

Unit 7: Natural Selection

Unit 7 covers how natural selection, genetic drift, and gene flow change populations over time, plus the evidence for evolution, how species form, and how to read phylogenetic trees. CED topics 7.1 through 7.12.

AP Biology

Natural Selection

About 12 minutes to read

How to use this guide

Read it in order the first time because the topics build on each other. Selection comes first, then the population genetics that measures it, then the evidence that it happened, then the trees that organize relationships, then speciation. Exam questions usually give a scenario and ask you to name the mechanism, so practice attaching each term to a concrete situation as you read.

After the first read, use the trap boxes and the tables to review the distinctions that exam questions test most often. Finish with the practice questions, then complete the recall check on the last page out loud and note any items you cannot explain yet.

How this unit connects. Natural selection is the mechanism behind change in every other unit. Population genetics applies the statistics of heredity to whole populations. The evidence for evolution draws on fossils, anatomy, and molecules. Speciation leads directly into the ecology of Unit 8, where isolated populations interact. Learn the logic here and it keeps paying off.

7.1 Introduction to Natural Selection

Darwin's mechanism has three parts. First, resources are limited, so individuals compete. Second, individuals differ in their observable traits, and some of those traits help their owners survive and reproduce. Third, the winners pass the helpful traits to offspring. The result is **differential survival**: individuals with more favorable phenotypes are more likely to survive and reproduce. **Natural selection** is the whole process, the major mechanism of evolution.

Evolutionary fitness is measured by reproductive success, not by strength, size, or speed. A large animal that leaves no offspring has zero fitness. Environments also fluctuate. **Biotic** factors (other living things) and **abiotic** factors (temperature, rainfall, and the rest of the nonliving environment) change over time, which changes the rate and direction of evolution. Different genetic variations can be favored in each generation.

Trap. Fitness means leaving more offspring, not being physically fit. If a question describes the biggest or fastest individual losing the mating contest, the smaller winner has the higher fitness.

7.2 Natural Selection

Selection acts on **phenotypic variation**, the differences in observable traits within a population. It does not act on genes directly, and it works on variation that is already present. **Selective pressure** is any environmental factor that favors certain phenotypes. When environments change, pressures change with them, and some phenotypic variations increase an organism's fitness in the new environment while others decrease it.

The course gives illustrative examples of variation under selection: flowering time shifting in relation to global climate change, sickle cell anemia, and DDT resistance in insects. In each case the environment changed what counted as a favorable phenotype.

7.3 Artificial Selection

Artificial selection is the same basic process with a different agent. Humans decide which individuals reproduce, so human preference becomes the selective pressure. The underlying logic, differential reproduction of favored variants, is identical to natural selection.

FEATURE	NATURAL SELECTION	ARTIFICIAL SELECTION
Selective agent	The environment, biotic and abiotic	Humans choosing breeding stock
What is favored	Traits that raise survival and reproduction in that environment	Traits humans want, whether or not they help survival
Example	Insects resistant to DDT surviving spraying	Choosing which plants or animals breed each generation

7.4 Population Genetics

Evolution is measured in **allele frequency**, the proportion of each allele in a population's gene pool. If allele frequencies change from one generation to the next, evolution has occurred. That single sentence is the lens for this whole topic.

Genetic drift changes allele frequencies through a nonselective process in small populations. It is random, not adaptive, and it can let a small population diverge from other populations of the same species. Two named forms appear on the exam. The **bottleneck effect** happens when a population is reduced to a small number of individuals for at least one generation, as after a disaster. The **founder effect** happens when a few individuals separate from the main population and start a new one, so the new population's gene frequencies reflect the founders' genes.

Gene flow is the addition or removal of alleles through migration. Because it mixes genes between populations, it works against divergence. Gene flow between two populations prevents them from splitting into separate species.

Trap. Bottleneck and founder effect are both genetic drift, which means both are random. A bottleneck is a disaster that shrinks a population. A founder effect is a few individuals leaving to start a new one. If the scenario mentions selection favoring a trait, it is not drift at all.

