Course Title:	Content Area:	Grade Level:	Credit (if applicable)
AP Biology	Science	11-12	1.0

Course Description:

AP Biology is an introductory college-level biology course that builds off of students' previous high school biology course. Students cultivate their understanding of biology through inquiry-based investigations as they explore the following topics: evolution, cellular processes, energy and communication, genetic information transfer, ecology, and interactions. This course requires that 25% of the instructional time will be spent in hands-on laboratory work, with an emphasis on inquiry-based investigations that provides opportunities to apply the science practices. Inquiry-based laboratory experiences support the AP Biology course and AP Course Audit curricular requirements by providing opportunities for students to engage in the science practices as they design plans for experiments, make predictions, collect and analyze data, apply mathematical routines, develop explanations, and communicate about their work. Students will be required to take the Advanced Placement Examination in May.

Aligned Core Resources:

- Campbell Biology In Focus: AP Edition (2025) 4e
- AP Biology CED (Effective Fall 2025)
- AP Biology Investigative Labs: An Inquiry-Based Approach - Teacher Lab Manual (Effective Fall 2019)
- AP Classroom

Connection to the *BPS Vision of the Graduate*

The ECE program will provide students with a pathway to meet the Bristol Public School's vision of the graduate through advanced learning opportunities such as:

- Problem solving
- Critical thinking
- Effective Communication

The Science Practice Standards support the VOG Skills:

- Science Practice 1: Effective Communication
- Science Practice 2: Critical Thinking
- Science Practice 3: Problem Solving
- Science Practice 4: Effective Communication
- Science Practice 5: Critical Thinking
- Science Practice 6: Effective Communication

Additional Course Information:
Knowledge/Skill Dependent courses/prerequisites

PREREQUISITES

- Precalculus ACC taken concurrently or permission of instructor
- Biology ACC - Minimum final grade of 83 or Biology ACA - Minimum final grade of 93
- Biology ACC may be taken concurrently for grade 10 students with instructor permission if a final average of 83 was earned in Physical Science ACC.

Link to *Completed Equity Audit*

Equity Curriculum Review Audit - ECE/AP Bio (2025)

Standard Matrix

Standard	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Pre-Work
Science Practice 1: Explain biological concepts, processes, and models presented in written format.	✓	✓	✓	✓	✓	✓	✓	
Science Practice 2: Analyze visual representations of biological concepts and processes.	✓	✓				✓	✓	
Science Practice 3: Determine scientific questions and methods.		✓	✓		✓		✓	✓
Science Practice 4: Represent and describe data		✓	✓	✓			✓	✓

Science Practice 5: Perform statistical tests and mathematical calculations to analyze and interpret data.		✓		✓	✓		✓	✓
Science Practice 6: Develop and justify scientific arguments using evidence.	✓	✓	✓	✓	✓	✓	✓	✓
Big Idea 1: Evolution (EVO) The process of evolution drives the diversity and unity of life.		✓			✓		✓	✓
Big Idea 2: Energetics (ENE) Biological systems use energy and molecular building blocks to grow, reproduce, and maintain dynamic homeostasis	✓	✓	✓	✓				✓
Big Idea 3: Information Storage and Transmission (IST) Living systems store, retrieve, transmit, and respond to information essential to life processes.	✓			✓	✓	✓		✓
Big Idea 4: Systems Interactions (SYI) Biological systems interact, and these systems and their interactions exhibit complex properties	✓	✓	✓		✓		✓	✓

Unit Links

Pre-Course Summer Work: Ecology (Unit 8 in AP Curriculum)
Unit 0: Experimental Design and Data Analysis
Unit 1: Chemistry of Life
Unit 2: Cell Structure and Function
Unit 3: Cellular Energetics
Unit 4: Cell Communication and Cell Cycle
Unit 5: Heredity
Unit 6: Gene Expression and Regulation
Unit 7: Natural Selection

Unit Title:

Pre-Work: Ecology (Unit 8 in AP Curriculum)

Relevant Standards: Bold indicates priority

Course Content:
Evolution (EVO)
Energetics (ENE)
Information Storage and Transmission (IST)
Systems Interactions (SYI)

Science Practices:
3 - Questions and Methods
- 3.C: Identify experimental procedures that align with the question, including identifying independent and dependent variables and appropriate controls.

4 - Representing and Describing Data
- 4.A: Construct a graph to represent the data, including: x-y graphs (bar,histogram, line, log scale, dual y), scatterplot, box and whisker plot, and pie chart.

5 - Statistical Tests and Data Analysis
- 5.A: Perform mathematical calculations, including mathematical equations in the curriculum, means, rates, ratios, percentages and percent changes
- 5.B: Use confidence intervals and error bars to estimate whether sample means are statistically different.
- 5.D: Use data to evaluate a hypothesis or prediction, including rejecting or failing to reject the null hypothesis.

6 - Argumentation
- 6.D: Explain the relationship between experimental results and larger biological concepts, processes, or theories.
- 6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system.

Essential Question(s):	**Enduring Understanding(s):**
• How does diversity among and between species in a biological system affect the evolution of species within the system? • How does the acquisition of energy relate to the health of a biological system? • How do communities and ecosystems change, for better or worse, due to biological disruption? • How does a disruption of a biological system affect genetic information storage and transmission? • How do species interactions affect the survival of an ecosystem?	Students learn how a system's interactions are directly related to the system's available energy and its ability to evolve and respond to changes in its environment. When highly complex living systems interact, communities and ecosystems change based on those interactions. The more biodiversity present in a system, the more likely that system is to maintain its health and success in the face of disruption. Energy flows through systems; the rate of flow determines the success of the species within the systems.
Demonstration of Learning:	**Pacing for Unit**
Students complete the majority of this unit independently before the course begins. Resources, including Google Slides and a comprehensive guided notes packet (with practice and application questions), will be provided via Google Classroom. Once available, AP Daily videos and topic questions will also be assigned via AP Classroom. Learning will be assessed on an open-note assessment using their completed guided notes packet, typically during the second week of school. Students will conduct a laboratory investigation in which they analyze three different "pasta ecosystems" and compare their relative biodiversity using Simpson's Diversity Index.	Independent summer work plus 2-4 class periods at start of school year
Family Overview:	**Integration of Technology:**
AP Biology: Family Course Overview (English) AP Biology: Family Course Overview (Spanish)	• Google Slides • AP Classroom Personal Progress Check, AP Daily videos and topic questions • *Desmos scientific calculator*

Unit-specific Vocabulary:		Aligned Unit Materials, Resources, and Technology (beyond core resources):
Ecosystem Community Population Biome Habitat Niche Abiotic Biotic Endotherm Ectotherm Photosynthetic Chemosynthetic Trophic level Trophic pyramid Producer Consumer Predator Prey Parasitism Symbiosis Biodiversity Species richness Simpson's diversity index Invasive species	Apex predator Decomposer Detritivore Food chain Food web Biomass Water cycle Hydrologic cycle Carbon cycle Nitrogen cycle Phosphorus cycle Population density Carrying capacity Limiting factor (density dependent and independent) Exponential growth Logistic growth Competition Predation Mutualisms Commensalism Eutrophication Biomagnification	• Campbell Biology In Focus Chapters 40-43 • AP Classroom Unit 8
Opportunities for Interdisciplinary Connections:		**Anticipated misconceptions:**
• Math (algebra, statistics) • Health and Wellness • Chemistry • Anatomy and Physiology • Environmental Science/Sustainability studies		• Ecosystems are always changing, they are not stagnant and are not always stable. • Carrying capacity is not a fixed number, but can change as other biotic and abiotic factors in the ecosystem change. • Population growth cannot be infinitely exponential, and is actually both rare and temporary---eventually population size and growth will be limited by a variety of ecological factors. • Predators are not always "bad" for a prey population but rather they help cull unhealthy individuals and keep prey populations stable such that they don't overuse resources. • Not all keystone species are producers nor apex predators. • Not all interactions between species are predator-prey. • Students often assume that invasive species spread because they are "stronger" or "better" than native species, but typically they gain a foothold in their new environment because of a lack of natural predators and/or competitors. • Students often struggle to see themselves/humans as part of the ecosystem and its nutrient cycles and energy flow.
Connections to Prior Units:		**Connections to Future Units:**
N/A		Ecology shows how all preceding biological principles apply to the large-scale interactions of life. Ecological processes like energy flow and nutrient cycling are direct

	applications of the Laws of Thermodynamics and cellular processes like photosynthesis and cellular respiration established in Unit 3 (Energetics) and Unit 2 (The Cell). Crucially, ecology defines the selective pressures (biotic and abiotic factors) that are the driving force behind Natural Selection (Unit 7). The resulting adaptations and population dynamics are only possible because of heritable variation (Unit 5) and the mechanisms of Gene Expression (Unit 6), which allow organisms to respond to their environment.

Differentiation through *Universal Design for Learning*
Learning Targets and Teacher Actions

Learning Target 1:

- Representation: Provide content via multiple modalities: text, video clips showing a plant growing toward light (phototropism), and diagrams/models of nerve reflexes.
- Action/Expression: Offer choices for explanation: oral presentation, written essay, or creating a flowchart/concept map showing the stimulus-response pathway.
- Engagement: Use real-world examples (e.g., a dog panting to cool off, pupils dilating in the dark). Allow students to choose an organism to research its unique detection/response system.

Learning Target 2:

- Representation: Offer case studies with varied formats: written articles about mating rituals, infographics about foraging strategies, and video examples of cooperative behaviors.
- Action/Expression: Students can create a brief documentary about a specific adaptive behavior or design an infographic that links a behavior to increased survival/reproduction.
- Engagement: Use high-interest scenarios (e.g., fight-or-flight, mimicry, migration). Include a debate on whether a learned or inherited behavior contributes more to fitness.

Learning Target 3:

- Representation: Use visual models: food chains, food webs, and energy pyramids. Incorporate digital simulations where students can adjust trophic levels and observe the energy transfer impact.
- Action/Expression: Students can physically model energy flow (e.g., using colored blocks or manipulatives), draw and label a food web, or write a narrative tracing a joule of energy through an ecosystem.
- Engagement: Relate to the student's local environment (schoolyard, local park) to build a food web. Use a gamified approach to calculate energy loss at each trophic level.

Learning Target 4:

- Representation: Provide annotated diagrams of the water, carbon, and nitrogen cycles. Use a narrated animation to show the movement of an atom through the cycle components.
- Action/Expression: Students can create a 3D model of a cycle (e.g., using pipe cleaners and beads), present a multimedia report on human impact on one cycle, or write a children's book from the perspective of a carbon atom.
- Engagement: Connect cycles to global issues (e.g., carbon cycle and climate change, nitrogen cycle and fertilizer runoff). Allow students to choose which cycle they will focus their in-depth study on.

Learning Target 5:

- Representation: Use graphs/data tables for different growth models (exponential vs. logistic). Provide scaffolding for mathematical models (e.g., templates, step-by-step guides, calculators).
- Action/Expression: Allow students to use a spreadsheet program to model population change, create a presentation analyzing real-world population data (e.g., human population or an endangered species), or write a detailed explanation of limiting factors.
- Engagement: Use simulations/online games to manage a virtual population (e.g., adjusting birth/death rates). Use a case study on a relevant local animal population or invasive species.

Learning Target 6:

- Representation: Use a comparison chart to differentiate interaction types (competition, predation, symbiosis). Show paired video clips illustrating each interaction (e.g., a predator/prey clip next to a mutualism clip).
- Action/Expression: Students can role-play or use puppets to illustrate an interaction, design a visual matrix linking interactions to effects on energy/matter flow, or write a scientific abstract summarizing a key interaction.
- Engagement: Puzzles or matching activities to pair organisms with their interaction type. Use a jigsaw activity where groups become "experts" on one interaction type and teach the others.

Learning Target 7:

- Representation: Use visual metaphors (e.g., a diverse portfolio vs. a single investment) to explain resilience. Provide before-and-after case studies (written and visual) of ecosystems recovering from a disturbance.
- Action/Expression: Students can develop a conservation proposal justifying the protection of a diverse ecosystem, create a short public service announcement (PSA), or design a graphic organizer that illustrates the variables influencing resilience.
- Engagement: Introduce an authentic problem (e.g., coral bleaching, a major wildfire). Students brainstorm and evaluate solutions based on their understanding of biodiversity and resilience.

Learning Target 8:

- Representation: Use interactive maps/data visualizations that show the impact of a specific change (e.g., dam construction, invasive species). Provide annotated scientific articles summarizing major ecological disturbances.
- Action/Expression: Offer a structured analysis template (if writing a report), the option to create a "domino effect" diagram illustrating cascading impacts, or to build a computer-based model of a changing ecosystem.
- Engagement: Assign different roles to students (ecologist, politician, local resident) to analyze an ecosystem change from various perspectives. Use a "What If?" scenario activity to explore hypothetical disturbances.

Supporting Multilingual/English Learners (*CELP standards*)
Differentiated Learning Targets

	Emerging	Bridging	Expanding
LT 1	I can describe an organism's basic detection (stimulus) and response using a key term or phrase (e.g., detect, respond), perhaps with a simple model or drawing.	I can explain the process of how an organism detects and responds to a change, using a logical sequence of events and academic vocabulary.	I can analyze and explain in detail how an organism's body systems work together to detect a change and maintain homeostasis, using complex, descriptive language and precise academic terminology.
LT 2	I can name one behavior and identify how it helps an organism survive (e.g., The animal runs. It is safe.).	I can describe a behavior and explain how it increases an organism's survival or reproductive rate (fitness) using connected sentences and content-specific words (e.g., adaptation, survival).	I can analyze a complex behavioral adaptation (e.g., migration, social structure) and construct a detailed argument supported by evidence to explain its impact on an organism's fitness across generations.
LT 3	I can label the main parts of a simple food chain (e.g., producer, consumer) and show the direction of energy flow with an arrow.	I can describe the flow of energy in a food web, identifying the roles of different trophic levels, and use sequencing words to show the energy transfer.	I can create a detailed model of energy flow in an ecosystem and explain the concept of trophic efficiency (e.g., the 10% rule), using precise and sophisticated academic language.
LT 4	I can identify the key components (e.g., water, sun, plant) and a major step (e.g., rain) of a basic cycle using labeled diagrams or single sentences.	I can describe the main sequence of steps in a major biogeochemical cycle (e.g., carbon or water) using connecting words (e.g., after that, as a result) and content-specific terms.	I can explain and illustrate the different states and pathways of matter in a complex biogeochemical cycle (e.g., nitrogen or phosphorus), analyzing the role of living and nonliving factors using coherent and detailed language.
LT 5	I can list 2-3 factors that change a population's size (e.g., births, deaths, food) and identify the direction of the change (bigger or smaller).	I can describe the difference between density-dependent and density-independent factors and use a simple graph or equation to illustrate an example of growth.	I can analyze a population scenario and use a mathematical model to predict future growth, explaining the factors that regulate population size (e.g., carrying capacity) with supporting evidence and precise calculations.
LT 6	I can define one basic population interaction (e.g., predator-prey) and name the organisms involved.	I can describe and categorize different types of population interactions (e.g., mutualism, competition) and explain how one interaction affects the balance of energy access using transition words and academic terms.	I can analyze the complex web of interactions within a community (e.g., keystone species) and explain the resulting community structure and the differential access to energy and matter using detailed, evidence-based reasoning.
LT 7	I can define diversity and identify that more diversity helps when an	I can describe the relationship between biodiversity (e.g., species	I can evaluate the relationship between species diversity and ecosystem

	ecosystem changes.	richness) and an ecosystem's stability or resistance to a common change, using comparison/contrast language (e.g., in contrast, similarly).	resilience, using supporting examples and analyzing how specific environmental changes (e.g., invasive species) impact long-term stability using precise, academic discourse.
LT 8	I can identify one simple change to an ecosystem (e.g., a fire) and name one thing that changes as a result (e.g., plants die).	I can describe how a specific change (e.g., drought, human development) affects one or two components (e.g., structure, biodiversity) of an ecosystem using cause and effect language (e.g., because, leads to).	I can analyze a complex scenario of ecosystem change and construct a detailed explanation of the interdependent effects on ecosystem structure, biodiversity, and stability, using evidence-based claims and sophisticated vocabulary to support the analysis.

