ores, coal, crude oil, and gas, is not uniform and depends on regions' geologic history.	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 526)
6.5 Fossil Fuels	ENG-3.E Describe the use and methods of fossil fuels in power generation.	ENG-3.E.1 The combustion of fossil fuels is a chemical reaction between the fuel and oxygen that yields carbon dioxide and water and releases energy.	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 529)
		ENG-3.E.2 Energy from fossil fuels is produced by burning those fuels to generate heat, which then turns water into steam. That steam turns a turbine, which generates electricity.	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 535)
		ENG-3.E.3 Humans use a variety of methods to extract fossil fuels from the earth for energy generation.	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 538)

	ENG-3.F Describe the effects of fossil fuels on the environment.	ENG-3.F.1 Hydrologic fracturing (fracking) can cause groundwater contamination and the release of volatile organic compounds.	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 539)
6.6 Nuclear Power	ENG-3.G Describe the use of nuclear energy in power generation.	ENG-3.G.1 Nuclear power is generated through fission, where atoms of Uranium-235, which are stored in fuel rods, are split into smaller parts after being struck by a neutron. Nuclear fission releases a large amount of heat, which is used to generate steam, which powers a turbine and generates electricity.	Ch. 20 Conventional Energy Alternatives (pg. 564)
		ENG-3.G.2 Radioactivity occurs when the nucleus of a radioactive isotope loses energy by emitting radiation.	Ch. 20 Conventional Energy Alternatives (pg. 567)
		ENG-3.G.3 Uranium-235 remains radioactive for a long time, which leads to the problems associated with the disposal of nuclear waste.	Ch. 20 Conventional Energy Alternatives (pg. 572)

		ENG-3.G.4 Nuclear power generation is a nonrenewable energy source. Nuclear power is considered a cleaner energy source because it does not produce air pollutants, but it does release thermal pollution and hazardous solid waste.	Ch. 20 Conventional Energy Alternatives (pg. 566)
	ENG-3.H Describe the effects of the use of nuclear energy on the environment	ENG-3.H.1 Three Mile Island, Chernobyl, and Fukushima are three cases where accidents or natural disasters led to the release of radiation. These releases have had short- and long-term impacts on the environment	Ch. 20 Conventional Energy Alternatives (pg. 567)
		ENG-3.H.2 A radioactive element's half-life can be used to calculate a variety of things, including the rate of decay and the radioactivity level at specific points in time.	Ch. 20 Conventional Energy Alternatives (pg. 565)
6.7 Energy from Biomass	ENG-3.I Describe the effects of the use of biomass in power generation on the environment.	ENG-3.I.1 Burning of biomass produces heat for energy at a relatively low cost, but it also produces carbon dioxide, carbon monoxide, nitrogen oxides, particulates, and volatile organic compounds. The overharvesting of trees for fuel also causes deforestation	Ch. 21 New Renewable Energy Sources (pg. 575)

		ENG-3.I.2 Ethanol can be used as a substitute for gasoline. Burning ethanol does not introduce additional carbon into the atmosphere via combustion, but the energy return on energy investment for ethanol is low.	Ch. 20 Conventional Energy Alternatives (pg. 575)
6.8 Solar Energy	ENG-3.J Describe the use of solar energy in power generation.	ENG-3.J.1 Photovoltaic solar cells capture light energy from the sun and transform it directly into electrical energy. Their use is limited by the availability of sunlight	Ch. 21 New Renewable Energy Sources (pg. 597)
		ENG-3.J.2 Active solar energy systems use solar energy to heat a liquid through mechanical and electric equipment to collect and store the energy captured from the sun.	Ch. 21 New Renewable Energy Sources (pg. 597)
		ENG-3.J.3 Passive solar energy systems absorb heat directly from the sun without the use of mechanical and electric equipment, and energy cannot be collected or stored.	Ch. 21 New Renewable Energy Sources (pg. 597)
	ENG-3.K Describe the effects of the use of solar energy in power generation on the environment.	ENG-3.K.1 Solar energy systems have low environmental impact and produce clean energy, but they can be expensive. Large solar energy farms may negatively impact desert ecosystems.	Ch. 21 New Renewable Energy Sources (pg. 597)

6.9 Hydroelectric Power	ENG-3.L Describe the use of hydroelectricity in power generation.	ENG-3.L.1 Hydroelectric power can be generated in several ways. Dams built across rivers collect water in reservoirs. The moving water can be used to spin a turbine. Turbines can also be placed in small rivers, where the flowing water spins the turbine.	Ch. 20 Conventional Energy Alternatives (pg. 582)
		ENG-3.L.2 Tidal energy uses the energy produced by tidal flows to turn a turbine.	Ch. 21 New Renewable Energy Sources (pg. 611)
	ENG-3.M Describe the effects of the use of hydroelectricity in power generation on the environment.	ENG-3.M.1 Hydroelectric power does not generate air pollution or waste, but construction of the power plants can be expensive, and there may be a loss of or change in habitats following the construction of dams.	Ch. 20 Conventional Energy Alternatives (pg. 582)
6.10 Geothermal Energy	ENG-3.N Describe the use of geothermal energy in power generation.	ENG-3.N.1 Geothermal energy is obtained by using the heat stored in the Earth's interior to heat up water, which is brought back to the surface as steam. The steam is used to drive an electric generator.	Ch. 21 New Renewable Energy Sources (pg. 608)

	ENG-3.O Describe the effects of the use of geothermal energy in power generation on the environment.	ENG-3.O.1 The cost of accessing geothermal energy can be prohibitively expensive, as is not easily accessible in many parts of the world. In addition, it can cause the release of hydrogen sulfide.	Ch. 21 New Renewable Energy Sources (pg. 608)
6.11 Hydrogen Fuel Cell	ENG-3.P Describe the use of hydrogen fuel cells in power generation.	ENG-3.P.1 Hydrogen fuel cells are an alternate to nonrenewable fuel sources. They use hydrogen as fuel, combining the hydrogen and oxygen in the air to form water and release energy (electricity) in the process. Water is the product (emission) of a fuel cell.	Ch. 21 New Renewable Energy Sources (pg. 613)
	ENG-3.Q Describe the effects of the use of hydrogen fuel cells in power generation on the environment.	ENG-3.Q.1 Hydrogen fuel cells have low environmental impact and produce no carbon dioxide when the hydrogen is produced from water. However, the technology is expensive and energy is still needed to create the hydrogen gas used in the fuel cell.	Ch. 21 New Renewable Energy Sources (pg. 613)
6.12 Wind Energy	ENG-3.R Describe the use of wind energy in power generation.	ENG-3.R.1 Wind turbines use the kinetic energy of moving air to spin a turbine, which in turn converts the mechanical energy of the turbine into electricity.	Ch. 21 New Renewable Energy Sources (pg. 602)

	ENG-3.S Describe the effects of the use of wind energy in power generation on the environment.	ENG-3.S.1 Wind energy is a renewable, clean source of energy. However, birds and bats may be killed if they fly into the spinning turbine blades.	Ch. 21 New Renewable Energy Sources (pg. 602)
6.13 Energy Conservation	ENG-3.T Describe methods for conserving energy.	ENG-3.T.1 Some of the methods for conserving energy around a home include adjusting the thermostat to reduce the use of heat and air conditioning, conserving water, use of energy-efficient appliances, and conservation landscaping.	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 552)
		ENG-3.T.2 Methods for conserving energy on a large scale include improving fuel economy for vehicles, using BEVs (battery electric vehicles) and hybrid vehicles, using public transportation, and implementing green building design features.	Ch. 19 Fossil Fuels and Energy Efficiency (pg. 552)
Unit 7: Atmospheric Pollution			
7.1 Introduction to Air Pollution	STB-2.A Identify the sources and effects of air pollutants.	STB-2.A.1 Coal combustion releases air pollutants including carbon dioxide, sulfur dioxide, toxic metals, and particulates.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 456)

		STB-2.A.2 The combustion of fossil fuels releases nitrogen oxides into the atmosphere. They lead to the production of ozone, formation of photochemical smog, and convert to nitric acid in the atmosphere, causing acid rain. Other pollutants produced by fossil fuel combustion include carbon monoxide, hydrocarbons, and particulate matter	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 475)
		STB-2.A.3 Air quality can be affected through the release of sulfur dioxide during the burning of fossil fuels, mainly diesel fuels.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 475)
		STB-2.A.4 Through the Clean Air Act, the Environmental Protection Agency (EPA) regulated the use of lead, particularly in fuels, which dramatically decreased the amount of lead in the atmosphere.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 458)
		STB-2.A.5 Air pollutants can be primary or secondary pollutants.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 458)
7.2 Photochemical Smog	STB-2.B Explain the causes and effects of photochemical smog and methods to reduce it.	STB-2.B.1 Photochemical smog is formed when nitrogen oxides and volatile organic hydrocarbons react with heat and sunlight to produce a variety of pollutants.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 467)

		STB-2.B.2 Many environmental factors affect the formation of photochemical smog.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 468)
		STB-2.B.3 Nitrogen oxide is produced early in the day. Ozone concentrations peak in the afternoon and are higher in the summer because ozone is produced by chemical reactions between oxygen and sunlight.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 468)
		STB-2.B.4 Volatile Organic Compounds (VOCs), such as formaldehyde and gasoline, evaporate or sublimate at room temperature. Trees are a natural source of VOCs.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 459)
		STB-2.B.5 Photochemical smog often forms in urban areas because of the large number of motor vehicles there.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 468)
		STB-2.B.6 Photochemical smog can be reduced through the reduction of nitrogen oxide and VOCs.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 468)
		STB-2.B.7 Photochemical smog can harm human health in several ways, including causing respiratory problems and eye irritation.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 468)

7.3 Thermal Inversion	STB-2.C Describe thermal inversion and its relationship with pollution.	STB-2.C.1 During a thermal inversion, the normal temperature gradient in the atmosphere is altered as the air temperature at the Earth's surface is cooler than the air at higher altitudes.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 454)
		STB-2.C.2 Thermal inversion traps pollution close to the ground, especially smog and particulates.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 455)
7.4 Atmospheric CO2 and Particulates	STB-2.D Describe natural sources of CO2 and particulates.	STB-2.D.1 CO2 appears naturally in the atmosphere from sources such as respiration, decomposition, and volcanic eruptions.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 457)
		STB-2.D.2 There are a variety of natural sources of particulate matter.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 457)
7.5 Indoor Air Pollutants	STB-2.E Identify indoor air pollutants.	STB-2.E.1 Carbon monoxide is an indoor air pollutant that is classified as an asphyxiant.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 477)
		STB-2.E.2 Indoor air pollutants that are classified as particulates include asbestos, dust, and smoke.	Ch. 14 Environmental Health and Toxicology)pg. 366)
		STB-2.E.3 Indoor air pollutants can come from natural sources, human-made sources, and combustion.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 478)
		STB-2.E.4 Common natural source indoor air pollutants include radon, mold, and dust.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 478)

