AP BIOLOGY

UNIT 7

Natural Selection

13–20%
AP EXAM WEIGHTING

~20–23
CLASS PERIODS

Remember to go to **AP Classroom** to assign students the online **Personal Progress Check** for this unit.

Whether assigned as homework or completed in class, the **Personal Progress Check** provides each student with immediate feedback related to this unit's topic and skills.

Personal Progress Check 7

Multiple-choice: ~40 questions
Free-response: 2 questions

- Interpreting and Evaluating Experimental Results with Graphing
- Analyze Data

UNIT 7

13–20% AP EXAM WEIGHTING | **~20–23** CLASS PERIODS

Natural Selection

BIG IDEA 1
Evolution EVO

- What conditions in a population make it more or less likely to evolve?
- Scientifically defend the theory of evolution.

BIG IDEA 4
Systems Interactions SYI

- How does species interaction encourage or slow changes in species?

Developing Understanding

The concepts in Unit 7 build on foundational content from previous units as students discover natural selection, a mechanism of evolution—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. Biological principles studied here and in previous units will culminate in Unit 8, which covers ecology.

Building Science Practices

1.B 2.A 2.D.c 3.B 3.E.a 4.B.c 5.A.a 6.C 6.E.b

By now, students should be accustomed to using visual models and representations to explain or illustrate biological processes. This unit provides students the opportunity to gain proficiency in describing a given model or representation and communicating the biological meaning it represents. Mastery is demonstrated when students can create or use models such as cladograms and phylogenetic trees to communicate biological phenomena, analyze situations, or solve new problems.

Hardy-Weinberg equations are used with respect to a specific gene. Thus, when teaching students how to use the equations, be careful to distinguish between allele and genotype frequencies. The Hardy-Weinberg principle clarifies the factors that alter allele frequency, but it does not imply that allele frequencies are static. This is an important understanding that students need in order to make predictions about a change in a population and to justify the reasoning for their predictions.

Preparing for the AP Exam

The principle of natural selection and its components appears throughout the course. It is important that students are precise in the language they use when writing about evolution, being careful to avoid writing statements that are Lamarckian. A common student error is using buzzwords such as "fitness" without proper explanation of the underlying concept. Students should recall the sources of genetic variation learned in Unit 5 in order to demonstrate the understanding that genetic variation is necessary for natural selection and describe its role in reproductive success. In their writing, students should be clear that while natural selection acts on individuals, it is populations that evolve. Another common error on the exam is that students do not clearly differentiate the types of reproductive isolating mechanisms that lead to speciation.

UNIT AT A GLANCE

Enduring Understanding	Topic	Suggested Skill	Class Periods ~20–23 CLASS PERIODS
EVO-1	**7.1 Introduction to Natural Selection**	2.A Describe characteristics of a biological concept, process, or model represented visually.	
	7.2 Natural Selection	1.B Explain biological concepts and/or processes.	
	7.3 Artificial Selection	4.B.c Describe data from a table or graph, including describing relationships between variables.	
	7.4 Population Genetics	3.B State the null or alternative hypotheses, or predict the results of an experiment.	
	7.5 Hardy-Weinberg Equilibrium	5.A.a Perform mathematical calculations, including mathematical equations in the curriculum. 1.C Explain biological concepts, processes, and/or models in applied contexts.	
EVO-1 EVO-2	**7.6 Evidence of Evolution**	4.B.a Describe data from a table or graph, including identifying specific data points.	
EVO-2	**7.7 Common Ancestry**	6.E.b Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on a visual representation of a biological concept, process, or model.	

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UNIT AT A GLANCE *(cont'd)*

Enduring Understanding	Topic	Suggested Skill	Class Periods ~20–23 CLASS PERIODS
EVO-3	**7.8 Continuing Evolution**	3.E.a Propose a new/next investigation based on an evaluation of the evidence from an experiment.	
	7.9 Phylogeny	2.D.c Represent relationships within biological models, including flowcharts.	
	7.10 Speciation	6.E.a Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on biological concepts or processes. 2.B.a Explain relationships between different characteristics of biological concepts, processes, or models represented visually in theoretical contexts.	
	7.11 Extinction	3.B State the null or alternative hypotheses, or predict the results of an experiment.	
SYI-3	**7.12 Variations in Populations**	6.C Provide reasoning to justify a claim by connecting evidence to biological theories.	
	7.13 Origin of Life on Earth	3.B State the null or alternative hypotheses, or predict the results of an experiment.	
	Go to **AP Classroom** to assign the **Personal Progress Check** for Unit 7. Review the results in class to identify and address any student misunderstandings.		

