

AP Biology Unit 7

Natural Selection

One-page sprint review
Free at Sophriva

EXAM WEIGHT

13-20%

MCQs

8-12

FRQ APPEARANCE

Every Year

SPRINT TIME

~2.5 hours

Inside this pack

- **Quick Glance at every Unit topic with priority + format**
- **Topic-by-topic key traps, must-know rules, and exam frames**
- **Worked example questions on the highest-yield topics**

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Unit 7 Natural Selection & Evolution

AP Biology Sprint Review · Highest-weight unit · 13–20% of exam

 ~MCQs 8–12

 FRQ Appearance: EVERY Year

 Sprint Time: ~2.5 hours

★ **Three absolute must-masters:** Hardy-Weinberg calculations, Darwinian language (NO Lamarckism), and pre- vs post-zygotic isolation.

At a Glance

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7.4 Population Genetics	★★★★	MCQ FRQ	Genetic drift is random and strongest in small populations. Bottleneck ≠ founder effect.
7.5 Hardy-Weinberg	★★★★	Calc FRQ	Always start from q^2 (recessive phenotype). HWE is a null model; deviation = evolution.
7.6–7.8 Evidence & Continuing Evolution	★★★★	MCQ FRQ	Homologous ≠ analogous. Antibiotic resistance is pre-existing variation selected, not created.
7.9 Phylogeny & Cladograms	★★★★	MCQ Data	All tips are equally evolved. Nodes = MRCA.
7.10 Speciation	★★★★	MCQ FRQ	Gene flow prevents speciation. Know all pre- vs post-zygotic isolation types.
7.11–7.12 Variation & Origins of Life	★★	MCQ	RNA World: RNA was first informational + catalytic molecule.

Language Police — #1 AP FRQ Point Loser

✗ Wrong

- ✗ “The giraffe evolved a longer neck to reach food.”
- ✗ “Bacteria developed resistance to antibiotics.”
- ✗ “The organism adapted to its environment.”
- ✗ “Species evolved because they needed to survive.”
- ✗ “Organisms evolved traits over their lifetime.”

✓ Correct Darwinian Language

- ✓ Giraffes with longer necks had higher reproductive success; the long-neck allele increased in frequency over generations.
- ✓ Bacteria with pre-existing resistance alleles survived antibiotic treatment and reproduced; resistance became more common.
- ✓ Individuals with the trait better suited to the environment left more offspring.
- ✓ Selection acted on existing heritable variation in the population.

 **Individuals are selected. Populations evolve.**

Darwin's 4 Postulates — all 4 are required

1 Variation Exists



Individuals in a population differ in phenotypic traits; without variation no selection is possible; sources: mutation + sexual reproduction.

2 Variation is Heritable



Some variation is encoded in DNA and passed to offspring; non-heritable traits like scars or tanning cannot be selected.

3 Overproduction



Populations produce more offspring than resources can support; limited resources create competition; not all offspring survive to reproduce.

4 Differential Reproduction



Individuals with advantageous traits survive and reproduce more; fitness = relative reproductive success; over generations allele frequencies change.

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● Fitness is always relative to the current environment.

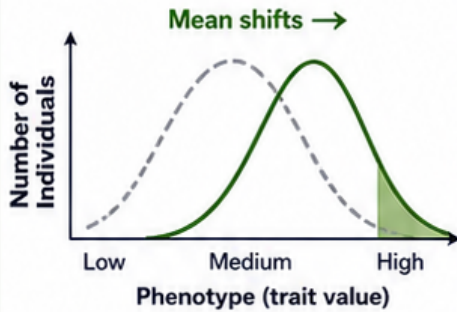
7.1–7.3 Natural Selection Modes

Directional, stabilizing, disruptive, and artificial selection

1. Three Modes of Natural Selection

A Directional Selection

One extreme phenotype favored.
Bell curve shifts toward the favored extreme.



- ✓ Mean changes.
- ✓ Variance may decrease.