		STB-2.E.5 Common human-made indoor air pollutants include insulation, Volatile Organic Compounds (VOCs) from furniture, paneling and carpets; formaldehyde from building materials, furniture, upholstery, and carpeting; and lead from paints.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 479)
		STB-2.E.6 Common combustion air pollutants include carbon monoxide, nitrogen oxides, sulfur dioxide, particulates, and tobacco smoke.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 480)
		STB-2.E.7 Radon-222 is a naturally occurring radioactive gas that is produced by the decay of uranium found in some rocks and soils.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 479)
	STB-2.F Describe the effects of indoor air pollutants.	STB-2.F.1 Radon gas can infiltrate homes as it moves up through the soil and enters homes via the basement or cracks in the walls or foundation. It is also dissolved in groundwater that enters homes through a well.	Ch. 14 Environmental Health and Toxicology (pg. 366)
		STB-2.F.2 Exposure to radon gas can lead to radoninduced lung cancer, which is the second leading cause of lung cancer in America.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 480)
7.6 Reduction of Air Pollutants	STB-2.G Explain how air pollutants can be reduced at the source.	STB-2.G.1 Methods to reduce air pollutants include regulatory practices, conservation practices, and alternative fuels	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 456)
		STB-2.G.2 A vapor recovery nozzle is an	Not Found

		air pollution control device on a gasoline pump that prevents fumes from escaping into the atmosphere when fueling a motor vehicle.	
		STB-2.G.3 A catalytic converter is an air pollution control device for internal combustion engines that converts pollutants (CO, NOx, and hydrocarbons) in exhaust into less harmful molecules (CO2, N2, O2, and H2O).	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 475)
		STB-2.G.4 Wet and dry scrubbers are air pollution control devices that remove particulates and/or gases from industrial exhaust streams.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 475)
		STB-2.G.5 Methods to reduce air pollution from coalburning power plants include scrubbers and electrostatic precipitators.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 475)
7.7 Acid Rain	STB-2.H Describe acid deposition.	STB-2.H.1 Acid rain and deposition is due to nitrogen oxides and sulfur oxides from anthropogenic and natural sources in the atmosphere.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 475)
		STB-2.H.2 Nitric oxides that cause acid deposition come from motor vehicles and coal-burning power plants. Sulfur dioxides that cause acid deposition come from coal-burning power plants.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 475)

	STB-2.I Describe the effects of acid deposition on the environment.	STB-2.I.1 Acid deposition mainly affects communities that are downwind from coal-burning power plants.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 475)
		STB-2.I.2 Acid rain and deposition can lead to the acidification of soils and bodies of water and corrosion of human-made structures	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 476)
		STB-2.I.3 Regional differences in soils and bedrock affect the impact that acid deposition has on the region—such as limestone bedrock's ability to neutralize the effect of acid rain on lakes and ponds.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 476)
7.8 Noise Pollution	STB-2.J Describe human activities that result in noise pollution and its effects.	STB-2.J.1 Noise pollution is sound at levels high enough to cause physiological stress and hearing loss.	Ch. 16. Marine and Coastal Systems and Resources (pg. 437)
		STB-2.J.2 Sources of noise pollution in urban areas include transportation, construction, and domestic and industrial activity.	Ch. 13 The Urban Environment: Creating sustainable Cities (pg. 352)
		STB-2.J.3 Some effects of noise pollution on animals in ecological systems include stress, the masking of sounds used to communicate or hunt, damaged hearing, and causing changes to migratory routes.	Ch. 13 The Urban Environment: Creating sustainable Cities (pg. 353)

Unit 8: Aquatic and Terrestrial Pollution			
8.1 Sources of Pollution	STB-3.A Identify differences between point and nonpoint sources of pollution.	STB-3.A.1 A point source refers to a single, identifiable source of a pollutant, such as a smokestack or waste discharge pipe.	Ch. 13 The Urban Environment: Creating sustainable Cities (pg. 342)
		STB-3.A.2 Nonpoint sources of pollution are diffused and can therefore be difficult to identify, such as pesticide spraying or urban runoff.	Ch. 15 Freshwater Systems and Resources (pg. 408)
8.2 Human Impacts on Ecosystems	STB-3.B Describe the impacts of human activities on aquatic ecosystems.	STB-3.B.1 Organisms have a range of tolerance for various pollutants. Organisms have an optimum range for each factor where they can maintain homeostasis. Outside of this range, organisms may experience physiological stress, limited growth, reduced reproduction, and in extreme cases, death.	Ch. 19 Fossil Fuel and Energy Efficiency (pg. 541)
		STB-3.B.2 Coral reefs have been suffering damage due to a variety of factors, including increasing ocean temperature, sediment runoff, and destructive fishing practices.	Ch. 16 Marine and Coastal Systems and Resources (pg. 431)

		STB-3.B.3 Oil spills in marine waters cause organisms to die from the hydrocarbons in oil. Oil that floats on the surface of water can coat the feathers of birds and fur of marine mammals. Some components of oil sink to the ocean floor, killing some bottom-dwelling organisms.	Ch. 16 Marine and Coastal Systems and Resources (pg. 435)
		STB-3.B.4 Oil that washes up on the beach can have economic consequences on the fishing and tourism industries.	Ch. 16 Marine and Coastal Systems and Resources (pg. 435)
		STB-3.B.5 Oceanic dead zones are areas of low oxygen in the world's oceans caused by increased nutrient pollution.	Ch. 16 Marine and Coastal Systems and Resources (pg. 436)
		STB-3.B.6 An oxygen sag curve is a plot of dissolved oxygen levels versus the distance from a source of pollution, usually excess nutrients and biological refuse.	Not found
		STB-3.B.7 Heavy metals used for industry, especially mining and burning of fossil fuels, can reach the groundwater, impacting the drinking water supply	Ch. 15 Freshwater Systems and Resources (pg. 414)

		STB-3.B.8 Litter that reaches aquatic ecosystems, besides being unsightly, can create intestinal blockage and choking hazards for wildlife and introduce toxic substances to the food chain.	Ch. 15 Freshwater Systems and Resources (pg. 411)
		STB-3.B.9 Increased sediment in waterways can reduce light infiltration, which can affect primary producers and visual predators. Sediment can also settle, disrupting habitats.	Ch. 15 Freshwater Systems and Resources (pg. 410)
		STB-3.B.10 When elemental sources of mercury enter aquatic environments, bacteria in the water convert it to highly toxic methylmercury	Ch. 14 Environmental Health and Toxicity (pg. 373)
8.3 Endocrine Disruptors	STB-3.C Describe endocrine disruptors.	STB-3.C.1 Endocrine disruptors are chemicals that can interfere with the endocrine system of animals.	Ch. 14 Environmental Health and Toxicity (pg. 371)
	STB-3.D Describe the effects of endocrine disruptors on ecosystems.	STB-3.D.1 Endocrine disruptors can lead to birth defects, developmental disorders, and gender imbalances in fish and other species.	Ch. 14 Environmental Health and Toxicity (pg. 371)
8.4 Human Impacts on Wetlands and Mangroves	STB-3.E Describe the impacts of human activity on wetlands and mangroves.	STB-3.E.1 Wetlands are areas where water covers the soil, either part or all of the time.	Ch. 16. Marine and Coastal Systems and Resources (pg. 430)
		STB-3.E.2 Wetlands provide a variety of ecological services, including water purification, flood protection, water filtration, and habitat.	Ch. 6 Ethics, Economics, and Sustainable Development (pg. 149)

		STB-3.E.3 Threats to wetlands and mangroves include commercial development, dam construction, overfishing, and pollutants from agriculture and industrial waste	Ch. 15 Freshwater Systems and Resources (pg. 399)
8.5 Eutrophication	STB-3.F Explain the environmental effects of excessive use of fertilizers and detergents on aquatic ecosystems.	STB-3.F.1 Eutrophication occurs when a body of water is enriched in nutrients.	Ch. 16. Marine and Coastal Systems and Resources (pg. 436)
		STB-3.F.2 The increase in nutrients in eutrophic aquatic environments causes an algal bloom. When the algal bloom dies, microbes digest the algae, along with the oxygen in the water, leading to a decrease in the dissolved oxygen levels in the water. The lack of dissolved oxygen can result in large die-offs of fish and other aquatic organisms.	Ch. 16. Marine and Coastal Systems and Resources (pg. 436)
		STB-3.F.3 Hypoxic waterways are those bodies of water that are low in dissolved oxygen.	Ch. 5 Environmental Systems and Ecosystem Ecology (pg. 106)
		STB-3.F.4 Compared to eutrophic waterways, oligotrophic waterways have very low amounts of nutrients, stable algae populations, and high dissolved oxygen.	Ch. 15 Freshwater Systems and Resources (pg. 398)
		STB-3.F.5 Anthropogenic causes of eutrophication are agricultural runoff and wastewater release.	Ch. 15 Freshwater Systems and Resources (pg. 408)
8.6 Thermal Pollution	STB-3.G Describe the effects of thermal	STB-3.G.1 Thermal pollution occurs when	Ch. 15 Freshwater Systems and

	pollution on aquatic ecosystems.	heat released into the water produces negative effects to the organisms in that ecosystem.	Resources (pg. 411)
		STB-3.G.2 Variations in water temperature affect the concentration of dissolved oxygen because warm water does not contain as much oxygen as cold water.	Ch. 15 Freshwater Systems and Resources (pg. 411)
8.7 Persistent Organic Pollutants (POPS)	STB-3.H Describe the effect of persistent organic pollutants (POPs) on ecosystems.	STB-3.H.1 Persistent organic pollutants (POPs) do not easily break down in the environment because they are synthetic, carbon-based molecules (such as DDT and PCBs).	Ch. 14 Environmental Health and Toxicity (pg. 384)
		STB-3.H.2 Persistent organic pollutants (POPs) can be toxic to organisms because they are soluble in fat, which allows them to accumulate in organisms' fatty tissues.	Ch. 14 Environmental Health and Toxicity (pg. 384)
		STB-3.H.3 Persistent organic pollutants (POPs) can travel over long distances via wind and water before being redeposited.	Ch. 14 Environmental Health and Toxicity (pg. 384)
8.8 Bioaccumulation and Biomagnification	STB-3.I Describe bioaccumulation and biomagnification.	STB-3.I.1 Bioaccumulation is the selective absorption and concentration of elements or compounds by cells in a living organism, most commonly fat-soluble compounds.	Ch. 14 Environmental Health and Toxicity (pg. 373)