SAMPLE INSTRUCTIONAL ACTIVITIES

The sample activities on this page are intended to give you ideas of ways to incorporate varied instructional approaches in the teaching of this course. You do not need to use these activities or approaches and are free to alter or edit them in any way you choose. The following examples were developed in partnership with teachers from the AP community to share ways that they approach teaching some of the topics in this unit. Please refer to the Instructional Approaches section beginning on p. 171 for more examples of activities and strategies.

Activity	Topic	Suggested Activity
1	7.3	**Construct an Argument** Students can perform a brine shrimp lab, placing groups of brine shrimp eggs in petri dishes with various concentrations of salt in the water. They monitor the number of eggs and swimming shrimp in the petri dishes at regular time intervals over a period of two to three days. Students can calculate the hatching viability in each petri dish and then graph their data. Chi-square can be used to analyze the null hypothesis.
2	7.5	**Error Analysis** Have students use one of the Rock Pocket Mouse activities available online to learn the principles of the Hardy-Weinberg theorem and to calculate allele frequencies in a population.
3	7.10	**Ask the Expert** Show students a cartoon of an isolating mechanism that leads to speciation. Discuss with students what is happening in this cartoon and how it relates to speciation. Students should do research on other isolating mechanisms and draw their own cartoon to illustrate their learnings.

Unit Planning Notes

Use the space below to plan your approach to the unit. Consider how you want to pace your course and your methods of instruction and assessment.

TOPIC 7.1
Introduction to Natural Selection

SUGGESTED SKILL

Visual Representations

2.A

Describe characteristics of a biological concept, process, or model represented visually.

AVAILABLE RESOURCES

- Classroom Resources > **Visualizing Information**
- Classroom Resources > **Evolution and Change**

Required Course Content

ENDURING UNDERSTANDING

EVO-1

Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
EVO-1.C Describe the causes of natural selection.	**EVO-1.C.1** Natural selection is a major mechanism of evolution.
	EVO-1.C.2 According to Darwin's theory of natural selection, competition for limited resources results in differential survival. Individuals with more favorable phenotypes are more likely to survive and produce more offspring, thus passing traits to subsequent generations.
EVO-1.D Explain how natural selection affects populations.	**EVO-1.D.1** Evolutionary fitness is measured by reproductive success.
	EVO-1.D.2 Biotic and abiotic environments can be more or less stable/fluctuating, and this affects the rate and direction of evolution; different genetic variations can be selected in each generation.

SUGGESTED SKILL

Concept Explanation

1.B

Explain biological concepts and/or processes.

AVAILABLE RESOURCES

- Classroom Resources > **Evolution and Change**

ILLUSTRATIVE EXAMPLES

EVO-1.E.2

- Flowering time in relation to global climate change
- Peppered moth

EVO-1.E.3 B

- Sickle cell anemia
- DDT resistance in insects

TOPIC 7.2
Natural Selection

Required Course Content

ENDURING UNDERSTANDING

EVO-1

Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence.

LEARNING OBJECTIVE

EVO-1.E

Describe the importance of phenotypic variation in a population.

ESSENTIAL KNOWLEDGE

EVO-1.E.1

Natural selection acts on phenotypic variations in populations.

EVO-1.E.2

Environments change and apply selective pressures to populations.

EVO-1.E.3

Some phenotypic variations significantly increase or decrease fitness of the organism in particular environments.

TOPIC 7.3
Artificial Selection

Required Course Content

ENDURING UNDERSTANDING

EVO-1

Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence.

LEARNING OBJECTIVE

EVO-1.F

Explain how humans can affect diversity within a population.

EVO-1.G

Explain the relationship between changes in the environment and evolutionary changes in the population.

ESSENTIAL KNOWLEDGE

EVO-1.F.1

Through artificial selection, humans affect variation in other species.

EVO-1.G.1

Convergent evolution occurs when similar selective pressures result in similar phenotypic adaptations in different populations or species.

SUGGESTED SKILL

Representing and Describing Data

4.B.c

Describe data from a table or graph, including describing relationships between variables.

AVAILABLE RESOURCES

- Classroom Resources > **Evolution and Change**
- AP Biology Lab Manual > **Artificial Selection Lab**

SUGGESTED SKILL

Questions and Methods

3.B

State the null or alternative hypotheses, or predict the results of an experiment.