Examples



Antibiotic resistance in bacteria



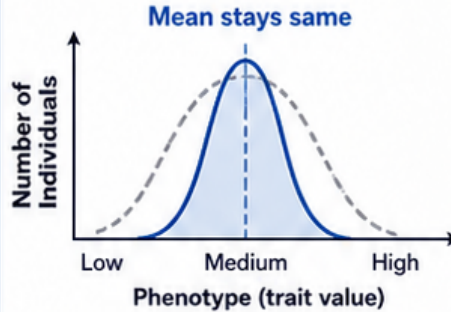
Larger beak size in finches during drought



Industrial melanism in peppered moths

B Stabilizing Selection

Intermediate phenotype favored.
Both extremes eliminated.
Bell curve narrows.



- ✓ Mean stays the same.
- ✓ Variance decreases.

Examples



Human birth weight: neither too small nor too large

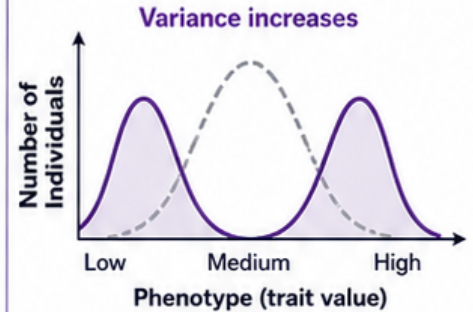


Clutch size in birds: intermediate number of eggs is best

★ Most common in stable environments.

C Disruptive Selection

Both extremes favored and intermediate selected against.
Bell curve splits into two peaks.



- ✓ Mean may stay the same.
- ✓ Variance increases.
- ✓ Can drive sympatric speciation.

Examples



Seedcracker finch: large and small beaks favored over medium



African cichlids: asymmetric vs. symmetric mouths both favored

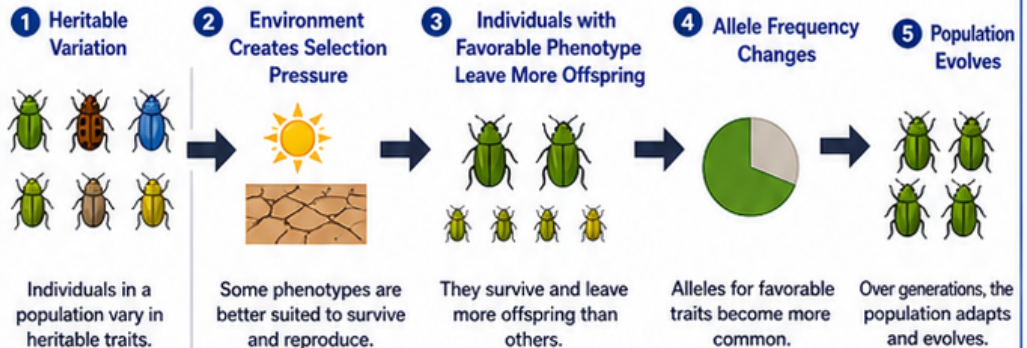
2. Artificial Selection



- ✓ Humans choose which individuals reproduce.
- ✓ Still changes allele frequencies across generations.
- ✓ Demonstrates the same mechanism as natural selection, but the selecting agent is humans.

Examples: dog breeds, crop varieties

3. Natural Selection Logic



★ Evolution is a change in allele frequency over generations.



Exam Sniper






- If one extreme is favored, call it directional selection.
- If the middle is favored and the curve narrows, call it stabilizing selection.
- If both extremes are favored and the middle is selected against, call it disruptive selection.
- Artificial selection proves populations can change rapidly through differential reproduction.
- Always describe evolution as a change in allele frequency across generations.



7.4 Population Genetics

The 5 evolutionary forces + drift, founder effect, bottleneck, and gene flow

The 5 Evolutionary Forces

Force	Mechanism	Directional?	HWE Violation	Key Example
 Natural Selection	differential survival/reproduction based on phenotype	Yes—favors better-adapted alleles	Yes	antibiotic resistance, camouflage, beak size.
 Mutation	random DNA changes create new alleles	Random, usually small effect alone	Yes	raw material for evolution.
 Genetic Drift	random change in allele frequency due to chance sampling; strongest in small populations	Random	Yes	bottleneck effect, founder effect.
 Gene Flow	movement of alleles between populations by migration	depends on source	Yes	immigration/emigration; prevents divergence.
 Non-Random Mating	mate choice/inbreeding/sexual selection changes genotype frequencies	depends on preference	Yes	inbreeding increases homozygosity; sexual selection.

