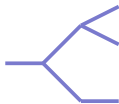


Natural Selection

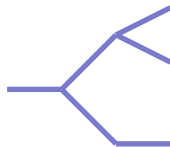
AP Biology ■ Unit 7

AP Biology



What we will cover

- 1 Natural selection
- 2 Types of selection
- 3 Population genetics
- 4 Hardy–Weinberg equilibrium
- 5 Evidence and ancestry
- 6 Speciation and phylogeny





Natural selection

Natural selection (Darwin): helpful traits spread because their carriers reproduce more. It needs three things:

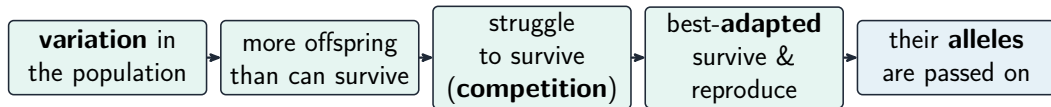
- **variation** among individuals
- the trait is **heritable**
- **differential reproductive success**

An individual does not evolve – the **population** does, as **allele frequencies** shift.



Helpful alleles spread; fitness is surviving offspring

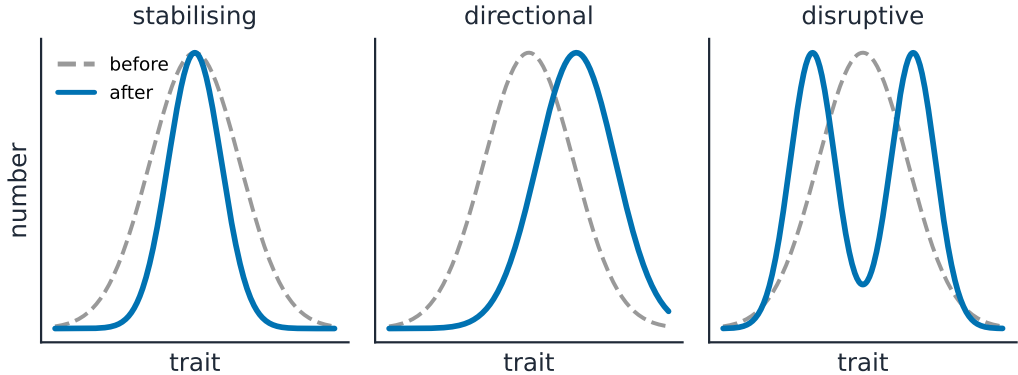
Natural selection: the best-adapted survive



over many generations the population becomes better adapted

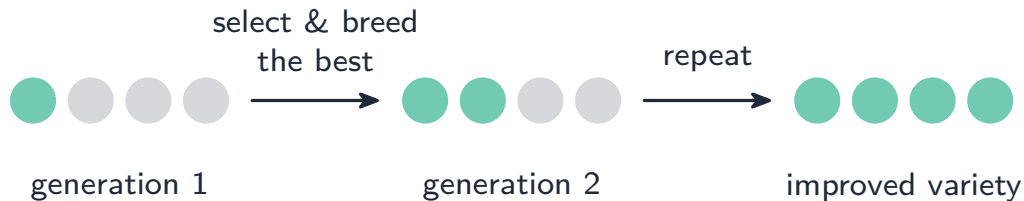
Natural selection: the best-adapted survive, reproduce, and pass on their alleles

Stabilising



Stabilising, directional, and disruptive selection

Artificial Selection



Selective breeding makes a wanted feature more common over generations

Artificial selection, and the evolution we can watch

artificial selection

humans, not nature, choose which individuals breed – crops, livestock, dogs

the mechanism

identical to natural selection; only the *selecting agent* differs

the evidence it gives

large phenotypic change in a few hundred generations, from existing variation

evolution is ongoing

antibiotic-resistant bacteria, pesticide-resistant insects, and rapid change in fast-breeding species

why those examples

a short generation time makes the change **observable within a human lifetime**

Artificial selection was Darwin's own opening argument, because it shows selection producing change in a timescale anyone can check.



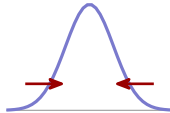
Types of selection

Selection can push a trait three ways:



Directional

one extreme wins



Stabilizing

middle wins



Disruptive

both extremes win



*Antibiotics select for
resistant bacteria*

Artificial selection (breeding) does the same, faster –
proof that populations **change**.

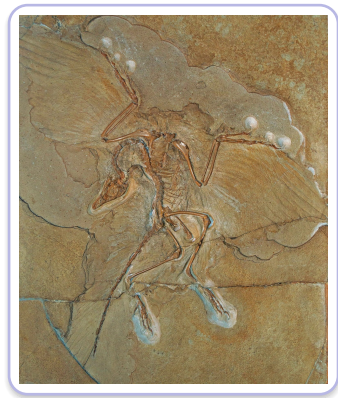


Population genetics

The **gene pool** is all the alleles in a population. Frequencies shift by more than selection:

- **genetic drift** – random, strong when small
- **gene flow** – **migration** in/out

Bottleneck and **founder effect** : a few survivors carry only some alleles.



