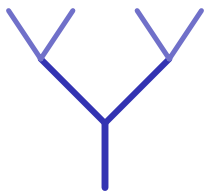
Selection & Evolution

A-Level Biology ▪ Topic 17

A-Level Biology



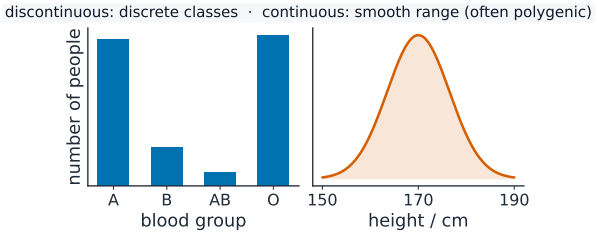
What we will cover

1. Variation
2. Natural selection
3. Types of selection
4. Changing allele frequencies
5. Selective breeding
6. Speciation

striking natural variation

1 Variation and selection

Variation



Variation 变异 is the differences between individuals: genes only, **environmental factors** 环境因素 only (a scar), or a combination – height depends on both.

- **discontinuous** 不连续变异 – separate groups (blood group)
- **continuous** 连续变异 – a smooth range (height)

The **t-test** t 检验 compares two sample means.

Two kinds of variation

Discontinuous variation	**Discontinuous variation** 不连续变异: clear, separate groups with nothing in between – blood group A, B, AB or O. Controlled by one or a few **genes** 基因.
Continuous variation	**Continuous variation** 连续变异: a smooth range from one extreme to the other, such as height. Controlled by many genes together, plus the environment.
Where it comes from	A chance **mutation** 突变 is the only source of a genuinely *new* allele; meiosis and fertilisation then shuffle what already exists.

The shape of the graph gives it away: separate bars for discontinuous, a bell-shaped curve for continuous.

Natural selection

Too many offspring **compete** 竞争; the best **adapted** 适应 survive & **reproduce** 繁殖, passing on their alleles.

> Over generations, helpful alleles become common – **natural selection** 自然选择. **Antibiotic resistance** 耐药性 is the same process.

Types of selection

- **stabilising** 稳定选择 – favours the average
- **directional** 定向选择 – shifts the mean one way
- **disruptive** 分裂选择 – favours both extremes

Selection pushes three different ways

stabilising
the middle is fittest, so the extremes are trimmed – birth mass in humans

directional
one extreme is fittest, so the whole distribution shifts – the **peppered moth** 桦尺蛾 darkening on sooty bark

disruptive
both extremes beat the middle, so the population splits in two

The peppered moth is the standard example because *both* forms are still there: the pale one hides on **lichen** 地衣, the dark one on soot, and which is commoner follows the bark.

The three types of selection

Stabilising selection	**Stabilising selection** 稳定选择 favours the average and removes both extremes – the population stays as it is. Human birth weight is the standard example.
Directional selection	**Directional selection** 定向选择 favours one extreme, so the mean shifts that way – antibiotic resistance, beak size in a drought.
Disruptive selection	**Disruptive selection** 分裂选择 favours both extremes and removes the average, which can split one population into two.

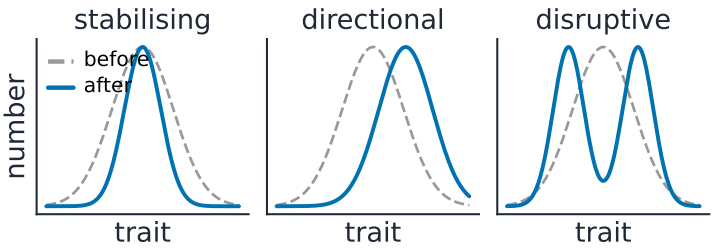
Sketch the curve before and after: stabilising narrows it, directional slides it, disruptive splits it in two.

Comparing samples, and comparing species

To compare the means of two samples – plant heights in sun and in shade – use the **t-test** t 检验: it says whether the difference is bigger than the scatter within each sample would explain.

To compare two species, use DNA **sequence** 序列 data: the more alike the sequences, the more recently they shared a common ancestor. **Speciation** 物种形成 happens when two populations become genetically isolated and can no longer interbreed.

Types of selection, in detail



directional: favors one extreme · stabilising: favors mean · disruptive: favors both extremes

> Stabilising narrows the range, directional shifts the mean, disruptive splits it in two

Changing allele frequencies

- **founder effect** 奠基者效应 – a few start a new population
- **genetic drift** 遗传漂变 – chance change in small populations
- **bottleneck** 瓶颈效应 – a crash cuts variety

The **Hardy–Weinberg** 哈迪-温伯格原理 principle calculates allele frequencies.

When allele frequencies drift, and when they hold still

The bottleneck effect

The **bottleneck effect** 瓶颈效应: a sudden fall in population size leaves few survivors, so the recovered population carries only part of the original variety of alleles.

The Hardy–Weinberg principle

The **Hardy–Weinberg principle** 哈迪-温伯格原理 calculates **allele frequencies** 等位基因频率 and **genotype** 基因型 frequencies – $p+q=1$ and $p^2+2pq+q^2=1$.

