

Selection and evolution

A-Level Biology 9700 · Topic 17 revision notes

Everything from the 5 lessons of this topic on a few pages: the key idea of each lesson, the diagram to remember, the points to learn and the traps examiners set. Read it, cover it, test yourself.

1. Variation and the t-test

2. Natural selection, drift and resistance

3. The Hardy-Weinberg principle

4. Selective breeding

5. Evolution and speciation

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1 Variation and the t-test

Syllabus 17.1

Phenotypic variation is caused by **genetic factors** (different alleles, produced by mutation and shuffled by meiosis and random fertilisation), by **environmental factors** (diet, light, soil minerals, temperature), or by a **combination** of both. **Discontinuous variation** gives a few distinct classes with no intermediates (ABO blood group); it is controlled by **one gene or a few genes** with large effects and is little affected by the environment. **Continuous variation** gives a range with no clear classes (height, mass, leaf length); it is controlled by **many genes (polygenes)**, each with a small **additive** effect, and the environment adds further variation. To decide whether the means of two samples of continuous data differ significantly, calculate **t** and compare it with the critical value at **$p = 0.05$** for **$n_1 + n_2 - 2$** degrees of freedom.

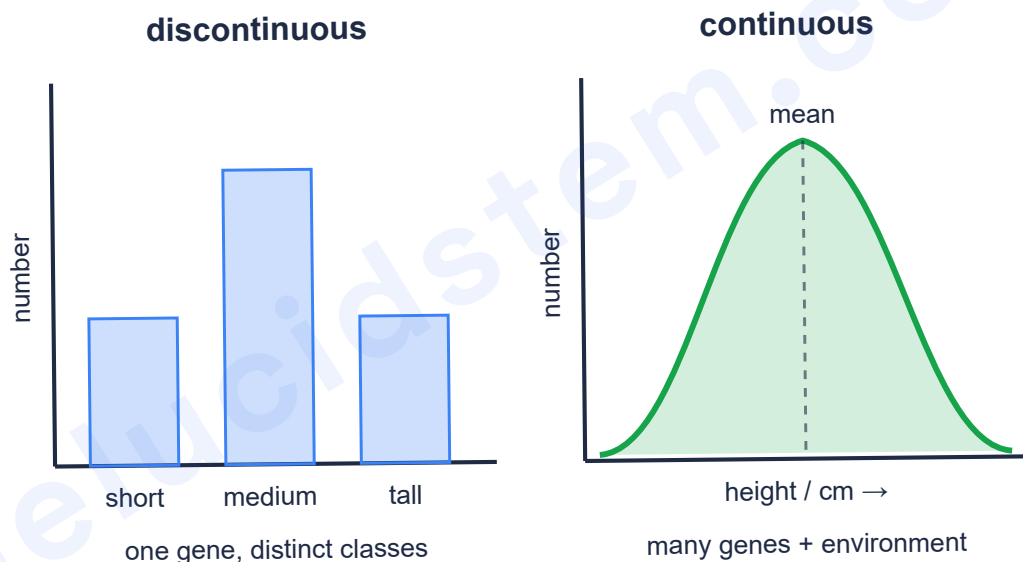


Fig. 1: discontinuous variation (a few distinct classes) compared with continuous variation (a smooth, roughly normal distribution)

How many genes, how much environment?

- ✓ **Discontinuous:** one or a few genes, large effects, distinct classes, little environmental effect.
- ✓ **Continuous:** polygenes with small additive effects plus the environment.
- ✓ **t-test:** compares two means; degrees of freedom = $n_1 + n_2 - 2$.
- ✓ **$t > \text{critical value at } p = 0.05$:** significant; reject the null hypothesis.

Watch out!

Variation caused only by the environment is **not passed on** to offspring, because it does not change the alleles in the gametes. Only genetic variation can be acted on by natural selection.

Continuous variation is not caused by alleles blending. Each gene is still inherited as discrete alleles; it is the **number of genes** and the **environment** that make the overall range look smooth.

A large difference between means is not enough on its own. If the data are very spread out (large standard deviations) or the samples are small, t can still be below the critical value.

2 Natural selection, drift and resistance

Syllabus 17.2

Populations have the capacity to produce **many more offspring** than can survive, so individuals **compete** for limited resources such as food, mates and territory. Because of **variation**, some individuals have alleles that make them **better adapted** to the conditions. In this **struggle for existence** they are more likely to **survive and reproduce** and **pass on their alleles**, so the frequency of those alleles rises in the next generation. Environmental factors act as **selection pressures** that may be **stabilising** (the mean is favoured), **directional** (one extreme is favoured) or **disruptive** (both extremes are favoured). Allele frequencies also change by chance: **genetic drift**, the **founder effect** and the **bottleneck effect** all have the greatest effect in **small** populations. **Antibiotic resistance** is directional selection in action.