Bottleneck vs Founder Effect



Bottleneck

Dramatic reduction in population size due to a catastrophe.



- Surviving alleles are a random sample.
- Diversity falls.
- Some alleles lost or fixed.

Example: Cheetahs—severe bottleneck thousands of years ago → very low genetic diversity today.

Founder Effect



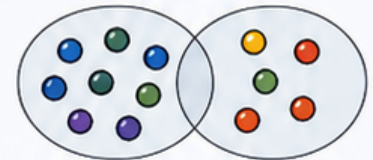
Small group establishes a new population elsewhere.

- Founder allele frequencies may differ from the original population.
- Diversity reduced.

Example: A few birds colonize an island → new population has different allele frequencies than the source.

Shared Point

Both reduce diversity and increase drift.



- Can increase harmful recessive alleles by chance.

Both processes change allele frequencies through chance, not adaptation.

Gene Flow vs Genetic Drift

Gene Flow



Homogenizes populations, makes them more similar, and prevents divergence/speciation.

Populations become more similar; reduces differences.

Low gene flow → drift still possible, but gene flow is minimal.

High gene flow + minimal drift = little divergence.



Process



Effect on Populations



Small Isolated Populations



Large Connected Populations

Genetic Drift



Random and can make isolated populations more different over time.

Populations become more different; increases differences.

High drift + no gene flow = rapid divergence.

Low drift + high gene flow = little divergence.



Exam Sniper

- A rare allele becoming common on a small island often indicates genetic drift, especially founder effect.
- Increased gene flow most reduces the rate of divergence between populations.
- Drift matters more in small populations because random events change allele frequencies more dramatically.
- Drift is not adaptive; it can fix harmful alleles by chance.



7.5 Hardy-Weinberg Equilibrium

Null model, equations, 5 conditions, and the must-use calculation sequence

1 Core Equations

$$p + q = 1$$

p = dominant allele frequency

q = recessive allele frequency

p^2 = homozygous dominant

$2pq$ = heterozygous carriers

q^2 = homozygous recessive

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

2 Always in This Order

1 Find q^2 from the data: recessive phenotype frequency.

2 Find q : $q = \sqrt{q^2}$.

3 Find p : $p = 1 - q$.

4 Find genotype frequencies: p^2 , $2pq$, q^2 .

5 Find actual numbers if needed by multiplying frequency \times population size.

! Always start from q^2 , never from p .

3 5 Conditions for Equilibrium

1 Large population (no drift)



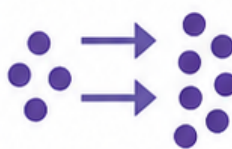
2 No natural selection



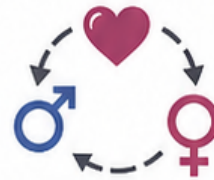
3 No mutation



4 No gene flow



5 Random mating



★ HWE is a null model; deviations mean evolution is occurring at that locus.

4 Full Practice Problem

In a population of 1,000 squirrels, gray coat (G) is dominant over white coat (g). If 160 white squirrels are observed, assuming HWE, calculate (a) allele frequencies and (b) expected number of heterozygous gray squirrels.

- $q^2 = \frac{160}{1000} = 0.16$ \rightarrow White squirrels = q^2
- $q = \sqrt{q^2} = \sqrt{0.16} = 0.4$ \rightarrow Recessive allele frequency
- $p = 1 - q = 1 - 0.4 = 0.6$ \rightarrow Dominant allele frequency
- $2pq = 2(0.6)(0.4) = 0.48$ \rightarrow Heterozygous frequency
- Heterozygous number = $0.48 \times 1000 = 480$ \rightarrow Multiply by population size

✓ Final Answer: $p = 0.6$, $q = 0.4$, heterozygous gray squirrels = 480.

5 Major Exam Insight



Carriers ($2pq$) are often much more common than affected individuals (q^2) when the allele is rare.

Example:

- If $q^2 = 0.0001$
 - Then $q = \sqrt{0.0001} = 0.01$
 - $p = 1 - 0.01 = 0.99$
 - $2pq = 2(0.99)(0.01) = 0.0198$
- ≈ 1 in 50**

6 Exam Sniper



- HWE means none of the 5 forces act on this gene.
- If allele frequency changes, at least one condition is violated.
- Identify the most plausible violated condition from the biological scenario.