AVAILABLE RESOURCES

- Classroom Resources > **Evolution and Change**

TOPIC 7.4
Population Genetics

Required Course Content

ENDURING UNDERSTANDING

EVO-1

Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
EVO-1.H Explain how random occurrences affect the genetic makeup of a population.	**EVO-1.H.1** Evolution is also driven by random occurrences— a. Mutation is a random process that contributes to evolution. b. Genetic drift is a nonselective process occurring in small populations— i. Bottlenecks. ii. Founder effect. c. Migration/gene flow can drive evolution.
EVO-1.I Describe the role of random processes in the evolution of specific populations.	**EVO-1.I.1** Reduction of genetic variation within a given population can increase the differences between populations of the same species.
EVO-1.J Describe the change in the genetic makeup of a population over time.	**EVO-1.J.1** Mutation results in genetic variation, which provides phenotypes on which natural selection acts.

TOPIC 7.5
Hardy-Weinberg Equilibrium

Required Course Content

ENDURING UNDERSTANDING

EVO-1

Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence.

LEARNING OBJECTIVE

EVO-1.K

Describe the conditions under which allele and genotype frequencies will change in populations.

ESSENTIAL KNOWLEDGE

EVO-1.K.1

Hardy-Weinberg is a model for describing and predicting allele frequencies in a nonevolving population. Conditions for a population or an allele to be in Hardy-Weinberg equilibrium are—(1) a large population size, (2) absence of migration, (3) no net mutations, (4) random mating, and (5) absence of selection. These conditions are seldom met, but they provide a valuable null hypothesis.

EVO-1.K.2

Allele frequencies in a population can be calculated from genotype frequencies.

RELEVANT EQUATION

Hardy-Weinberg Equation—

$$p^2 + 2pq + q^2 = 1$$

$$p + q = 1$$

where:

p = frequency of allele 1 in the population

q = frequency of allele 2 in the population

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SUGGESTED SKILLS

Statistical Tests

5.A.a

Perform mathematical calculations, including mathematical equations in the curriculum.

Data Analysis and Concept Explanation

1.C

Explain biological concepts, processes, and/or models in applied contexts.

AVAILABLE RESOURCES

- Classroom Resources > **Evolution and Change**
- AP Biology Lab Manual > **Mathematical Modeling**

ILLUSTRATIVE EXAMPLE

EVE-1.K.2

- Graphical analysis of allele frequencies in a population

UNIT 7

Natural Selection

LEARNING OBJECTIVE

EVO-1.L

Explain the impacts on the population if any of the conditions of Hardy-Weinberg are not met.

ESSENTIAL KNOWLEDGE

EVO-1.L.1

Changes in allele frequencies provide evidence for the occurrence of evolution in a population.

EVO-1.L.2

Small populations are more susceptible to random environmental impact than large populations.

TOPIC 7.6
Evidence of Evolution

Required Course Content

ENDURING UNDERSTANDING

EVO-1

Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
EVO-1.M Describe the types of data that provide evidence for evolution.	**EVO-1.M.1** Evolution is supported by scientific evidence from many disciplines (geographical, geological, physical, biochemical, and mathematical data).
EVO-1.N Explain how morphological, biochemical, and geological data provide evidence that organisms have changed over time.	**EVO-1.N.1** Molecular, morphological, and genetic evidence from extant and extinct organisms adds to our understanding of evolution— a. Fossils can be dated by a variety of methods. These include: i. The age of the rocks where a fossil is found ii. The rate of decay of isotopes including carbon-14 iii. Geographical data b. Morphological homologies, including vestigial structures, represent features shared by common ancestry. **EVO-1.N.2** A comparison of DNA nucleotide sequences and/or protein amino acid sequences provides evidence for evolution and common ancestry.

SUGGESTED SKILL

Representing and Describing Data

4.B.a

Describe data from a table or graph, including identifying specific data points.

AVAILABLE RESOURCES

- Classroom Resources > **Evolution and Change**

UNIT 7

Natural Selection

ENDURING UNDERSTANDING

EVO-2

Organisms are linked by lines of descent from common ancestry.

LEARNING OBJECTIVE

EVO-2.B

Describe the fundamental molecular and cellular features shared across all domains of life, which provide evidence of common ancestry.

ESSENTIAL KNOWLEDGE

EVO-2.B.1

Many fundamental molecular and cellular features and processes are conserved across organisms.

EVO-2.B.2

Structural and functional evidence supports the relatedness of organisms in all domains.

TOPIC 7.7
Common Ancestry

Required Course Content

ENDURING UNDERSTANDING

EVO-2

Organisms are linked by lines of descent from common ancestry.

LEARNING OBJECTIVE

EVO-2.C

Describe structural and functional evidence on cellular and molecular levels that provides evidence for the common ancestry of all eukaryotes.

ESSENTIAL KNOWLEDGE

EVO-2.C.1

Structural evidence indicates common ancestry of all eukaryotes—

a. Membrane-bound organelles

b. Linear chromosomes

c. Genes that contain introns

SUGGESTED SKILL

Argumentation

6.E.b

Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on a visual representation of a biological concept, process, or model.