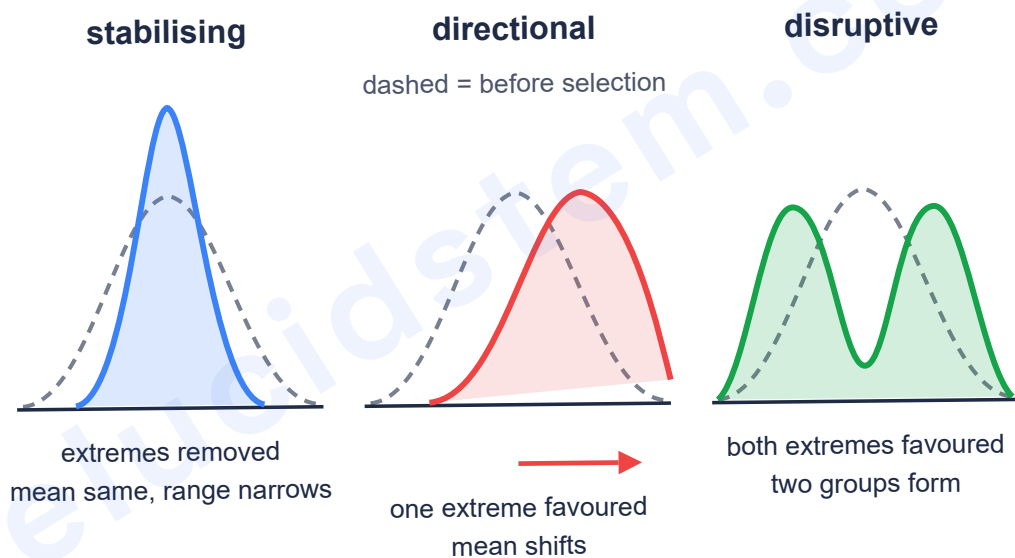


Fig. 1: the three forces of natural selection acting on a continuous feature; the dashed curve is the population before selection

Variation, selection, inheritance.

- ✓ **Overproduction** and **competition** lead to a struggle for existence.
- ✓ Best adapted survive, **reproduce** and **pass on alleles**: allele frequency rises.
- ✓ **Stabilising** keeps the mean; **directional** shifts it; **disruptive** splits it.
- ✓ **Drift, founder, bottleneck**: chance changes, biggest in small populations.

Watch out!

Organisms do not change **in order to** survive, and an individual does not evolve. Variation already exists; the environment selects among it, and it is the **population's allele frequencies** that change.

Drift is not caused by an allele being harmful. A neutral or even an advantageous allele can be lost by chance in a very small population.

Bacteria do not become resistant because they are exposed to the antibiotic or get used to it. The resistant mutants were already present; the antibiotic simply removes their competitors.

3 The Hardy-Weinberg principle

Syllabus 17.2

For a gene with a dominant allele **A** (frequency **p**) and a recessive allele **a** (frequency **q**): **$p + q = 1$** (allele frequencies) and **$p^2 + 2pq + q^2 = 1$** (genotype frequencies), where $p^2 = AA$, $2pq = Aa$ and $q^2 = aa$. Only the recessive phenotype reveals its genotype, so the usual method is: **q^2** = frequency of the recessive phenotype, **$q = \sqrt{q^2}$** , **$p = 1 - q$** , then calculate **$2pq$** (carriers) and **p^2** . The principle predicts that allele frequencies stay **constant** from generation to generation only if the population is **large**, mating is **random**, there is **no selection**, **no mutation** and **no migration** (gene flow) in or out, and the organism is **diploid** and reproduces sexually. If observed frequencies differ from the prediction, one of these conditions is not being met.

