Selection and evolution

A-Level Biology

Variation

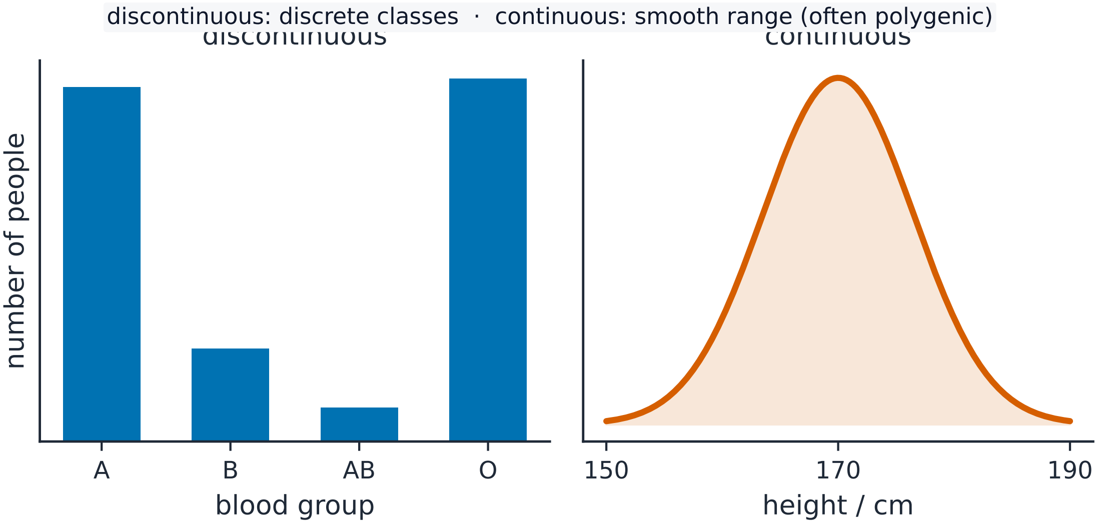
Variation 变异 means the differences between individuals. It has three possible causes:

- **genetic** factors only — set by the **alleles** 等位基因 you inherit (for example human blood group).
- **environmental factors** 环境因素 only — set by your surroundings (for example a scar, or the language you speak).
- a **combination** of both — most features, such as height and body mass, depend on genes **and** on diet and lifestyle.

Banded snails (Cepaea nemoralis) show striking variation in shell colour and banding

There are two patterns of variation:

- **discontinuous variation** 不连续变异 — clear, separate groups with nothing in between (for example blood group A, B, AB or O). It is usually controlled by one or a few **genes** 基因, with little effect from the environment.
- **continuous variation** 连续变异 — a smooth range from one extreme to the other (for example height). It is controlled by many genes together, plus the environment.



Discontinuous variation falls into separate groups; continuous variation is a smooth range

To compare the means of two samples (for example the heights of plants in sun and in shade), you use the **t-test**, which tells you whether the difference is large enough to be real, or just due to chance.

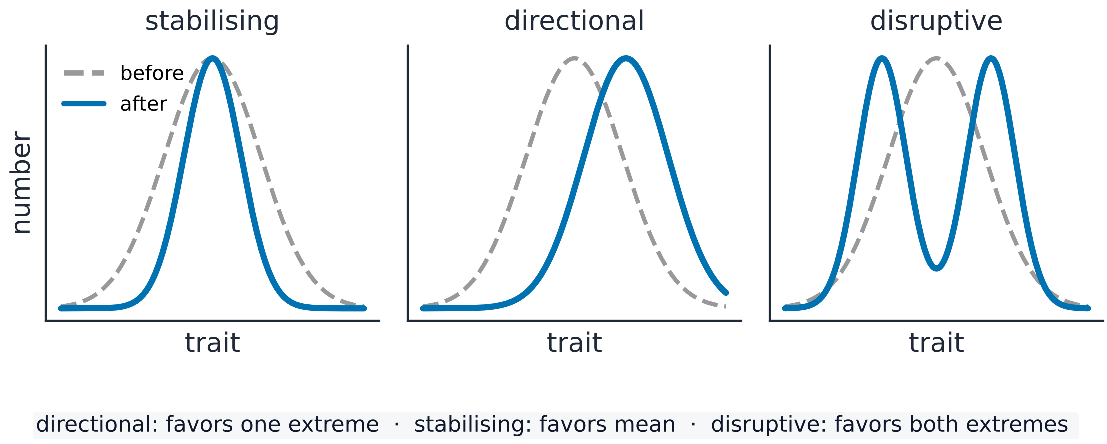
Natural selection

A **population** 种群 produces far more **offspring** 后代 than can survive, so the offspring must **compete** 竞争 for resources such as food and space. This is the “struggle for existence”. The individuals that are best **adapted** 适应 are most likely to survive, **reproduce** 繁殖, and pass on their alleles to the next generation. Over many generations, the helpful alleles become more common in the population. This is **natural selection** 自然选择.