Lesson Sequence	Learning Target	Success Criteria/Assessment/Resources
Pre-Work	**Learning Target 1** I can explain how organisms detect and respond to changes in their environment.	• I can differentiate between innate and learned behaviors. • I can explain how signals (visual, auditory, tactile, chemical) trigger behavioral responses. • I can describe how behavioral adaptations can influence the success and evolution of populations over time.
Pre-Work	**Learning Target 2** I can describe how behaviors increase an organism's fitness.	• I can provide examples of how behaviors such as cooperation, communication, or courtship improve survival or reproduction.
Pre-Work	**Learning Target 3** I can describe and model how energy flows through an ecosystem from producers to consumers.	• I can identify the roles of autotrophs (e.g., photosynthesizers or chemosynthesizers) and heterotrophs in energy flow. • I can explain the 10% rule and calculate energy transfer between trophic levels. • I can construct and interpret food webs, food chains, and trophic pyramids. • I can identify how disruptions to one trophic level affect the entire system. • I can differentiate between abiotic and biotic factors within an ecosystem.
Pre-Work	**Learning Target 4** I can describe how matter and nutrients cycle between organisms and the environment through biogeochemical cycles.	• I can identify reservoirs within major biogeochemical cycles (e.g., water, carbon, nitrogen) and describe the basic processes that move resources between reservoirs in these systems (e.g., evaporation, precipitation, nitrogen fixation, decomposition).
Pre-Work	**Learning Target 5** I can describe factors that influence population size and growth over time and use mathematical models to represent/predict population growth.	• I can interpret growth curves (exponential vs. logistic) and carrying capacity. • I can calculate population growth using r and N values. • I can explain how limiting factors regulate population size. • I can explain how the density of a population affects and is determined by resource availability in the environment.
1	**Learning Target 6** I can explain how interactions among populations influence community structure and affect access to energy and matter within a community.	• I can identify and define examples of interspecies interactions (competition, predation, mutualism, commensalism, parasitism). • I can explain how positive and negative interactions influence population sizes and distribution of species in a community. • I can predict how changing one population (e.g.,

		predator removal) might impact the community.
2	**Learning Target 7** I can describe the relationship between ecosystem diversity and its resilience to changes in the environment.	• I can define “biodiversity” in the context of species diversity and ecosystem complexity. • I can explain why ecosystems with greater diversity tend to be more stable and resilient to environmental changes. • I can describe how removing or losing a keystone species or a critical abiotic component can disproportionately affect the ecosystem.
3	**Learning Target 8** I can explain and analyze how changes to ecosystem components affect ecosystem structure, biodiversity, and stability.	• I can explain how invasive species affect ecosystem dynamics. • I can describe how human activities (such as biomagnification and eutrophication) can lead to changes in ecosystem structure and dynamics. • I can explain how geological and meteorological activity leads to changes in ecosystem structure and dynamics.

Unit Title:

Unit 0: Experimental Design and Data Analysis

Relevant Standards: Bold indicates priority

Science Practices:

3 - Questions and Methods

- 3.A: Identify or pose a testable question based on an observation, data, or a model
- 3.B: State the null hypothesis or predict the results of an experiment
- 3.C: Identify experimental procedures that align with the question, including identifying independent and dependent variables and appropriate controls.
- 3.D: Propose a new investigation based on an evaluation of the experimental design or evidence.

4 - Representing and Describing Data

- 4.A: Construct a graph to represent the data, including: x-y graphs (bar,histogram, line, log scale, dual y), scatterplot, box and whisker plot, and pie chart.
- 4.B: Describe data from a table or graph, including identifying specific data points, describing trends and patterns in the data, and describing relationships between variables.

5 - Statistical Tests and Data Analysis

- 5.A: Perform mathematical calculations, including mathematical equations in the curriculum, means, rates, ratios, percentages and percent changes
- 5.B: Use confidence intervals and error bars to estimate whether sample means are statistically different.
- 5.D: Use data to evaluate a hypothesis or prediction, including rejecting or failing to reject the null hypothesis.

6 - Argumentation

- 6.A: Make a scientific claim.
- 6.B: Support a claim with evidence from biological principles, concepts, processes, and data.

Essential Question(s):	**Enduring Understanding(s):**
• How do scientists design experiments that produce reliable, unbiased, and meaningful data? • What is the role of the null and alternative hypotheses in helping scientists evaluate whether an effect or difference truly exists? • How do variables (independent, dependent, and controlled) shape the structure and interpretation of an experiment? • How can graphs, data tables, and statistical tools (such as standard error and error bars) help us understand patterns in biological data? • When does evidence allow us to reject or fail to reject a hypothesis, and how do we know whether differences in data are real or due to chance? • How do scientists use quantitative evidence and biological reasoning to build and defend scientific claims?	Unit 0 is designed to build the scientific skills students will use throughout AP Biology. Its primary purpose is to teach students how to think and work like scientists. In this unit, students learn to ask testable questions, design valid experiments, represent data clearly, and use statistical tools to evaluate evidence. Since students have some of these skills already, the central focus is helping students identify variables and controls, differentiate between null and alternative hypotheses, and calculate and interpret the standard error of the mean (SEM).
Demonstration of Learning:	**Pacing for Unit**
Students will complete several sets of practice problems and questions in which they must identify variables and control groups and calculate, graph, and interpret standard error of the mean. Students will conduct a lab investigation in which they determine whether “Double Stuf” Oreos are actually “double the stuff” of regular Oreos. Students must collect reliable data and analyze it, including determining and graphing mean and standard error of the mean, to determine whether their two data sets can be considered statistically meaningful.	3-5 class periods

Students will be assessed on this content throughout the course, but specifically as part of the Unit 1 end-of-unit assessment.	
Family Overview:	**Integration of Technology:**
AP Biology: Family Course Overview (English) AP Biology: Family Course Overview (Spanish)	• Google Slides • *Desmos scientific calculator*
Unit-specific Vocabulary:	**Aligned Unit Materials, Resources, and Technology (beyond core resources):**
Null hypothesis Alternative hypothesis Independent variable Dependent variable Constants Control group (positive and negative) Experimental group Data table Mean (average) Standard deviation Standard error of the mean Confidence interval Error bars Significant difference	None
Opportunities for Interdisciplinary Connections:	**Anticipated misconceptions:**
Math (algebra, statistics)	• Students confuse the Null Hypothesis with a general statement of "no change." • Students write the Alternative Hypothesis as a simple, un-justified prediction or guess. • Students mistakenly identify the Dependent Variable as the factor the scientist changes or controls. • Students confuse the Control Group with the Controlled Variables (Constants). • Students believe the Control Group is simply the group where "everything is held constant." • Students struggle to understand the purpose of a Positive Control, believing only a negative control is necessary. • Students believe Standard Deviation measures the difference between two sample means. • Students use the terms Standard Error and Standard Deviation interchangeably. • Students believe that any overlap in error bars (specifically SEM) definitively proves the results are *not* statistically significant. • Students write a conclusion that only states whether the data "supported" or "did not support" the hypothesis, without citing specific evidence.
Connections to Prior Units:	**Connections to Future Units:**
Students may make connections to the basic statistics and probability content covered in their Geometry course.	Unit 0 provides essential scientific skills that students will use throughout AP Biology. The ability to write hypotheses, identify variables and controls, construct graphs, calculate standard error, interpret error bars, and support claims with evidence forms the foundation for every content unit. Students apply these skills when analyzing enzyme activity and membrane transport (Units 1–2), evaluating rates of photosynthesis and respiration (Unit 3), interpreting cell signaling and division data (Unit

	4), examining inheritance patterns (Unit 5), analyzing gene expression results (Unit 6), evaluating evolutionary changes (Unit 7), and interpreting ecological models and population data. In every unit, scientific practices introduced in Unit 0 enable students to understand data, evaluate evidence, and justify biological explanations.

Differentiation through *Universal Design for Learning*
Learning Targets and Teacher Actions

Learning Target 1:

- Representation: Use a comparison table to clearly contrast the structure, notation, and verbal phrasing of the null hypothesis and the alternative hypothesis. Provide both simple, non-scientific examples (e.g., flipping a coin) and scientific examples (e.g., drug efficacy).
- Action/Expression: Students can be given a research question and asked to write both hypotheses in both symbolic and sentence form. Offer a multiple-choice quiz where students match given sentences to the correct hypothesis type.
- Engagement: Use "myth-busting" scenarios where the null hypothesis represents the established claim or common assumption that the alternative hypothesis attempts to discredit. This adds a compelling real-world challenge.

Learning Target 2:

- Representation: Use color-coding to consistently highlight the independent variable (the factor being manipulated), the dependent variable (the factor being measured), and the control group across different experimental descriptions. Use simple visual models to illustrate the relationship.
- Action/Expression: Provide short summaries of experiments and have students create a visual organizer (like a graphic organizer or Frayer Model) to define and list the variables for each study. Students can also design a simple experiment and label its components.
- Engagement: Use case studies related to student interests (e.g., sports performance, plant growth, reaction time) to practice identification. Use interactive drag-and-drop activities to label the parts of an experimental setup.

Learning Target 3:

- Representation: Provide the formula for SEM and a scaffolded template for calculation. Use visual representations like graphs with error bars (representing SEM) to show how the standard error relates to the spread of sample means and precision of estimation.
- Action/Expression: Students can use a spreadsheet program (like Excel or Google Sheets) to input data and calculate SEM, rather than manual calculation. They can also be asked to write a one-paragraph interpretation of a calculated SEM value in the context of a given study (e.g., "A small SEM suggests the sample mean is a highly precise estimate of the true population mean.").
- Engagement: Introduce SEM as the measure of confidence in their findings. Use a scenario where different groups collect data on the same topic, calculate their SEMs, and discuss which group's result is more reliable, fostering peer discussion and critical thinking about data quality.That's an essential skill for any science course! Here are the UDL strategies for the learning target focused on data and statistical reasoning.

Learning Target 4:

- Representation: Provide multiple examples of data analysis where the conclusion is well-supported versus poorly supported. This should include data presented in different formats: tables, various types of graphs (bar, line, scatter), and written statistical summaries.
- Action/Expression: Offer options for demonstrating understanding: Students can write a formal Conclusion section for a lab report, create a presentation where they walk through a dataset and justify their findings, or use an annotation tool to mark up a peer's conclusion, identifying where data is used effectively or ineffectively.
- Engagement: Use "Evidence vs. Claim" challenge cards where students are given a claim and must find the specific data points or statistical metrics (mean, median, SEM, etc.) that support or refute it. This introduces an element of intellectual play and forces focus on the data-to-conclusion link.

Supporting Multilingual/English Learners (*CELP standards*)

Differentiated Learning Targets

	Emerging	Bridging	Expanding
LT 1	I can identify the two types of hypotheses (null and alternative) and	I can distinguish between the null (H0) and alternative (Ha) hypotheses by	I can formulate precise null and alternative hypotheses (H0 and Ha) for

	state which one predicts no change using key terms (e.g., null, alternative).	writing a simple sentence for each based on a given research question.	a complex scientific investigation and explain the role of each in statistical inference using formal, sophisticated language.
LT 2	I can identify and label the three main parts of an experiment (Independent Variable, Dependent Variable, Control Group) using a diagram or a simple list.	I can describe the function of the independent variable, dependent variable, and control group in an experiment, using connecting words to explain their relationship (e.g., The IV changes, and the DV measures the result).	I can analyze a detailed experimental design and justify the selection of the independent and dependent variables, as well as the importance of the control group, using precise scientific vocabulary and clear rationale.
LT 3	I can define average (mean) and identify that the Standard Error of the Mean (SEM) relates to how accurate the average is.	I can calculate the SEM using a given formula and data set and describe its meaning in a simple sentence (e.g., The SEM tells us how close the sample mean is to the true population mean).	I can calculate and interpret the SEM for a data set, and use it to construct a margin of error or confidence interval, explaining how the SEM relates to sampling variability and statistical significance using mathematical precision and detailed analysis.
LT 4	I can look at a simple bar graph and state which groups are different.	I can describe a simple data pattern (e.g., increase/decrease) and use a piece of evidence (e.g., a mean or a simple p-value) to write a basic conclusion that addresses the research question.	I can evaluate complex data (including measures of variation and significance, like SEM or p-value) and construct an evidence-based conclusion that justifies the support or rejection of the null hypothesis using formal statistical reasoning and cohesive language.

Lesson Sequence	Learning Target	Success Criteria/Assessment/Resources
1	**Learning Target 1** I can distinguish between null and alternative hypotheses.	• I can correctly write a null hypothesis (H_0) that states there is no effect, no difference, or no relationship. • I can write an alternative hypothesis (H_1) that proposes an expected effect, difference, or relationship. • I can decide, based on data, whether to reject or fail to reject the null hypothesis.
2	**Learning Target 2** I can identify independent variables, dependent variables, and control groups.	• I can correctly identify the independent variable (IV) and dependent variable (DV) in an experiment. • I can propose reasonable, specific IV and DV for an experiment based on a scientific question or hypothesis. • I can distinguish constants from variables and explain why consistency matters in a scientific experiment. • I can identify or propose an appropriate control group for an investigation. • I can distinguish between and identify positive and negative controls. • I can explain how control groups help interpret the results of an experiment. • I can evaluate whether an experimental design includes all necessary variables and controls.
3	**Learning Target 3** I can calculate and interpret the standard error of the mean (SEM).	• I can calculate and describe standard deviation for a data set. • I can calculate the standard error of the mean for a data set. • I can accurately add error bars to a graph. • I can interpret error bars to determine whether two

		sample means are statistically significantly different from each other.
4	**Learning Target 4** I can use data and statistical reasoning to support a scientific conclusion.	• I can select accurate evidence from tables, graphs, or experiments. • I can state a clear claim that answers the investigative question. • I can use data patterns such as mean differences, trends, or error-bar interpretation as evidence to support my claim.

Unit Title:

Unit 1: Chemistry of Life

Relevant Standards:

Course Content:
Energetics (ENE)
Information Storage and Transmission (IST)
Systems Interactions (SYI)

Science Practices:
1 - Concept Explanation
1.A: Describe biological concepts and processes.
2 - Visual Representations
2.A: Describe characteristics of visual representations of biological concepts and processes.
6 - Argumentation
6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system.

Essential Question(s):	**Enduring Understanding(s):**
• What is the role of energy in the making and breaking of polymers? • How do living systems transmit information in order to ensure their survival? • How would living systems function without the polarity of the water molecule?	This first unit sets the foundation for students to understand the chemical basis of life, which is needed for mastery of future areas of focus and provides students with a survey of the elements necessary for carbon-based systems to function. Students learn that water and the properties of water play a vital role in the survival of individuals and biological systems. They also learn that living systems exist in a highly complex organization that requires input of energy and the exchange of macromolecules. This unit also addresses in detail how and in what conformations molecules called monomers bond together to form polymers. The structure of monomers and polymers determines their function. In the units that follow, students will need to understand and explain the interaction and bonding of atoms to form molecules.
Demonstration of Learning:	**Pacing for Unit**
Students will construct and present a brief (2-3 minutes) lesson detailing a specific example of how water's unique properties contribute to the success of life on Earth. Students will plan and conduct an experiment investigating how adding solute may impact the surface tension of water. Students will complete the Personal Progress Check MCQs and FRQs for unit 1 on AP Classroom. Students will take a unit assessment at the end of the unit that includes AP-style multiple choice on AP Classroom as well as written responses.	6 class periods 2-3 lab days
Family Overview:	**Integration of Technology:**
AP Biology: Family Course Overview (English) AP Biology: Family Course Overview (Spanish)	• Google Slides • AP Classroom Personal Progress Check
Unit-specific Vocabulary:	**Aligned Unit Materials, Resources, and Technology (beyond core resources):**
Atom Element Compound Cohesion Adhesion Capillary Action	Campbell Biology In Focus Chapter 2 and 3 AP Classroom Unit 1

Molecule Ion Covalent Bond Ionic Bond Hydrogen Bond Polar Nonpolar Solvent Solute Solution Hydrophilic Hydrophobic Surface Tension Polypeptide Enzyme Denaturation Nucleic Acid Nucleotide DNA (Deoxyribonucleic Acid) RNA (Ribonucleic Acid) Double Helix Reactant Product ATP (Adenosine triphosphate)	pH Acid Base Buffer Macromolecule Monomer Polymer Carbohydrate Monosaccharide Disaccharide Polysaccharide Lipid Fatty Acid Triglyceride Phospholipid Steroid Protein Amino Acid Peptide Bond Triphosphate) Isomer Functional Group Saturated Fat Unsaturated Fat

Opportunities for Interdisciplinary Connections:	**Anticipated misconceptions:**
• Math (algebra, geometry, statistics) • Health and Wellness • Chemistry • Anatomy and Physiology	• Students confuse ionic bonds with covalent bonds and/or hydrogen bonds. • They confuse adhesion and cohesion, often believing that cohesion is water sticking to other substances, or that adhesion is only important in capillary action, ignoring its role in surface tension. • They think that a high specific heat means water heats up quickly, instead of understanding that it means water resists changes in temperature. • Students confuse dehydration synthesis (condensation) with hydrolysis, often mixing up which one forms polymers and which one breaks them down. • They believe lipids are made from the same monomer-to-polymer structure as other macromolecules; they don't grasp that lipids (like triglycerides) are assembled from smaller components (glycerol and fatty acids) but aren't true polymers.
Connections to Prior Units:	**Connections to Future Units:**
This unit builds upon the subject matter covered in accelerated biology.	Properties of water as well as the structures and functions of biological macromolecules will be fundamental to all future units as they are the chemical building blocks of all life on Earth.

