

Niche, allele frequency and conservation

Revision notes · Niche and adaptations, the Hardy-Weinberg equation, mutation, selection and speciation, and evaluating zoos and seed banks.

For Pearson Edexcel International AS Biology XBI11 and International A Level Biology YBI11. **A Level only** is IA2 content (Units 4 to 6), not needed for the International AS.

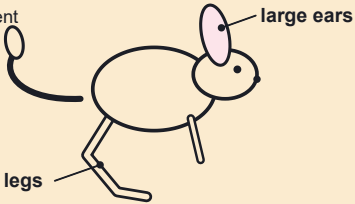
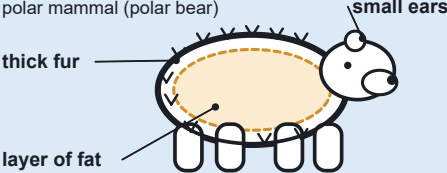
Niche, allele frequency and conservation **Spec 4.19–4.21**

Niche and adaptations to the environment **Spec 4.19**

Niche	The role of a species within its habitat: how it obtains food and other resources, the abiotic conditions it tolerates and the biotic interactions it has with other species (such as feeding relationships, competition and predation).
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Each species in a habitat has its own niche. If two species have very similar niches they compete for the same resources, and one is likely to decline, so competition tends to separate the niches of species living together. Organisms are adapted to their niche: a feature that helps survival and reproduction in a particular environment is an **adaptation**. Adaptations are the result of natural selection.

Types of adaptation		
Type	Meaning	Examples
Behavioural	The way an organism acts	Hibernation in winter; migration; nocturnal activity in desert animals to avoid the heat of the day; courtship displays; basking to warm up
Anatomical	Structural features of the body that can be seen in a dissection or section	Marram grass has rolled leaves, hairs and sunken stomata that reduce transpiration; thick fur and a layer of fat in polar bears; large ears in desert foxes that lose heat
Physiological	Processes inside the body, including biochemical ones	Kangaroo rats produce very concentrated urine, conserving water; antifreeze proteins in polar fish; production of venom or toxins; slowed metabolism during hibernation

	Behavioural	Anatomical	Physiological
Hot dry habitat desert rodent  large ears long hind legs	Nocturnal: active at night and shelters in a cool burrow by day, avoiding the heat	Large ears lose heat; long hind legs let it hop fast, keeping the body off the hot ground	Very concentrated urine, so little water is lost (as in the kangaroo rat)
Cold habitat polar mammal (polar bear)  thick fur layer of fat small ears	Shelters from wind and cold in a snow den (mothers den to give birth to cubs)	Thick fur and a layer of fat insulate the body; small ears reduce heat loss	Stored fat is broken down for energy and water when food is scarce

Behavioural, anatomical and physiological adaptations in a hot dry habitat and a cold habitat.

Exam tip: When asked to discuss adaptations, name the type (behavioural, anatomical or physiological), give the feature and link it to survival in that environment, for example by reducing water loss.

The Hardy-Weinberg equation, mutation and natural selection Spec 4.20(i), 4.20(ii)

The **allele frequency** is the proportion of a particular allele among all the alleles of that gene in a population. For a gene with two alleles, the dominant allele has frequency p and the recessive allele has frequency q .

$$p + q = 1$$

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

- p = frequency of the dominant allele; q = frequency of the recessive allele
- p^2 = frequency of the homozygous dominant genotype; q^2 = frequency of the homozygous recessive genotype
- $2pq$ = frequency of the heterozygous genotype

Conditions for the equation to hold

The equation predicts that allele frequencies stay the same from one generation to the next only if the population is large, mating is random, there is no mutation, no natural selection and no migration into or out of the population (gene flow).

Using it to detect change

If the population does not meet these conditions, allele frequencies may change over time. Allele frequencies are calculated from a sample of one generation and used to predict the genotype frequencies (p^2 , $2pq$, q^2) expected if nothing changes. These are compared with the frequencies observed in later generations: if they differ significantly, a change in allele frequency is occurring, that is, the population is evolving.