		STB-3.I.2 Biomagnification is the increase in concentration of substances per unit of body tissue that occurs in successively higher trophic levels of a food chain or in a food web.	Ch. 14 Environmental Health and Toxicity (pg. 373)
	STB-3.J Describe the effects of bioaccumulation and biomagnification.	STB-3.J.1 Some effects that can occur in an ecosystem when a persistent substance is biomagnified in a food chain include eggshell thinning and developmental deformities in top carnivores of the higher trophic levels	Ch. 14 Environmental Health and Toxicity (pg. 374)
		STB-3.J.2 Humans also experience harmful effects from biomagnification, including issues with the reproductive, nervous, and circulatory systems.	Ch. 14 Environmental Health and Toxicity (pg. 374)
		STB-3.J.3 DDT, mercury, and PCBs are substances that bioaccumulate and have significant environmental impacts.	Ch. 14 Environmental Health and Toxicity (pg. 374)
8.9 Solid Waste Disposal	STB-3.K Describe solid waste disposal methods.	STB-3.K.1 Solid waste is any discarded material that is not a liquid or gas. It is generated in domestic, industrial, business, and agricultural sectors.	Ch. 22 Managing Our Waste (pg. 621)
		STB-3.K.2 Solid waste is most often disposed of in landfills. Landfills can contaminate groundwater and release harmful gases.	Ch. 22 Managing Our Waste (pg. 621)

		STB-3.K.3 Electronic waste, or e-waste, is composed of discarded electronic devices including televisions, cell phones, and computers.	Ch. 22 Managing Our Waste (pg. 635)
		STB-3.K.4 A sanitary municipal landfill consists of a bottom liner (plastic or clay), a storm water collection system, a leachate collection system, a cap, and a methane collection system.	Ch. 22 Managing Our Waste (pg. 637)
	STB-3.L Describe the effects of solid waste disposal methods.	STB-3.L.1 Factors in landfill decomposition include the composition of the trash and conditions needed for microbial decomposition of the waste.	Ch. 22 Managing Our Waste (pg. 624)
		STB-3.L.2 Solid waste can also be disposed of through incineration, where waste is burned at high temperatures. This method significantly reduces the volume of solid waste but releases air pollutants.	Ch. 22 Managing Our Waste (pg. 631)
		STB-3.L.3 Some items are not accepted in sanitary landfills and may be disposed of illegally, leading to environmental problems. One example is used rubber tires, which when left in piles can become breeding grounds for mosquitoes that can spread disease.	Ch. 22 Managing Our Waste (pg. 635)

		STB-3.L.4 Some countries dispose of their waste by dumping it in the ocean. This practice, along with other sources of plastic, has led to large floating islands of trash in the oceans. Additionally, wildlife can become entangled in the waste, as well as ingest it.	Ch. 16 Marine and Coastal Systems and Resources (pg. 422)
8.10 Waste Reduction Methods	STB-3.M Describe changes to current practices that could reduce the amount of generated waste and their associated benefits and drawbacks.	STB-3.M.1 Recycling is a process by which certain solid waste materials are processed and converted into new products.	Ch. 22 Managing Our Waste (pg. 623)
		STB-3.M.2 Recycling is one way to reduce the current global demand on minerals, but this process is energy-intensive and can be costly	Ch. 22 Managing Our Waste (pg. 624)
		STB-3.M.3 Composting is the process of organic matter such as food scraps, paper, and yard waste decomposing. The product of this decomposition can be used as fertilizer. Drawbacks to composting include odor and rodents.	Ch. 22 Managing Our Waste (pg. 624)

		STB-3.M.4 E-waste can be reduced by recycling and reuse. E-wastes may contain hazardous chemicals, including heavy metals such as lead and mercury, which can leach from landfills into groundwater if they are not disposed of properly.	Ch. 22 Managing Our Waste (pg. 635)
		STB-3.M.5 Landfill mitigation strategies range from burning waste for energy to restoring habitat on former landfills for use as parks.	Ch. 22 Managing Our Waste (pg. 631)
		STB-3.M.6 The combustion of gases produced from decomposition of organic material in landfills can be used to turn turbines and generate electricity. This process reduces landfill volume.	Ch. 22 Managing Our Waste (pg. 632)
8.11 Sewage Treatment	STB-3.N Describe best practices in sewage treatment.	STB-3.N.1 Primary treatment of sewage is the physical removal of large objects, often through the use of screens and grates, followed by the settling of solid waste in the bottom of a tank.	Ch. 15 Freshwater Systems and Resources (pg. 415)

		STB-3.N.2 Secondary treatment is a biological process in which bacteria break down organic matter into carbon dioxide and inorganic sludge, which settles in the bottom of a tank. The tank is aerated to increase the rate at which the bacteria break down the organic matter.	Ch. 15 Freshwater Systems and Resources (pg. 415)
		STB-3.N.3 Tertiary treatment is the use of ecological or chemical processes to remove any pollutants left in the water after primary and secondary treatment.	Ch. 15 Freshwater Systems and Resources (pg. 415)
		STB-3.N.4 Prior to discharge, the treated water is exposed to one or more disinfectants (usually, chlorine, ozone, or UV light) to kill bacteria.	Ch. 15 Freshwater Systems and Resources (pg. 415)
8.12 Lethal Dose 50% (LD50)	EIN-3.A Define lethal dose 50% (LD_{50}).	EIN-3.A.1 Lethal dose 50% (LD_{50}) is the dose of a chemical that is lethal to 50% of the population of a particular species.	Ch. 14 Environmental Health and Toxicity (pg. 376)
8.13 Dose Response Curve	EIN-3.B Evaluate dose response curves.	EIN-3.B.1 A dose response curve describes the effect on an organism or mortality rate in a population based on the dose of a particular toxin or drug.	Ch. 14 Environmental Health and Toxicity (pg. 376)

8.14 Pollution and Human Health	EIN-3.C Identify sources of human health issues that are linked to pollution.	EIN-3.C.1 It can be difficult to establish a cause and effect between pollutants and human health issues because humans experience exposure to a variety of chemicals and pollutants.	Ch. 14 Environmental Health and Toxicity (pg. 370)
		EIN-3.C.2 Dysentery is caused by untreated sewage in streams and rivers.	Ch. 15 Freshwater Systems and Resources (pg. 410)
		EIN-3.C.3 Mesothelioma is a type of cancer caused mainly by exposure to asbestos.	Ch. 14 Environmental Health and Toxicity (pg. 364)
		EIN-3.C.4 Respiratory problems and overall lung function can be impacted by elevated levels of tropospheric ozone.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 461)
8.15 Pathogens and Infectious Diseases	EIN-3.D Explain human pathogens and their cycling through the environment.	EIN-3.D.1 Pathogens adapt to take advantage of new opportunities to infect and spread through human populations.	Ch. 14 Environmental Health and Toxicity (pg. 364)
		EIN-3.D.2 Specific pathogens can occur in many environments regardless of the appearance of sanitary conditions.	Ch. 14 Environmental Health and Toxicity (pg. 364)
		EIN-3.D.3 As equatorial-type climate zones spread north and south in to what are currently subtropical and temperate climate zones, pathogens, infectious diseases, and any associated vectors are spreading into these areas where the disease has not previously been known to occur.	Ch. 18 Global Climate Change (pg. 506)
		EIN-3.D.4 Poverty-stricken, low-income	Ch. 18 Global Climate Change (pg. 506)

		areas often lack sanitary waste disposal and have contaminated drinking water supplies, leading to havens and opportunities for the spread of infectious	
		EIN-3.D.5 Plague is a disease carried by organisms infected with the plague bacteria. It is transferred to humans via the bite of an infected organism or through contact with contaminated fluids or tissues.	Ch. 14 Environmental Health and Toxicity (pg. 364)
		EIN-3.D.6 Tuberculosis is a bacterial infection that typically attacks the lungs. It is spread by breathing in the bacteria from the bodily fluids of an infected person.	Ch. 14 Environmental Health and Toxicity (pg. 364)
		EIN-3.D.7 Malaria is a parasitic disease caused by bites from infected mosquitoes. It is most often found in sub-Saharan Africa.	Ch. 14 Environmental Health and Toxicity (pg. 364)
		EIN-3.D.8 West Nile virus is transmitted to humans via bites from infected mosquitoes.	Ch. 14 Environmental Health and Toxicity (pg. 364)
		EIN-3.D.9 Severe acute respiratory syndrome (SARS) is a form of pneumonia. It is transferred by inhaling or touching infected fluids.	Ch. 14 Environmental Health and Toxicity (pg. 364)

		EIN-3.D.10 Middle East Respiratory Syndrome (MERS) is a viral respiratory illness that is transferred from animals to humans.	Ch. 14 Environmental Health and Toxicity (pg. 364)
		EIN-3.D.11 Zika is a virus caused by bites from infected mosquitoes. It can be transmitted through sexual contact.	Ch. 14 Environmental Health and Toxicity (pg. 369)
		EIN-3.D.12 Cholera is a bacterial disease that is contracted from infected water.	Ch. 15 Freshwater Systems and Resources (pg. 410)
Unit 9: Global Change			
9.1 Stratospheric Ozone Depletion	STB-4.A Explain the importance of stratospheric ozone to life on Earth.	STB-4.A.1 The stratospheric ozone layer is important to the evolution of life on Earth and the continued health and survival of life on Earth.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Controll (pg. 470)
		STB-4.A.2 Stratospheric ozone depletion is caused by anthropogenic factors, such as chlorofluorocarbons (CFCs), and natural factors, such as the melting of ice crystals in the atmosphere at the beginning of the Antarctic spring.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Controll (pg. 471)
		STB-4.A.3 A decrease in stratospheric ozone increases the UV rays that reach the Earth's surface. Exposure to UV rays can lead to skin cancer and cataracts in humans.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Controll (pg. 471)