7.5 Hardy-Weinberg Equilibrium

The **Hardy-Weinberg equilibrium** is a model of a population that is not evolving. It holds under five conditions: large population size, no migration, no new mutations, random mating, and no natural selection. Those conditions are never all met in nature, which is exactly the point. The model is a null hypothesis. If real frequencies match it, nothing is acting. If they differ, something is.

The **Hardy-Weinberg equation** is $p^2 + 2pq + q^2 = 1$, with $p + q = 1$, where p and q are the frequencies of the two alleles. From genotype frequencies you can calculate allele frequencies, and the reverse.

Worked example: suppose 16 percent of a population shows the recessive phenotype. Then $q^2 = 0.16$, so $q = 0.4$ and $p = 0.6$. Heterozygotes are $2pq = 2(0.6)(0.4) = 0.48$, or 48 percent of the population.

Trap. Take the square root of the recessive phenotype frequency to find q . Students commonly take the square root of the dominant side instead, or forget to double pq . Also, the equation only describes a population where no evolution is happening.

7.6 Evidence of Evolution

Four independent lines of evidence point the same direction. **Fossils** are preserved remains or traces that document change over time. They are dated by the age of the rocks where they are found, by the rate of decay of isotopes including carbon-14, and by geographical data. **Morphological homology** is similarity in body structure across species, including **vestigial structures**, that indicates common ancestry. A vestigial structure is a reduced or nonfunctional remnant of a structure that worked in an ancestor.

Molecular evidence for evolution comes from comparing DNA nucleotide sequences and protein amino acid sequences. Species with more similar sequences share more recent ancestry. Molecular data are typically more accurate and reliable than morphological traits for building phylogenies, because similar body shapes can mislead while sequences rarely do.

Trap. A vestigial structure is evidence of ancestry, not evidence of uselessness. It can keep a minor function and still count as vestigial. The point is the reduction from the ancestral state, which only makes sense if the species descended from an ancestor that used it fully.

7.7 Common Ancestry

All eukaryotes share common ancestry. The evidence is structural and functional: membrane-bound organelles, linear chromosomes, and genes that contain introns. Features this fundamental are shared because they were present in the common ancestor, not because each lineage invented them separately.

7.8 Continuing Evolution

Evolution is still happening. The evidence includes genomic changes measured over time, continuous change in the fossil record, the **evolution of resistance** to antibiotics, pesticides, herbicides, and chemotherapy drugs, and pathogens evolving to cause emergent diseases. **Ongoing evolution** is the name for this pattern: all species have evolved and continue to evolve.

Trap. Antibiotics do not create resistant bacteria. Resistant variants already exist in the population, and the antibiotic kills the rest, leaving the resistant ones to reproduce. That is natural selection acting on existing variation, the same mechanism as everywhere else in this unit.

7.9 Phylogeny

A **phylogenetic tree** is a diagram of hypothetical evolutionary relationships among lineages. It shows the amount of change over time, calibrated by fossils or a **molecular clock**, which uses steady rates of molecular change to measure evolutionary change over time. Because the relationships are hypothetical, trees can be tested against new data. A **cladogram** shows the same relationships but carries no time scale and no measure of how much groups differ.

Trees are built from **shared derived characters**, traits gained or lost during evolution that appear in more than one lineage and indicate common ancestry. The **outgroup** is the lineage least closely related to the rest, and it roots the tree. Each **node** represents the **most recent common ancestor** of the two groups or lineages that meet there.

FEATURE	PHYLOGENETIC TREE	CLADOGRAM
Relationships shown	Yes, hypothetical and testable	Yes, hypothetical and testable
Time scale	Yes, calibrated by fossils or a molecular clock	No
Amount of change	Shown	Not shown

Trap. Relatedness is read from shared nodes, not from the left-to-right order of the tips. Two groups that share a more recent common ancestor are more closely related, no matter how the branches are drawn. And a cladogram can never tell you when a split happened, because it has no time axis.