Differentiation through *Universal Design for Learning*
Learning Targets and Teacher Actions

Learning Targets 1 and 2:

- Representation: Provide visual aids (diagrams or videos) showing water molecules and their interactions. Use analogies or metaphors (e.g., comparing water molecules to magnets) to explain polarity.

- Action/Expression: Act out “tug of war” with electrons between oxygen and hydrogen in a water molecule to demonstrate polarity.Students demonstrate understanding by creating a brief presentation of their own design to teach a property of water to their classmates.
- Engagement: Encourage group discussions and peer teaching to explore the properties of water. Incorporate hands-on activities, such as experiments demonstrating water's properties (e.g., surface tension of water on a penny).

Learning Target 3:

- Representation: Provide models of macromolecules (carbohydrates, proteins, lipids, nucleic acids). Use videos or animations to show how macromolecules are formed and function.
- Action/Expression: Allow students to create a chart or poster summarizing the types of macromolecules and their functions. Encourage students to build a physical model of a macromolecule using craft materials.
- Engagement: Organize a scavenger hunt where students find examples of macromolecules in everyday items. Use gamification techniques to quiz students on the composition of macromolecules.

Learning Target 4:

- Representation: Provide labeled diagrams showing monomers and polymers with bond types highlighted. Use simulations to visualize the formation of bonds between monomers.
- Action/Expression: Allow students to create flashcards with monomers and their corresponding biological molecules. Encourage students to demonstrate understanding through a creative project, such as a comic strip.
- Engagement: Facilitate collaborative group work where students teach each other about different monomers and bonds. Utilize interactive quizzes or online platforms for students to engage with the content.

Supporting Multilingual/English Learners (*CELP standards*)
Differentiated Learning Targets

	Emerging	Bridging	Expanding
LT 1	I can label a water molecule as polar and name 2-3 of its basic properties (e.g., cohesion, good solvent).	I can describe how the partial charges on a water molecule lead to hydrogen bonding and explain two specific properties (e.g., cohesion and adhesion) using cause-and-effect language.	I can analyze and explain how the polarity of water and the resulting hydrogen bonds are responsible for at least three properties (e.g., high specific heat, surface tension, versatility as a solvent), using precise chemistry terminology.
LT 2	I can match one property of water (e.g., adhesion) to a simple function in a living thing (e.g., plants get water).	I can describe two specific ways water's properties (e.g., high specific heat and low density of ice) support life on Earth, using connected sentences and academic terms (e.g., temperature regulation, insulation).	I can construct a detailed argument that explains and justifies at least three properties of water that are essential for maintaining biological processes (e.g., capillary action in plants, solvent capability in cells), using coherent, evidence-based reasoning.
LT 3	I can name the four types of macromolecules (e.g., carbohydrates, lipids, proteins, nucleic acids) and list one main element in each (e.g., carbon).	I can describe the basic elemental composition and general function for each of the four macromolecules (e.g., Carbohydrates have C, H, O and are for energy), using academic vocabulary.	I can compare and contrast the elemental composition and diverse functions of the four major macromolecules, analyzing how their chemical make-up dictates their roles in a cell, using detailed and precise scientific language.
LT 4	I can match each macromolecule with its correct monomer (e.g., protein: amino acid) and identify that a covalent bond connects them.	I can describe the relationship between monomers and polymers for at least three macromolecules and explain that a dehydration synthesis reaction creates the covalent bond that links them.	I can analyze and explain the process of polymerization (dehydration synthesis/hydrolysis) for at least three macromolecules, naming the specific covalent bonds (e.g., peptide bond, glycosidic bond) that link their monomers, using high-level scientific discourse.

Lesson Sequence	Learning Target	Success Criteria/Assessments Resources
1 -2	**Learning Target 1**	• I can define and connect key properties to molecular interactions: T • I can explain how water's polarity causes hydrogen

	I can identify the properties of water that result from its polarity and hydrogen bonding.	bonding. • I can describe examples in nature and link them directly back to the unique properties of water driven by hydrogen bonding. • I can compare and contrast water with a non-polar liquid by predicting differences in properties such as boiling point, solubility, or surface tension, and justifying these differences based on the presence or absence of hydrogen bonding.
	Learning Target 2 I can explain specific ways in which the properties of water are critical to life on Earth.	• I can link properties of water to biological processes or environmental functions.. • I can justify why specific functions of water are critical to the survival of an organism or ecosystem.
3 - 6	**Learning Target 3** I can describe the composition of macromolecules required by living organisms.	• I can identify the biological macromolecules fundamental to all living things (carbohydrates, proteins, lipids, and nucleic acids). • I can describe the role that carbon plays in biological molecules. • I can identify the biological molecule types that use nitrogen and phosphorus in their structures.
	Learning Target 4 I can name and describe the monomers in biological molecules as well as the types of bonds that connect them.	• I can define the term hydrolysis and describe how it is used to cleave covalent bonds between monomers. • I can define the term dehydration synthesis and describe how it is used to form covalent bonds between monomers. • I can recognize, name and describe the monomers of nucleic acids. • I can recognize, name and describe the monomers of proteins. • I can recognize, name and describe the monomers of carbohydrates. • I can describe the basic properties of lipids and explain how differences in saturation determine their structure and function. • I can describe the structure of a phospholipid and explain how these molecules interact with one another to form membranes.

Unit Title:

Unit 2: Cell Structure and Function

Relevant Standards:

Course Content:
Energetics (ENE)
Evolution (EVO)
Systems Interactions (SYI)

Science Practices:
1 - Concept Explanation
- 1.A: Describe biological concepts and processes.
- 1.B: Explain biological concepts and processes.

2 - Visual Representations
- 2.A: Describe characteristics of visual representations of biological concepts and processes.
- 2.D: Represent relationships within biological models, including mathematical models, diagrams, flowcharts, and systems.

3 - Questions and Methods
- 3.D: Propose a new investigation based on an evaluation of the experimental design or evidence.

4 - Representing and Describing Data
- 4.A: Construct a graph to represent the data, including: x-y graphs (bar,histogram, line, log scale, dual y), scatterplot, box and whisker plot, and pie chart.

5 - Statistical Tests and Data Analysis
- 5.A: Perform mathematical calculations, including mathematical equations in the curriculum, means, rates, ratios, percentages and percent changes
- 5.D: Use data to evaluate a hypothesis or prediction, including rejecting or failing to reject the null hypothesis.

6 - Argumentation
- 6.A: Make a scientific claim.
- 6.B: Support a claim with evidence from biological principles, concepts, processes, and data.
- 6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system.

Essential Question(s):	**Enduring Understanding(s):**
• How did eukaryotic cells originate? • How do the mechanisms for transport across membranes support energy conservation? • What are the advantages and disadvantages of cellular compartmentalization? • How are living systems affected by the presence or absence of subcellular components?	The cell is the basic unit of life. Cells contribute to the organization of life and provide the environment in which organelles function. Organelles in turn provide compartmentalization and organize cellular products for dispersal and waste for disposal. Cells have membranes that allow them to establish and maintain an internal environment. These membranes also control the exchange of material with the cell's external environment.
Demonstration of Learning:	**Pacing for Unit**
Students will create a "dating profile" or a chosen/assigned cell part and teach their classmates about its structure and function during a "speed dating" activity. Students will conduct and analyze an experiment investigating how cell size (and therefore surface area-to-volume ratio) impacts the efficiency of its access to materials in its environment.. Students will conduct an experiment investigating the tonicity of potato cells and use the results to calculate the sucrose concentration of the potato cells. Students will complete the Personal Progress Check MCQs and FRQs for unit 2 on AP Classroom. Students will take a unit assessment at the end of the unit	7-10 class periods 2-3 lab days

that includes AP-style multiple choice on AP Classroom as well as written responses (FRQs).	
Family Overview:	**Integration of Technology:**
AP Biology: Family Course Overview (English) AP Biology: Family Course Overview (Spanish)	*AP Classroom* *Desmos scientific calculator* *Google Sheets* *Google Slides* *AP Classroom topic quizzes and Progress Check*
Unit-specific Vocabulary:	**Aligned Unit Materials, Resources, and Technology (beyond core resources):**
Cell Theory Prokaryotic Cell Eukaryotic Cell Plasma Membrane Cytoplasm Nucleus Nucleolus Nuclear Envelope Chromatin Ribosome Smooth Endoplasmic Reticulum (Smooth ER) Rough Endoplasmic Reticulum (Rough ER) Golgi Apparatus (Golgi Body) Lysosome Vacuole Peroxisome Mitochondrion Chloroplast Cytoskeleton Microtubules Microfilaments Intermediate Filaments Centrioles Cilia Flagella Cell Wall Plasmodesmata Phospholipid Bilayer Fluid Mosaic Model Selective Permeability Transport Protein Diffusion Facilitated Diffusion Osmosis Isotonic Solution Hypertonic Solution Hypotonic Solution Active Transport Passive Transport Concentration Gradient Sodium-Potassium Pump Cotransport Endocytosis Exocytosis Phagocytosis Pinocytosis Receptor-Mediated Endocytosis	• Campbell Biology In Focus Chapters 4 and 5 • AP Classroom Unit 2
Opportunities for Interdisciplinary Connections:	**Anticipated misconceptions:**
• Math (algebra, geometry, statistics) • Health and Wellness • Chemistry • Anatomy and Physiology	• Students confuse the importance of cell size/volume with the importance of a high surface area-to-volume ratio. They often don't grasp that the ratio determines the efficiency of substance exchange, which limits cell size---it is not the cell size itself that is the key concept. • The typical process/flow of the endomembrane system can be difficult. Students find it hard to grasp the sequence of molecule production in the ER, vesicle transport to the Golgi for modification/sorting/packaging, and then subsequent transport to a variety of cellular regions depending on function. • Students often begin with the misconception that the cell membrane is a rigid, static barrier, not understanding that it is a fluid mosaic where proteins and lipids constantly shift position (lateral movement). • They confuse facilitated diffusion with active transport. Students struggle to remember that

	facilitated diffusion is still passive (no ATP is required) and moves substances down the concentration gradient, using a transport protein. • They assume all movement across a concentration gradient requires a pump, overlooking the role of co-transport which uses the energy of an existing gradient. • Hypotonic vs. hypertonic are confusing vocabulary terms. Students struggle to differentiate between the relative concentrations of water vs. relative concentrations of a solute in order to accurately compare tonicity and predict movement of water.
Connections to Prior Units:	**Connections to Future Units:**
Students will need to apply their knowledge of biological macromolecules from Unit 1 to understand the structural components of cell membranes and the various functions of those components.	The structure of membranes and organelles dictates where and how energy is harvested (Unit 3: Cellular Energetics), how the functions of membrane proteins are essential for receiving and relaying information (Unit 4: Cell Communication), and how the nucleus and ribosomes serve as the machinery for genetics and protein synthesis (Units 5 & 6). Therefore, Unit 2 establishes the crucial context for compartmentalization, transport, and communication that defines life's processes.

Differentiation through *Universal Design for Learning*
Learning Target and Teacher Actions

Learning Target 1:

- Representation: Provide detailed, color-coded diagrams of both prokaryotic and eukaryotic cells, along with a comparison chart summarizing the function of each key organelle (e.g., mitochondria, nucleus, endoplasmic reticulum). Use 3D models or virtual tours of a cell to visualize compartmentalization.
- Action/Expression: Students can create a metaphor or analogy for a cell (e.g., the cell as a factory) and assign an organelle's function to a factory component. They can also build a presentation or write a report specifically explaining how the endosymbiotic theory relates to the origin of some organelles and compartmentalization.
- Engagement: Introduce a "Cell City" design challenge where students must design and label a city based on organelle functions, reinforcing their roles and interactions.

Learning Target 2:

- Representation: Provide visual examples and mathematical calculations showing how the surface area-to-volume ratio changes as cell size increases. Use a graph to plot cell size to clearly show the diminishing ratio.
- Action/Expression: Students can conduct a lab or simulation (e.g., using agar blocks) to calculate and visually compare the rate of diffusion in objects with different ratios. They could also write a persuasive argument explaining why cells must remain small or why large organisms require specialized exchange surfaces (like lungs or gills).
- Engagement: Use real-world examples of optimization, such as the folding of the small intestine or the flatness of leaves, allowing students to choose an organism to analyze its structure based on this ratio.

Learning Target 3:

- Representation: Use a clear, labeled diagram of the plasma membrane that highlights and defines the roles of the key components: phospholipids, proteins (integral and peripheral), cholesterol, and glycocalyx (glycoproteins/glycolipids).
- Action/Expression: Students can build a physical model of the cell membrane using different colored materials to represent the components. Alternatively, they can create a chart or table summarizing the specific function of each component (e.g., protein channels transport, cholesterol stability).
- Engagement: Use a "Membrane Barrier" activity where students are given scenarios and must determine which membrane component is responsible for the interaction (e.g., receiving a signal, transport, or cell identification).

Learning Target 4:

- Representation: Use dynamic animations or video clips that illustrate the "fluid" nature of the membrane (lateral movement of phospholipids) and the "mosaic" nature (embedded, scattered proteins). Provide a

written definition alongside a visual metaphor.
- Action/Expression: Students can create an annotated drawing of the fluid mosaic model, labeling and explaining the two key terms ("fluid" and "mosaic"). They could also write a descriptive poem or narrative from the perspective of a protein moving within the lipid bilayer.
- Engagement: Introduce a compare/contrast task challenging students to explain how the modern Fluid Mosaic Model is different from earlier, more static models of the cell membrane.

Learning Target 5:
- Representation: Use a step-by-step flowchart illustrating the permeability path:
- Action/Expression: Students can be given a list of molecules and asked to predict and justify their ease of movement across the membrane. They could also create a "bouncer" analogy where the membrane structure acts as a bouncer, admitting only certain molecules.
- Engagement: Introduce a critical thinking task asking students to design a synthetic membrane and choose specific components to make it selectively permeable to a certain drug molecule.

Learning Target 6:
- Representation: Provide side-by-side diagrams and photos of plant cells, fungi cells, and bacterial cells, highlighting the cell wall structure and composition in each. Use written case studies on the structural differences between plant cells (cellulose) and bacterial cells (peptidoglycan).
- Action/Expression: Students can compare and contrast the primary role of the cell wall (structural support, protection, maintaining turgor) with the primary role of the plasma membrane. They could also create a model demonstrating how the cell wall prevents excessive water uptake (turgidity).
- Engagement: Discuss the medical relevance of the cell wall by exploring how antibiotics target the bacterial cell wall, which can lead to a discussion on antibiotic resistance.

Learning Target 7:
- Representation: Use visual examples of cells in different tonicity environments (isotonic, hypotonic, hypertonic), clearly showing the direction of water movement via osmosis. Provide a concept chart summarizing osmoregulatory mechanisms in different organisms (e.g., fish in fresh vs. salt water, plants in drought).
- Action/Expression: Students can draw and label the results of placing animal and plant cells in different solutions (e.g., hemolysis, plasmolysis, turgidity). They could also write an expository essay detailing the specific adaptations an organism uses to maintain water balance in a challenging environment.
- Engagement: Use a clinical case study about dehydration or kidney function to relate the concepts of solute and water balance to human homeostasis.