9.2 Reducing Ozone Depletion	STB-4.B Describe chemicals used to substitute for chlorofluorocarbons (CFCs).	STB-4.B.1 Ozone depletion can be mitigated by replacing ozone-depleting chemicals with substitutes that do not deplete the ozone layer. Hydrofluorocarbons (HFCs) are one such replacement, but some are strong greenhouse gases.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Controll (pg. 470)
9.3 The Greenhouse Effect	STB-4.C Identify the greenhouse gases.	STB-4.C.1 The principal greenhouse gases are carbon dioxide, methane, water vapor, nitrous oxide, and chlorofluorocarbons (CFCs).	Ch. 18 Global Climate Change (pg. 488)
		STB-4.C.2 While water vapor is a greenhouse gas, it doesn't contribute significantly to global climate change because it has a short residence time in the atmosphere	Ch. 18 Global Climate Change (pg. 488)
		STB-4.C.3 The greenhouse effect results in the surface temperature necessary for life on Earth to exist.	Ch. 18 Global Climate Change (pg. 488)
	STB-4.D Identify the sources and potency of the greenhouse gases.	STB-4.D.1 Carbon dioxide, which has a global warming potential (GWP) of 1, is used as a reference point for the comparison of different greenhouse gases and their impacts on global climate change. Chlorofluorocarbons (CFCs) have the highest GWP, followed by nitrous oxide, then methane.	Ch. 18 Global Climate Change (pg. 488)

9.4 Increases in the Greenhouse Gases	STB-4.E Identify the threats to human health and the environment posed by an increase in greenhouse gases.	STB-4.E.1 Global climate change, caused by excess greenhouse gases in the atmosphere, can lead to a variety of environmental problems including rising sea levels resulting from melting ice sheets and ocean water expansion, and disease vectors spreading from the tropics toward the poles. These problems can lead to changes in population dynamics and population movements in response.	Ch. 18 Global Climate Change (pg. 488)
9.5 Global climate Change	STB-4.F Explain how changes in climate, both short- and longterm, impact ecosystems.	STB-4.F.1 The Earth has undergone climate change throughout geologic time, with major shifts in global temperatures causing periods of warming and cooling as recorded with CO2 data and ice cores.	Ch. 18 Global Climate Change (pg. 486)
		STB-4.F.2 Effects of climate change include rising temperatures, melting permafrost and sea ice, rising sea levels, and displacement of coastal populations.	Ch. 18 Global Climate Change (pg. 487)

		STB-4.F.3 Marine ecosystems are affected by changes in sea level, some positively, such as in newly created habitats on now-flooded continental shelves, and some negatively, such as deeper communities that may no longer be in the photic zone of seawater.	Ch. 18 Global Climate Change (pg. 505)
		STB-4.F.4 Winds generated by atmospheric circulation help transport heat throughout the Earth. Climate change may change circulation patterns, as temperature changes may impact Hadley cells and the jet stream.	Ch. 17 The Atmosphere, Air Quality, and Air Pollution Control (pg. 455)
		STB-4.F.5 Oceanic currents, or the ocean conveyor belt, carry heat throughout the world. When these currents change, it can have a big impact on global climate, especially in coastal regions.	Ch. 18 Global Climate Change (pg. 490)
		STB-4.F.6 Climate change can affect soil through changes in temperature and rainfall, which can impact soil's viability and potentially increase erosion.	Ch. 18 Global Climate Change (pg. 502)

		STB-4.F.7 Earth's polar regions are showing faster response times to global climate change because ice and snow in these regions reflect the most energy back out to space, leading to a positive feedback loop.	Ch. 18 Global Climate Change (pg. 500)
		STB-4.F.8 As the Earth warms, this ice and snow melts, meaning less solar energy is radiated back into space and instead is absorbed by the Earth's surface. This in turn causes more warming of the polar regions.	Ch. 18 Global Climate Change (pg. 502)
		STB-4.F.9 Global climate change response time in the Arctic is due to positive feedback loops involving melting sea ice and thawing tundra, and the subsequent release of greenhouse gases like methane.	Ch. 18 Global Climate Change (pg. 502)
		STB-4.F.10 One consequence of the loss of ice and snow in polar regions is the effect on species that depend on the ice for habitat and food.	Not Found
9.6 Ocean Warming	STB-4.G Explain the causes and effects of ocean warming	STB-4.G.1 Ocean warming is caused by the increase in greenhouse gases in the atmosphere.	Ch. 18 Global Climate Change (pg. 490)

		STB-4.G.2 Ocean warming can affect marine species in a variety of ways, including loss of habitat, and metabolic and reproductive changes.	Ch. 16 Marine and Coastal Systems and Resources (pg. 446)
		STB-4.G.3 Ocean warming is causing coral bleaching, which occurs when the loss of algae within corals cause the corals to bleach white. Some corals recover and some die.	Ch. 16 Marine and Coastal Systems and Resources (pg. 437)
9.7 Ocean Acidification	STB-4.H Explain the causes and effects of ocean acidification.	STB-4.H.1 Ocean acidification is the decrease in pH of the oceans, primarily due to increased CO2 concentrations in the atmosphere, and can be expressed as chemical equations.	Ch. 16 Marine and Coastal Systems and Resources (pg. 437)
		STB-4.H.2 As more CO2 is released into the atmosphere, the oceans, which absorb a large part of that CO2, become more acidic.	Ch. 16 Marine and Coastal Systems and Resources (pg. 437)
		STB-4.H.3 Anthropogenic activities that contribute to ocean acidification are those that lead to increased CO2 concentrations in the atmosphere: burning of fossil fuels, vehicle emissions, and deforestation.	Ch. 16 Marine and Coastal Systems and Resources (pg. 437)
		STB-4.H.4 Ocean acidification damages coral because acidification makes it difficult for them to form shells, due to the loss of calcium carbonate.	Ch. 16 Marine and Coastal Systems and Resources (pg. 437)

9.8 Invasive Species	EIN-4.A Explain the environmental problems associated with invasive species and strategies to control them.	EIN-4.A.1 Invasive species are species that can live, and sometimes thrive, outside of their normal habitat. Invasive species can sometimes be beneficial, but they are considered invasive when they threaten native species.	Ch. 4 Species Interactions and Community Ecology (pg.88)
		EIN-4.A.2 Invasive species are often generalist, r-selected species and therefore may outcompete native species for resources.	Ch. 4 Species Interactions and Community Ecology (pg.89)
		EIN-4.A.3 Invasive species can be controlled through a variety of human interventions.	Ch. 4 Species Interactions and Community Ecology (pg.89)
9.9 Endangered Species	EIN-4.B Explain how species become endangered and strategies to combat the problem.	EIN-4.B.1 A variety of factors can lead to a species becoming threatened with extinction, such as being extensively hunted, having limited diet, being outcompeted by invasive species, or having specific and limited habitat requirements.	Ch. 11 Biodiversity and Its Conservation (pg. 296)
		EIN-4.B.2 Not all species will be in danger of extinction when exposed to the same changes in their ecosystem. Species that are able to adapt to changes in their environment or that are able to move to a new environment are less likely to face extinction.	Ch. 11 Biodiversity and Its Conservation (pg. 294)

		EIN-4.B.3 Selective pressures are any factors that change the behaviors and fitness of organisms within an environment.	Ch. 11 Biodiversity and Its Conservation (pg. 296)
		EIN-4.B.4 Species in a given ecosystem compete for resources like territory, food, mates, and habitat, and this competition may lead to endangerment or extinction.	Ch. 4 Species Interactions and Community Ecology (pg.77)
		EIN-4.B.5 Strategies to protect animal populations include criminalizing poaching, protecting animal habitats, and legislation.	Ch. 11 Biodiversity and Its Conservation (pg. 290)
9.10 Human Impacts on Biodiversity	EIN-4.C Explain how human activities affect biodiversity and strategies to combat the problem.	EIN-4.C.1 HIPPCO (habitat destruction, invasive species, population growth, pollution, climate change, and over exploitation) describes the main factors leading to a decrease in biodiversity.	Ch. 11 Biodiversity and Its Conservation (pg. 295)
		EIN-4.C.2 Habitat fragmentation occurs when large habitats are broken into smaller, isolated areas. Causes of habitat fragmentation include the construction of roads and pipelines, clearing for agriculture or development, and logging.	Ch. 12 Forests, Forest Management, and Protected Areas (pg. 329)

		EIN-4.C.3 The scale of habitat fragmentation that has an adverse effect on the inhabitants of a given ecosystem will vary from species to species within that ecosystem.	Ch. 12 Forests, Forest Management, and Protected Areas (pg. 329)
		EIN-4.C.4 Global climate change can cause habitat loss via changes in temperature, precipitation, and sea level rise.	Ch. 12 Forests, Forest Management, and Protected Areas (pg. 329)
		EIN-4.C.5 Some organisms have been somewhat or completely domesticated and are now managed for economic returns, such as honeybee colonies and domestic livestock. This domestication can have a negative impact on the biodiversity of that organism	Ch. 3 Evolution and Population Ecology (pg. 52)
		EIN-4.C.6 Some ways humans can mitigate the impact of loss of biodiversity include creating protected areas, use of habitat corridors, promoting sustainable land use practices, and restoring lost habitats.	Ch. 11 Biodiversity and Its Conservation (pg. 299)

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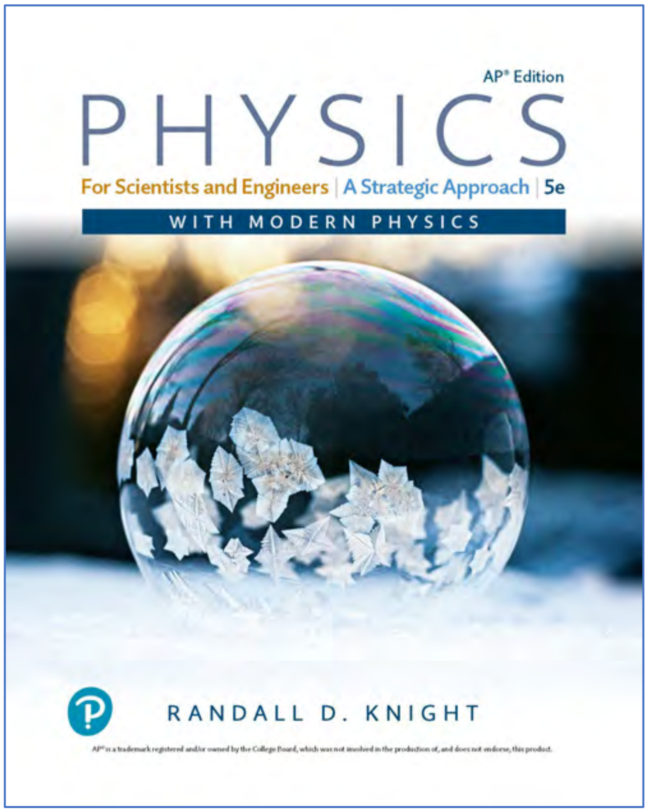

To the

AP® Physics C: Electricity and Magnetism

Course Framework (Fall 2024)

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The units above reflect the College Board's AP® Physics C: Electricity and Magnetism Course Framework.