7.10 Speciation

Speciation is the formation of new species. It happens when two populations become **reproductively isolated**, separated so they cannot exchange genes. Isolation is maintained by **reproductive isolating mechanisms**, pre-zygotic and post-zygotic, that prevent gene flow between populations. The **biological species concept** defines a species, for sexually reproducing organisms, as a group capable of interbreeding and exchanging genetic information to produce viable, fertile offspring.

PATTERN	WHAT HAPPENS
Allopatric speciation	Populations are geographically isolated when they diverge. A barrier splits them first.
Sympatric speciation	Populations diverge with geographic overlap. No barrier is required.

The course gives illustrative examples of speciation: Hawaiian Drosophila, Caribbean Anolis, and the apple maggot Rhagoletis. Two larger patterns describe the tempo of change. **Gradualism** is slow change over hundreds of thousands or millions of years. **Punctuated equilibrium** is rapid change after a long period of stasis. Two more describe the direction. **Divergent evolution** is adaptation to new habitats producing phenotypic diversification. **Convergent evolution** is similar selective pressures producing similar adaptations in different populations or species. **Adaptive radiation** is a burst of especially rapid speciation when new habitats become available.

Trap. Divergent evolution splits one lineage into different forms. Convergent evolution pushes different lineages toward similar forms. If the question names one starting population spreading into new habitats, think divergent. If it names unrelated species solving the same problem the same way, think convergent.

7.11 Extinction

A population's **genetic diversity** decides how well it survives pressure. Populations with little genetic variation are at risk of decline or extinction when the environment shifts, because no individual may carry what survival requires. Genetically diverse populations are more resilient, since they are more likely to contain individuals that can withstand the pressure. The course illustrates this with California condors, black-footed ferrets, prairie chickens, potato blight, corn rust, and antibiotic resistance in bacteria. Each is a case where diversity, or the lack of it, decided the outcome.

7.12 Variations in Populations

The unit closes with the origin of life itself. Earth formed approximately 4.6 billion years ago, the environment stayed too hostile for life until about 3.9 billion years ago, and the earliest fossil evidence for life dates to 3.5 billion years ago. That sequence gives a plausible range for when life began. The **RNA world hypothesis** proposes that RNA was the earliest genetic material. It rests on three assumptions: genetic continuity was assured by RNA replication, base-pairing is necessary for replication, and genetically encoded proteins were not involved as catalysts.

Confusions That Cost Points

Most missed questions in this unit come from a short list of pairs that look alike under time pressure. Review each pair carefully so you can tell them apart when you see them in a question.

PAIR	HOW TO SEPARATE THEM
Evolutionary fitness vs physical fitness	Evolutionary fitness is reproductive success, offspring left behind. Physical fitness is strength or speed. They often disagree.
Bottleneck effect vs founder effect	Bottleneck is a disaster shrinking a population for at least one generation. Founder effect is a few individuals leaving to start a new population. Both are random drift.
Genetic drift vs gene flow	Drift is random change in small populations with no selection involved. Gene flow is migration of alleles between populations, and it prevents divergence.
Phylogenetic tree vs cladogram	A tree shows change over time, calibrated by fossils or a molecular clock. A cladogram shows relationships only, with no time scale and no measure of difference.
Allopatric vs sympatric speciation	Allopatric needs geographic isolation, a barrier. Sympatric happens with geographic overlap and no barrier.
Punctuated equilibrium vs gradualism	Punctuated equilibrium is rapid change after long stasis. Gradualism is slow change over hundreds of thousands or millions of years.
Divergent vs convergent evolution	Divergent starts with one lineage and produces different forms in new habitats. Convergent starts with different lineages and produces similar forms under similar pressures.
Pre-zygotic vs post-zygotic mechanisms	Pre-zygotic mechanisms block fertilization from happening. Post-zygotic mechanisms act after fertilization, on the hybrid offspring.
Vestigial structure vs morphological homology	A vestigial structure is a reduced remnant of an ancestral structure. Homology is the broader pattern, similarity across species from common ancestry. One structure can be both.