*The **peppered moth** shows natural selection: the dark form hides on dark, sooty bark, while the pale speckled form hides on pale **lichen** — birds eat whichever stands out*

Environmental conditions can push selection in three ways:

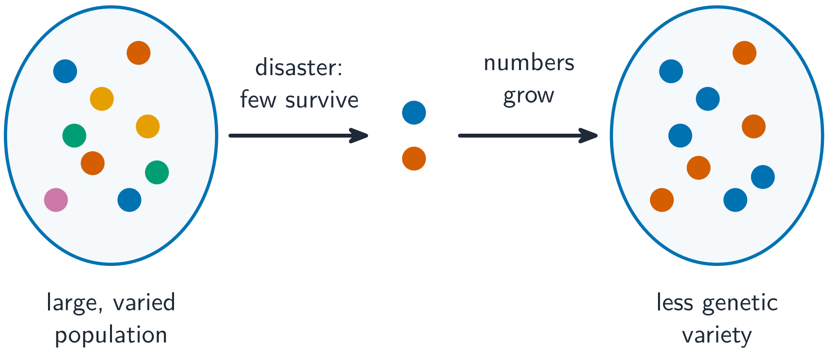
- **stabilising selection** 稳定选择 favours the average and removes the extremes (the population stays the same).
- **directional selection** 定向选择 favours one extreme, so the mean shifts that way.
- **disruptive selection** 分裂选择 favours both extremes and removes the average.



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

Allele frequencies can also change in other ways:

- the **founder effect** 奠基者效应 — a few individuals start a new population, so they carry only some of the alleles of the original group.
- **genetic drift** 遗传漂变 — in a small population, allele frequencies change by chance from generation to generation.
- the **bottleneck effect** 瓶颈效应 — a sudden fall in population size leaves few survivors, reducing the variety of alleles.



A bottleneck: only a few survive a disaster, so the recovered population has less genetic variety

Antibiotic resistance as natural selection

A chance **mutation** 突变 makes a few bacteria **resistant** to an **antibiotic** 抗生素. When the antibiotic is used, the non-resistant bacteria die, but the resistant ones survive and reproduce. Over time the **resistance** 耐药性 spreads through the population. This is natural selection in action.

The Hardy–Weinberg principle

The **Hardy–Weinberg principle** 哈迪-温伯格原理 lets you calculate the **allele frequencies** 等位基因频率 and **genotype** 基因型 frequencies in a population. It only holds true when there is a large population, mating is random, and there is no mutation, no migration and no natural selection.

Call the frequency of the dominant allele p and the frequency of the recessive allele q. There are only two alleles, so:

$$p + q = 1.$$

The genotype frequencies then add up to 1, where p^2 is homozygous dominant, $2pq$ is heterozygous (the carriers), and q^2 is homozygous recessive:

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

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

Only the homozygous recessive genotype (q^2) shows the condition, so $q^2 = \frac{1}{100} = 0.01$, giving $q = \sqrt{0.01} = 0.1$. Then $p = 1 - q = 0.9$. The carriers are the heterozygotes:

$$2pq = 2 \times 0.9 \times 0.1 = 0.18.$$

So about 18% of the population are carriers — far more than the 1% who show the condition.

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

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

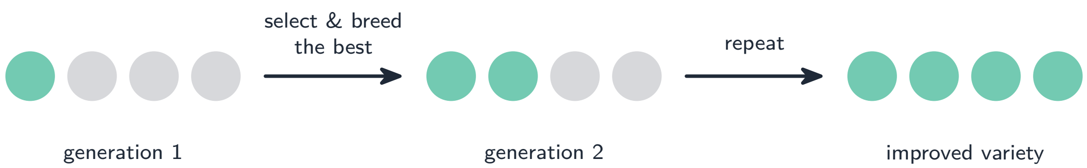
H–W equilibrium: no selection, mutation, migration, drift, or non-random mating

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

Selective breeding (artificial selection)

In **selective breeding** 选择育种, also called **artificial selection** 人工选择, humans (not nature) choose which organisms breed, so that useful features are passed on. Examples:

- breeding **disease resistance** 抗病性 into varieties of wheat and rice.
- using **inbreeding** 近交 and **hybridisation** 杂交 (crossing different lines) to make vigorous, uniform maize.
- breeding dairy cattle to improve their milk **yield** 产量.



Selective breeding: choosing only the best to breed each generation makes the wanted feature more and more common

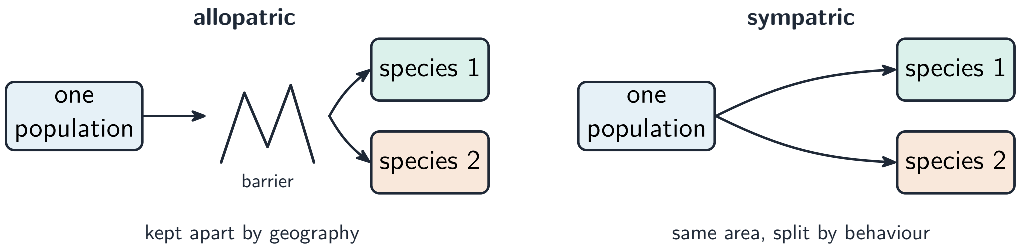
Evolution

Evolution 进化 is the slow formation of new **species** 物种 from earlier ones, as the **gene pool** 基因库 (all the alleles in a population) changes from generation to generation.

DNA **sequence** 序列 data can show how closely related two species are: the more similar their DNA sequences, the more recently they shared a common ancestor.

Speciation 物种形成 happens when two populations become genetically separated, so they can no longer breed together. This genetic **isolation** 隔离 can come about in two ways:

- **allopatric speciation** 异域物种形成 — the populations are kept apart by a **geographical separation** 地理隔离, such as a sea or a mountain range.
- **sympatric speciation** 同域物种形成 — the populations live in the same area but are separated by differences in behaviour or way of life.



Allopatric speciation needs a physical barrier; sympatric speciation happens in the same area

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).