Unit 8: Electric Charges, Fields, and Gauss's Law (6 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
8.1 Electric Charge and Electric Force	8.1.A Describe the electric force that results from the interactions between charged objects or systems. 8.1.B Describe the electric and gravitational forces that result from interactions between charged objects with mass. 8.1.C Describe the electric permittivity of a material or medium.	22.1 The Charge Model 22.2 Charge 22.3 Insulators and Conductors 22.4 Coulomb's Law
8.2 Conservation of Electric Charge and the Process of Charging	8.2.A Describe the behavior of a system using conservation of charge.	22.2 Charge 22.3 Insulators and Conductors
8.3 Electric Fields	8.3.A Describe the electric field produced by a charged object or configuration of point charges. 8.3.B Describe the electric field generated by charged conductors or insulators.	22.5 The Electric Field 23.1 Electric Field Models 23.2 The Electric Field of Point Charges
8.4 Electric Fields of Charge Distributions	8.4.A Describe the electric field resulting from a given charge distribution.	23.3 The Electric Field of a Continuous Charge Distribution

		23.4 The Electric Fields of Some Common Charge Distributions

Unit 8: Electric Charges, Fields, and Gauss's Law (6 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
8.5 Electric Flux	8.5.A Describe the electric flux through an arbitrary area or geometric shape.	24.2 The Concept of Flux 24.3 Calculating Electric Flux
8.6 Gauss's Law	8.6.A Describe the properties of a charge distribution by applying Gauss’s law.	24.1 Symmetry 24.4 Gauss's Law 24.5 Using Gauss's Law 31.4 Maxwell's Equations

Pearson

Unit 9: Electric Potential (3 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
9.1 Electric Potential Energy	9.1.A Describe the electric potential energy of a system.	25.1 Electric Potential Energy 25.2 The Potential Energy of Point Charges 25.3 The Potential Energy of a Dipole
9.2 Electric Potential	9.2.A Describe the electric potential due to a configuration of charged objects. 9.2.B Describe the relationship between electric potential and electric field.	25.4 The Electric Potential 25.5 The Electric Potential Inside a Parallel-Plate Capacitor 25.6 The Electric Potential of a Point Charge 25.7 The Electric Potential of Many Charges 26.1 Connecting Potential and Field 26.2 Finding the Electric Field from the Potential
9.3 Conservation of Electric Energy	9.3.A Describe changes in energy in a system due to a difference in electric potential between two locations.	25.4 The Electric Potential

Pearson

Unit 10: Conductors and Capacitors (4 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
10.1 Electrostatics with Conductors	10.1.A Describe the charge distribution within a conductor.	22.3 Insulators and Conductors 24.6 Conductors in Electrostatic Equilibrium 26.3 A Conductor in Electrostatic Equilibrium
10.2 Redistribution of Charge between Conductors	10.2.A Describe the movement of charge and the resulting interactions when conductors physically contact each other.	22.3 Insulators and Conductors 28.8 Getting Grounded
10.3 Capacitors	10.3.A Describe the physical properties of a parallel-plate capacitor.	23.5 The Parallel-Plate Capacitor 23.6 Motion of a Charged Particle in an Electric Field 25.5 The Electric Potential Inside a Parallel-Plate Capacitor 26.5 Capacitance and Capacitors 26.6 The Energy Stored in a Capacitor
10.4 Dielectrics	10.4.A Describe how a dielectric inserted between the plates of a capacitor changes the properties of the capacitor.	26.7 Dielectrics

Unit 11: Electric Circuits (8 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
11.1 Electric Current	11.1.A Describe the movement of electric charges through a medium.	27.1 The Electron Current 27.2 Creating a Current 27.3 Current and Current Density 27.4 Conductivity and Resistivity
11.2 Simple Circuits	11.2.A Describe the behavior of a circuit.	28.1 Circuit Elements and Diagrams 28.2 Kirchhoff's Laws and the Basic Circuit
11.3 Resistance, Resistivity, and Ohm's Law	11.3.A Describe the resistance of an object using physical properties of that object. 11.3.B Describe the electrical characteristics of elements of a circuit.	27.5 Resistance and Ohm's Law
11.4 Electric Power	11.4.A Describe the transfer of energy into, out of, or within an electric circuit, in terms of power.	28.3 Energy and Power
11.5 Compound Direct Current Circuits	11.5.A Describe the equivalent resistance of	28.4 Series Resistors 28.5 Real Batteries

	multiple resistors connected in a circuit. 11.5.B Describe a circuit with resistive wires and a battery with internal resistance. 11.5.C Describe the measurement of current and potential difference in a circuit.	28.6 Parallel Resistors

Unit 11: Electric Circuits (8 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
11.6 Kirchhoff's Loop Rule	11.6.A Describe a circuit or elements of a circuit by applying Kirchhoff's loop rule.	26.2 Finding the Electric Field from the Potential 28.2 Kirchhoff's Laws and the Basic Circuit
11.7 Kirchhoff's Junction Rule	11.7.A Describe a circuit or elements of a circuit by applying Kirchhoff's junction rule.	27.3 Current and Current Density 28.2 Kirchhoff's Laws and the Basic Circuit
11.8 Resistor Capacitor (RC) Circuits	11.8.A Describe the equivalent capacitance of multiple capacitors. 11.8.B Describe the behavior of a circuit containing combinations of resistors and capacitors.	28.9 RC Circuits

Unit 12: Magnetic Fields and Electromagnetism (4 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
12.1 Magnetic Fields	12.1.A Describe the properties of a magnetic field. 12.1.B Describe the magnetic behavior of a material as a result of the configuration of magnetic dipoles in the material. 12.1.C Describe the magnetic permeability of a material.	29.1 Magnetism 29.2 The Discovery of the Magnetic Field 29.5 Magnetic Dipoles 29.10 Magnetic Properties of Matter 31.4 Maxwell's Equations
12.2 Magnetism and Moving Charges	12.2.A Describe the magnetic field produced by moving charged objects.	29.3 The Source of the Magnetic Field: Moving Charges 29.7 The Magnetic Force on a Moving Charge

	12.2.B Describe the force exerted on moving charged objects by a magnetic field.	
12.3 Magnetic Fields of Current-Carrying Wires and the Biot-Savart Law	12.3.A Describe the magnetic field produced by a current-carrying wire. 12.3.B Describe the force exerted on a current-carrying wire by a magnetic field.	29.4 The Magnetic Field of a Current 29.8 Magnetic Forces on Current-Carrying Wires
12.4 Ampere's Law	12.4.A Use Ampère's law to describe the magnetic field created by a moving charge carrier.	29.6 Ampere's Law and Solenoids 31.4 Maxwell's Equations

Unit 13: Electromagnetic Induction (6 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
13.1 Magnetic Flux	13.1.A Describe the magnetic flux through an arbitrary area or geometric shape.	30.3 Magnetic Flux
13.2 Electromagnetic Induction	13.2.A Describe the induced electric potential difference resulting from a change in magnetic flux.	30.4 Lenz's Law 30.5 Faraday's Law 30.6 Induced Fields 31.4 Maxwell's Equations 31.5 Electromagnetic Waves
13.3 Induced Currents and Magnetic Forces	13.3.A Describe the force exerted on a conductor due to the interaction between an external	29.8 Magnetic Forces on Current-Carrying Wires 29.9 Forces and Torques on Current Loops 30.1 Induced Currents

	magnetic field and an induced current within that conductor.	30.2 Motional emf
13.4 Inductance	13.4.A Describe the physical and electrical properties of an inductor.	30.8 Inductors
13.5 Circuits with Resistors and Inductors (LR Circuits)	13.5.A Describe the physical and electrical properties of a circuit containing a combination of resistors and a single inductor.	30.10 LR Circuits
13.6 Circuits with Capacitors and Inductors (LC Circuits)	13.6.A Describe the physical and electrical properties of a circuit containing a combination of capacitors and a single inductor.	30.9 LC Circuits

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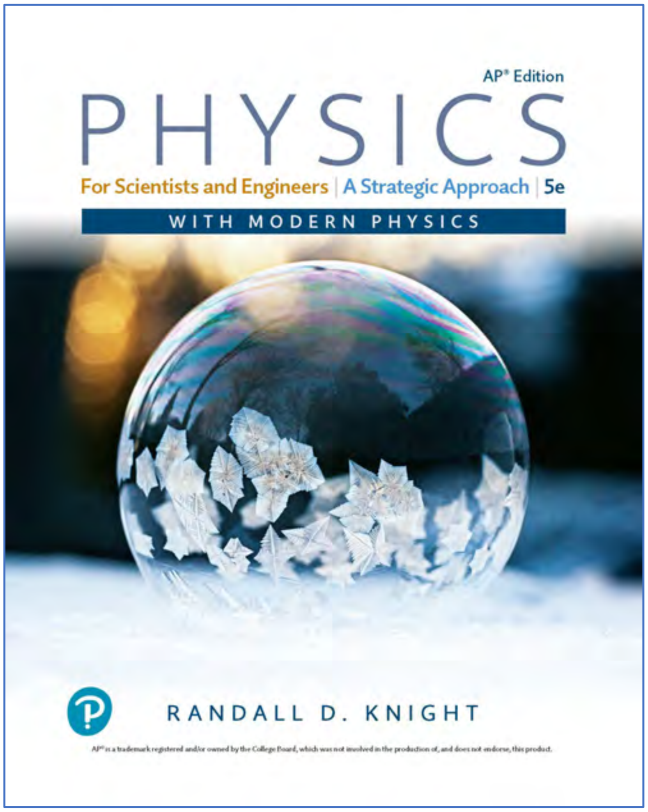

To the

AP® Physics C: Mechanics
Course Framework (Fall 2024)

Pearson

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The units above reflect the College Board's AP® Physics C: Mechanics Course Framework.