Allele frequencies change across populations and deep time



Hardy-Weinberg equilibrium

A **null hypothesis** : a population that is *not* evolving. It holds only with no mutation, no selection, no gene flow, large size, random mating.

$$p + q = 1$$

$$\underbrace{p^2}_{\text{hom. dom.}} + \underbrace{2pq}_{\text{het.}} + \underbrace{q^2}_{\text{hom. rec.}} = 1$$

From one measurement

16% show the recessive trait, so $q^2 = 0.16$.

$$q = \sqrt{0.16} = 0.4, \quad p = 0.6$$

$$p^2 = 0.36, \quad 2pq = 0.48$$

Check: $0.36 + 0.48 + 0.16 = 1.00$.
If real data differ, the population is **evolving**.

Hardy-Weinberg

$$p + q = 1$$

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

p frequency of allele A
 q frequency of allele a
 p^2 frequency of genotype AA
 $2pq$ frequency of genotype Aa
 q^2 frequency of genotype aa

H-W equilibrium: no selection, mutation, migration, drift, or non-random mating

Hardy-Weinberg: allele frequencies p and q give genotype frequencies p^2 , $2pq$, q^2



Evidence and common ancestry

Many independent lines all point to **evolution** :

- **Fossils** : change over time
- **Homologous structures** : same bones
- **Molecular** : shared DNA sequences
- **Biogeography** : where species live

One near-universal genetic code + ATP
+ ribosomes $\Rightarrow$ common ancestry.



Fossils record change and shared ancestry

What all life shares

the claim

all life descends from a **common ancestor**

the same machinery

DNA and RNA, transcribed and translated the same way in every domain

the same genetic code

the same codons specify the same amino acids, nearly universally

ribosomes

present in every cell, and structurally conserved

shared metabolism

core pathways such as glycolysis appear everywhere

the inference

features this arbitrary and this universal are far better explained by **inheritance** than by repeated invention

The argument is not that the features are useful – it is that the **particular arbitrary choices** are shared. A different code would work just as well.



Speciation and phylogeny

A **species** : members that breed fertile offspring. New species need **reproductive isolation** :

- **allopatric** – a physical barrier splits them
- **sympatric** – split in the same place

A **phylogenetic tree** shows relatedness; recent branch points = close cousins.



Isolation and extreme habitats can split lineages

Speciation, and reading a phylogenetic tree

speciation

the origin of new species, when populations become **reproductively isolated** and diverge

allopatric

a **geographic** barrier separates the populations

sympatric

divergence **without** physical separation – polyploidy, or a shift in habitat or mating time

a phylogenetic tree

a cladogram diagramming evolutionary relationships

branch points

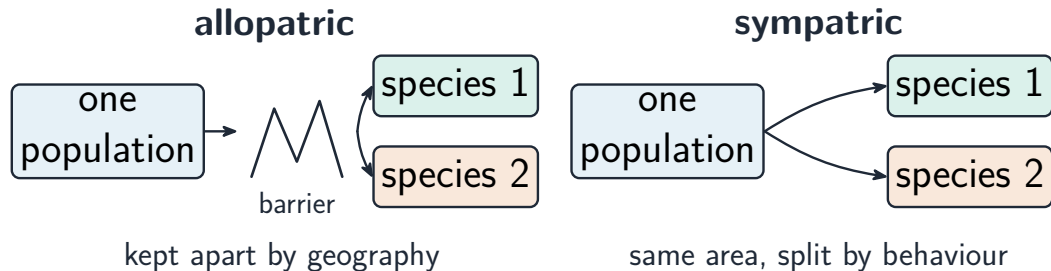
mark **common ancestors**; the shared derived characters define each clade

reading it

relatedness is read from **how recently two lines share a node**, never from proximity across the page

Two tips drawn next to each other can be distantly related. Trace back to the shared node – that is the only thing a tree asserts.

Allopatric and sympatric speciation



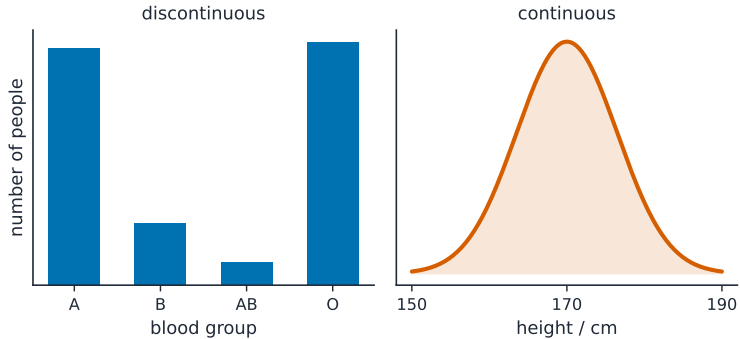
Allopatric and sympatric speciation

Variations in Populations

Genetic **diversity** helps a population survive change – if conditions shift, some variants may already be suited to them.