Only when nothing acts

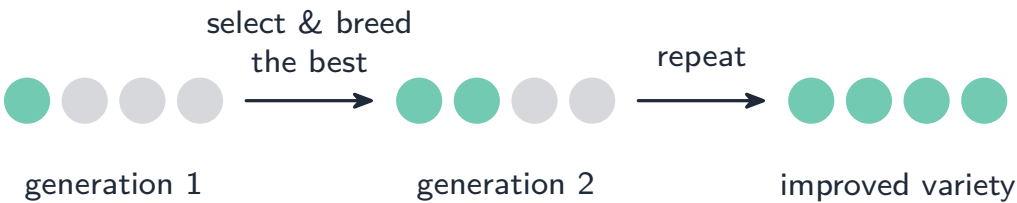
It holds only with no **mutation** 突变, no selection, no migration, random mating and a large population – so a *departure* from it is evidence that something is acting.

Hardy–Weinberg is the null model. Its value in an exam is what its failure tells you, not the arithmetic.

2 Breeding and evolution

Selective breeding

In **selective breeding** 选择育种 (**artificial selection** 人工选择), humans choose which organisms breed. Used to breed **disease resistance** 抗病性 into crops and raise milk **yield** 产量 in cattle.



Two tools of the plant and animal breeder

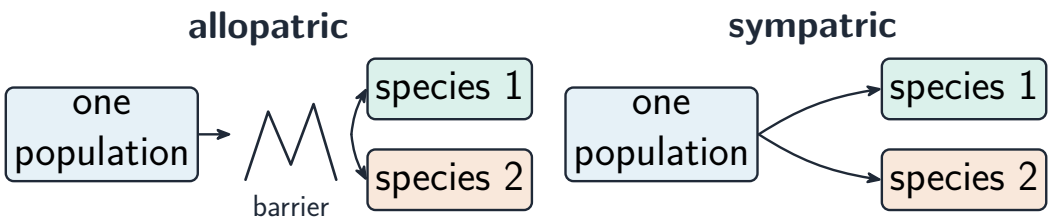
Inbreeding	**Inbreeding** 近交 crosses close relatives to fix a desired trait – at the cost of losing variety and exposing harmful recessives.
Hybridisation	**Hybridisation** 杂交 crosses two different inbred lines; the offspring are vigorous and uniform. This is how commercial maize is made.
The trade-off	Uniformity is what a farmer wants and what a population's future does not: an identical crop meets an identical disease.

Selective breeding is directional selection with a human doing the selecting – the mechanism is unchanged.

Speciation

Evolution 进化 changes a population's **gene pool** 基因库 over time; DNA shows how closely species are related.

- **allopatric** 异域物种形成 – a physical barrier
- **sympatric** 同域物种形成 – same area, different behaviour



Two routes to a new species

What speciation is	**Speciation** 物种形成 happens when two populations become genetically separated, so they can no longer breed together.
Allopatric speciation	**Allopatric speciation** 异域物种形成: the populations are kept apart by a **geographical separation** 地理隔离 – a sea, a mountain range, a new river.
Sympatric speciation	**Sympatric speciation** 同域物种形成: they live in the same area but are separated by differences in behaviour, timing or way of life.
Then what	Once gene flow stops, mutation and selection act separately on each population until the differences are large enough to prevent interbreeding.

Say which *barrier* first – geographical or reproductive – and the rest of the answer follows from it.

Exam tips

- Explain **natural selection** as a sequence: variation → selection pressure → the better-adapted survive and reproduce → allele frequency changes.
- Use the **Hardy–Weinberg** equations ($p + q = 1$, $p^2 + 2pq + q^2 = 1$); q^2 is the recessive-phenotype frequency – a common calculation.
- Distinguish **stabilising, directional and disruptive** selection with an example of each.
- Distinguish **allopatric vs sympatric** speciation (geographic vs reproductive isolation).

3 Recap

Worked example – Hardy-Weinberg

A recessive condition affects 1 in 100 people. Find the frequency of carriers.

- Affected are homozygous recessive $\Rightarrow q^2 = 0.01$.
- $q = \sqrt{0.01} = 0.1$, and $p = 1 - q = 0.9$.
- Carriers are heterozygous: $2pq = 2 \times 0.9 \times 0.1$
- $= 0.18 \Rightarrow 18\%$ – 18 times more carriers than affected people.

Two equations: $p + q = 1$ and $p^2 + 2pq + q^2 = 1$. Always start from q^2 – the recessive phenotype is the only frequency you can count directly.

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

Topic 17 – key takeaways

1 Variation

discontinuous (groups) vs continuous (range)

2 Natural selection

the best-adapted survive & reproduce

3 Selection types

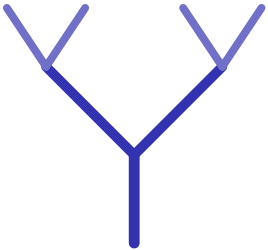
stabilising, directional, disruptive

4 Speciation

allopatric (barrier) vs sympatric (behaviour)

Check yourself

1. Blood group is which pattern of variation?
2. Which selection shifts the mean to one extreme?
3. What reduces variety after a population crash?
4. Speciation by a mountain range is which type?



Answers **1.** discontinuous **2.** directional **3.** a bottleneck **4.** allopatric