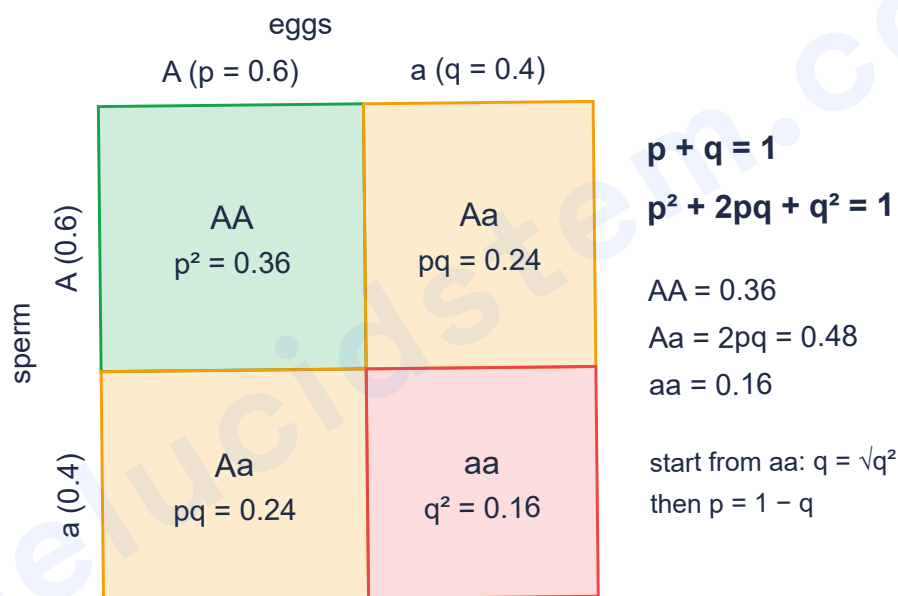


Fig. 1: random fusion of gametes in a population with $p = 0.6$ and $q = 0.4$ gives the genotype frequencies p^2 , $2pq$ and q^2

Square root, subtract, multiply.

- ✓ q^2 = frequency of the recessive phenotype.
- ✓ $q = \sqrt{q^2}$, then $p = 1 - q$.
- ✓ Carriers = $2pq$; homozygous dominant = p^2 .
- ✓ Valid only if large, random mating, no selection, mutation or migration.

Watch out!

Do not take the square root of the dominant phenotype frequency to find p . People with the dominant phenotype are AA and Aa , so their frequency is $p^2 + 2pq$, not p^2 . Always start from the recessive phenotype.

The Hardy-Weinberg principle does not say that the dominant allele becomes more common. Without selection, a dominant allele stays at the same frequency, however rare it is.

4 Selective breeding

Syllabus 17.2

In **selective breeding (artificial selection)**, humans choose individuals with **desirable characteristics** and allow only these to breed. Over many generations the frequency of the alleles for the desired features rises. It differs from natural selection because the **selection pressure is set by humans**, and the selected features need not help the organism survive. **Disease resistance** is introduced into wheat and rice by crossing a high-yielding but susceptible variety with a resistant variety, then **backcrossing** repeatedly to the high-yielder and selecting resistant, high-yielding offspring. **Maize** is **inbred** for several generations to give homozygous, uniform inbred lines, then two lines are **crossed (hybridisation)** to give F1 hybrids with **hybrid vigour** that are also uniform. The **milk yield** of dairy cattle is improved by selecting high-yielding cows and bulls chosen by **progeny testing**, using **artificial insemination**. Selective breeding reduces **genetic diversity**.

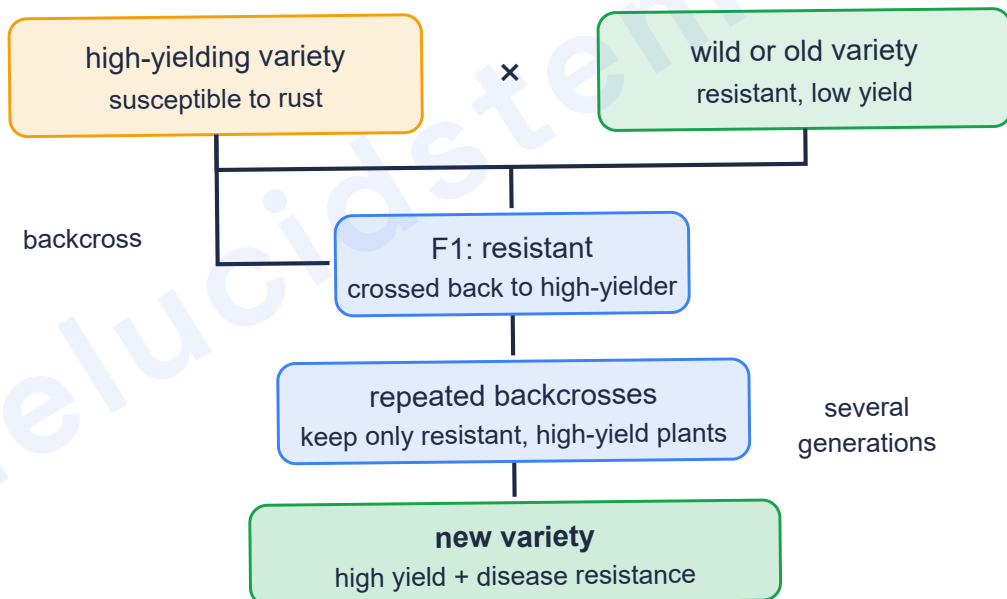


Fig. 1: introducing disease resistance into a high-yielding cereal by crossing and repeated backcrossing

Humans are the selection pressure.