AVAILABLE RESOURCES

- Classroom Resources > Evolution and Change

SUGGESTED SKILL

Questions and Methods

3.E.a

Propose a new/next investigation based on an evaluation of the evidence from an experiment.

AVAILABLE RESOURCES

- Classroom Resources > **Evolution and Change**

TOPIC 7.8
Continuing Evolution

Required Course Content

ENDURING UNDERSTANDING

EVO-3

Life continues to evolve within a changing environment.

LEARNING OBJECTIVE

EVO-3.A

Explain how evolution is an ongoing process in all living organisms.

ESSENTIAL KNOWLEDGE

EVO-3.A.1

Populations of organisms continue to evolve.

EVO-3.A.2

All species have evolved and continue to evolve—

a. Genomic changes over time.
b. Continuous change in the fossil record.
c. Evolution of resistance to antibiotics, pesticides, herbicides, or chemotherapy drugs.
d. Pathogens evolve and cause emergent diseases.

TOPIC 7.9 Phylogeny

SUGGESTED SKILL

Visual Representations

2.D.c

Represent relationships within biological models, including flowcharts.

AVAILABLE RESOURCES

- Classroom Resources > Evolution and Change

Required Course Content

ENDURING UNDERSTANDING

EVO-3

Life continues to evolve within a changing environment.

LEARNING OBJECTIVE

EVO-3.B

Describe the types of evidence that can be used to infer an evolutionary relationship.

ESSENTIAL KNOWLEDGE

EVO-3.B.1

Phylogenetic trees and cladograms show evolutionary relationships among lineages—

a. Phylogenetic trees and cladograms both show relationships between lineages, but phylogenetic trees show the amount of change over time calibrated by fossils or a molecular clock.
b. Traits that are either gained or lost during evolution can be used to construct phylogenetic trees and cladograms—
    i. Shared characters are present in more than one lineage.
    ii. Shared, derived characters indicate common ancestry and are informative for the construction of phylogenetic trees and cladograms.
    iii. The out-group represents the lineage that is least closely related to the remainder of the organisms in the phylogenetic tree or cladogram.
c. Molecular data typically provide more accurate and reliable evidence than morphological traits in the construction of phylogenetic trees or cladograms.

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UNIT 7

Natural Selection

LEARNING OBJECTIVE

EVO-3.C

Explain how a phylogenetic tree and/or cladogram can be used to infer evolutionary relatedness.

ESSENTIAL KNOWLEDGE

EVO-3.C.1

Phylogenetic trees and cladograms can be used to illustrate speciation that has occurred. The nodes on a tree represent the most recent common ancestor of any two groups or lineages.

EVO-3.C.2

Phylogenetic trees and cladograms can be constructed from morphological similarities of living or fossil species and from DNA and protein sequence similarities.

EVO-3.C.3

Phylogenetic trees and cladograms represent hypotheses and are constantly being revised, based on evidence.

TOPIC 7.10
Speciation

Required Course Content

ENDURING UNDERSTANDING

EVO-3

Life continues to evolve within a changing environment.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
EVO-3.D Describe the conditions under which new species may arise.	**EVO-3.D.1** Speciation may occur when two populations become reproductively isolated from each other. **EVO-3.D.2** The biological species concept provides a commonly used definition of species for sexually reproducing organisms. It states that species can be defined as a group capable of interbreeding and exchanging genetic information to produce viable, fertile offspring.
EVO-3.E Describe the rate of evolution and speciation under different ecological conditions.	**EVO-3.E.1** Punctuated equilibrium is when evolution occurs rapidly after a long period of stasis. Gradualism is when evolution occurs slowly over hundreds of thousands or millions of years. **EVO-3.E.2** Divergent evolution occurs when adaptation to new habitats results in phenotypic diversification. Speciation rates can be especially rapid during times of adaptive radiation as new habitats become available.

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SUGGESTED SKILLS

Argumentation

6.E.a

Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on biological concepts or processes.

Visual Representations

2.B.a

Explain relationships between different characteristics of biological concepts, processes, or models represented visually in theoretical contexts.

AVAILABLE RESOURCES

- Classroom Resources > **Evolution and Change**

ILLUSTRATIVE EXAMPLES

EVO-3.F.1

- Hawaiian *Drosophilia*
- Caribbean *Anolis*
- Apple maggot *Rhagoletis*

Natural Selection

LEARNING OBJECTIVE

EVO-3.F

Explain the processes and mechanisms that drive speciation.