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Unit 1: Kinematics (5 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
1.1 Scalars and Vectors	1.1.A Describe a scalar or vector quantity using magnitude and direction, as appropriate.	3.1 Scalars and Vectors 3.2 Using Vectors 3.3 Coordinate Systems and Vector Components 3.4 Unit Vectors and Vector Algebra
1.2 Displacement, Velocity, and Acceleration	1.2.A Describe a change in an object's position. 1.2.B Describe the average velocity and acceleration of an object. 1.2.C Describe the instantaneous position, velocity, and acceleration of an object as a function of time.	1.2 Models and Modeling 1.3 Position, Time, and Displacement 1.4 Velocity 1.5 Linear Acceleration 1.6 Motion in One Dimension 2.2 Instantaneous Velocity 2.7 Instantaneous Acceleration
1.3 Representing Motion	1.3.A Describe the position, velocity, and acceleration of an object using representations of that object's motion.	1.1 Motion Diagrams 1.7 Solving Problems in Physics 2.3 Finding Position from Velocity 2.4 Motion with Constant Acceleration 2.5 Free-Fall
1.4 Reference Frames and Relative Motion	1.4.A Describe the reference frame of a given observer. 1.4.B Describe the motion of objects as measured by observers in different inertial reference frames.	4.3 Relative Motion
1.5 Motion in Two or Three Dimensions	1.5.A Describe the motion of an object moving in two or three dimensions.	4.1 Motion in Two Dimensions 4.2 Projectile Motion

Unit 2: Force and Translational Dynamics (10 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
2.1 Systems and Center of Mass	2.1.A Describe the properties and interactions of a system. 2.1.B Describe the location of a system's center of mass with respect to the system's constituent parts.	7.1 Interacting Objects 12.2 Rotation about the Center of Mass
2.2 Forces and Free-Body Diagrams	2.2.A Describe a force as an interaction between two objects or systems. 2.2.B Describe the forces exerted on an object or system using a free-body diagram.	5.1 Force 5.2 A Short Catalog of Forces 5.3 Identifying Forces 5.7 Free-Body Diagrams
2.3 Newton's Third Law	2.3.A Describe the interaction of two objects or systems using Newton's third law and a representation of paired forces exerted on each object or system.	7.1 Interacting Objects 7.2 Analyzing Interacting Objects 7.3 Newton's Third Law 7.4 Ropes and Pulleys 7.5 Examples of Interacting-Objects Problems
2.4 Newton's First Law	2.4.A Describe the conditions under which a system's velocity remains constant.	5.6 Newton's First Law 6.1 The Equilibrium Model
2.5 Newton's Second Law	2.5.A Describe the conditions under which a system's velocity changes.	5.4 What Do Forces Do? 5.5 Newton's Second Law 6.2 Using Newton's Second Law 6.6 More Examples of Newton's Second Law

Unit 2: Force and Translational Dynamics (10 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
2.6 Gravitational Force	2.6.A Describe the gravitational interaction between two objects or systems with mass. 2.6.B Describe situations in which the gravitational force can be considered constant. 2.6.C Describe the conditions under which the magnitude of a system's apparent weight is different from the magnitude of the gravitational force exerted on that system. 2.6.D Describe inertial and gravitational mass. 2.6.E Describe the gravitational force exerted on an object by a uniform spherical distribution of mass.	6.3 Mass, Weight, and Gravity 13.3 Newton's Law of Gravity 13.4 Little g and Big G
2.7 Kinetic and Static Friction	2.7.A Describe kinetic friction between two surfaces.	6.4 Friction

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	2.7.B Describe static friction between two surfaces.	

2.8 Spring Forces	2.8.A Describe the force exerted on an object by an ideal spring. 2.8.B Describe the equivalent spring constant of a combination of springs exerting forces on an object.	9.4 Restoring Forces and the Work Done by a Spring
2.9 Resistive Forces	2.9.A Describe the motion of an object subject to a resistive force.	6.5 Drag
2.10 Circular Motion	2.10.A Describe the motion of an object traveling in a circular path. 2.10.B Describe circular orbits using Kepler's third law.	4.4 Uniform Circular Motion 4.5 Centripetal Acceleration 8.2 Uniform Circular Motion 8.3 Circular Orbits 13.1 A Little History 13.6 Satellite Orbits and Energies

Unit 3: Work, Energy, and Power (5 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
3.1 Translational Kinetic Energy	3.1.A Describe the translational kinetic energy of an object in terms of the object's mass and velocity.	9.2 Work and Kinetic Energy for a Single Particle
3.2 Work	3.2.A Describe the work done on an object or system by a given force or collection of forces.	9.2 Work and Kinetic Energy for a Single Particle 9.3 Calculating the Work Done 9.4 Restoring Forces and the Work Done by a Spring
3.3 Potential Energy	3.3.A Describe the potential energy of a system.	10.1 Potential Energy 10.2 Gravitational Potential Energy 10.3 Elastic Potential Energy 10.6 Force and Potential Energy 10.7 Conservative and Nonconservative Forces 13.5 Gravitational Potential Energy
3.4 Conservation of Energy	3.4.A Describe the energies present in a system. 3.4.B Describe the behavior of a system using conservation of mechanical energy principles.	9.1 Energy Overview 10.4 Conservation of Energy 10.5 Energy Diagrams 10.8 The Energy Principle Revisited

	3.4.C Describe how the selection of a system determines whether the energy of that system changes.	
3.5 Power	3.5.A Describe the transfer of energy into, out of, or within a system in terms of power.	9.6 Power

Unit 4: Linear Momentum (4 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
4.1 Linear Momentum	4.1.A Describe the linear momentum of an object or system.	11.1 Momentum and Impulse
4.2 Change in Momentum and Impulse	4.2.A Describe the impulse delivered to an object or system. 4.2.B Describe the relationship between the impulse exerted on an object or a system and the change in momentum of the object or system.	11.1 Momentum and Impulse
4.3 Conservation of Linear Momentum	4.3.A Describe the behavior of a system	11.2 Conservation of Momentum 11.4 Explosions 11.5 Momentum in Two Dimensions

	using conservation of linear momentum. 4.3.B Describe how the selection of a system determines whether the momentum of that system changes.	
4.4 Elastic and Inelastic Collisions	4.4.A Describe whether an interaction between objects is elastic or inelastic.	11.3 Collisions

Unit 5: Torque and Rotational Dynamics (6 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
5.1 Rotational Kinematics	5.1.A Describe the rotation of a system with respect to time using angular displacement, angular velocity, and angular acceleration.	12.1 Rotational Motion
5.2 Connecting Linear and Rotational Motion	5.2.A Describe the linear motion of a point on a rotating rigid system that corresponds to the rotational motion of that point, and vice versa.	4.4 Uniform Circular Motion 4.6 Nonuniform Circular Motion
5.3 Torque	5.3.A Identify the torques exerted on a rigid system. 5.3.B Describe the torques exerted on a rigid system.	12.5 Torque

5.4 Rotational Inertia	5.4.A Describe the rotational inertia of a rigid system relative to a given axis of rotation. 5.4.B Describe the rotational inertia of a rigid system rotating about an axis that does not pass through the system's center of mass.	12.3 Rotational Energy 12.4 Calculating Moment of Inertia
5.5 Rotational Equilibrium and Newton's First Law in Rotational Form	5.5.A Describe the conditions under which a system's angular velocity remains constant.	12.5 Torque 12.8 Static Equilibrium
5.6 Newton's Second Law in Rotational Form	5.6.A Describe the conditions under which a system's angular velocity changes.	12.5 Torque 12.6 Rotational Dynamics 12.7 Rotation About a Fixed Axis
Unit 6: Energy and Momentum of Rotating Systems (6 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
6.1 Rotational Kinetic Energy	6.1.A Describe the rotational kinetic energy of a rigid system in terms of the rotational inertia and angular velocity of that rigid system.	12.3 Rotational Energy
6.2 Torque and Work	6.2.A Describe the work done on a rigid system by a given torque or collection of torques.	(none)
6.3 Angular Momentum and Angular Impulse	6.3.A Describe the angular momentum of an object or rigid system.	12.11 Angular Momentum

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	6.3.B Describe the angular impulse delivered to an object or rigid system by a torque. 6.3.C Relate the change in angular momentum of an object or rigid system to the angular impulse given to that object or rigid system.	
6.4 Conservation of Angular Momentum	6.4.A Describe the behavior of a system using conservation of angular momentum. 6.4.B Describe how the selection of a system determines whether the angular momentum of that system changes.	12.11 Angular Momentum

Unit 6: Energy and Momentum of Rotating Systems (6 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
6.5 Rolling	6.5.A Describe the kinetic energy of a system that has translational and rotational motion. 6.5.B Describe the motion of a system that is rolling without slipping. 6.5.C Describe the motion of a system that is rolling while slipping.	12.9 Rolling Motion

6.6 Motion of Orbiting Satellites	6.6.A Describe the motions of a system consisting of two objects interacting only via gravitational forces.	13.5 Gravitational Potential Energy 13.6 Satellite Orbits and Energies

Unit 7: Oscillations (5 topics)		
Topic	**Learning Objectives**	**Physics for Scientists and Engineers Chapters and Sections**
7.1 Defining Simple Harmonic Motion (SHM)	7.1.A Describe simple harmonic motion.	15.1 Simple Harmonic Motion
7.2 Frequency and Period of SHM	7.2.A Describe the frequency and period of an object exhibiting SHM.	15.1 Simple Harmonic Motion 15.3 Energy in Simple Harmonic Motion 15.6 The Pendulum

7.3 Representing and Analyzing SHM	7.3.A Describe the displacement, velocity, and acceleration of an object exhibiting SHM.	15.1 Simple Harmonic Motion 15.4 The Dynamics of SHM 15.8 Driven Oscillations and Resonance
7.4 Energy of Simple Harmonic Oscillators	7.4.A Describe the mechanical energy of a system exhibiting SHM.	15.3 Energy in Simple Harmonic Motion
7.5 Simple and Physical Pendulums	7.5.A Describe the properties of a physical pendulum.	15.6 The Pendulum