Using the Hardy-Weinberg equation

In a population of 500 plants, 45 plants have white flowers. White is caused by a recessive allele and the population is in Hardy-Weinberg equilibrium. Calculate the number of heterozygous plants.

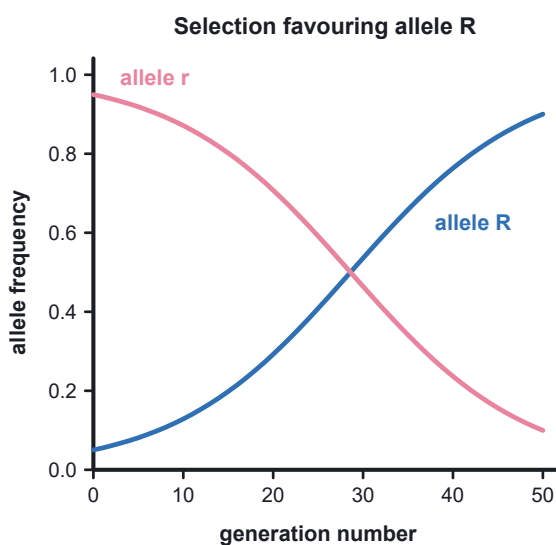
1. $q^2 = 45 \div 500 = 0.09$
2. $q = \sqrt{0.09} = 0.3$
3. $p = 1 - 0.3 = 0.7$
4. $2pq = 2 \times 0.7 \times 0.3 = 0.42$
5. number = 0.42×500

Answer: 210 heterozygous plants

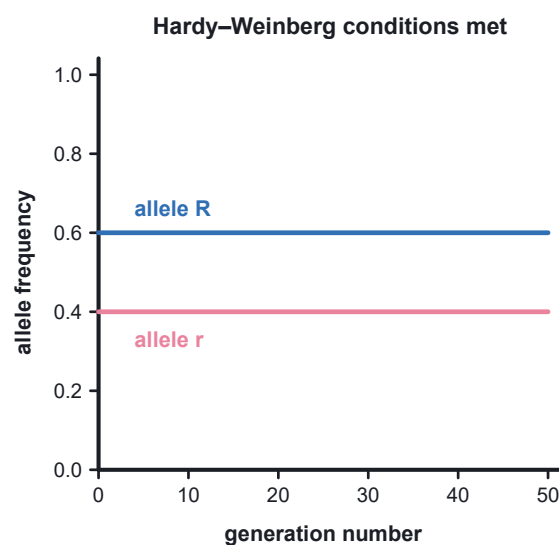
Maths skill: Always start from the one genotype you can see: the homozygous recessive (q^2). Take the square root to get q , then $p = 1 - q$, then $2pq$.

How allele frequencies change

- **Mutation**: a change in the DNA base sequence can create a new allele. Mutation is random and rare, but it is the source of new alleles.
- **Natural selection**: individuals with advantageous alleles are more likely to survive and reproduce and to pass those alleles on, so the frequency of advantageous alleles increases from generation to generation. For example, a mutation giving bacteria resistance to an antibiotic is selected for when the antibiotic is present, and the frequency of the resistance allele increases.



Illustrative data



no selection: allele frequencies stay constant

Allele frequencies change under selection (left) but stay constant when the Hardy-Weinberg conditions are met (right).
Illustrative data.