Learning Target 8:
- Representation: Use animated diagrams or videos to illustrate the processes of endocytosis (phagocytosis, pinocytosis, receptor-mediated endocytosis) and exocytosis. Provide a narrated explanation of the bulk transport mechanisms.
- Action/Expression: Students can create a sequence of panels (like a comic strip) to visually explain the steps of phagocytosis or exocytosis. They could also create a short skit or demonstration to act out the membrane changes required for bulk transport.
- Engagement: Discuss the roles of endocytosis and exocytosis in essential processes like neurotransmitter release at synapses or immune system activity (macrophages engulfing bacteria), highlighting biological significance.

Learning Target 9:
- Representation: Use simple, clear diagrams with color gradients to illustrate a concentration gradient. Use an analogy like a ball rolling down a hill (passive transport) versus a ball being pushed up a hill (active transport) to explain movement with and against the gradient.
- Action/Expression: Students can write a set of rules for molecular movement, stating whether a molecule will move up or down the gradient and whether energy is required. They could also design a simple experiment to show the effect of changing the steepness of a gradient on the rate of diffusion.
- Engagement: Use a sorting activity where students classify transport mechanisms (simple diffusion, facilitated diffusion, active transport) based on whether they require a gradient or energy (ATP).

Supporting Multilingual/English Learners (*CELP standards*)
Differentiated Learning Targets

	Emerging	Bridging	Expanding
LT 1	I can identify and name 3-4 major organelles (e.g., nucleus, mitochondria,	I can describe the basic structure and function of several organelles and explain that internal membranes	I can analyze and explain in detail how the unique structure of key organelles contributes to the overall function of

	chloroplast) and state their simple function.	create separate spaces (compartments) in a eukaryotic cell using connected sentences.	the cell, justifying how compartmentalization by internal membranes increases efficiency for complex processes using sophisticated and precise scientific language.
LT 2	I can identify that a smaller cell has a better ratio (more surface area for its inside volume).	I can describe the concept of the surface area-to-volume ratio (SA/V) and explain using a simple comparison how a high SA/V ratio facilitates more efficient exchange of materials (e.g., nutrients and waste).	I can calculate and analyze the SA/V ratio of different cell shapes/sizes, and construct a detailed argument to explain how organisms and cells (e.g., intestinal lining, plant roots) have structural modifications that increase the ratio for optimal exchange.
LT 3	I can label the main parts of the membrane (e.g., phospholipid, protein) and state that it controls what goes in and out.	I can describe the roles of the phospholipid bilayer and membrane proteins in maintaining homeostasis and regulating transport across the cell's internal environment, using academic vocabulary.	I can analyze the interplay between phospholipids, various proteins (e.g., integral, peripheral), and cholesterol, and explain how their specific molecular roles dynamically maintain the cell's internal environment and selective permeability.
LT 4	I can define fluid and mosaic in the context of the cell membrane model.	I can describe the fluid mosaic model by explaining that the proteins float within the fluid phospholipid bilayer, and use this to explain the dynamic nature of the membrane.	I can explain and justify why the fluid mosaic analogy is accurate, detailing how the lateral movement of phospholipids (fluid) and the random distribution of proteins (mosaic) contribute to the membrane's structure and function.
LT 5	I can identify that the membrane only lets some things in (selective) and name a molecule that can pass easily (e.g., water, oxygen).	I can explain how the nonpolar core of the phospholipid bilayer makes the membrane selectively permeable, and describe how the size and charge of a molecule affect its ability to cross.	I can analyze and explain how the interaction between the hydrophobic tails and hydrophilic heads of the bilayer, coupled with the presence of transport proteins, determines the passage of a diverse range of molecules, using precise chemistry and physics terms.
LT 6	I can name the type of cell that has a cell wall (e.g., plant, bacteria) and state that its function is for support/protection.	I can describe the structural composition of the cell wall in plants (or other cells) and explain how it maintains cell shape and prevents excessive water uptake (lysis).	I can compare and contrast the composition and specific roles of the cell wall in different domains (e.g., plants vs. fungi vs. bacteria), and analyze its importance in turgor pressure and overall organism function.
LT 7	I can define solute and water balance (osmosis) and identify that water moves from high to low concentration.	I can describe the process of osmosis and explain two mechanisms (e.g., contractile vacuole, turgor pressure) that organisms or cells use to achieve osmoregulation in different environments (e.g., fresh vs. salt water).	I can analyze and explain the mechanisms of osmoregulation and tonicity (hypo-, iso-, hypertonic) in both plant and animal cells, justifying the structural adaptations that allow different organisms to maintain solute and water homeostasis.
LT 8	I can name the two types of bulk transport (endocytosis and exocytosis) and state that they move big things.	Can describe the sequential steps of endocytosis and exocytosis using transition words (e.g., first, then, the vesicle moves).	Can explain and justify why bulk transport is the only viable mechanism for large molecules (like proteins or polysaccharides) that are too big for protein channels or carriers.
LT 9	I can identify and name 3-4 major organelles (e.g., nucleus, mitochondria, chloroplast) and state their simple function.	I can describe the basic structure and function of several organelles and explain that internal membranes create separate spaces (compartments) in a eukaryotic cell using connected sentences.	I can analyze and explain in detail how the unique structure of key organelles contributes to the overall function of the cell, justifying how compartmentalization by internal membranes increases efficiency for complex processes using sophisticated and precise scientific language.

Lesson Sequence	Learning Target	Success Criteria/Assessment/Resources
1	**Learning Target 1** I can explain how the structure and function of subcellular components and organelles contribute to the function of cells, and can describe how internal membranes/membrane-bound organelles contribute to compartmentalization of eukaryotic cell functions.	• I can describe the structure and function of ribosomes. • I can describe the structure and function of the endomembrane system that work together to modify, package, and transport macromolecules. • I can identify the functions of the smooth and rough regions of the endoplasmic reticulum. • I can identify the functions of organelles including the Golgi complex, mitochondria, lysosomes, vacuoles, and chloroplasts. • I can describe how membranes and membrane-bound organelles within eukaryotic cells compartmentalize and facilitate intracellular metabolic processes.
2	**Learning Target 2** I can explain the effect of surface area-to-volume ratios on the exchange of materials between cells or organisms and the environment.	• I can describe how surface area-to-volume ratios affect the ability of a biological system to obtain necessary nutrients, eliminate waste products, and exchange chemicals and energy with the environment, thereby restricting cell size and shape.
3	**Learning Target 3** I can describe the roles of each of the components of the cell membrane in maintaining the internal environment of the cell.	• I can describe how the properties of phospholipids cause them to organize into bilayer membranes with polar external and nonpolar internal regions.
4	**Learning Target 4** I can describe the fluid mosaic model of cell membranes.	• I can explain how the structural components of membranes, including phospholipids, cholesterol, and proteins relate to describing membranes as “fluid mosaics”.
5	**Learning Target 5** I can explain how the structure of biological membranes influences selective permeability and how the structure of a molecule affects its ability to pass through membranes.	• I can explain how membranes separate the internal environment of the cell from the external environment. • I can differentiate between molecules that can freely pass across the membrane, can pass in small amounts, or require facilitated transport based on their properties. • I can describe the function of aquaporins.
6	**Learning Target 6** I can describe the role of the cell wall in maintaining cell structure and function.	• I can describe how the cell walls of bacteria, archaea, fungi and plants provide structural boundaries as well as permeability barriers. • I can describe how cell walls provide protection from osmotic lysis.
7	**Learning Target 7** I can describe the mechanisms that organisms use to maintain solute and water balance.	• I can define the term concentration gradient and predict the direction of diffusion of molecules toward equilibrium. • I can differentiate between passive and active transport of molecules across a membrane.
8	**Learning Target 8** I can describe the mechanisms that organisms use to transport large molecules across the plasma membrane.	• I can describe and differentiate between the processes of endocytosis and exocytosis.
9	**Learning Target 9** I can explain how concentration gradients affect the movement of molecules across membranes.	• I can compare hypotonic, hypertonic and isotonic environments . • I can calculate water potential and use it to predict the movement of water by osmosis • I can explain how osmoregulation contributes to the health and survival of organisms.

Unit Title:	
Unit 3: Cellular Energetics	
Relevant Standards:	
Course Content: Energetics (ENE) Systems Interactions (SYI) **Science Practices:** 1 - Concept Explanation 1.B: Explain biological concepts and processes. 3 - Questions and Methods 3.C: Identify experimental procedures that align with the question, including identifying independent and dependent variables and appropriate controls. 4 - Representing and Describing Data 4.A: Construct a graph to represent the data, including: x-y graphs (bar,histogram, line, log scale, dual y), scatterplot, box and whisker plot, and pie chart. 6 - Argumentation 6.B: Support a claim with evidence from biological principles, concepts, processes, and data. 6.C: Provide reasoning to justify a claim by connecting evidence to biological theories. 6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system.	
Essential Question(s):	**Enduring Understanding(s):**
• How is energy captured and then used by a living system? • How do organisms use energy or conserve energy to respond to environmental stimuli?	Living systems are complex in their organization and require constant energy input. This unit provides students with the knowledge necessary to master the concepts of energy capture and usage. Students work through enzyme structure and function, learning the ways in which the environment plays a role in how enzymes perform their function(s). Students gain a deeper understanding of the processes of photosynthesis and cellular respiration and how they are critical to transforming energy into usable forms for cellular process, which is knowledge they will use in Unit 6 while studying how cells use energy to fuel life processes.
Demonstration of Learning:	**Pacing for Unit**
Students will participate in a demonstration of energy transfer and transformation within part 1 of photosynthesis by acting out the various proteins and protein complexes involved in the light-dependent reactions. Students will conduct and analyze an experiment investigating how enzymes are impacted by a wide variety of environmental factors, including temperature, inhibitors, substrate concentration and enzyme concentration. Students will conduct and analyze an experiment investigating the rate of cellular respiration in peas that have been subjected to different environmental temperatures. Students will design and conduct an inquiry-based investigation into the relative rates of photosynthesis and cellular respiration in algae by manipulating one variable of their choosing (ex. temperature, pH, light intensity, light color).	6-10 class periods 2-3 lab days

Students will complete the Personal Progress Check MCQs and FRQs for unit 3 on AP Classroom. Depending on timing, students may take a unit assessment at the end of the unit that includes AP-style multiple choice on AP Classroom as well as written responses (FRQs). If they do not take a stand-alone unit 3 assessment, they will instead be assessed on unit 3 content in a similar format as part of their midterm exam.	
Family Overview:	**Integration of Technology:**
AP Biology: Family Course Overview (English) AP Biology: Family Course Overview (Spanish)	• Google Slides • AP Classroom Personal Progress Check, AP Daily videos, and topic quizzes • *Desmos scientific calculator* • *Google Sheets*
Unit-specific Vocabulary:	**Aligned Unit Materials, Resources, and Technology (beyond core resources):**
Free energy Enzyme Catalyst Active sit Substrate Induced fit Activation energy Cofactor Coenzyme Allosteric regulation Inhibitor Competitive inhibition Noncompetitive inhibition ATP Phosphorylation Cellular respiration Glycolysis Krebs (Citric Acid) Cycle Electron transport chain (ETC) Oxidative phosphorylation Chemiosmosis Aerobic Anaerobic Fermentation Photosynthesis Light-dependent reactions Calvin cycle Carbon Oxidation Chlorophyll Photosystem Proton gradient NADPH/NADP+/NADH/NAD+ Photon Autotroph heterotroph	• Campbell Biology In Focus Chapters 6-8 • AP Classroom Unit 3
Opportunities for Interdisciplinary Connections:	**Anticipated misconceptions:**
• Math (algebra, statistics) • Health and Wellness • Chemistry • Anatomy and Physiology	• Students often think enzymes provide energy to start a reaction instead of understanding that enzymes work by lowering the energy of activation • Students confuse or struggle to differentiate between allosteric binding sites and active sites of enzymes • Students often assume that oxygen gas is the goal/primary product of photosynthesis rather than a product of the processes needed to synthesize glucose. • Electron carriers (NADPH, NADH, $FADH_2$) are not overall reactants/products of photosynthesis and cellular respiration, but rather temporarily store and transfer energy throughout these processes in the form of high-energy electrons. • Cellular respiration is not the same as breathing---it is a metabolic pathway in all organisms. • Students confuse protons and proteins often in the

	unit as they sound similar and are both used frequently. • Students sometimes struggle to understand that a proton gradient powers the process of synthesizing ATP from ADP but the ions themselves are not actually added to ADP.
Connections to Prior Units:	**Connections to Future Units:**
Unit 3 is the culmination of chemical and structural foundations from Units 1 and 2. The entire study of cellular energetics—how cells acquire and use energy—is fundamentally dependent on biological macromolecules (Unit 1), particularly enzymes (proteins) that catalyze every step in the metabolic pathways of photosynthesis and cellular respiration. Furthermore, these energy transformations occur within the physical confines established in Unit 2: Cell Structure and Function. Specifically, the elaborate membrane structure and compartmentalization of the mitochondria and chloroplasts are required to maintain the H^+ gradients that drive ATP synthesis via chemiosmosis. Moreover, the study of chloroplasts and mitochondria needed for photosynthesis and aerobic respiration provides key evidence for Evolution (Unit 7) through adaptation and endosymbiosis, and the overall balance between photosynthesis and respiration dictates the flow of energy through ecosystems, linking directly to Ecology (Pre-Work).	The chemical energy generated in Unit 3, primarily in the form of ATP, is the immediate energy currency that powers all processes studied in subsequent units. For example, ATP is required to fuel the pumps and active transport necessary for signal transduction in Cell Communication (Unit 4), and it provides the energy for the polymerization of DNA and RNA in Heredity and Gene Expression (Units 5 and 6).

Differentiation through *Universal Design for Learning*
Learning Targets and Teacher Actions

Learning Target 1:

- Representation: Use dynamic animations or 3D models to show the induced-fit model of enzyme action, highlighting the active site and the interaction with the substrate. Provide a labeled diagram of an enzyme and substrate, along with a written explanation of how enzymes lower the activation energy.
- Action/Expression: Students can build a physical model of an enzyme, substrate, and active site using manipulatives. They could also create a flow chart showing how an enzyme speeds up a reaction, or write a short script explaining the lock-and-key or induced-fit analogy.
- Engagement: Introduce a real-world problem where an organism is lacking a critical enzyme (e.g., lactase deficiency) and have students explain the resulting chemical inefficiency.

Learning Target 2:

- Representation: Provide graphs showing the effect of pH and temperature on enzyme activity, and clearly label the optimum conditions and the point of denaturation. Use a visual diagram to show the difference between competitive and non-competitive inhibitors.
- Action/Expression: Students can design and sketch a simple experiment to test how changing the temperature or pH affects a common enzyme (e.g., catalase or amylase). They could also create a comparison table detailing the mechanism and site of action for allosteric, competitive, and non-competitive regulators.
- Engagement: Use a case study on the medical use of enzyme inhibitors (e.g., certain drugs) or the effect of fever on human enzyme function to ground the concepts in health and medicine.

Learning Target 3:

- Representation: Use a summary diagram of the light-dependent reactions that shows the flow of electrons through Photosystem II and I. Provide a narrated video explaining how pigments capture light energy and transfer it to the reaction center complex.
- Action/Expression: Students can create a labeled diagram of the thylakoid membrane, tracing the path of light, water, electrons, and resulting ATP and NADPH. They could also write a step-by-step procedure of the light-dependent reactions.

- Engagement: Use a digital simulation where students can adjust light intensity and wavelength to see the effect on ATP and NADPH production.

Learning Target 4:

- Representation: Provide a simplified cyclical diagram of the Calvin cycle, focusing on the key phases: carbon fixation, reduction, and regeneration of RuBP. Use an input/output chart to track the number of CO2, ATP and NADPH molecules required to produce one molecule of G3P.
- Action/Expression: Students can physically model the cycle using colored tokens or blocks to represent carbon molecules at each stage. They could also write a narrative from the perspective of a carbon atom traveling through the cycle.
- Engagement: Compare the Calvin cycle to a chemical "assembly line" that uses the energy currency ATP and NADPH created in the light reactions to build the final product.