Practice Questions

Original questions written for this guide in the style of the AP exam. Answers and explanations are on the next page, so complete the questions before checking them.

- 1.** In a population of beetles, large males win fights for mates, but smaller males that avoid fights mate more often and leave more offspring. Which statement about fitness is correct?
 - A. The large males are more fit because they are stronger and win fights
 - B. The small males are more fit because they leave more offspring
 - C. Fitness is equal because all the males belong to one population
 - D. Neither group has fitness because fitness only applies between species

- 2.** A hurricane kills 95 percent of the lizards on an island. The few survivors repopulate the island over the next decade. This scenario best illustrates
 - A. the founder effect
 - B. the bottleneck effect
 - C. gene flow
 - D. natural selection favoring the survivors

- 3.** In a population of 1,000 plants, 490 show the recessive phenotype for flower color. Assuming Hardy-Weinberg equilibrium, what percentage of the population is heterozygous?
 - A. 49%
 - B. 70%
 - C. 42%
 - D. 21%

- 4.** The pelvis of a whale is a small internal bone with no role in swimming. It is best described as
 - A. a fossil
 - B. a vestigial structure
 - C. a homologous structure shared with walking mammals
 - D. molecular evidence for evolution

- 5.** A hospital finds that a bacterial infection no longer responds to an antibiotic that was effective last year. The most accurate explanation is that
- A. the antibiotic caused mutations that made the bacteria resistant
 - B. individual bacteria became immune during their lifetimes and passed the immunity to offspring
 - C. bacteria with pre-existing resistant variants survived and reproduced more
 - D. the bacteria migrated in from another hospital
- 6.** A cladogram shows groups A and B sharing a node, with group C branching off at an earlier node. Which statement is correct?
- A. A and B are more closely related to each other than either is to C
 - B. A is more evolved than C because it appears farther to the right
 - C. The cladogram shows that A and B diverged 10 million years ago
 - D. C is the outgroup, so it shares no characters with A and B
- 7.** Two populations of the same bird species live on opposite sides of a mountain range. They can no longer produce fertile offspring together. This is an example of
- A. sympatric speciation
 - B. allopatric speciation
 - C. adaptive radiation
 - D. convergent evolution
- 8.** A researcher tracks allele frequencies in a small island bird population for ten generations. No selection is acting, yet the frequencies shift each generation. The best explanation is that
- A. the small population size lets genetic drift change allele frequencies
 - B. new mutations appear every generation
 - C. the population meets all Hardy-Weinberg conditions
 - D. natural selection is favoring certain alleles

Answer Key

- 1. B.** Fitness is measured by reproductive success, so the small males that leave more offspring are more fit. A is the physical-fitness trap. C misunderstands fitness as a property of the whole population instead of individuals. D invents a rule that fitness only applies between species.
- 2. B.** A disaster reducing the population to a few survivors for generations is the bottleneck effect. A is the founder trap: no small group left to start a new population, the survivors stayed put. C needs migration, which the scenario never mentions. D assumes the survivors were favored by selection, but nothing says their traits caused their survival.
- 3. C.** $q^2 = 0.49$, so $q = 0.7$ and $p = 0.3$. Heterozygotes are $2pq = 2(0.3)(0.7) = 0.42$, or 42 percent. A reports q^2 as the answer. B reports q . D computes pq and forgets to double it.
- 4. B.** A reduced, nonfunctional remnant of an ancestral structure is a vestigial structure. A is wrong because fossils are preserved remains, not living anatomy. C is tempting because the bone is homologous, but the question asks for the best description of its reduced state, which is vestigial. D names the wrong line of evidence entirely.
- 5. C.** Resistance evolves when pre-existing resistant variants survive treatment and reproduce. A is the classic misconception: antibiotics select, they do not create mutations. B describes inheritance of acquired traits, which does not happen. D invokes migration, but the scenario gives no movement between hospitals.
- 6. A.** Groups sharing a more recent node are more closely related. B reads left-to-right position as advancement, which means nothing on a cladogram. C treats the cladogram as if it had a time scale, which it does not. D overstates the outgroup: least related does not mean sharing no characters.
- 7. B.** A mountain range is a geographic barrier, so divergence in isolation is allopatric speciation. A requires geographic overlap. C needs rapid speciation into new habitats, not a single split. D describes unrelated lineages converging under similar pressures, not one species dividing.
- 8. A.** In a small population with no selection, random shifts in allele frequency are genetic drift. B blames mutations, which are far too rare to drive steady generational shifts. C contradicts the data: Hardy-Weinberg predicts no change at all. D contradicts the premise that no selection is acting.