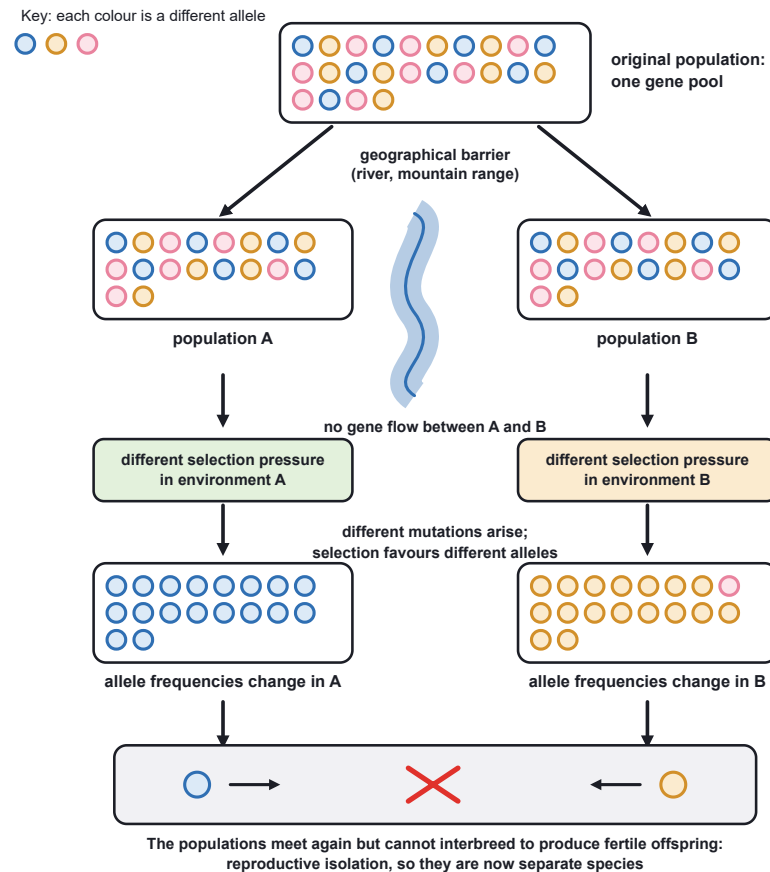
Reproductive isolation and the formation of new species Spec 4.20(iii)

Reproductive isolation means that two populations can no longer exchange genes, so their gene pools become separate. It can be caused by:

- geographical barriers, such as a mountain range, river or sea (a population is divided into two)
- ecological or seasonal barriers, such as flowering or breeding at different times
- behavioural barriers, such as different courtship songs or displays that stop mating

1. A population is split into two (or two populations stop interbreeding).

2. There is no gene flow between them.
3. Mutations occur independently in each population, creating different alleles.
4. If the environments differ, natural selection favours different alleles in each population.
5. Allele frequencies in the two gene pools become increasingly different.
6. Eventually members of the two populations cannot interbreed to produce fertile offspring. A new species has formed (**speciation**).



Allopatric speciation: **geographical isolation** is followed by different selection pressures and, eventually, **reproductive isolation**.

Exam tip: Include all of: isolation, no gene flow, different mutations, different selection pressures, change in allele frequency, and finally the inability to interbreed to produce fertile offspring.

Evaluating zoos and seed banks in conservation Spec 4.21

Zoos

- **Captive breeding programmes**: animals are bred under controlled conditions. Studbooks record pedigrees and animals are exchanged between zoos so mating partners are unrelated, to maintain genetic diversity and avoid inbreeding.
- **Reintroduction programmes**: animals bred in captivity are released into protected habitat, increasing wild populations.
- **Scientific research**: study of the biology, behaviour and breeding of species, and techniques such as artificial insemination and embryo storage, help conservation in the wild.
- **Education**: visitors learn about threatened species, which increases support and funding.

Seed banks

Seed banks store seeds from many species, dried to a low water content and kept at low temperature (for example -20°C), which slows metabolism and keeps seeds viable for many years. Seeds can later

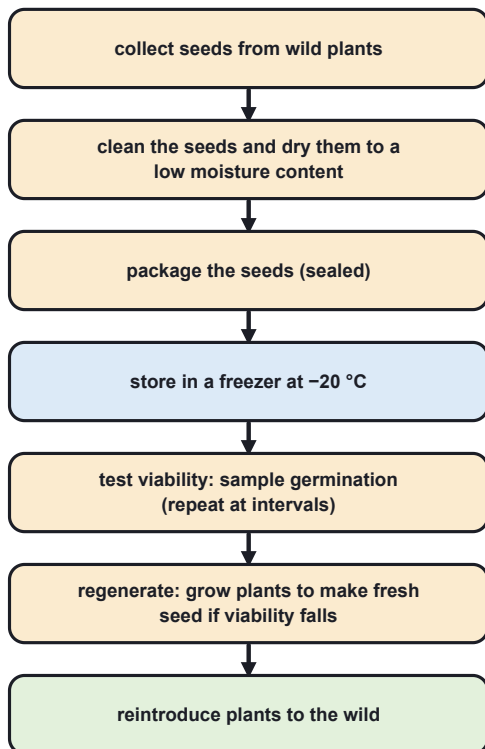
be germinated to grow new plants or to reintroduce a species.