7.6–7.8 Evidence for Evolution

Fossils, molecules, structures, biogeography, and continuing evolution

~MCQs 8–12

FRQ Appearance: EVERY Year

Sprint Time: ~2.5 hours

1 Fossil Record

Gradual change over time; transitional forms.

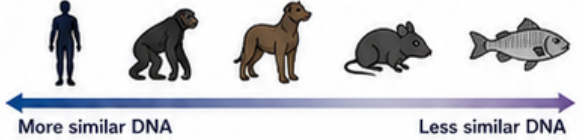


- Radiometric dating uses radioactive isotopes.
- ^{14}C for recent fossils (up to ~50,000 years).
- $^{40}\text{K}/^{40}\text{Ar}$ for old fossils (millions to billions of years).
- Half-life = time for 50% of a sample to decay.
- Fossil gaps do not mean evolution did not occur—fossilization is rare and conditions are specific.

2 Molecular & DNA Evidence



● More DNA similarity = more recent common ancestry.



● Cytochrome c protein is nearly identical across many eukaryotes.



● Universal genetic code, ATP, and ribosomes support common ancestry.



● rRNA (16S/18S) sequences are used to build phylogenetic trees.

3 Structural Evidence

Homologous Structures

Same underlying anatomy, different function; evidence of common ancestry.



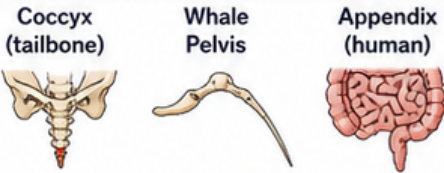
Analogous Structures

Same function, different origin; evidence of convergent evolution.



Vestigial Structures

Reduced remnants of structures; evidence of common ancestry.



4 Biogeography & Direct Observation



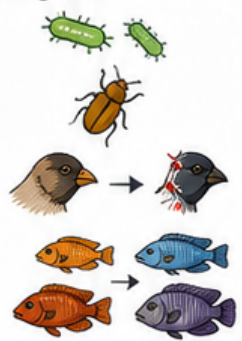
Biogeography: Related species found near each other geographically.

- Darwin's finches: different beaks, same islands.
- Australian marsupials vs. similar placental mammals elsewhere.



Direct Observation: Evolution happening now.

- Antibiotic resistance in bacteria.
- Pesticide resistance in insects.
- HIV evolution and drug resistance.
- Finch beak changes during drought.
- Adaptive radiation: many species from one common ancestor (e.g., cichlids in African lakes).



Critical: Antibiotic Resistance Logic

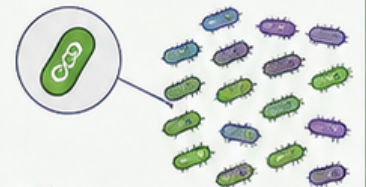
✗ **Wrong**

"Bacteria mutated to become resistant because of the antibiotic."



✓ **Correct**

- ✓ Rare bacteria already had resistance alleles from pre-existing random mutations.
- ✓ Antibiotic kills susceptible bacteria.
- ✓ Resistant bacteria survive and reproduce.
- ✓ Resistant allele becomes more common.
- ✓ Antibiotic is the selection pressure, not the cause of mutation.



⚠ **Selection acts on variation that already exists—antibiotics do not cause mutations.**