Learning Target 5:

- Representation: Provide a flowchart of glycolysis that highlights the initial investment phase and the energy payoff phase, noting the production of ATP (net 2), NADH and pyruvate. Use a diagram to show the pyruvate oxidation step (transition) that prepares the molecule for the Krebs cycle.
- Action/Expression: Students can complete a balance sheet tracking the carbon atoms and energy molecules at the end of glycolysis and the transition phase. They could also create a labeled concept map detailing the location and inputs/outputs of these processes.
- Engagement: Use a gamified quiz where students have to correctly identify the location (cytoplasm vs. mitochondrion) and products of each stage of glucose breakdown.

Learning Target 6:

- Representation: Use a detailed diagram or animation showing the ETCin the mitochondrial inner membrane, illustrating how electrons from NADH and FADH2 power the pumping of H+ ions to create a gradient. Clearly show the role of ATP synthase and chemiosmosis (the flow of H+ back into the matrix.
- Action/Expression: Students can create a visual model of the inner mitochondrial membrane to demonstrate the proton gradient and the action of ATP synthase. They could also write an explanation focusing on the role of oxygen as the final electron acceptor.
- Engagement: Use the analogy of a hydroelectric dam to explain how the H+ gradient (water behind the dam) powers the ATP synthase (turbine) to generate energy.

Learning Target 7:

- Representation: Provide a comparison chart clearly contrasting aerobic respiration (requires O2) with the two main types of fermentation (lactic acid and alcohol). Use a diagram to specifically show how NADH is recycled back to NAD+ during fermentation.
- Action/Expression: Students can create a small informational poster explaining the role of fermentation in a specific application (e.g., making yogurt or bread). They could also write a short answer explaining why NAD+ regeneration is the key function of fermentation.
- Engagement: Engage students in a discussion about the "burn" felt in muscles during intense exercise (lactic acid fermentation) or the processes involved in making common fermented foods and drinks.

Supporting Multilingual/English Learners (*CELP standards*)
Differentiated Learning Targets

	Emerging	Bridging	Expanding
LT 1	I can define enzyme and identify the active site on a diagram. I can state that enzymes speed up reactions.	I can describe the lock-and-key or induced-fit model and explain how the specific shape of the active site allows the enzyme to efficiently catalyze (speed up) a reaction.	I can analyze and explain how the tertiary structure of an enzyme creates the specific microenvironment of the active site, and justify how this structural specificity lowers the activation energy to control reaction rates with precise vocabulary.
LT 2	I can identify two conditions that can stop an enzyme from working (e.g., high heat, extreme pH) and state that the enzyme becomes denatured.	I can describe how changes in pH and temperature affect an enzyme's three-dimensional structure and explain the difference between a competitive and non-competitive inhibitor using cause-and-effect language.	I can analyze and evaluate the effect of allosteric regulation and various environmental factors on enzyme kinetics, explaining how these regulatory mechanisms maintain cellular homeostasis and control metabolic pathways using detailed scientific rationale.
LT 3	I can identify the overall inputs (CO2, H2O) and outputs (O2, sugar) of	I can describe that the photosystems (I and II) in the thylakoid membranes	I can explain and analyze the conversion of light energy to chemical energy

	photosynthesis and state that it uses light energy.	capture light and use that energy to create ATP and NADPH, using sequencing words to show the flow of energy.	during the light-dependent reactions, detailing the excitation of electrons in photosystems and the subsequent generation of ATP and NADPH through an electron transport chain.
LT 4	I can name the Calvin Cycle and state that it uses CO2 to make sugar (carbohydrates).	I can describe the Calvin cycle as the light-independent reactions and explain its role in fixing carbon from CO2 into an organic molecule, using the energy from ATP and NADPH from the light reactions.	I can analyze and explain the three main phases of the Calvin cycle (carbon fixation, reduction, and regeneration), detailing the role of the enzyme RuBisCO and the net output of G3P, using complex academic language to connect the overall process.
LT 5	I can identify that glycolysis breaks glucose into two parts and produces a small amount of ATP in the cytoplasm.	I can describe that glycolysis is the first step of cellular respiration, produces pyruvate, and that this pyruvate is then oxidized as it moves into the mitochondria to become Acetyl-CoA for the Krebs cycle.	I can explain and analyze the net energy yield of glycolysis (ATP and NADH) and the decarboxylation of pyruvate during the transition step, justifying the movement of molecules and the readiness for the subsequent Krebs cycle.
LT 6	I can identify the ETC as the step that makes the most ATP and state that it uses oxygen and the inner mitochondrial membrane.	I can describe the role of NADH and FADH2 in supplying electrons to the ETC, and explain how the movement of electrons powers proton pumps to build an H+ gradient for chemiosmosis.	
LT 7	I can define enzyme and identify the active site on a diagram. I can state that enzymes speed up reactions.	I can describe the lock-and-key or induced-fit model and explain how the specific shape of the active site allows the enzyme to efficiently catalyze (speed up) a reaction.	I can analyze and explain how the tertiary structure of an enzyme creates the specific microenvironment of the active site, and justify how this structural specificity lowers the activation energy to control reaction rates with precise vocabulary.

Lesson Sequence	Learning Target	Success Criteria/Assessment/Resources
1	**Learning Target 1** I can explain how the structure and function of enzymes, including their active sites, help organisms efficiently control the rate of chemical reactions.	• I can explain that enzymes are proteins whose shape determines their function and specificity. • I can describe the role of the active site in binding to a substrate. • I can explain that enzymes lower the activation energy of a reaction without being consumed by it. • I can identify and explain the steps of the Enzyme-Substrate Complex formation.
2	**Learning Target 2** I can explain how enzyme function is affected by environmental conditions and other regulatory molecules.	• I can describe the effect of temperature and pH changes on enzyme shape and activity and can accurately apply the term denaturation. • I can explain how changes in substrate, product or enzyme concentration affect the reaction rate. • I can differentiate between competitive and noncompetitive inhibitors and explain their effect on enzyme activity. • I can describe the process of allosteric regulation and feedback inhibition in metabolic pathways.
3	**Learning Target 3** I can describe the process of photosynthesis and explain how photosystems capture and convert light energy into chemical energy.	• I can identify the primary locations of photosynthesis (chloroplasts, specifically thylakoids and stroma) in eukaryotic cells. • I can explain the role of chlorophyll and other pigments in absorbing light energy. • I can explain that Photosystem II splits water to replace lost electrons and release oxygen as a

		byproduct. • I can describe the movement of electrons through the electron transport chain of the light-dependent reactions of photosynthesis. • I can explain how a proton gradient is established and used to synthesize ATP and NADPH in the light-dependent reactions of photosynthesis.
4	**Learning Target 4** I can describe and explain the role of the Calvin cycle in producing carbohydrates from CO_2.	• I can identify the location of the Calvin cycle in chloroplasts. • I can describe how energy captured in the light reactions and transferred to ATP and NADPH powers the production of carbohydrate from carbon dioxide in the Calvin cycle.
5	**Learning Target 5** I can describe the process of glycolysis and the transition to the Krebs cycle in breaking down glucose.	• I can identify the location of glycolysis and summarize its net results. • I can explain how pyruvate is modified (oxidized) as it moves into the mitochondrial matrix. • I can explain the role of the Krebs Cycle (Citric Acid Cycle) in producing electron carriers (NADH and $FADH_2$).
6	**Learning Target 6** I can explain how the electron transport chain (ETC) and chemiosmosis release energy to synthesize large amounts of ATP.	• I can identify the location of the ETC within the mitochondria. • I can explain how NADH and $FADH_2$ powers the ETC. • I can explain the role of oxygen in aerobic respiration. • I can explain how ATP synthase uses a proton gradient (chemiosmosis) to synthesize most of the cell's ATP.
7	**Learning Target 7** I can explain how fermentation allows cells to continue glycolysis in the absence of oxygen.	• I can differentiate between aerobic and anaerobic processes. • I can describe how fermentation's main role is to regenerate NAD+ for glycolysis and identify the organic byproducts (such as alcohol or lactic acid.

Unit Title:	
Unit 4: Cell Communication and Cell Cycle	
Relevant Standards: Bold indicates priority	
Course Content: Energetics (ENE) Information Storage and Transmission (IST) **Science Practices:** 1 - Concept Explanation 1.A: Describe biological concepts and processes. 1.B: Explain biological concepts and processes. 4 - Representing and Describing Data 4.B: Describe data from a table or graph, including identifying specific data points, describing trends and patterns in the data, and describing relationships between variables. 5 - Statistical Tests and Data Analysis 5.A: Perform mathematical calculations, including mathematical equations in the curriculum, means, rates, ratios, percentages and percent changes 6 - Argumentation 6.C: Provide reasoning to justify a claim by connecting evidence to biological theories. 6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system.	
Essential Question(s):	**Enduring Understanding(s):**
In what ways do cells use energy to communicate with one another? How does the cell cycle aid in the conservation of genetic information? Why and in what ways do cells communicate with one another?	Students continue to learn about the role of cells, focusing on how cells use energy and information transmission to communicate and replicate. Through systems of complex transduction pathways, cells can communicate with one another. Cells can also generate and receive signals, coordinate mechanisms for growth, and respond to environmental cues. To maintain homeostasis, cells respond to their environment. They can also replicate and regulate replication as part of the cell cycle that provides for the continuity of life.
Demonstration of Learning:	**Pacing for Unit**
Students will review their knowledge of nucleic acid from unit 1 so that it can be applied here and in subsequent units by using chalk markers to create illustrative diagrams on their desktops. These diagrams must include relevant structural features and vocabulary for both RNA and DNA, and must compare DNA in prokaryotes and eukaryotes. Students will create and present a brief lesson to teach their classmates about a specific feedback mechanism found in organisms or ecosystems. Students will create a live-action or animated video or a hand-drawn poster showing and explaining two different cell signaling pathways: an intracellular hormone receptor pathway and a G-protein coupled receptor pathway. Students will complete the Personal Progress Check MCQs and FRQs for unit 4 on AP Classroom. Students will take a unit assessment at the end of the unit that includes AP-style multiple choice on AP Classroom as well as written responses (FRQs).	6-7 class periods 2-3 lab days

Family Overview:	**Integration of Technology:**
AP Biology: Family Course Overview (English) AP Biology: Family Course Overview (Spanish)	• Google Slides • AP Classroom Personal Progress Check, AP Daily videos and topic quizzes • *Desmos scientific calculator* • *YouTube*
Unit-specific Vocabulary:	**Aligned Unit Materials, Resources, and Technology (beyond core resources):**
Ligand Receptor Signal transduction pathway Second messenger Hormone Feedback (positive and negative) Homeostasis Checkpoint Cell cycle Cyclin Cyclin-dependent kinase (CDK) Apoptosis Interphase Mitosis Prophase Metaphase Anaphase telophase Cytokinesis	• Campbell Biology In Focus Chapter 9 • AP Classroom Unit 4
Opportunities for Interdisciplinary Connections:	**Anticipated misconceptions:**
• Math • Visual arts • Health and Wellness • Chemistry • Anatomy and Physiology	• Cell signaling is not limited to hormones or nerves, but rather all kinds of different cells use cell signaling pathways including short-distance signaling and self-signaling. • Responses are not immediate once a signal reaches a receptor, but rather there are usually many stops in between as cells use chains of molecules and multi-step cascades to transfer and amplify signals. • Different cells can react differently to the same signal because they have different receptors and different proteins within a signal transduction pathway. • The cell cycle doesn't happen randomly, but rather cells move through the cycle in a specific order and use checkpoints controlled by cyclins and CDKs to regulate this process. • Cell division is not just for overall organism growth, but also for development and damage repair. • "Any mistake in the cell cycle automatically causes cancer" is a common misconception. Not every error leads to cancer, and cells have multiple safeguards that lead to repair or apoptosis instead. • Positive feedback does not = "good" or beneficial results and negative feedback does not mean the response is "bad" but rather these terms refer to whether a response is increasing/amplifying or decreasing/stopping a stimulus.

Connections to Prior Units:	Connections to Future Units:
Cell Communication heavily relies on Unit 2, as it requires an understanding of the plasma membrane. Furthermore, the ultimate cellular response to a signal often involves gene regulation, linking directly to DNA and protein synthesis, so the biochemistry of Unit 1 is an important foundation here. The cell cycle also requires knowledge of Unit 1 for the replication of DNA and the role of enzymes. Therefore, Unit 4 brings together the structure of the cell, the molecular machinery of proteins, and the information stored in DNA to regulate life-sustaining processes.	Unit 4 lays the foundational mechanisms for nearly all subsequent AP Biology units. The concept of signal transduction (cell communication) is crucial for understanding Unit 6: Gene Expression and Regulation, as many signaling pathways ultimately control which genes are turned on or off. This control, in turn, dictates cellular differentiation and function, linking directly to the section of the Pre-Work: Ecology that pertains to how organisms respond to environmental signals and Unit 7: Natural Selection as it pertains to how changes in signaling pathways can lead to evolutionary adaptations. Furthermore, the Cell Cycle provides the context for Unit 5: Heredity, as meiosis is a modified cell cycle that ensures the proper transmission of chromosomes to gametes, thereby establishing the principles of inheritance. Without Unit 4, the regulation, adaptation, and inheritance discussed in the later units would lack their essential mechanistic basis.

Differentiation through *Universal Design for Learning*
Learning Targets and Teacher Actions

Learning Target 1:

- Representation: Use a clear, step-by-step diagram or flowchart to illustrate the three stages of the pathway: Reception, Transduction, and Response. Provide a vocabulary list defining key terms like ligand, receptor protein, and second messenger.
- Action/Expression: Students can create a three-panel comic strip or a narrative that traces a specific signal (ligand) from its arrival at the cell surface to the final cellular response. They could also write a function matrix listing each component and its specific role.
- Engagement: Introduce an analogy of a cell signal pathway as a cellular telephone system or a relay race to make the abstract sequence more concrete and memorable.

Learning Target 2:

- Representation: Use side-by-side diagrams contrasting a normally shaped signaling molecule (ligand) with a mutated or inhibited ligand, showing how the change prevents binding to the receptor. Provide case studies of drugs that mimic or block natural signaling molecules.
- Action/Expression: Students can be given a specific structural change (e.g., loss of a functional group) and asked to predict and justify the resulting effect on the pathway's activation or termination. They could also write a short mechanism of action for a drug that targets a specific step in a pathway.
- Engagement: Introduce a medical puzzle related to a disease caused by a faulty receptor or an altered signaling molecule, encouraging students to analyze the structural consequence.

Learning Target 3:

- Representation: Provide two distinct flowcharts clearly illustrating a negative feedback loop (output reduces input, e.g., body temperature regulation) and a positive feedback loop (output intensifies input, e.g., labor contractions). Use color-coding to highlight the component that acts to either reverse or amplify the original stimulus.
- Action/Expression: Students can select two real-world examples (one positive, one negative) and draw and label their own diagram of the feedback mechanism. They could also write a short comparative essay on which type of loop is more common in maintaining stability.
- Engagement: Use a scenario-based activity where students must categorize several biological processes as either positive or negative feedback and justify their choice.

Learning Target 4:

- Representation: Use a visual diagram of the cell cycle (Interphase: G1, G2; and Mitotic Phase: Mitosis and Cytokinesis), including a brief description of the key events occurring in each phase (e.g., DNA synthesis in S. Provide a written summary of the cell cycle's overall function (growth, repair, asexual reproduction).
- Action/Expression: Students can create a timeline or storyboard of the cell cycle, depicting the main events in each phase. They could also write a brief report contrasting the cell cycle in somatic cells versus germ cells.
- Engagement: Use a digital matching game where students pair descriptions of cellular activity (e.g., cell growth, chromosome alignment) with the correct phase of the cell cycle.

Learning Target 5:

- Representation: Provide detailed, sequential diagrams or animations of the stages of mitosis (Prophase, Metaphase, Anaphase, Telophase). Emphasize the role of the spindle fibers and show how the process results in two genetically identical daughter cells.
- Action/Expression: Students can use pipe cleaners or physical models to manipulate chromosomes and model the movement through each phase of mitosis. They could also write a short, instructional manual titled "How to Divide a Cell to Maintain Genetic Consistency."
- Engagement: Use a "Chromosome Tracker" activity where students are given a starting cell (e.g., 2n=4) and must track the number of chromosomes and DNA molecules through all the stages of mitosis and cytokinesis.