- Seeds are collected from many plants across a species' range, to capture as much of its genetic diversity as possible.
- **Scientific research**: seed banks study the best conditions for drying, storing and germinating each species, and regularly test samples for viability by germinating them.
- **Reintroduction**: plants grown from stored seeds can be used to restore populations in protected or restored habitats.
- **Education**: seed banks and botanic gardens explain the value of plant diversity, for example as a source of food crops and medicines.

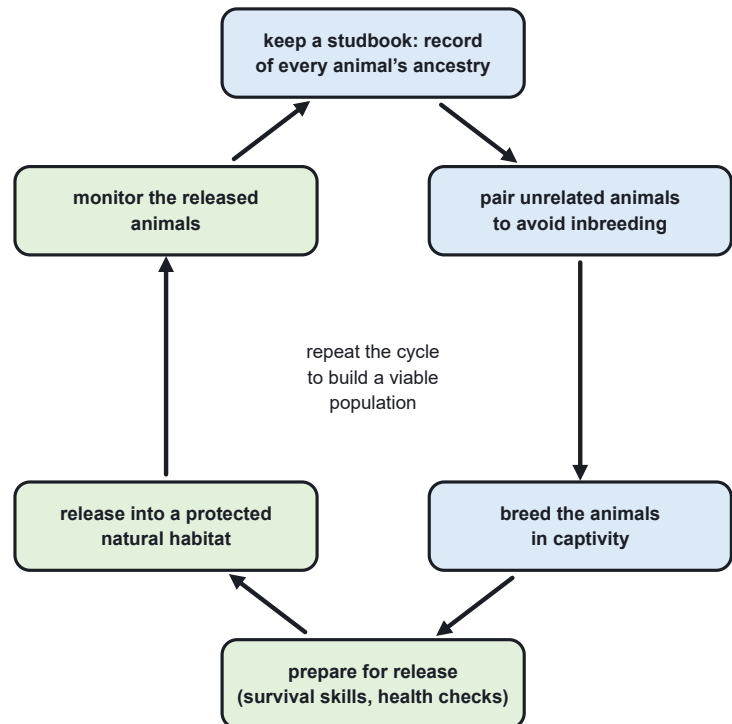
Evaluating zoos and seed banks		
	Strengths	Limitations
Zoos	Protect animals from threats such as hunting and habitat loss; managed breeding maintains genetic diversity; research and education; reintroduction can restore wild populations	Expensive and space-limited, so only a few individuals of a few species; small populations may lose genetic diversity; animals may lose natural behaviours and not survive reintroduction; habitat must still be protected for release; risk of disease
Seed banks	Cheap, take little space and store many individuals of many species; protect against loss in the wild; store a wide range of alleles for future use; seeds can be tested for viability and regrown	Some seeds cannot be dried or frozen; seeds may lose viability, so need testing and regrowing; plants in storage do not adapt to changing conditions; seeds from small samples may carry limited genetic diversity; a reintroduction needs suitable habitat

Exam tip: In evaluate questions give a balanced judgement: weigh strengths against limitations and end with a reasoned conclusion, for example that both are useful but only if natural habitats are also protected.

Seed bank



Zoo captive breeding programme



Two ex situ conservation methods: a **seed bank** (left) and a **captive breeding** programme in a zoo (right).

Quick check

1. Define niche.
2. Name the three types of adaptation.
3. In the Hardy-Weinberg equation, what does $2pq$ represent?
4. Name two causes of changes in allele frequency.
5. Why are seeds dried before storage in a seed bank?

Quick check answers

Niche, allele frequency and conservation

- 1 . The role of a species within its habitat, including how it obtains resources and its interactions with other species.
- 2 . Behavioural, anatomical and physiological.
- 3 . The frequency of the heterozygous genotype.
- 4 . Mutation and natural selection.
- 5 . To reduce water content, which slows metabolism and prevents germination and damage from ice crystals.