Exam Sniper

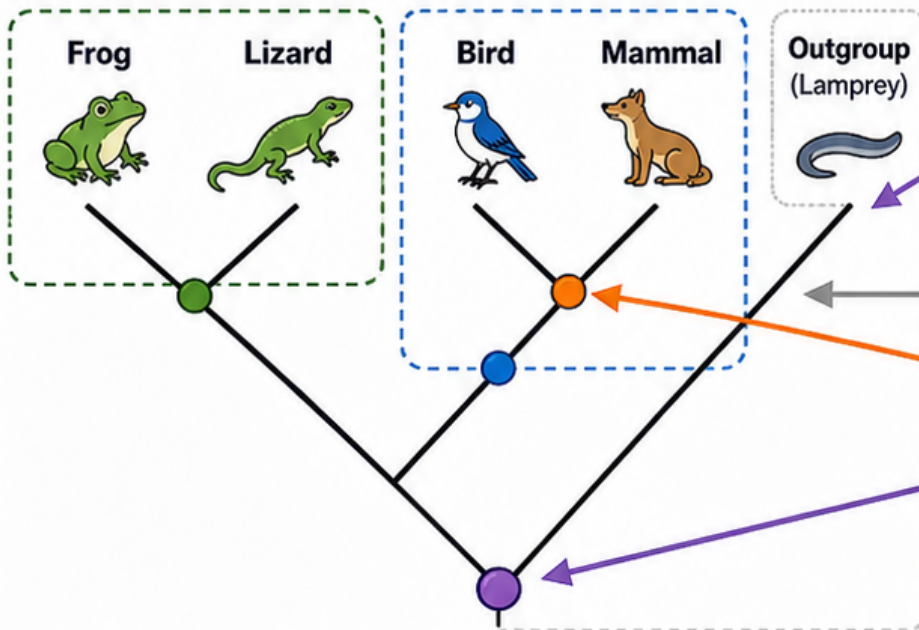
- Bird wing + insect wing = analogous, not homologous.
- Coccyx = vestigial structure, evidence of common ancestry.
- Pesticide or antibiotic resistance FRQs must include variation, survival, heritability, and allele-frequency increase.



7.9 Phylogeny & Cladograms

How to read trees, identify MRCA, outgroup, clades, and common traps

1 Reading a Cladogram — Key Parts



- **node = most recent common ancestor (MRCA)**
Each dot is an ancestor of all lineages above it.
- **outgroup = least related lineage at base**
Used to root the tree and infer direction of evolution.
- clade = ancestor plus all descendants**
Example: Bird + Mammal form a clade (blue box).
- **shared derived characters (synapomorphies)**
Traits that evolved at a node and are shared by all descendants above it.

★ Closer on the tree = more recently shared common ancestor. The more recent the shared ancestor, the closer the relationship.

2 Key Rules

- ✓ **Nodes are MRCAs.**
Every node represents the most recent common ancestor of the lineages above it.
- ✓ **Relatedness depends on branching pattern, not tip order.**
Tip order can be rearranged; relationships stay the same.
- ✓ **You can rotate branches without changing relationships.**
Tree topology (branching pattern) is what matters, not orientation.
- ✓ **Branch length in a cladogram does not indicate time.**
Cladograms show order of divergence only.
- ✓ **Molecular data are often preferred because convergent evolution can mislead morphology.**
DNA sequences provide many independent characters.

3 Common Cladogram Errors

- ✗ **All tips are equally evolved; no species is more advanced.**
Trees show relationships, not a ladder of progress.
- ✗ **The left-to-right order of tips does not rank organisms.**
It has no evolutionary meaning.
- ✗ **To find the MRCA of two taxa, trace each back to the first shared node.**
That node is their most recent common ancestor.
- ✗ **Convergent evolution can produce analogous traits that confuse morphology-based trees.**
Use multiple lines of evidence, especially molecular data.

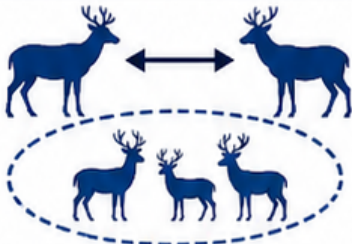
4 Exam Sniper — Q & A

- | | | | | | |
|---|--|---|---|--|--|
| Q | Which two organisms are most closely related? | ➔ | A | The pair sharing the most recent common ancestor (sister taxa). | |
| Q | A and B share a more recent node than A and C—what does that mean? | ➔ | A | A and B are more closely related than A and C. | |
| Q | DNA tree and bone-structure tree disagree—what is more reliable? | ➔ | A | DNA/molecular data.
Molecular data are less affected by convergent evolution. | |
| Q | What is the outgroup? | ➔ | A | The lineage that branched off first; least closely related to the others. | |