Learning Target 6:

- Representation: Use a diagram of the cell cycle showing the major checkpoints (G1, G2, and M checkpoint). Introduce key regulatory molecules like cyclins and cyclin-dependent kinases Cdks and show how their concentration changes to control the cycle.
- Action/Expression: Students can create a metaphor for the cell cycle checkpoints (e.g., traffic lights, quality control stations). They could also research and present a report on how disruptions to cell cycle regulation lead to cancer.
- Engagement: Introduce a role-playing scenario where one student is a Cdk and another is a cyclin, explaining their interaction and the consequences if the Cdk is permanently activated.

Supporting Multilingual/English Learners (*CELP standards*)
Differentiated Learning Targets

	Emerging	Bridging	Expanding
LT 1	I can label the three main stages of the pathway (reception, transduction, response) and name the signaling molecule (ligand).	I can describe the three stages of a pathway and explain how the signal is transferred from the outside of the cell to the inside, using sequencing words and academic terms (e.g., receptor, relay proteins).	I can analyze and explain how a conformational change in the receptor initiates a phosphorylation cascade (transduction) to amplify and produce a specific cellular response, detailing the role of each component.
LT 2	I can identify that if the signaling molecule's shape changes, it will not fit the receptor, and the cell will not respond.	I can describe how a structural change in the signaling molecule (or the receptor) prevents it from binding or activating the receptor, using this to explain why the signaling pathway is disrupted.	I can analyze a specific example (e.g., a drug or toxin) that alters the structure of a component (ligand or receptor) and predict and justify the resulting loss or gain of function in the signaling pathway and the cellular response.
LT 3	I can define homeostasis and identify the difference between positive (more/increase) and negative (less/stop) feedback loops.	I can describe both positive and negative feedback loops and explain the role of each in maintaining a stable internal environment (e.g., body temperature or childbirth) using cause-and-effect language.	I can compare and contrast the specific regulatory roles of positive and negative feedback systems, analyzing how they dynamically maintain biological set points and the conditions under which a positive feedback loop is beneficial or detrimental.
LT 4	I can list the main phases of the cell cycle (G1,S,G2,M) and state that its function is to make new cells.	I can describe the main events of Interphase (G1,S,G2) and Mitosis (M), explaining the biological function of the cycle (growth, repair, or reproduction) using sequential transition words.	I can analyze the cell cycle, detailing the precise molecular events that occur during each phase and justifying why the cell cycle is essential for both asexual reproduction and the maintenance of multicellularity in complex organisms.
LT 5	I can name the main stages of mitosis (Prophase, Metaphase, Anaphase, Telophase) and state that the daughter cells are identical to the parent cell.	I can describe the movement of chromosomes during each stage of mitosis and explain how the process ensures that each new daughter cell receives an identical set of genetic material (chromosomes).	I can analyze and explain how the precise mechanisms (e.g., spindle fiber attachment, sister chromatid separation) of mitosis guarantee the fidelity of chromosome transmission from a parent cell to two genetically identical daughter cells.
LT 6	I can identify that the cell cycle has checkpoints and that if regulation fails, it can lead to cancer.	I can describe the main cell cycle checkpoints (G1,G2,M) and explain that key regulatory proteins (e.g., cyclins	I can analyze and explain the role of cyclin-CDK complexes and tumor suppressor genes (e.g., p53) in

		and CDK) control the progression of the cycle.	regulating the cell cycle, and justify how specific disruptions (e.g., mutation in p53) lead to uncontrolled cell division and tumor formation.

Lesson Sequence	Learning Target	Success Criteria/Assessment/Resources
1	**Learning Target 1** I can identify the components of a signal transduction pathway and describe their role in producing a cellular response.	• I can describe the roles of ligands and receptor proteins in signal transduction. • I can describe how signaling cascades relay signals from receptors to cellular targets, including through amplification. • I can describe the role of G-protein coupled receptors, second messengers, and hormones in signaling cascades • I can identify different types of cellular responses elicited by a signal transduction pathway.
2	**Learning Target 2** I can explain how a change in the structure of any signaling molecule affects the activity of the signaling pathway	• I can describe how mutations in components of a signaling pathway may affect the downstream components. • I can describe how chemicals that interact with components of a signaling pathway may activate or inhibit the pathway.
3	**Learning Target 3** I can describe how positive and negative feedback help maintain homeostasis.	• I can explain negative feedback and describe how these mechanisms maintain homeostasis at the molecular, cellular, and organismal levels. • I can explain positive feedback and describe how these mechanisms amplify a stimulus and result in changes to a system.
4	**Learning Target 4** I can describe the events of the cell cycle and its biological function.	• I can describe the purpose of the cell cycle for growth, repair, and asexual reproduction. • I can identify the main events that occur in each phase of Interphase (G1, S, G2). • I can identify the role of G0 in the cell cycle • I can identify the timing and role of mitosis and cytokinesis in the cell cycle.
5	**Learning Target 5** I can explain how mitosis results in the transmission of chromosomes from one generation of cells to the next.	• I can name the sequential steps of mitosis and describe the main events that occur in each step. • I can describe the process and result of cytokinesis in animal cells and in plant cells.
6	**Learning Target 6** I can describe how the cell cycle is regulated and the effects of disruptions to the cell cycle on the cell or organism.	• I can explain the role of checkpoints in regulating progression through the cell cycle. • I can describe the role of cyclins and cyclin-dependent kinases in controlling the cell cycle. • I can describe how and why disruptions to the cell cycle may result in cancer or apoptosis.

Unit Title:	
Unit 5: Heredity	
Relevant Standards:	
Course Content: Evolution (EVO) Information Storage and Transmission (IST) Systems Interactions (SYI) **Science Practices:** 1 - Concept Explanation. 1.B: Explain biological concepts and processes. 1.C: Explain biological concepts and processes in applied contexts. 3 - Questions and Methods 3.A: Identify or pose a testable question based on an observation, data, or a model 5 - Statistical Tests and Data Analysis 5.C: Perform chi-square hypothesis testing. 6 - Argumentation 6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system.	
Essential Question(s):	**Enduring Understanding(s):**
• How is our understanding of evolution influenced by our knowledge of genetics? • Why is it important that not all inherited characteristics get expressed in the next generation? • How would Mendel's laws have been affected if he had studied a different type of plant? • How does the diversity of a species affect inheritance?	Unit 5 focuses on heredity and the biological concepts and processes involved in ensuring the continuity of life. Students learn that the storage and transmission of genetic information via chromosomes from one generation to the next occur through meiosis. Meiotic division ensures genetic diversity, which is crucial to the survival of a species. In this unit, students gain a deeper understanding of Mendelian genetics and learn how non-Mendelian genetics describes patterns of inheritance that seem to violate Mendel's laws. This unit also covers the roles played by chromosomal inheritance, environmental factors, and nondisjunction on an individual's phenotype.
Demonstration of Learning:	**Pacing for Unit**
Students will conduct a DNA extraction and amplification of the ACE gene using micropipetting techniques and PCR. They will then genotype their samples using gel electrophoresis to determine which samples are homozygous for either version of the gene or heterozygous for the ACE gene. Students will complete practice problems for both Mendelian and non-Mendelian genetics scenarios. Students will complete the Personal Progress Check MCQs and FRQs for unit 5 on AP Classroom. Students will take a unit assessment at the end of the unit that includes AP-style multiple choice on AP Classroom as well as written responses (FRQs).	5-6 class periods 2-3 lab days
Family Overview:	**Integration of Technology:**
AP Biology: Family Course Overview (English) AP Biology: Family Course Overview (Spanish)	• Google Slides • AP Classroom Personal Progress Check, AP Daily videos and topic quizzes • *Desmos scientific calculator* • *Google Sheets* • *Gel electrophoresis*

	• *PCR*
Unit-specific Vocabulary:	**Aligned Unit Materials, Resources, and Technology (beyond core resources):**
Gene Allelle Locus Homologous chromosomes Haploid (n) Diploid (2n) Gamete Zygote Meiosis Crossing over Independent assortment Mendelian genetics Homozygous Heterozygous dominant Recessive Genotype Phenotype Phenotypic ratio Genotypic ratio Punnett square pedigree Monohybrid Dihybrid non-Mendelian inheritance Incomplete dominance Codominance Multiple alles Polygenic inheritance Pleiotropy Epistasis Phenotypic plasticity	• Campbell Biology In Focus Chapters 10-13 • AP Classroom Unit 5 • Jackson Laboratories Teaching the Genome • Generation (TtGG) extraction • PCR and gel electrophoresis protocols • BioRad pGlo bacterial transformation lab (or similar kit) • miniPCR BioBits Central Dogma experiment
Opportunities for Interdisciplinary Connections:	**Anticipated misconceptions:**
• Math (statistics) • Health and Wellness • Chemistry • Anatomy and Physiology	• Students struggle to differentiate between and appropriately apply the terms “gene” and “allele”. • Dominant traits are not necessarily more common or “better” than recessive traits, but students often assume one or both of these to be true. • A common misconception is that Punnett squares predict what offspring will be/look like, but rather they show possibilities and probabilities (not guarantees). • Some students struggle with the concept of sex-linked traits and have a hard time explaining why x-linked traits show up more often in males. • Mutations do not always cause visible changes, and can happen in noncoding DNA since not every single nucleotide base is directly part of a gene.
Connections to Prior Units:	**Connections to Future Units:**
Unit 5 acts as the crucial link between the cellular machinery and evolutionary change. It builds upon Unit 1 (Chemistry of Life) and Unit 2 (The Cell) by explaining how the physical structure of DNA and chromosomes within the nucleus determines traits. Most critically, Unit 5 utilizes the processes of meiosis and the Cell Cycle (Unit 4) to explain the reliable transmission of genetic material, which forms the basis for Mendel's Laws and the concept of heritable variation.	Unit 5 becomes the foundation for all remaining material: it defines the genotype that is physically expressed via Gene Expression (Unit 6) and provides the essential genetic variation (through crossing over and mutation) that is required for Natural Selection and Evolution (Unit 7) to occur in the context of Ecology (Pre-Work).
Differentiation through *Universal Design for Learning* **Learning Targets and Teacher Actions**	
Learning Target 1: • Representation: Use sequential animations or labeled diagrams to show the stages of Meiosis I and Meiosis II, emphasizing the reduction in chromosome number and the production of four non-identical haploid cells. Provide a visual explanation of key events like crossing over and independent assortment to show how variation is generated. • Action/Expression: Students can model meiosis using colored string or pipe cleaners, physically tracking one pair of homologous chromosomes through both divisions. They could also write a comparative essay	

contrasting the outcomes and biological functions of mitosis and meiosis.
- Engagement: Introduce the concept of genetic variation as an "advantage" of sexual reproduction. Use a simulation to show how different outcomes of independent assortment affect the final gametes.

Learning Target 2:
- Representation: Clearly define and illustrate Mendel's Laws (Segregation and Independent Assortment). Use Punnett Squares (monohybrid and dihybrid) with color-coding to visualize how alleles separate and recombine. Provide a glossary of terms like allele, homozygous, heterozygous, genotype, and phenotype.
- Action/Expression: Students can solve a variety of genetic crosses using Punnett Squares, probability rules, or pedigree charts. They could also create an instructional video explaining how to calculate the probability of a specific genotype from a dihybrid cross.
- Engagement: Use a role-playing scenario where students act as Mendel's pea plants to demonstrate segregation and independent assortment. Use real-world examples of simple human genetic traits (e.g., earlobe attachment).

Learning Target 3:
- Representation: Provide a comparison chart that summarizes the non-Mendelian patterns: Incomplete Dominance, Codominance, Multiple Alleles, Polygenic Inheritance, and Sex-Linked Inheritance. Use a distinct example for each (e.g., blood types for multiple alleles, red/white/pink flowers for incomplete dominance).
- Action/Expression: Students can be given a specific inheritance pattern (e.g., codominance) and asked to develop a Punnett Square key and solve a problem demonstrating the phenotypic ratios. They could also create a presentation on one deviation and its real-world impact (e.g., colorblindness as a sex-linked trait).
- Engagement: Introduce a "Genetic Detective" challenge where students must analyze a pedigree chart or phenotypic data set and determine which pattern of inheritance (Mendelian or non-Mendelian) best explains the results.

Learning Target 4:
- Representation: Use visual examples of epigenetic influences or environmental effects on phenotype (e.g., Himalayan rabbits whose fur color changes with temperature, or human height/weight influenced by diet). Provide a concept diagram showing Genotype + Environment to Phenotype.
- Action/Expression: Students can write a short case study explaining how pH affects the color of hydrangea flowers, linking the genetic potential to the environmental factor. They could also create a simple experiment proposal to test the effect of a specific environmental variable on a given organism's trait.
- Engagement: Discuss the concept of nature vs. nurture and engage students in a debate or discussion about which plays a stronger

Supporting Multilingual/English Learners (*CELP standards*)
Differentiated Learning Targets

	Emerging	Bridging	Expanding
LT 1	I can define meiosis and state that it makes sex cells (gametes) and reduces the number of chromosomes by half.	I can describe the main goal of meiosis and explain how the process ensures that each resulting gamete receives one set of chromosomes from the parent cell, using sequencing words to show the two divisions.	I can analyze and explain the precise mechanisms of Meiosis I and Meiosis II, detailing how events like crossing over and independent assortment generate genetic variation and ensure the halving of the chromosome number for sexual reproduction.
LT 2	I can define dominant and recessive alleles and identify the genotypes and phenotypes for a simple monohybrid trait.	I can use a Punnett square to predict the offspring's genotypic and phenotypic ratios for a single-gene cross and explain the difference between a homozygous and heterozygous individual.	I can apply statistical reasoning to a dihybrid cross or complex inheritance problem, calculating and justifying the probabilities of specific genotypes/phenotypes based on the principles of Segregation and Independent Assortment.
LT 3	I can name one non-Mendelian pattern (e.g., incomplete dominance) and identify that the results are not simple dominant/recessive.	I can describe different non-Mendelian patterns (e.g., codominance, sex-linked traits) and explain how these patterns lead to phenotypic ratios that deviate from Mendel's simple 3:1 or 9:3:3:1 ratios.	I can analyze and justify the inheritance pattern of complex traits (e.g., epistasis, polygenic traits) by comparing them to Mendelian principles and explaining the molecular reasons for the observed phenotypic ratios.

LT 4	I can identify that the environment (e.g., sun, food) can change how a trait looks, even if the gene is the same.	I can describe a specific example (e.g., hydrangea color or coat color in some animals) where the environment modifies the expression of a gene, and explain the resulting phenotypic plasticity in a clear sentence.	I can analyze and evaluate empirical data to show how the reaction norm of a specific genotype is influenced by a range of environmental factors (e.g., temperature, nutrition), constructing a detailed argument on gene-environment interaction.

Lesson Sequence	Learning Target	Success Criteria/Assessment/Resources
1	**Learning Target 1** I can explain how meiosis results in the transmission of chromosomes from one generation to the next.	• I can name and describe the features of each step of meiosis. • I can identify the intended outcome of meiosis and its role in sexually reproducing diploid organisms. • I can describe similarities and differences between the phases and outcomes of mitosis and meiosis. • I can explain how the process of meiosis generates genetic diversity.
2	**Learning Target 2** I can explain the inheritance of genes and traits as described by Mendel's laws.	• I can describe Mendel's laws of segregation and independent assortment. • I can apply the rules of probability to predict and analyze the passing of single-gene traits from parent to offspring in monohybrid, dihybrid and test crosses. • I can apply the terms homozygous and heterozygous when describing an organism's genotype. • I can differentiate between genotype and phenotype. • I can describe patterns of inheritance, both autosomal and sex-linked, dominant and recessive. • I can use Punnett squares to predict the genotypes and phenotypes of parents and offspring.
3-4	**Learning Target 3** I can explain deviations from Mendel's model of the inheritance of traits.	• I can identify and describe patterns of inheritance that do not follow the ratios predicted by Mendel's laws, including codominance, incomplete dominance, sex-linked traits, and pleiotropy. • I can describe the probability of genes segregating together can be used for gene mapping. • I can identify sources of non-nuclear genetic inheritance in plants and animals.
5	**Learning Target 4** I can explain how the same genotype can result in multiple phenotypes under different environmental conditions	• I can describe how environmental conditions influence gene expression and can lead to phenotypic plasticity.