ESSENTIAL KNOWLEDGE

EVO-3.F.1

Speciation results in diversity of life forms.

EVO-3.F.2

Speciation may be sympatric or allopatric.

EVO-3.F.3

Various prezygotic and postzygotic mechanisms can maintain reproductive isolation and prevent gene flow between populations.

TOPIC 7.11 Extinction

Required Course Content

ENDURING UNDERSTANDING

EVO-3

Life continues to evolve within a changing environment.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
EVO-3.G Describe factors that lead to the extinction of a population.	**EVO-3.G.1** Extinctions have occurred throughout Earth's history. **EVO-3.G.2** Extinction rates can be rapid during times of ecological stress.
EVO-3.H Explain how the risk of extinction is affected by changes in the environment.	**EVO-3.H.1** Human activity can drive changes in ecosystems that cause extinctions.
EVO-3.I Explain species diversity in an ecosystem as a function of speciation and extinction rates.	**EVO-3.I.1** The amount of diversity in an ecosystem can be determined by the rate of speciation and the rate of extinction.
EVO-3.J Explain how extinction can make new environments available for adaptive radiation.	**EVO-3.J.1** Extinction provides newly available niches that can then be exploited by different species.

SUGGESTED SKILL

Questions and Methods

3.B

State the null or alternative hypotheses, or predict the results of an experiment.

AVAILABLE RESOURCES

- Classroom Resources > **Evolution and Change**

SUGGESTED SKILL

Argumentation

6.C

Provide reasoning to justify a claim by connecting evidence to biological theories.

AVAILABLE RESOURCES

- Classroom Resources > **Evolution and Change**

ILLUSTRATIVE EXAMPLES

SYI-3.D.1.a

- California condors
- Black-footed ferrets
- Prairie chickens
- Potato blight
- Corn rust
- Genetic diversity and selective pressures
- Antibiotic resistance in bacteria. (Not all individuals in a diverse population are susceptible to a disease outbreak.)

TOPIC 7.12
Variations in Populations

Required Course Content

ENDURING UNDERSTANDING

SYI-3

Naturally occurring diversity among and between components within biological systems affects interactions with the environment.

LEARNING OBJECTIVE

SYI-3.D

Explain how the genetic diversity of a species or population affects its ability to withstand environmental pressures.

ESSENTIAL KNOWLEDGE

SYI-3.D.1

The level of variation in a population affects population dynamics—

a. Population ability to respond to changes in the environment is influenced by genetic diversity. Species and populations with little genetic diversity are at risk of decline or extinction.
b. Genetically diverse populations are more resilient to environmental perturbation because they are more likely to contain individuals who can withstand the environmental pressure.
c. Alleles that are adaptive in one environmental condition may be deleterious in another because of different selective pressures.

TOPIC 7.13 Origins of Life on Earth

Required Course Content

ENDURING UNDERSTANDING

SYI-3

Naturally occurring diversity among and between components within biological systems affects interactions with the environment.

LEARNING OBJECTIVE

SYI-3.E

Describe the scientific evidence that provides support for models of the origin of life on Earth.

ESSENTIAL KNOWLEDGE

SYI-3.E.1

Several hypotheses about the origin of life on Earth are supported with scientific evidence—

a. Geological evidence provides support for models of the origin of life on Earth.
   i. Earth formed approximately 4.6 billion years ago (bya). The environment was too hostile for life until 3.9 bya, and the earliest fossil evidence for life dates to 3.5 bya. Taken together, this evidence provides a plausible range of dates when the origin of life could have occurred.

b. There are several models about the origin of life on Earth—
   i. Primitive Earth provided inorganic precursors from which organic molecules could have been synthesized because of the presence of available free energy and the absence of a significant quantity of atmospheric oxygen (O_2).
   ii. Organic molecules could have been transported to Earth by a meteorite or other celestial event.

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SUGGESTED SKILL

Questions and Methods

3.B

State the null or alternative hypotheses, or predict the results of an experiment.

AVAILABLE RESOURCES

- Classroom Resources > **Evolution and Change**

Natural Selection

LEARNING OBJECTIVE

SYI-3.E

Describe the scientific evidence that provides support for models of the origin of life on Earth.

ESSENTIAL KNOWLEDGE

c. Chemical experiments have shown that it is possible to form complex organic molecules from inorganic molecules in the absence of life—
   i. Organic molecules/monomers served as building blocks for the formation of more complex molecules, including amino acids and nucleotides.
   ii. The joining of these monomers produced polymers with the ability to replicate, store, and transfer information.

SYI-3.E.2

The RNA World Hypothesis proposes that RNA could have been the earliest genetic material.