- ✓ **Select** parents with the trait, **cross**, **select** the best offspring, **repeat**.
- ✓ **Wheat and rice:** cross with a resistant variety, then **backcross** to the high-yielder.
- ✓ **Maize:** inbreed to homozygous lines, then cross for uniform, vigorous F1 hybrids.
- ✓ **Cattle:** select cows by yield, bulls by **progeny testing**; use AI.

Watch out!

Selective breeding does not create new alleles. It can only increase the frequency of alleles that already exist in the breeding population or its wild relatives.

The vigorous hybrids are not the inbred lines. Inbreeding makes plants uniform but weak; it is **crossing two inbred lines** that gives vigour, and the F1 is uniform because both parents are homozygous.

A bull does carry alleles affecting milk yield even though he produces no milk. That is exactly why progeny testing works: his daughters show the effect of the alleles he passes on.

5 Evolution and speciation

Syllabus 17.3

The **theory of evolution** states that new species form from **pre-existing species** over time, as a result of **changes to gene pools** from generation to generation, driven by mutation, natural selection and genetic drift. **DNA sequence data** give evidence of relationships: mutations accumulate at a roughly steady rate, so the **fewer the differences** between the base sequences of two species, the **more recently** they shared a **common ancestor**. A **species** is a group of organisms that can interbreed to produce **fertile offspring**. **Speciation** needs **genetic isolation**, so that there is **no gene flow** between two populations. In **allopatric speciation** a **geographical barrier** separates them; in **sympatric speciation** they live in the same area but are separated **ecologically** (different habitats or food) or **behaviourally** (different courtship or breeding times). Different mutations, selection pressures and drift then change each gene pool until the populations can no longer interbreed.

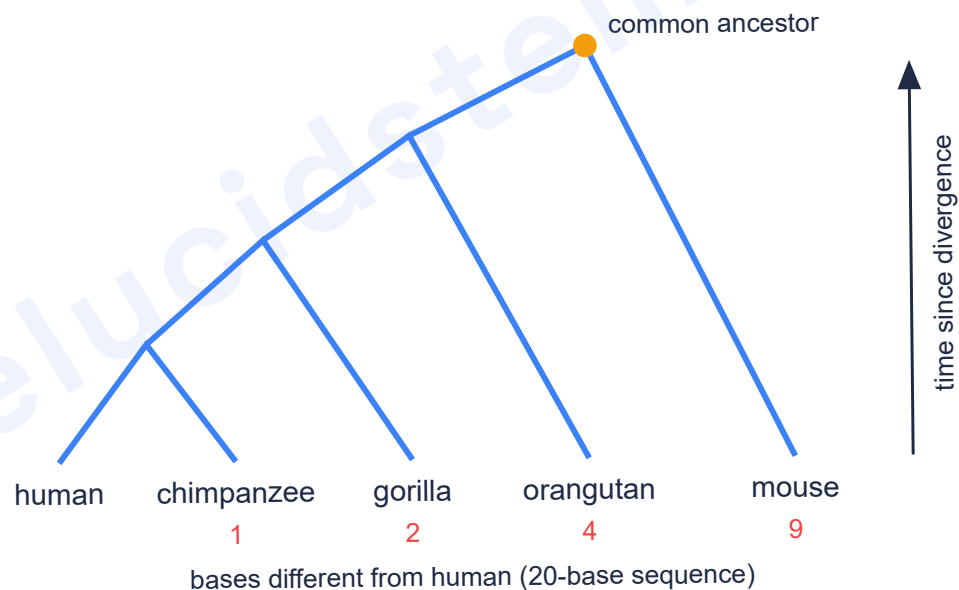


Fig. 1: an evolutionary tree built from the number of base differences, as in the simulator; fewer differences means a more recent common ancestor

No gene flow, then new species.

- ✓ **Evolution:** gene pools change over generations, forming new species from old.
- ✓ **Fewer DNA differences** = more recent common ancestor.
- ✓ **Allopatric:** geographical barrier.
Sympatric: ecological or behavioural separation.
- ✓ **New species:** can no longer interbreed to produce fertile offspring.

Watch out!

Humans did not evolve from chimpanzees. The tree shows that humans and chimpanzees share a **common ancestor** more recently than either does with gorillas; both lineages have changed since the split.

Separation alone does not make a new species. The populations must become **reproductively isolated**: unable to interbreed to produce fertile offspring. Two populations separated briefly that can still interbreed are still one species.