7.10 Speciation

Biological species concept, allopatric vs sympatric, and reproductive isolation

1 Biological Species Concept

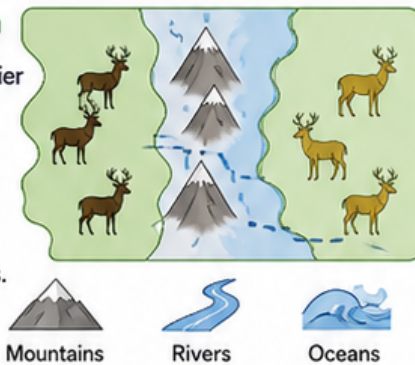


- A species is a group of populations that can interbreed and produce fertile offspring and are reproductively isolated from other groups.
- Limits: not ideal for asexual organisms, fossils, or some hybridizing plants.
- Speciation = evolution of reproductive isolation.
- Requires interruption of gene flow + accumulation of genetic differences.

2 Allopatric vs Sympatric

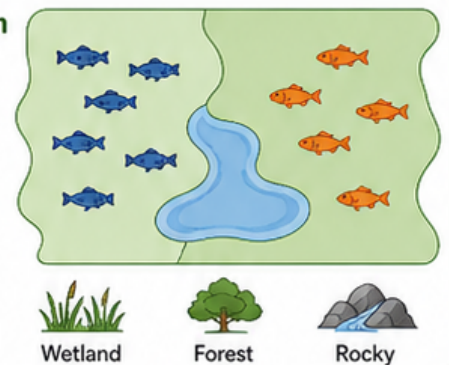
Allopatric Speciation

- Physical geographic barrier (mountain, river, ocean) stops gene flow.
- Populations diverge independently.
- More common in animals.



Sympatric Speciation

- Occurs in the same geographic area.
- Caused by disruptive selection, habitat specialization, or polyploidy in plants.
- Common in plants.



3 Pre-Zygotic vs Post-Zygotic Isolation

Pre-Zygotic (prevent mating or fertilization)

- Temporal isolation:** populations breed at different times of day or different seasons.
- Behavioral isolation:** different courtship behaviors prevent mating.
- Habitat isolation:** populations live in different habitats within the same area.
- Mechanical isolation:** differences in reproductive structures prevent successful mating.
- Gametic isolation:** sperm and egg are incompatible; fertilization does not occur.

Post-Zygotic (act after fertilization)

- Reduced hybrid viability:** hybrid zygote forms but develops abnormally or does not survive.
- Reduced hybrid fertility:** hybrid is viable but sterile or has very low fertility (e.g., mule).
- Hybrid breakdown:** first-generation hybrids are fertile, but later generations have reduced viability or fertility.

Note: Post-zygotic barriers waste gametes and can favor reinforcement of pre-zygotic barriers.

4 Evolutionary Patterns

Divergent Evolution



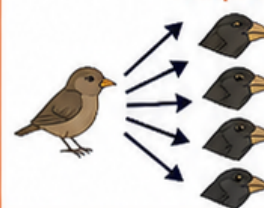
- Related species become more different over time.
- Share homologous structures.
- Drives speciation.

Convergent Evolution



- Unrelated species evolve similar traits in similar environments.
- Results in analogous structures.

Adaptive Radiation



- One ancestral species rapidly diversifies into many niches.
- Examples: Galapagos finches and cichlids.

Exam Sniper



- Mule sterility = post-zygotic reduced hybrid fertility.
- Different firefly flash patterns = behavioral isolation, pre-zygotic.
- Mountain range scenario: barrier stops gene flow, populations diverge, reproductive isolation evolves, speciation is complete when fertile interbreeding no longer occurs.



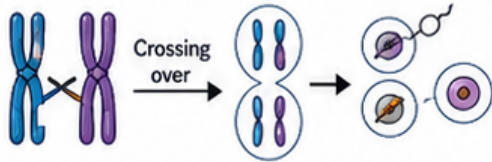
7.11–7.12 Variation & Origins of Life

Genetic diversity, balanced polymorphism, RNA World, and protocells

1 Sources of Genetic Variation



- **Mutation** creates new alleles.



- **Sexual reproduction** shuffles existing alleles through crossing over, independent assortment, and random fertilization.



- **High genetic diversity** improves response to environmental change and disease resistance.



- **Low genetic diversity** increases extinction risk and disease vulnerability.
- Example: cheetahs have very low diversity at key immune genes.