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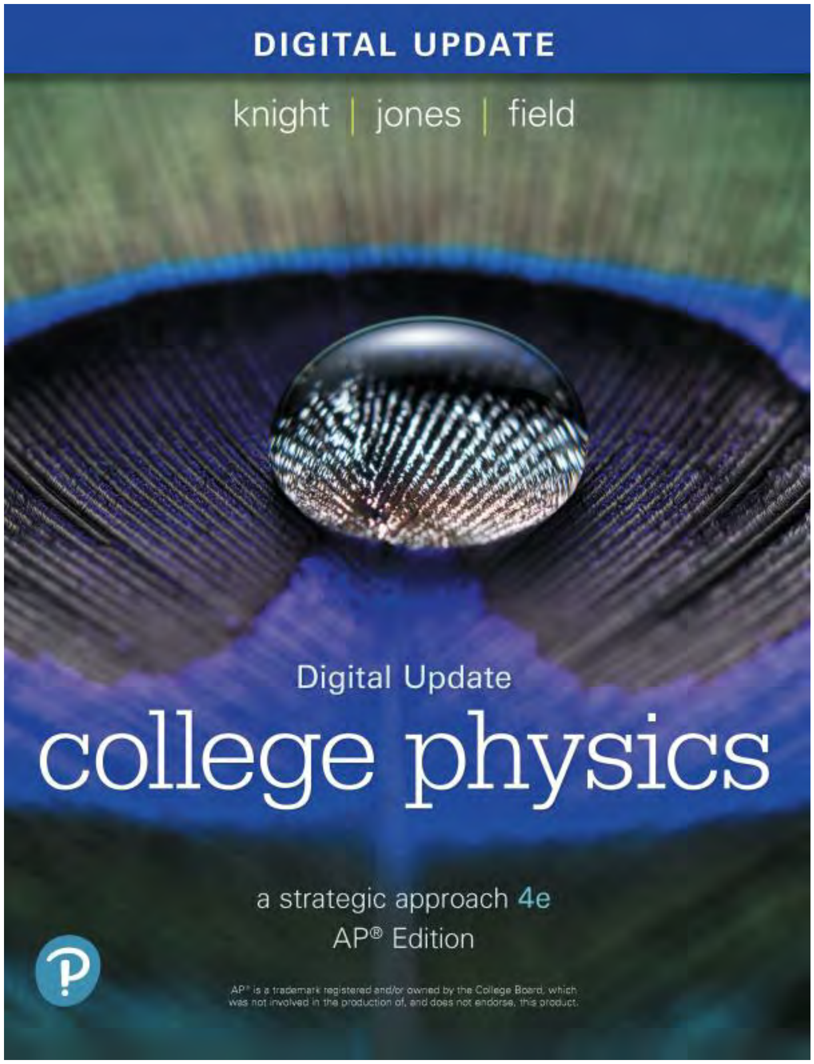

To the
AP® Physics 2 Course Framework
Effective Fall 2024

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The units above reflect the College Board's AP® Physics 2 Course Framework.

Unit 9: Thermodynamics (6 topics) AP® Physics 2 Course Framework		
Topic	**Learning Objectives**	**College Physics: A Strategic Approach Chapters and Sections**
9.1 Kinetic Theory of Temperature and Pressure	9.1.A Describe the pressure a gas exerts on its container in terms of atomic motion within that gas. 9.1.B Describe the temperature of a system in terms of the atomic motion within that system.	11.3 Temperature, Thermal Energy, and Heat 12.2 The Atomic Model of an Ideal Gas
9.2 The Ideal Gas Law	9.2.A Describe the properties of an ideal gas.	12.1 The Atomic Model of Matter 12.3 Ideal-Gas Processes
9.3 Thermal Energy Transfer and Equilibrium	9.3.A Describe the transfer of energy between two systems in thermal contact due to temperature differences of those two systems.	11.4 The First Law of Thermodynamics 12.8 Heat Transfer
9.4 The First Law of Thermodynamics	9.4.A Describe the internal energy of a system. 9.4.B Describe the behavior of a system using thermodynamic processes.	11.4 The First Law of Thermodynamics
9.5 Specific Heat and Thermal Conductivity	9.5.A Describe the energy required to change the temperature of an object by a certain amount. 9.5.B Describe the rate at which energy is transferred by conduction through a given material.	12.5 Specific Heat and Heat of Transformation 12.6 Calorimetry 12.8 Heat Transfer

9.6 Entropy and the Second Law of Thermodynamics	9.6.A Describe the change in entropy for a given system over time.	11.7 Entropy and the Second Law of Thermodynamics
Unit 10: Electric Force, Field, and Potential (7 topics) AP® Physics 2 Course Framework		
Topic	**Learning Objectives**	**College Physics: A Strategic Approach Chapters and Sections**
10.1 Electric Charge and Electric Force	10.1.A Describe the electric force that results from the interactions between charged objects or systems. 10.1.B Describe the electric and gravitational forces that result from interactions between charged objects with mass. 10.1.C Describe the electric permittivity of a material or medium.	20.1 Charges and Forces 20.2 Charges, Atoms, and Molecules 20.3 Coulomb's Law
10.2 Conservation of Electric Charge and the Process of Charging	10.2.A Describe the behavior of a system using conservation of charge.	20.1 Charges and Forces 20.2 Charges, Atoms, and Molecules
10.3 Electric Fields	10.3.A Describe the electric field produced by a charged object or configuration of point charges. 10.3.B Describe the electric field generated by charged conductors or insulators.	20.4 The Concept of the Electric Field 20.5 The Electric Field of Multiple Charges 20.6 Conductors and Electric Fields 20.7 Forces and Torques in Electric Fields

10.4 Electric Potential Energy	10.4.A Describe the electric potential energy of a system.	21.1 Electric Potential Energy and Electric Potential

Unit 10: Electric Force, Field, and Potential (7 topics) AP® Physics 2 Course Framework		
Topic	**Learning Objectives**	**College Physics: A Strategic Approach Chapters and Sections**
10.5 Electric Potential	10.5.A Describe the electric potential due to a configuration of charged objects. 10.5.B Describe the relationship between electric potential and electric field.	21.1 Electric Potential Energy and Electric Potential 21.3 Electric Potential and Conservation of Energy 21.4 Calculating the Electric Potential 21.5 Connecting Potential and Field
10.6 Capacitors	10.6.A Describe the physical properties of a parallel-plate capacitor.	21.7 Capacitance and Capacitors 21.8 Energy and Capacitors
10.7 Conservation of Electric Energy	10.7.A Describe changes in energy in a system due to a difference in electric potential between two locations.	21.1 Electric Potential Energy and Electric Potential 21.3 Electric Potential and Conservation of Energy

Unit 11: Electric Circuits (8 topics) AP® Physics 2 Course Framework		
Topic	**Learning Objectives**	**College Physics: A Strategic Approach Chapters and Sections**
11.1 Electric Current	11.1.A Describe the movement of electric charges through a medium.	22.1 A Model of Current 22.2 Defining and Describing Current 22.3 Batteries and emf
11.2 Simple Circuits	11.2.A Describe the behavior of a circuit.	22.5 Ohm's Law and Resistor Circuits 23.1 Circuit Elements and Diagrams
11.3 Resistance, Resistivity, and Ohm's Law	11.3.A Describe the resistance of an object using physical properties of that object. 11.3.B Describe the electrical characteristics of elements of a circuit.	22.4 Connecting Potential and Current 22.5 Ohm's Law and Resistor Circuits
11.4 Electric Power	11.4.A Describe the transfer of energy into, out of, or within an electric circuit, in terms of power.	22.6 Energy and Power
11.5 Compound Direct Current (DC) Circuits	11.5.A Describe the equivalent resistance of multiple resistors connected in a circuit.	21.2 Sources of Electric Potential 23.3 Series and Parallel Circuits 23.4 Measuring Voltage and Current 23.5 More Complex Circuits

	11.5.B Describe a circuit with resistive wires and a battery with internal resistance. 11.5.C Describe the measurement of current and potential difference in a circuit.	
11.6 Kirchhoff's Loop Rule	11.6.A Describe a circuit or elements of a circuit by applying Kirchhoff's loop rule.	23.2 Kirchhoff's Laws
Unit 11: Electric Circuits (8 topics) AP® Physics 2 Course Framework		
Topic	**Learning Objectives**	**College Physics: A Strategic Approach Chapters and Sections**
11.7 Kirchhoff's Junction Rule	11.7.A Describe a circuit or elements of a circuit by applying Kirchhoff's junction rule.	22.2 Defining and Describing Current 23.2 Kirchhoff's Laws
11.8 Resistor-Capacitor (RC) Circuits	11.8.A Describe the equivalent capacitance of multiple capacitors. 11.8.B Describe the behavior of a circuit containing combinations of resistors and capacitors.	23.6 Capacitors in Parallel and Series 23.7 RC Circuits

Unit 12: Magnetism and Electromagnetism (4 topics) AP® Physics 2 Course Framework		
Topic	**Learning Objectives**	**College Physics: A Strategic Approach Chapters and Sections**
12.1 Magnetic Fields	12.1.A Describe the properties of a magnetic field. 12.1.B Describe the magnetic behavior of a material as a result of the configuration of magnetic dipoles in the material. 12.1.C Describe the magnetic permeability of a material.	24.1 Magnetism 24.2 The Magnetic Field 24.8 Magnets and Magnetic Materials
12.2 Magnetism and Moving Charges	12.2.A Describe the magnetic field produced by moving charged objects. 12.2.B Describe the force exerted on moving	24.5 Magnetic Fields Exert Forces on Moving Charges

	charged objects by a magnetic field.	
12.3 Magnetism and Current-Carrying Wires	12.3.A Describe the magnetic field produced by a current-carrying wire. 12.3.B Describe the force exerted on a current-carrying wire by a magnetic field.	24.3 Electric Currents Also Create Magnetic Fields 24.4 Calculating the Magnetic Field Due to a Current 24.6 Magnetic Fields Exert Forces on Currents
12.4 Electromagnetic Induction and Faraday's Law	12.4.A Describe the induced electric potential difference resulting from a change in magnetic flux.	25.1 Induced Currents 25.2 Motional emf 25.3 Magnetic Flux and Lenz's Law 25.4 Faraday's Law

