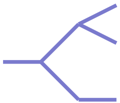
Natural Selection

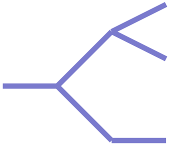
AP Biology ▪ Unit 7

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



1 Natural selection

Natural selection

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

- **variation** 变异 among individuals
- the trait is **heritable** 可遗传的
- **differential reproductive success** 繁殖成功

> An individual does not evolve – the **population** 种群 does, as **allele frequencies** 等位基因频率 shift.

Helpful alleles spread; fitness is surviving offspring

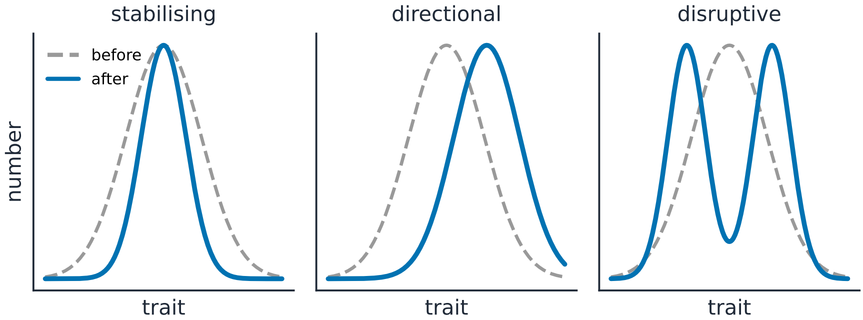
Natural selection: the best-adapted survive

variation in the population → more offspring than can survive → struggle to survive (**competition**) → best-**adapted** survive & reproduce → their **alleles** are passed on

over many generations the population becomes better adapted

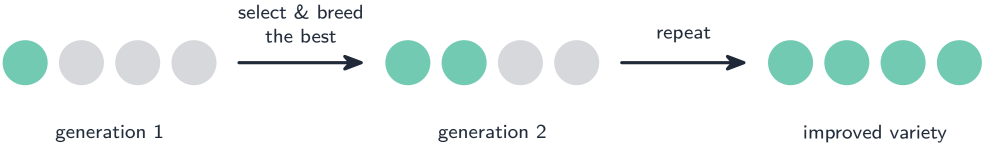
> Natural selection: the best-adapted survive, reproduce, and pass on their alleles

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

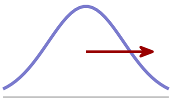
artificial selection 人工选择	humans, not nature, choose which individuals breed – crops, livestock, dogs
the mechanism	identical to natural selection; only the *selecting agent* differs
the evidence it gives	large phenotypic change in a few hundred generations, from existing variation
evolution is ongoing	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.

2 Types

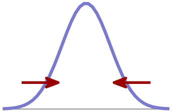
Types of selection

Selection can push a trait three ways:



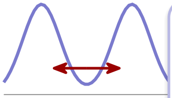
Directional

one extreme wins



Stabilizing

middle wins



Disruptive

both extremes win

Antibiotics select for resistant bacteria

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

3 Population genetics

Population genetics

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

- **genetic drift** 遗传漂变 – random, strong when small
- **gene flow** 基因流 – **migration** 迁移 in/out

> **Bottleneck** 瓶颈效应 and **founder effect** 奠基者效应: a few survivors carry only some alleles.

Allele frequencies change across populations and deep time

4 Hardy-Weinberg

Hardy–Weinberg equilibrium

A **null hypothesis** 零假设: 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

5 Evidence

Evidence and common ancestry

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

- **Fossils** 化石记录: change over time
- **Homologous structures** 同源结构: same bones
- **Molecular** 分子: shared DNA sequences
- **Biogeography** 生物地理学: where species live

> One near-universal genetic code + ATP + ribosomes ⇒ common ancestry.

Fossils record change and shared ancestry

What all life shares

the claim	all life descends from a **common ancestor** 共同祖先
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.

6 Speciation

Speciation and phylogeny

A **species** 物种: members that breed fertile offspring. New species need **reproductive isolation** 生殖隔离:

- **allopatric** 异域物种形成 – a physical barrier splits them
- **sympatric** 同域物种形成 – split in the same place

> A **phylogenetic tree** 系统发育树 shows relatedness; recent branch points = close cousins.