Unit Title:
Unit 6: Gene Expression and Regulation
Relevant Standards: Bold indicates priority
Course Content: **I**nformation Storage and Transmission (IST) **Science Practices:** 1 - Concept Explanation. 1.C: Explain biological concepts and processes in applied contexts. 2 - Visual Representations 2.B: Explain relationships between characteristics of biological models in both theoretical and applied contexts. 2.C: Explain how biological models relate to larger principles, concepts, processes, systems, or theories 2.D: Represent relationships within biological models, including mathematical models, diagrams, flowcharts, and systems. 6 - Argumentation 6.A: Make a scientific claim. 6.B: Support a claim with evidence from biological principles, concepts, processes, and data. 6.D: Explain the relationship between experimental results and larger biological concepts, processes, or theories. 6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system.

Essential Question(s):	**Enduring Understanding(s):**
• How does gene regulation relate to the continuity of life? • How is the genetic information of a species diversified from generation to generation?	Progressing from the continuity of life to gene expression, students gain in-depth knowledge about nucleic acids and their role in gene expression in this unit. There is also a finer focus on the comparison between the structures of DNA and RNA. This unit highlights how an individual's genotype is physically expressed through their phenotype, thus emphasizing the importance of protein synthesis (transcription and translation) in gene expression. Regulation of gene expression and cell specialization are instrumental in ensuring survival within an individual and across populations.
Demonstration of Learning:	**Pacing for Unit**
Students will conduct the miniPCR "biobits" Central Dogma experiment using p51 fluorescence viewers, which will require them to apply their knowledge of transcription, translation, and gene regulation to make and defend predictions and explain observed results. Students will use a PhET simulator to explore the parts of the lac operon and ultimately use their findings to explain the definition and function of prokaryotic operons. Students will create and present a brief lesson to teach their classmates about a specific type of genetic mutation, including its consequences at the DNA, RNA, and protein level and at least one specific example of a trait/condition/disease/syndrome caused by that type of mutation . Students will complete the Personal Progress Check MCQs and FRQs for unit 6 on AP Classroom. Students will take a unit assessment at the end of the unit that includes AP-style multiple choice on AP Classroom	9-11 class periods 2-3 lab days

as well as written responses (FRQs).	
Family Overview:	**Integration of Technology:**
AP Biology: Family Course Overview (English) AP Biology: Family Course Overview (Spanish)	• Google Slides • AP Classroom Personal Progress Check, AP Daily videos and topic quizzes • *Desmos scientific calculator* • *Google Sheets* • *YouTube* • *miniPCR P51 fluorescence viewers*
Unit-specific Vocabulary:	**Aligned Unit Materials, Resources, and Technology (beyond core resources):**
DNA RNA (mRNA, tRNA, rRNA) Nucleotide Base pairing Double helix Antiparallel 5' and 3' ends DNA replication Semiconservative Origin of replication Helicase DNA polymerase Leading strand Lagging strand Okazaki fragment Ligase Replication fork Point mutation Frameshift mutation Insertion PCR Deletion Transcription RNA processing Intron Exon Splicing 5' cap poly-A tail Translation Codon Anticodon Start codon Stop codon Ribosome Gene expression Differentiation Recombinant DNA Cloning Genetic engineering Electrophoresis	Campbell Biology In Focus Chapters 13-17 AP Classroom Unit 6
Opportunities for Interdisciplinary Connections:	**Anticipated misconceptions:**
• Math • Biotechnology and Forensics • Health and Wellness • Chemistry • Anatomy and Physiology	• What makes cells within an organism different is not that they have different genes, but rather that they express/regulate expression of the same set of DNA differently. • Students often confuse the roles of different types of RNA (mRNA, tRNA, rRNA). • Students sometimes struggle to understand that transcribing mRNA doesn't guarantee the production of a protein (since cells can regulate gene expression after transcription as well as during/before it). • While the central dogma of DNA to RNA to protein is essentially the same across all life, the regulation of this flow of information is different in prokaryotes vs. eukaryotes. • Operons are coordinated units of genes that are controlled/regulated as a unit/system, not just genes that happen to be located near each other. • Not every trait is controlled by a single gene, but rather most phenotypes are the result of many genes and often environmental factors as well. • Not all mutations are the same, and they are not necessarily "bad"---rather, there are many different

	ways in which DNA can be altered, which can in turn have a variety of implications for gene regulation, expression, and overall phenotype. The significance of a mutation ranges from incompatible with life to irrelevant to survival to evolutionarily advantageous depending on the type, severity, and environmental context.
Connections to Prior Units:	**Connections to Future Units:**
Unit 6 explains how the genetic blueprint translates into observable traits, tightly integrating with and completing the story started in prior units while setting the stage for future concepts. It relies heavily on Unit 1 (Chemistry of Life) and Unit 2 (The Cell) for the structure and function of DNA, RNA, ribosomes, and enzymes necessary for transcription and translation. It utilizes the concept of DNA replication from Unit 4 (Cell Cycle), as mutations introduced during replication are the basis for new alleles and changes in protein sequence. Crucially, it takes the genotype transmitted through Heredity (Unit 5) and provides the mechanism—the Central Dogma—by which the phenotype is physically expressed.	The principles of gene regulation (e.g., operons, transcription factors) connect directly to Unit 7 (Natural Selection) by showing how organisms evolve mechanisms to adapt to changing environments by altering which proteins they produce. This regulation informs the complexity of organismal function and interaction, which is critical for understanding Ecology (Pre-Work).

Differentiation through *Universal Design for Learning*
Learning Targets and Teacher Actions

Learning Target 1:

- Representation: Use visual aids that clearly depict the hierarchical structures of hereditary information: DNA → Gene → Chromosome. Provide labeled diagrams of the eukaryotic chromosome structure, showing DNA wrapped around histone proteins.
- Action/Expression: Students can create a set of nested boxes or models to demonstrate the size relationship between a nucleotide, a gene, and a chromosome. They could also write a descriptive essay explaining why the chromosome structure is essential for efficiently packing and transmitting genetic material.
- Engagement: Use a jigsaw activity where groups become "experts" on one structure (DNA, Gene, Chromosome) and teach the others, reinforcing the roles of each.

Learning Target 2:

- Representation: Use 3D models or animations of the double helix structure to highlight key characteristics: the sugar-phosphate backbone, the nitrogenous bases, and the complementary base pairing (A with T, C with G). Provide a summary chart listing the four key characteristics: stability, ability to replicate, information storage, and capacity for change (mutation).
- Action/Expression: Students can construct a paper model or digital drawing of a short segment of DNA, correctly labeling the bases and showing the complementary pairing. They could also write an argument explaining how the double helix structure enables reliable replication.
- Engagement: Introduce the history of DNA discovery (Watson, Crick, Franklin) to provide context and appreciation for the evidence that established DNA as the hereditary material.

Learning Target 3:

- Representation: Use sequential animations or flowcharts to illustrate the steps of semiconservative DNA replication, focusing on the roles of key enzymes like DNA polymerase, helicase, and ligase. Clearly differentiate between the synthesis of the leading strand and the lagging strand (Okazaki fragments).
- Action/Expression: Students can create a comic strip or short animation explaining the "replication bubble" and the different roles of the leading and lagging strands. They could also write a detailed sequence of events that occurs at the replication fork.
- Engagement: Use a "Build a Molecule" simulation where students must correctly place the replication enzymes and nucleotides to successfully copy a DNA strand.

Learning Target 4:

- Representation: Use a clear, three-step diagram of the Central Dogma (Transcription → Translation). Provide separate visual models for the process of Transcription (DNA to mRNA) in the nucleus and Translation (mRNA to protein) on the ribosome.

- Action/Expression: Students can create a concept map linking the three molecules (DNA, RNA, Protein) and the processes that connect them. They could also transcribe and translate a short segment of a gene, using a codon chart to determine the resulting amino acid sequence.
- Engagement: Introduce the concept of the genetic code as the universal language of life, and use a decoding challenge where students must translate mRNA sequences into polypeptide chains.

Learning Target 5:

- Representation: Provide visual examples of both prokaryotic regulation (e.g., the lac or trp operon) and eukaryotic regulation (e.g., transcription factors, RNA processing, chromatin modification). Use a comparison chart to categorize regulation by level: transcriptional, post-transcriptional, translational, and post-translational.
- Action/Expression: Students can draw and label the components of an operon and explain how a repressor molecule blocks transcription. They could also write a short mechanism of action for a specific type of eukaryotic gene regulation, such as gene silencing by microRNA.
- Engagement: Discuss how the regulation of gene expression is the reason why different cells in the body (e.g., a skin cell vs. a nerve cell) can perform unique functions despite having the same DNA.

Learning Target 6:

- Representation: Use a clear sequence diagram showing the flow: DNA Mutation → Altered mRNA → Altered Protein → Altered Phenotype. Provide specific examples of point mutations (silent, missense, nonsense) and frameshift mutations, explaining how each affects the final protein product.
- Action/Expression: Students can be given a wild-type DNA sequence and then asked to model a mutation and determine the resulting amino acid change and potential phenotypic consequence. They could also write a detailed case study on a disorder caused by a single gene mutation (e.g., sickle cell anemia).
- Engagement: Use a "Domino Effect" analogy to show how a small change in the DNA sequence can lead to large, cascading effects on protein structure and organismal function.

Learning Target 7:

- Representation: Provide flowcharts or labeled diagrams of key techniques, such as Polymerase Chain Reaction (PCR), gel electrophoresis, and the use of restriction enzymes and plasmids in recombinant DNA technology.
- Action/Expression: Students can write a short procedure explaining how to clone a gene into a bacterial plasmid. They could also create an infographic detailing the steps and purpose of PCR.
- Engagement: Discuss the ethical and societal implications of genetic engineering (e.g., genetically modified organisms or gene therapy) through a class debate or ethical scenario analysis.

Supporting Multilingual/English Learners (*CELP standards*)
Differentiated Learning Targets

	Emerging	Bridging	Expanding
LT 1	I can name the main structure (DNA) and the location where it is found (nucleus/cell).	I can describe the relationship between DNA, genes, and chromosomes, and explain that these structures are the physical carriers of hereditary information.	I can analyze and explain the hierarchical organization of genetic material, detailing how the structure of chromosomes (histones, chromatin) allows for the efficient storage and faithful transmission of DNA across cell generations.
LT 2	I can identify DNA's key features: it is a double helix and it has four bases (A, T, C, G).	I can describe the basic structure of the DNA molecule and explain the role of complementary base pairing in ensuring that the genetic code can be read and copied accurately.	I can analyze and justify how the double helix structure, the complementary base pairing, and the stability provided by hydrogen bonds are essential features that enable DNA to store and accurately replicate genetic information.
LT 3	I can state that DNA is copied and that the two new copies are the same as the original.	I can describe the overall process of DNA replication and explain the role of unwinding and complementary base pairing in producing two identical DNA molecules for transmission.	I can analyze and explain the precise molecular mechanisms of DNA replication (e.g., leading vs. lagging strand, role of polymerases) and justify why the process is considered semiconservative for faithful inheritance.

LT 4	I can state the Central Dogma (DNA → RNA → Protein) and name the steps: transcription and translation.	I can describe the two-step flow of information (transcription and translation) and explain the role of mRNA and the ribosome in converting the genetic code into a sequence of amino acids.	I can analyze and explain the complex process of gene expression (The Central Dogma), detailing the roles of regulatory sequences and the coordinated action of various RNA types in producing a functional protein.
LT 5	I can identify that not all genes are on at the same time and that gene regulation saves energy.	I can describe different levels of gene regulation (e.g., transcription vs. translation) and explain how the cell uses these interactions to control the amount of protein produced.	I can analyze and explain the roles of specific regulatory elements (e.g., transcription factors, enhancers, and operons) in controlling the timing and amount of gene expression, justifying the need for this control in specialized cells.
LT 6	I can define genotype and phenotype and state that a change in the gene (genotype) can change the trait (phenotype).	I can describe how a gene mutation alters the sequence of a protein and explain how this structural change can lead to a different or nonfunctional phenotype (trait).	I can analyze and predict the effect of different classes of gene mutations (e.g., frameshift vs. point, regulatory vs. coding sequence) on the resulting protein structure and its phenotypic outcome, using the genetic code to support the analysis.
LT 7	I can name one technique (e.g., gene therapy) and state that it is used to change DNA to fix a problem.	I can describe a common genetic engineering technique (e.g., recombinant DNA technology) and explain its purpose in isolating, modifying, or transferring genetic material between organisms.	I can analyze and justify the ethical and practical applications of advanced techniques like CRISPR-Cas9, PCR, or gel electrophoresis, detailing the precise molecular mechanisms used to manipulate or analyze DNA in research or medicine.

Lesson Sequence	Learning Target	Success Criteria/Assessment/Resources
1	**Learning Target 1** I can describe the structures involved in passing hereditary information from one generation to the next.	• I can describe how genetic information is stored in and passed to subsequent generations through DNA (and in some cases RNA) molecules. • I can compare and contrast chromosome structure in prokaryotes and eukaryotes.
2	**Learning Target 2** I can describe the characteristics of DNA that allow it to be used as hereditary material.	• I can explain the structure and pairing patterns of nucleotide bases in RNA and DNA.
3-4	**Learning Target 3** I can describe the mechanisms by which genetic information is copied for transmission between generations.	• I can describe the steps, direction and involved enzymes (including helicase, topoisomerase, DNA polymerase, and ligase) of DNA synthesis . • I can describe how DNA replication is a semiconservative process.
5-6	**Learning Target 4** I can describe the mechanisms by which genetic information flows from DNA to RNA to protein.	• I can describe how RNA polymerase synthesizes mRNA molecules by reading a template DNA strand during the process of transcription. • I can identify ways in which mRNA transcripts are modified in eukaryotes, including the addition of a poly-A tail and GTP cap, and through splicing. • I can explain the process of translating mRNA to generate a polypeptide and describe the role of ribosomes in this process. • I can compare the timing and location of translation in prokaryotes and eukaryotes. • I can describe the flow of genetic information in retroviruses and how it is made possible by reverse transcriptase.

7	**Learning Target 5** I can describe the types of interactions that regulate gene expression.	• I can explain how regulatory sequences in DNA are used to control transcription. • I can describe how epigenetic changes can affect gene expression. • I can describe how the phenotype of an organism is determined by its genotype as well as the ways and amounts in which genes are expressed. • I can describe the flow of genetic information in retroviruses and how it is made possible by reverse transcriptase. • I can describe how prokaryotes regulate operons through inducible or repressible systems. • I can explain how the binding of transcription factors to promoter regions affects gene expression and the phenotype of the organism. • I can explain how gene regulation results in differential gene expression and influences cell products and functions.
8	**Learning Target 6** I can explain how changes in genotype may result in changes in phenotype.	• I can describe the various types of mutations, including point mutations, frameshift mutations, nonsense mutations, and silent mutations. • I can identify ways in which random mutations can arise, including during DNA replication, mitosis or meiosis, and from external/environmental factors. • I can explain how alterations in DNA sequences contribute to variation that can be subject to natural selection.
9-10	**Learning Target 7** I can explain the use of genetic engineering techniques in analyzing or manipulating DNA.	• I can describe the process of gel electrophoresis and draw conclusions from resulting data. • I can describe the steps of polymerase chain reaction (PCR). • I can explain how bacterial transformation introduce foreign DNA into bacterial cells. • I can describe how DNA sequencing technology and techniques allow for the comparison of DNA sequences from various samples.

Unit Title:

Unit 7: Natural Selection

Relevant Standards:

Course Content:
Evolution (EVO)
Systems Interactions (SYI)

Science Practices:
1 - Concept Explanation.
- 1.B: Explain biological concepts and processes.
- 1.C: Explain biological concepts and processes in applied contexts.

2 - Visual Representations
- 2.A: Describe characteristics of visual representations of biological concepts and processes.
- 2.B: Explain relationships between characteristics of biological models in both theoretical and applied contexts.
- 2.D: Represent relationships within biological models, including mathematical models, diagrams, flowcharts, and systems.