Unit 13: Geometric Optics (4 topics) AP® Physics 2 Course Framework		
Topic	**Learning Objectives**	**College Physics: A Strategic Approach Chapters and Sections**
13.1 Reflection	13.1.A Describe light as a ray. 13.1.B Describe the reflection of light from a surface.	18.1 The Ray Model of Light 18.2 Reflection
13.2 Images Formed by Mirrors	13.2.A Describe the image formed by a mirror.	18.6 Image Formation with Spherical Mirrors 18.7 The Thin-Lens Equation
13.3 Refraction	13.3.A Describe the refraction of light between two media.	17.1 What Is Light? 18.3 Refraction
13.4 Images Formed by Lenses	13.4.A Describe the image formed by a lens.	18.4 Image Formation by Refraction 18.5 Thin Lenses: Ray Tracing 18.7 The Thin-Lens Equation

Unit 14: Waves, Sound, and Physical Optics (9 topics) AP® Physics 2 Course Framework		
Topic	**Learning Objectives**	**College Physics: A Strategic Approach Chapters and Sections**
14.1 Properties of Wave Pulses and Waves	14.1.A Describe the physical properties of waves and wave pulses.	15.1 The Wave Model 15.2 Traveling Waves 25.5 Electromagnetic Waves
14.2 Periodic Waves	14.2.A Describe the physical properties of a periodic wave.	15.3 Graphical and Mathematical Descriptions of Waves
14.3 Boundary Behavior of Waves and Polarization	14.3.A Describe the interaction between a wave and a boundary.	15.5 Energy and Intensity 25.5 Electromagnetic Waves
14.4 Electromagnetic Waves	14.4.A Describe the properties of an electromagnetic wave.	15.4 Sound and Light Waves 25.5 Electromagnetic Waves 25.7 The Electromagnetic Spectrum

14.5 The Doppler Effect	14.5.A Describe the properties of a wave based on the relative motion between the source of the wave and the observer of the wave.	15.7 The Doppler Effect and Shock Waves
14.6 Wave Interference and Standing Waves	14.6.A Describe the net disturbance that occurs when two or more wave pulses or waves overlap. 14.6.B Describe the properties of a standing wave.	16.1 The Principle of Superposition 16.2 Standing Waves 16.3 Standing Waves on a String 16.4 Standing Sound Waves 16.6 The Interference of Waves from Two Sources 16.7 Beats
14.7 Diffraction	14.7.A Describe the behavior of a wave and the diffraction pattern resulting from a wave passing through a single opening.	17.1 What Is Light? 17.5 Single-Slit Diffraction 17.6 Circular-Aperture Diffraction

Unit 14: Waves, Sound, and Physical Optics (9 topics) AP® Physics 2 Course Framework		
Topic	**Learning Objectives**	**College Physics: A Strategic Approach Chapters and Sections**
14.8 Double-Slit Interference and Diffraction Gratings	14.8.A Describe the behavior of a wave and the diffraction pattern resulting from the wave passing through multiple openings.	17.2 The Interference of Light 17.3 The Diffraction Grating
14.9 Thin-Film Interference	14.9.A Describe the behavior of light that interacts with a thin film.	17.4 Thin-Film Interference

Unit 15: Modern Physics (8 topics) AP® Physics 2 Course Framework		
Topic	**Learning Objectives**	**College Physics: A Strategic Approach Chapters and Sections**
15.1 Quantum Theory and Wave-Particle Duality	15.1.A Describe the properties and behavior of an object that exhibits both particle-like and wave-like behavior.	17.1 What Is Light? 25.6 The Photon Model of Electromagnetic Waves 28.3 Photons 28.4 Matter Waves 28.5 Energy Is Quantized 28.8 Applications and Implications of Quantum Theory
15.2 The Bohr Model of Atomic Structure	15.2.A Describe the properties of an atom.	28.6 Energy Levels and Quantum Jumps 29.2 Atoms 29.3 Bohr's Model of Atomic Quantization 29.4 The Bohr Hydrogen Atom

15.3 Emission and Absorption Spectra	15.3.A Describe the emission or absorption of photons by atoms.	29.1 Spectroscopy
15.4 Blackbody Radiation	15.4.A Describe the electromagnetic radiation emitted by an object due to its temperature.	(none)
15.5 The Photoelectric Effect	15.5.A Describe an interaction between photons and matter using the photoelectric effect.	28.2 The Photoelectric Effect
15.6 Compton Scattering	15.6.A Describe the interaction between photons and matter using Compton scattering.	(none)

Unit 15: Modern Physics (8 topics) AP® Physics 2 Course Framework		
Topic	**Learning Objectives**	**College Physics: A Strategic Approach Chapters and Sections**
15.7 Fission, Fusion, and Nuclear Decay	15.7.A Describe the physical properties that constrain the behavior of interacting nuclei, subatomic particles, and nucleons. 15.7.B Describe the radioactive decay of a given sample of material consisting of a finite number of nuclei.	30.1 Nuclear Structure 30.2 Nuclear Stability 30.3 Forces and Energy in the Nucleus 30.5 Nuclear Decay and Half-Lives

15.8 Types of Radioactive Decay	15.8.A Describe the processes by which individual nuclei decay.	30.4 Radiation and Radioactivity

Technology Supporting Document

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iv. Alternative text (image), captions and subtitles (videos), read-alouds, and other accessibility functions	Pearson works closely with key members of the disability and advocacy community who are committed to accessible instructional materials. We work with organizations such as W3C, the DIAGRAM Center, Book Industry Study Group, the Center for Accessible Materials Innovation, and the EDUPUB Alliance (EPUB for Education). Pearson is pleased to announce our collaboration with the Book Industry Study Group to promote the launch of Quick Start Guide to Accessible Publishing. Pearson staff contribute time, expertise, and creativity to moving accessibility forward. We conduct user studies and a variety of research and usability studies on important topics, such as assistive technology use, and on product prototypes. We collaborate with advocacy groups and share advances and insights through conference presentations. Students can now instantly purchase accessible digital textbooks for select Pearson titles, providing affordable, faster, and more efficient access to their learning materials. Alternate text files for other Pearson titles are available for qualified students upon request and at no added cost, provided the student has purchased or is renting the print or digital textbook. All other requests can be placed using Pearson's disability request form. Please understand that it may take up to 10 business days for you to receive the electronic file. https://www.pearson.com/en-us/legal-information/accessibility.html	Pearson works closely with key members of the disability and advocacy community who are committed to accessible instructional materials. We work with organizations such as W3C, the DIAGRAM Center, Book Industry Study Group, the Center for Accessible Materials Innovation, and the EDUPUB Alliance (EPUB for Education). Pearson is pleased to announce our collaboration with the Book Industry Study Group to promote the launch of Quick Start Guide to Accessible Publishing. Pearson staff contribute time, expertise, and creativity to moving accessibility forward. We conduct user studies and a variety of research and usability studies on important topics, such as assistive technology use, and on product prototypes. We collaborate with advocacy groups and share advances and insights through conference presentations. Students can now instantly purchase accessible digital textbooks for select Pearson titles, providing affordable, faster, and more efficient access to their learning materials. Alternate text files for other Pearson titles are available for qualified students upon request and at no added cost, provided the student has purchased or is renting the print or digital textbook. All other requests can be placed using Pearson's disability request form. Please understand that it may take up to 10 business days for you to receive the electronic file. https://www.pearson.com/en-us/legal-information/accessibility.html and https://accessibility.vitalsource.com
v. 508 compliant platform	We gratefully acknowledge and endorse the work of the Web Accessibility Initiative of the World Wide Web consortium on the Web Content Accessibility Guidelines (WCAG) 2.2, as well as the work of United States Access Board and the Information Technology Advisory Committee (TEITAC) on their Section 508 Refresh Drafts. We strive to provide equal access for all students. To achieve this goal, we've created the Pearson Accessibility Guidelines for eLearning. These guidelines provide developers standards for creating the most effective educational content. https://www.pearson.com/en-us/legal-information/accessibility.html	We gratefully acknowledge and endorse the work of the Web Accessibility Initiative of the World Wide Web consortium on the Web Content Accessibility Guidelines (WCAG) 2.2, as well as the work of United States Access Board and the Information Technology Advisory Committee (TEITAC) on their Section 508 Refresh Drafts. We strive to provide equal access for all students. To achieve this goal, we've created the Pearson Accessibility Guidelines for eLearning. These guidelines provide developers standards for creating the most effective educational content. https://www.pearson.com/en-us/legal-information/accessibility.html and https://accessibility.vitalsource.com
vi. Privacy-data security specifications	Pearson's privacy and data security specifications are linked here: https://www.pearson.com/en-us/privacy-center/privacy-notices.html	Vitalsource's privacy and data security specifications are linked here: https://www.pearson.com/en-us/privacy-center/privacy-notices.html and https://vitalsource.com/privacy

vii. Browser and OS support	Browser & OS Support Information can be found here: https://support.pearson.com/getsupport/s/article/Using-an-Alternate-Supported-Browser	Browser and OS Support Information can be found here: https://bookshelfsupport.vitalsource.com/hc/en-us/sections/32270458995095
b. LMS is a generic term for platforms like Canvas, Google, and Schoology. A software platform designed to manage, deliver, and track educational courses, training programs, or learning and development initiatives. It provides educators with tools to create and organize content, manage student enrollments, track progress, assess performance, and facilitate communication between instructors and learners. LMSs often include discussion forums, assignment submissions, quizzes, grading, and reporting.	Our LTI 1.3 app is available for Canvas, Schoology, Blackboard, Brightspace/D2L, Moodle and Sakai. We can also integrate with Clever and Classlink, but we would suggest integrating with one of the LMSes listed instead because those integrations have a bigger feature set, most notably grade sync.	Yes, Vitalsource is compatible with and can integrate with ClassGather.
c. ClassGather offers customers access to their digital instructional materials through direct integrations with publisher platforms. As a certified integration partner, ClassGather supports roster exchange with publishers via OneRoster (CSV or API) and SSO access via SAML, oAuth, or LTI. Through automated resource assignment, access to digital titles is provisioned at the time of purchase, so student and teacher access “just works” without additional content or integration configuration.	We don't currently integrate with ClassGather.	Yes, Vitalsource is compatible with and can integrate with ClassGather.