2 Balanced Polymorphism / Heterozygote Advantage

In malaria regions, individuals with one normal hemoglobin allele (HbA) and one sickle-cell allele (HbS) have the highest fitness.

HbA/HbA (AA)



Normal RBCs susceptible to malaria

HbA/HbS (AS)



Resistance to malaria; no sickle-cell disease

HbS/HbS (SS)



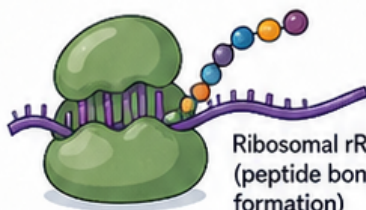
Sickle-cell disease; lower fitness

Because heterozygotes (AS) have higher fitness than either homozygote, both alleles are maintained in the population by natural selection.

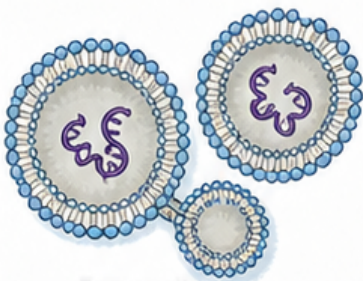
3 RNA World Hypothesis



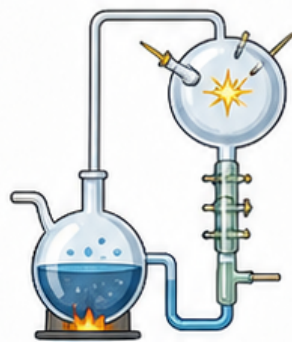
RNA



Ribosomal rRNA (peptide bond formation)



Protocell (lipid vesicle)



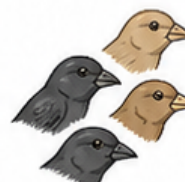
Miller-Urey experiment

- First genetic and catalytic molecules were **RNA**.
- RNA can store information and catalyze reactions.
- Ribosomal **rRNA** catalyzes peptide bond formation; this is evidence because the catalytic core of the ribosome is RNA (a **ribozyme**).
- DNA and proteins likely evolved later.
- **Protocells** were lipid bilayer vesicles that encapsulated early RNA and enabled compartmentalization.
- Life may have begun in a **primordial soup** of organic molecules or near **hydrothermal vents** on early Earth.
- The **Miller-Urey experiment** produced amino acids from inorganic gases with an energy source (simulated lightning).



Exam Sniper

- Mutation supplies raw material; selection acts on it.
- High diversity helps populations survive environmental change.
- RNA World is supported by the ribosome being RNA-catalyzed.
- Protocells = membrane-bound precursors to early cells.



Natural Selection FRQ Master Template

The 5-step framework + correct wording + mixed sprint practice

1 The 5-Step Natural Selection FRQ Framework

1 Variation



There was heritable variation in the trait within the population.

2 Selection pressure



Because of an environmental condition, individuals with trait A had higher fitness than those with trait B.

3 Heritability



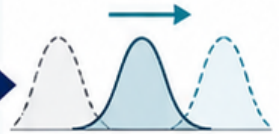
Because the trait is encoded in DNA and passed to offspring, selected individuals were more likely to produce offspring with trait A.

4 Allele-frequency change



Over generations, alleles for trait A increased while alleles for trait B decreased.

5 Outcome



The population became directionally different, more uniform, or more bimodal, showing evolution by natural selection.

2 Language Rules — 5 points at risk

⊗ Never Say This

- ⊗ "The organism evolved to..."
- ⊗ "The population learned to..."
- ⊗ "The antibiotic caused resistance..."
- ⊗ "The organism adapted..."
- ⊗ "Species evolved because they needed to..."

✔ Say This Instead

- ✔ Individuals with the trait had higher fitness and reproduced more.
- ✔ Allele frequencies changed over generations.
- ✔ The antibiotic favored pre-existing resistant individuals.
- ✔ The frequency of the adaptive trait increased in the population.
- ✔ Individuals with the beneficial variant had more offspring.

3 Sprint Practice 1 — Hardy-Weinberg + Selection

Question Summary

In snowy mice, white fur (ww) gives camouflage, brown fur (W_) is more visible.

- In 400 mice, 64 are brown.
- Under HWE, what are the allele frequencies, and what happens in a forest with brown soil?

