Natural selection, speciation and conservation

Allele frequencies and the Hardy-Weinberg equation, natural selection, isolation and speciation, and the conservation of endangered species by zoos and seed banks.

Evolution and natural selection

Evolution is a **change in allele frequency** in a population over time. It comes about through:

- **Gene mutation**, which produces new alleles (the raw material),
- **Natural selection**, in which individuals with advantageous alleles are more likely to survive and reproduce, and pass those alleles on.

The steps in natural selection:

1. There is **variation** within a population (from mutation, meiosis and fertilisation).
2. A **selection pressure** (predation, disease, competition, climate) acts.
3. Individuals with **advantageous alleles** are **more likely to survive** and **reproduce**.
4. They pass on their alleles to the next generation, so the **allele frequency** increases.

Types of selection:

Type	Effect	Example
Stabilising	Selects against the **extremes**, narrowing the range	Human birth mass
Directional	Selects for **one extreme**, shifting the mean	Antibiotic resistance in bacteria

The Hardy–Weinberg equation

For a gene with two alleles, with frequencies p (dominant) and q (recessive):

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

- p^2 is the frequency of the **homozygous dominant** genotype,
- $2pq$ is the frequency of **heterozygotes**,
- q^2 is the frequency of the **homozygous recessive** genotype.

> **TRY IT**
>
> Cystic fibrosis affects 1 in 2500 people ($q^2 = 0.0004$). Find the carrier frequency.

$q = \sqrt{0.0004} = 0.02$. $p = 1 - 0.02 = 0.98$. Carriers $= 2pq = 2 \times 0.98 \times 0.02 = 0.039$, about 1 in 25.

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The equation predicts that allele frequencies **stay constant** from generation to generation, **if**:

- the population is **large**,
- there is **random mating**,
- there is **no mutation**, **no selection**, and **no migration** (gene flow) in or out.

If the observed frequencies differ from those predicted, a change is occurring, so **evolution** is taking place. Changes in allele frequency can come from **mutation** and **natural selection**, as well as **genetic drift** (chance changes, strongest in small populations) and migration.

Isolation and speciation

Speciation is the formation of **new species**. It needs **reproductive isolation**, which stops **gene flow** between populations. The isolated populations then accumulate **different genetic information** by mutation and by natural selection in different environments, until they can no longer interbreed.

	Allopatric speciation	Sympatric speciation
Isolation	**Geographical** barrier (a mountain, a river, an island)	Within the **same area**
Cause	Different selection pressures and mutations in each population	**Ecological** (different niches or food), **behavioural** (different courtship or timing), or **genetic** (polyploidy in plants) isolation

> **Isolation reduces gene flow. Without it, interbreeding spreads alleles across the whole population and keeps it as one species.**

Conservation

Biodiversity is conserved for **ecological**, **economic** (resources, medicines), **ethical** and **aesthetic** reasons.

Zoos

- **Captive breeding programmes** maintain **genetically diverse** populations, with stud books and the exchange of animals to avoid **inbreeding**.
- **Reintroduction** into the wild (e.g. the Arabian oryx) after the cause of decline is removed.
- **Scientific research** on behaviour, diet and reproduction, and **education** of the public.
- Limitations: small populations lose **genetic diversity**; captive-bred animals may lack survival skills; expensive; the habitat must still be protected; not all species can be bred in captivity.

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Seed banks

- Seeds are stored at **low temperature and low humidity**, so they remain viable for many years, in a small space and at low cost.
- They preserve the **genetic diversity** of plants, including wild relatives of crops, and can be used to re-establish populations.
- Limitations: some seeds **cannot be stored** (recalcitrant seeds that die when dried), seeds must be **regenerated** from time to time, and storage does not conserve the **habitat** or the **relationships** between species. Collecting a small sample may not represent the **genetic diversity**.

NOTE

When evaluating conservation methods, give the advantages, the limitations, and a judgement. In situ conservation (protecting the habitat) is generally preferred, with ex situ methods as a backup.

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