Low diversity (as in an endangered species) leaves a population vulnerable.

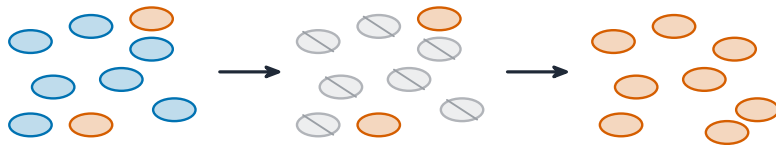
Variations in Populations, in detail



Discontinuous and continuous variation

Continuing Evolution

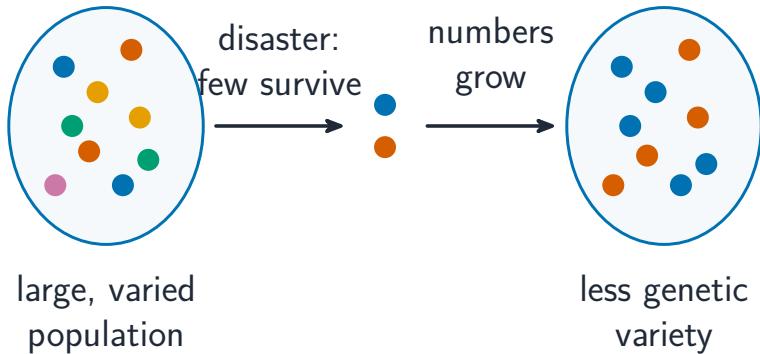
1. a few are resistant
2. antibiotic kills non-resistant
3. resistant multiply



(red = resistant mutant)

How antibiotic resistance spreads through a population by natural selection

Population Genetics, continued



A population bottleneck reduces genetic variety

Origins of Life on Earth



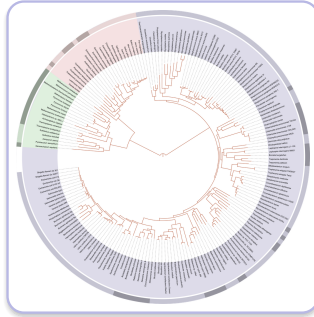
Stromatolites: layered microbial mats are among the oldest evidence of life on Earth

The evidence for common ancestry and early life

early Earth	its conditions could form simple organic molecules – the Miller–Urey type experiments
then	RNA as an early self-replicating and catalytic molecule, before DNA and protein
endosymbiosis	mitochondria and chloroplasts were free-living prokaryotes – their own DNA, double membranes and prokaryote-like ribosomes are the evidence
the fossil record	shows the order of appearance, and transitional forms
vestigial structures	reduced remnants of features that were functional in ancestors
adaptations	and shared developmental patterns, which are hard to explain except by descent

Each line of evidence is weak alone and decisive together. The exam asks you to name **several** and say what each independently supports.

Phylogeny



The tree of life: phylogeny groups organisms by shared ancestry from a common origin

Exam tips

- State natural selection cleanly: **variation** → **differential survival and reproduction** → **helpful traits become common**.
- **Fitness = reproductive success**, not strength or health.
- Evolution is a change in **allele frequencies** in a **population** – individuals do not evolve.
- Use **Hardy–Weinberg** ($p^2 + 2pq + q^2 = 1$): start from the recessive phenotype $q^2 \rightarrow q \rightarrow p$.
- Cite independent **evidence** (fossils, homologous structures, DNA) and explain speciation via reproductive isolation.



Unit 7 – key takeaways

1

Selection

variation + heritable + differential reproduction; the population evolves

2

Drift & flow

gene pool shifts; bottleneck/founder cut variation

3

Hardy–Weinberg

$p + q = 1$; $p^2 + 2pq + q^2 = 1$ as a null model

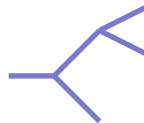
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Evidence

fossils, homology, molecules; common ancestry

Check yourself

- 1 What three conditions does natural selection need?
- 2 Which selection type favours both extremes?
- 3 If $q^2 = 0.09$, what are q and p ?
- 4 What kind of barrier drives allopatric speciation?



Answers 1. variation, heritable, differential reproduction 2. disruptive 3. $q = 0.3$, $p = 0.7$ 4. a physical/geographic barrier