When you check your answers, note which distinction each miss came from. Make a flashcard for that distinction and drill it spaced out over the next few days instead of rereading the whole section. If you missed one of these questions, the same distinction is worth practicing again in Rycal, where the Natural Selection deck has flashcards for it and more practice questions use the same kinds of traps.

One-Page Recall Check

Say each answer out loud before you look back, and mark the ones you cannot finish. Anything you cannot say out loud yet belongs in your flashcard deck. In Rycal, add those items to the Natural Selection deck and let spaced review bring them back over the next few days.

- State the mechanism of natural selection in one sentence, using competition, variation, and differential survival.
- Explain why a strong animal can still have zero evolutionary fitness.
- Define selective pressure and give one example of a pressure changing over time.
- Explain how artificial selection differs from natural selection, and what the two share.
- Define allele frequency and explain what a change in it tells you.
- Separate genetic drift, the bottleneck effect, the founder effect, and gene flow in one sentence each.
- List the five Hardy-Weinberg conditions and explain why the model is useful even though they are never all met.
- Work a Hardy-Weinberg problem: from a recessive phenotype frequency, find q , p , and the heterozygote frequency.
- Name the four lines of evidence for evolution and give one example of each.
- Explain why molecular evidence is preferred over morphology when building phylogenies.
- Describe what a node, an outgroup, and a shared derived character each tell you on a tree.
- Explain the difference between a phylogenetic tree and a cladogram.
- Define speciation and the biological species concept, then explain what reproductive isolation does.
- Contrast allopatric and sympatric speciation, gradualism and punctuated equilibrium, and divergent and convergent evolution.
- Explain why low genetic diversity puts a population at risk of extinction.
- State the RNA world hypothesis and the three assumptions behind it.

Where to go next. Turn every missed item above into flashcards and drill them spaced out over several days rather than in one sitting. In Rycal, open the Natural Selection deck under AP Biology. The deck covers the terms in this guide, and its practice questions target the same traps named here. If you have a test date, add it in the Test Planner. You can also start your next review with a Brain Dump, then check what you missed against this guide.

Key terms for this unit

Natural selection, differential survival, evolutionary fitness, biotic and abiotic environments, phenotypic variation, selective pressure, artificial selection, genetic drift, bottleneck effect, founder effect, gene flow, allele frequency, Hardy-Weinberg equilibrium, Hardy-Weinberg equation, fossil, morphological homology, vestigial structure, molecular evidence for evolution, common ancestry of eukaryotes, ongoing evolution, evolution of resistance, phylogenetic tree, cladogram, shared derived character, outgroup, most recent common ancestor, molecular clock, speciation, biological species concept, reproductive isolation, sympatric speciation, allopatric speciation, reproductive isolating mechanisms, punctuated equilibrium, gradualism, divergent evolution, adaptive radiation, convergent evolution, genetic diversity and survival, genetic diversity examples, molecular data in phylogenies, molecular variation and fitness, selection examples, speciation examples, origin of life timeline, RNA world hypothesis.