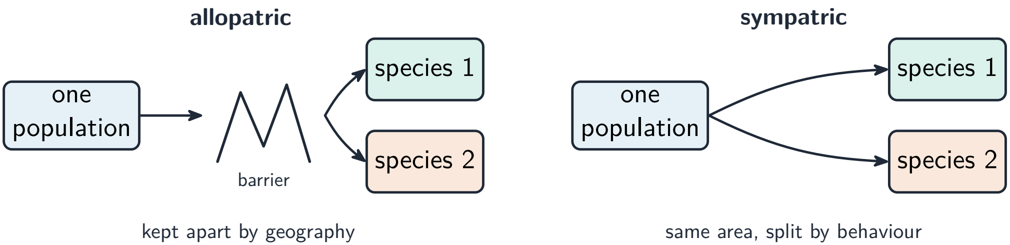
Isolation and extreme habitats can split lineages

Speciation, and reading a phylogenetic tree

speciation 物种形成	the origin of new species, when populations become **reproductively isolated** 生殖隔离 and diverge
allopatric 异域物种形成	a geographic barrier separates the populations
sympatric 同域物种形成	divergence without physical separation – polyploidy, or a shift in habitat or mating time
a phylogenetic tree 系统发育树	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



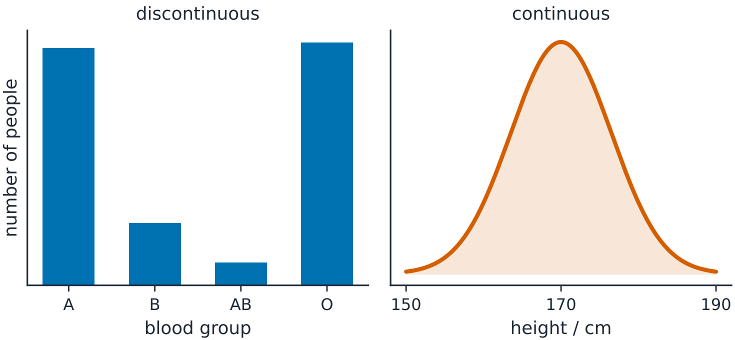
Allopatric and sympatric speciation

Variations in Populations

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

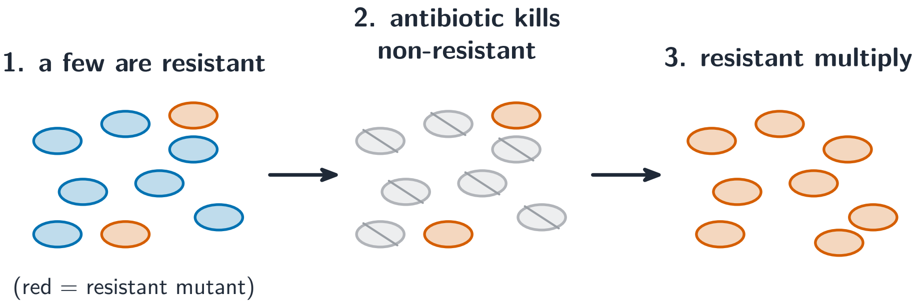
> Low diversity (as in an endangered species) leaves a population vulnerable.

Variations in Populations, in detail



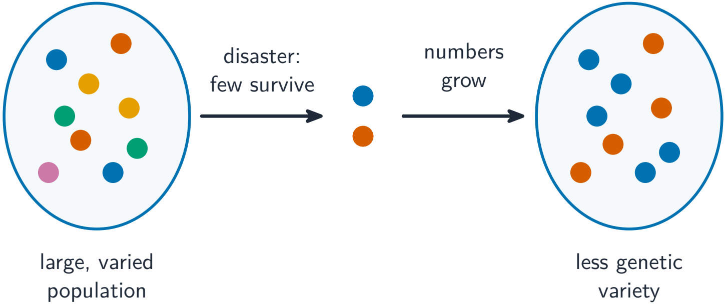
Discontinuous and continuous variation

Continuing Evolution



How antibiotic resistance spreads through a population by natural selection

Population Genetics, continued



A population bottleneck reduces genetic variety

Origins of Life on Earth

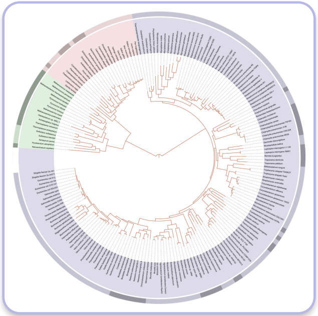
Stromatolites: layered microbial mats are among the oldest evidence of life on Earth

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 内共生	mitochondria and chloroplasts were free-living prokaryotes – their own DNA, double membranes and prokaryote-like ribosomes are the evidence
the fossil record 化石记录	shows the order of appearance, and transitional forms
vestigial structures 痕迹结构	reduced remnants of features that were functional in ancestors
adaptations 适应	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 $q^2 \to q \to p$.
- Cite independent **evidence** (fossils, homologous structures, DNA) and explain speciation via reproductive isolation.

7 Recap

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

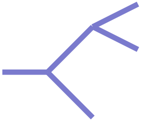
$p + q = 1$; $p^2 + 2pq + q^2 = 1$ as a null model

4 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