Answer Box

$q(w) \approx 0.917$ $p(W) \approx 0.083$
 Snow: w increases.
 Brown forest: W increases.

✔ Answer Logic & Key Points

- 1 Identify genotype: White fur is recessive (ww). Brown mice are W_.
- 2 Find q^2 (white frequency): 336 white mice $\rightarrow 336/400 = 0.84 = q^2$
- 3 Solve for q (w): $q = \sqrt{0.84} \approx 0.917$
- 4 Find p (W): $p = 1 - q = 1 - 0.917 \approx 0.083$
- 5 Interpretation in snow: White (ww) has higher fitness (camouflage), so w allele increases in frequency over generations.
- 6 In brown forest: Brown-furred mice are better camouflaged \rightarrow they have higher fitness \rightarrow W allele increases by directional selection.

★ Remember: Evolution occurs across generations, not within individuals.

4 Sprint Practice 2 — Speciation

Question Summary

Two salamander populations were separated by a mountain range for 50,000 years. They later mate, but offspring have low survival.

What type of isolation is this, and what does it indicate about speciation?

Answer Box

Post-zygotic isolation (reduced hybrid viability). Indicates allopatric speciation in progress or nearly complete.

✔ Answer Logic & Key Points

- 1 Type of isolation: Post-zygotic isolation — reduced hybrid viability.
- 2 What it indicates: Allopatric speciation in progress or nearly complete.
- 3 Why: The physical barrier interrupted gene flow, allowing populations to diverge genetically.
- 4 Evidence: Hybrids have low survival \rightarrow they are not well adapted.
- 5 Big picture: Over time, reproductive isolation strengthens. Reinforcement may favor pre-zygotic barriers in the future.

Exam Sniper

- Follow the 5-step framework.
- Explain selection, heritability, and allele-frequency change.
- Use correct wording.
- Always answer in population terms across generations.



Unit 7 Final Cheat Sheet

Exam traps, 10-minute checklist, and final sprint strategy

1 High-Frequency Exam Traps

1 Lamarckian language costs FRQ points



Never say organisms evolved traits because they needed them; use pre-existing variation and differential reproductive success.

2 Genetic drift is random



It does not favor better-adapted alleles; strongest in small populations.

3 Gene flow prevents speciation



It homogenizes populations rather than causing divergence.

4 Homologous ≠ analogous



Homologous means common ancestry; analogous means convergent evolution.

5 All tips of a cladogram are equally evolved



No ladder of progress.

6 Antibiotic resistance was not created by antibiotics



Pre-existing variants were selected.

7 Hardy-Weinberg always starts from q^2

$$q^2 \rightarrow q \rightarrow p \rightarrow 2pq$$

The recessive phenotype is the only direct starting point.

2 Pre-Exam 10-Minute Checklist

A Natural Selection (7.1–7.3)



- 4 postulates
- Avoid Lamarckian language
- Know directional vs stabilizing vs disruptive
- Fitness is relative to environment

B Population Genetics (7.4–7.5)



- 5 evolutionary forces
- Drift is random and strongest in small populations
- Gene flow homogenizes
- Know HWE equations ($p^2 + 2pq + q^2 = 1$)
- $q^2 \rightarrow q \rightarrow p \rightarrow 2pq$

C Evidence & Continuing Evolution (7.6–7.8)



- Homologous vs analogous
- Antibiotic resistance logic
- Universal genetic code / ATP / ribosomes = common ancestry

D Phylogeny & Speciation (7.9–7.10)



- Nodes = MRCA
- Outgroup least related
- Allopatric vs sympatric
- All pre-zygotic and post-zygotic barriers

3 Final Sprint Strategy for Unit 7



Highest point concentration:

H-W calculations, natural selection FRQ language, pre/post-zygotic isolation, cladogram reading, antibiotic/pesticide resistance explanations.



FRQ must-include chain:

heritable variation → differential reproductive success → allele-frequency change over generations.



Carrier trap:

when q is small, $2pq$ is far more common than q^2 .



Unit connections:

Unit 1 DNA evidence, Unit 2 endosymbiosis, Unit 3 universal ATP, Unit 5 meiosis and variation, Unit 6 mutation and universal genetic code.

Individuals are selected. Populations evolve. Start H-W from q^2 .

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