3 - Questions and Methods
- 3.B: State the null hypothesis or predict the results of an experiment
- 3.D: Propose a new investigation based on an evaluation of the experimental design or evidence.

4 - Representing and Describing Data
- 4.B: Describe data from a table or graph, including identifying specific data points, describing trends and patterns in the data, and describing relationships between variables.

5 - Statistical Tests and Data Analysis
- 5.A: Perform mathematical calculations, including mathematical equations in the curriculum, means, rates, ratios, percentages and percent changes

6 - Argumentation
- 6.C: Provide reasoning to justify a claim by connecting evidence to biological theories.
- 6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system.

Essential Question(s):	**Enduring Understanding(s):**
• What conditions in a population make it more or less likely to evolve? • What evidence is available that scientifically defends the theory of evolution? • How does species interaction encourage or slow changes in species?	The concepts in Unit 7 build on foundational content from previous units as students discover natural selection—a mechanism of evolution. Natural selection is the theory that populations that are better adapted to their environment will survive and reproduce. Thus, the evolution of a species involves a change in its genetic makeup over time. In this unit, students study the evidence for and mechanisms of evolutionary change. Students also learn what happens when a species does not adapt to a changing or volatile environment and about the Hardy–Weinberg equilibrium as a model for describing and predicting allele frequencies in nonevolving populations. Students will learn to calculate and draw conclusions about the evolution, or lack thereof, of a population from data related to allele frequencies.
Demonstration of Learning:	**Pacing for Unit**
Students will complete Hardy-Weinberg equilibrium practice problems. Students will conduct a chi-square analysis lab investigation using m&ms. Students will apply their understanding of cladograms to create and defend their own cladogram when provided either a varied assortment of Peeps/related candy or teddy grahams/related cookies, depending on	10-12 class periods 2-3 lab days

materials availability. Students will complete the Personal Progress Check MCQs and FRQs for unit 7 on AP Classroom. If there is time before the AP test, students will take a unit assessment at the end of the unit that includes AP-style multiple choice on AP Classroom as well as written responses (FRQs).	
Family Overview:	**Integration of Technology:**
AP Biology: Family Course Overview (English) AP Biology: Family Course Overview (Spanish)	• Google Slides • AP Classroom Personal Progress Check, AP Daily videos and topic quizzes • *Desmos scientific calculator*
Unit-specific Vocabulary:	**Aligned Unit Materials, Resources, and Technology (beyond core resources):**
Natural selection Artificial selection Fitness Adaptation Selective pressure Genetic drift Gene flow Bottleneck effect Founder effect Population genetics Allele frequency Hardy-Weinberg equilibrium Speciation Species Allopatric Sympatric Reproductive isolation Common ancestor Phylogeny/phylogenetic tree clade/cladogram Homologous structure Analogous structure Vestigial structure Molecular evolution	• Campbell Biology In Focus Chapters 18-23 • AP Classroom Unit 7
Opportunities for Interdisciplinary Connections:	**Anticipated misconceptions:**
• Math (algebra, statistics) • Anatomy and Physiology	• Individuals don't evolve, populations do (over many generations). • Organisms do not evolve because they need or want to, nor does life progress toward "perfect"---rather, changes happen because of random mutations that happen to be beneficial to survival and reproduction within the context of that population's ecosystem. • "Fittest" does not mean "strongest" in the context of natural selection, but rather the most successful at reproduction of surviving offspring. • Adaptations must be heritable to be relevant to evolution; acquired traits cannot be passed to the next generation so they are not considered adaptations. • Adaptations are environment-specific. Traits that are "good" in one environment might be a detriment to survival in another. • Not all changes in populations are because of natural selection, but rather random changes in allele frequency can occur as well (genetic drift). • Small and large populations do not evolve the same way (especially due to bottlenecks and founder effects), and not all evolution occurs at the same pace. • Humans did not "evolve from monkeys" but rather humans and modern primates share a recent common ancestor. • A theory is not just a guess, but rather it is a

	well-supported explanation backed by a tremendous amount of supporting and corroborating evidence.
Connections to Prior Units:	**Connections to Future Units:**
Unit 7: Natural Selection is the unifying theme of biology, directly connecting the molecular processes of the cell to the patterns observed in nature. It depends on heritable variation, drawing directly from the mechanisms introduced in Unit 5 (Heredity) and Unit 6 (Gene Expression), where mutations and crossing over generate the variation upon which selection acts. The unit also relies on Unit 4 (Cell Cycle), as the frequency of reproduction (and therefore fitness) is linked to the rate of cell division. Understanding how organisms adapt requires knowledge of metabolic pathways (Unit 3: Energetics) and cell structures (Unit 2) that provide different functional efficiencies. The environmental pressures discussed in Pre-Work: Ecology (predation, resource availability, competition) are the selective agents that drive evolutionary change, shaping the distribution, abundance, and interactions of species in an ecosystem.	None

Differentiation through *Universal Design for Learning*
Learning Targets and Teacher Actions

Learning Target 1:

- Representation: Provide the four key postulates of natural selection (variation, inheritance, overproduction, differential survival/reproduction) in a sequential checklist or flow chart. Use a real-world case study like the peppered moth or antibiotic resistance to illustrate the process.
- Action/Expression: Students can write a detailed explanation of how a specific trait (e.g., a long giraffe neck) became prevalent in a population, using all four postulates. They could also create a short narrative from the perspective of an individual organism, explaining its struggle for existence.
- Engagement: Use a simulation or game where students "act" as the selective pressure, making choices that determine which traits survive and reproduce over generations.

Learning Target 2:

- Representation: Use case studies (written and visual) on both positive and negative human impacts, specifically contrasting artificial selection (e.g., dog breeding, crop modification) with effects like habitat fragmentation or overharvesting.
- Action/Expression: Students can design a public service announcement (PSA) warning against a human activity that decreases genetic diversity (e.g., monoculture farming). They could also write a comparative analysis of natural vs. artificial selection, focusing on the selection criteria.
- Engagement: Engage students in a debate on the ethical implications of genetic engineering or selective breeding, focusing on the risks of reducing genetic variation.

Learning Target 3:

- Representation: Clearly define and provide examples for Genetic Drift (specifically the bottleneck effect and the founder effect) and Gene Flow. Use a visual analogy like marbles being randomly drawn from a bag to demonstrate the chance events in genetic drift.
- Action/Expression: Students can analyze two different population scenarios (one a bottleneck, one a founder effect) and explain the long-term impact on allele frequencies. They could also model the concept of gene flow between two populations using visual manipulatives.
- Engagement: Introduce a historical disaster scenario (e.g., a massive flood or disease) and have students predict the impact on the remaining genetic diversity of a small, isolated population.

Learning Target 4:

- Representation: Provide graphs illustrating different modes of selection (directional, stabilizing, and disruptive) and explain how each changes the allele and phenotype frequencies of a population over time. Define the term microevolution as change in allele frequency.
- Action/Expression: Students can be given a specific environmental pressure (e.g., an extremely cold winter) and asked to sketch or describe the expected shift in the frequency distribution of a trait (e.g., fur thickness).

- Engagement: Use a "Trait Tracker" activity where students follow the frequency of a certain allele in a virtual population as various selective pressures are introduced.

Learning Target 5:

- Representation: Provide the two Hardy-Weinberg equations along with a scaffolded template for applying them. Clearly list the five conditions required for a population to be in non-evolving equilibrium.
- Action/Expression: Students can solve calculation problems to determine allele and genotype frequencies. They could also write a justification for why Hardy-Weinberg is considered a "null hypothesis" in evolutionary studies.
- Engagement: Challenge students to analyze a real population's data and determine if it is currently evolving, using the Hardy-Weinberg equations to identify which condition for equilibrium is likely being violated.

Learning Target 6:

- Representation: Provide a comparison matrix summarizing the major lines of evidence: Fossil Record, Biogeography, Comparative Anatomy (homologous vs. analogous structures), Comparative Embryology, and Molecular Biology protein sequence comparisons). Use simple analogies to explain homologous structures.
- Action/Expression: Students can choose one line of evidence and create a visual report or presentation highlighting three specific examples that support the theory of descent with modification. They could also write an analytical essay arguing which type of evidence provides the strongest support for common ancestry.
- Engagement: Use a "Mystery Box" activity where students examine different "artifacts" (pictures of bones, DNA sequences, geographic maps) and must deduce which line of evidence they represent.

Learning Target 7:

- Representation: Clearly define speciation and differentiate between the two main modes: allopatric (geographic separation) and sympatric (no geographic separation). Provide a flowchart detailing the role of reproductive isolation in preventing gene flow.
- Action/Expression: Students can create a short story or scenario illustrating how a single population of birds could evolve into two distinct species via allopatric speciation (e.g., separated by a new mountain range). They could also compare and contrast prezygotic vs. postzygotic barriers.
- Engagement: Use a map analysis task where students identify natural geographic barriers that could potentially lead to allopatric speciation in different regions of the world.

Learning Target 8:

- Representation: Use a visual comparison to contrast the rates of evolution: gradualism (slow, steady change) versus punctuated equilibrium (long periods of stasis interrupted by rapid change). Explain how ecological factors like a stable environment versus sudden environmental shifts drive these different rates.
- Action/Expression: Students can sketch two phylogenetic trees, one representing gradualism and one representing punctuated equilibrium, labeling the axes and nodes to explain the difference in rate. They could also write an argument supporting which model better explains the origin of human evolution.
- Engagement: Analyze the fossil record for examples that support one model over the other, encouraging students to interpret empirical data.

Learning Target 9:

- Representation: Use hypothetical scenarios comparing two populations: one with high genetic diversity (many alleles) and one with low diversity (few alleles). Show how a new environmental pressure (e.g., a new disease or change in temperature) affects each population differently.
- Action/Expression: Students can write a formal paragraph explaining the evolutionary advantage of high genetic diversity, using terms like "buffering capacity" and "adaptation potential." They could also create a graph showing the relationship between genetic diversity and extinction risk.
- Engagement: Use a current event case study (e.g., the low genetic diversity in cheetahs or the Tasmanian devil) to discuss the real-world vulnerability of species with restricted gene pools

Supporting Multilingual/English Learners (*CELP standards*)
Differentiated Learning Targets

	Emerging	Bridging	Expanding
LT 1	I can name the four basic steps of natural selection (e.g., variation, selection) and state that it leads to better survival.	I can analyze and construct a detailed explanation of how the four principles of natural selection (variation, inheritance, overproduction, differential survival/reproduction) interact to drive adaptive evolution in a specific environment.	I can describe the four main tenets of natural selection and explain how a species with an advantageous trait will have a better chance of survival and reproduction in a specific environment.

LT 2	I can identify two ways people change animals/plants (e.g., hunting, breeding) and state that it makes them less diverse.	I can analyze and justify the long-term impacts of human activities (e.g., habitat fragmentation, over-harvesting, or artificial selection) on a population's genetic diversity and its future evolutionary potential.	I can describe both artificial selection (selective breeding) and human-caused environmental changes, and explain how each can quickly increase or decrease the genetic diversity of a population.
LT 3	I can name two random events (e.g., fire, flood) and state that they change the genes in a population by chance.	I can compare and contrast the effects of different forms of genetic drift (bottleneck and founder effect) and analyze and explain how these random events disproportionately impact the genetic makeup of small populations.	I can describe the mechanisms of genetic drift and gene flow and explain how these random processes lead to non-adaptive changes in a population's allele frequencies.
LT 4	I can define evolution and state that a population's traits change over many years.	I can analyze and explain the definition of evolution in terms of changes in allele frequencies over generations, detailing how microevolutionary forces (selection, drift, etc.) contribute to this change.	I can describe how the percentage of different traits (or alleles) in a population can increase or decrease over time, and explain that this change is the definition of evolution.
LT 5	I can identify that the Hardy-Weinberg formula can predict if a population is not changing (not evolving).	I can calculate and interpret allele (p,q) and genotype (p2,2pq,q2) frequencies in a population, analyzing whether the population is in equilibrium and justifying which assumption of H-W is being violated if it is not.	I can state the Hardy-Weinberg equation (p+q=1 and p2+2pq+q2=1) and explain what p and q represent in terms of allele frequencies.
LT 6	I can name two types of evidence (e.g., fossils, DNA) and state that they show animals change over time.	I can analyze and evaluate multiple lines of evidence (e.g., comparative embryology, molecular data, biogeography) and construct a detailed argument explaining how they collectively support the theory of descent with modification and common ancestry.	I can describe the evidence provided by the fossil record and homologous structures, and explain how these data points suggest a common ancestor and evolutionary relationships.
LT 7	I can define species and state that a new species forms when two groups of animals cannot reproduce anymore.	I can analyze and explain the different forms of reproductive isolation (pre-zygotic and post-zygotic) and justify how these mechanisms lead to the divergence of populations and the formation of new species (speciation).	I can describe the condition of geographic isolation and explain how the lack of gene flow between two isolated populations allows them to diverge and potentially form a new species.
LT 8	I can state that evolution can happen slowly or quickly and that the environment affects the speed.	I can compare and contrast the models of gradualism and punctuated equilibrium, and analyze how differing ecological conditions (e.g., stable vs. rapidly changing) drive different rates and patterns of speciation.	I can describe the two general paces of evolution (fast and slow) and explain how sudden environmental changes can lead to a rapid rate of speciation.
LT 9	I can identify that a population with more types of genes is safer when the environment changes.	I can analyze and evaluate the relationship between high genetic diversity and population fitness, justifying why diverse populations are more resilient to major environmental changes or disease outbreaks.	I can describe what genetic diversity is and explain how a population with many different alleles is more likely to have individuals with traits that allow them to survive a new environmental pressure.

Lesson Sequence	**Learning Target**	**Success Criteria/Assessment/Resources**
1	**Learning Target 1** I can describe the causes and effects of natural selection according to Darwin's theory.	• I can explain how competition for limited resources results in differential survival and reproduction of offspring, which in turn influences the phenotypes of subsequent generations. • I can compare biotic and abiotic environmental factors and explain how they can affect the rate and direction of evolution.

		• I can describe the importance of phenotypic variation in a population. • I can explain how variation in molecules within cells connects to the fitness of an organism.
2	**Learning Target 2** I can explain how humans can affect diversity within a population.	• I can describe how humans affect variation in other species through artificial selection.
3	**Learning Target 3** I can explain how random occurrences affect the genetic makeup of a population.	• I can explain how evolution is driven not only by natural selection, but also by random occurrences and genetic drift. • I can describe how the bottleneck effect, founder effect, and migration affect allele frequencies in a population.
4	**Learning Target 4** I can describe the change in the genetic makeup of a population over time.	• I can explain how changes in allele frequencies provide evidence for the occurrence of evolution in a population. • I can explain how evolution is an ongoing process in all living organisms.
5-6	**Learning Target 5** I can use the Hardy-Weinberg Equilibrium model to describe and predict allele frequencies in non-evolving populations.	• I can identify the conditions for a population or allele to be in Hardy-Weinberg equilibrium and use them to provide a null hypothesis.
7	**Learning Target 6** I can describe the types of data that provide evidence for evolution.	• I can explain how morphological and geological data provide evidence that organisms have changed over time, including from fossils, vestigial structures, and morphological homologies. • I can explain how the comparison of DNA nucleotide sequences and protein amino acid sequences from both extant and extinct organisms provide biochemical evidence for evolution and common ancestry. • I can describe structural and functional evidence indicating common ancestry of all eukaryotes, including membrane-bound organelles, linear chromosomes, and genes that include introns. • I can use phylogenetic trees and caldograms to show and infer evolutionary relatedness. • I can describe the scientific evidence that supports models of the origin of life on earth.
8	**Learning Target 7** I can describe the conditions under which new species may arise.	• I can define speciation and identify what makes one species different from another.
9	**Learning Target 8** I can describe the rate and driving processes of evolution and speciation under different ecological conditions.	• I can define and compare punctuated equilibrium and gradualism. • I can define and compare divergent and convergent evolution. • I can define and compare sympatric and allopatric speciation.
10	**Learning Target 9** I can explain how the genetic diversity of a species or population affects its ability to withstand environmental pressures.	• I can describe how and why species and populations with little genetic diversity are at risk of decline or extinction while genetically diverse populations are more resilient to environmental perturbation. • I can explain how the adaptiveness of an allele is environment-specific due to different selective pressures.