Edexcel International AS Biology

Your notes

Classification & Biodiversity

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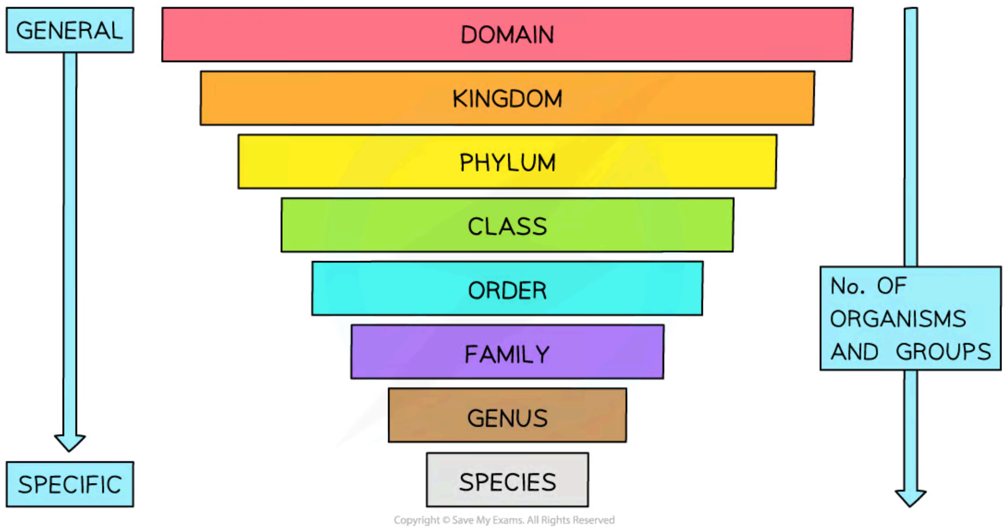
Your notes

Why Classify Organisms?

- Taxonomy is the practice of biological classification
- The phylogenetic classification system enables us to arrange **species** into **groups** based on their **evolutionary origins** and **evolutionary relationships**
- By grouping organisms into taxa, it can make them easier to understand and remember
- There are several **different ranks** or levels within the **hierarchical** classification system used in biology
  - There is **no overlap between groups**
  - Each group is called a **taxon** (plural **taxa**)
  - Multiple smaller taxa can be put in the same larger taxa
- **Species** is the **lowest taxonomic rank** in the system
  - Similar species can be grouped in a **genus**
  - Similar genera can be grouped in a **family**
  - Similar families can be grouped into an **order**
  - Similar orders can be grouped into a **class**
  - Similar classes can be grouped into a **phylum**
  - Similar phyla can be grouped into a **kingdom**
  - Similar kingdoms can be grouped into a **domain**
- **Domains are the highest taxonomic rank** in the system
  - They include the **Archaea** (prokaryotes), **Eubacteria** (prokaryotes) and **Eukarya** (eukaryotes)
- There are a few different rhymes that exist to help you remember the different ranks in the taxonomic classification system. You can always make up your own but the one below is super helpful!
  - The first letters of all the different ranks below the domains can be remembered as:
    - **K**ings **P**lay **C**hess **O**n **F**ancy **G**old **S**quares
    - **K**ingdom **P**hylum **C**lass **O**rder **F**amily **G**enus **S**pecies



The different levels within the hierarchical classification system – the higher ranks contain more organisms with less similarity between them, while the lower ranks contain fewer organisms with more similarity between them

- Many **different species** with similar genotypes and phenotypes can be grouped together in the **same genus**
- They are, however, still **separate species** since they **cannot produce fertile offspring**
  - This is known as the **species concept**
- Early classification systems only relied on the **outward appearance** (phenotype) of organisms to classify them
  - Looks can be deceiving however as many non-related organisms share similar phenotypes - e.g. whales and sharks
  - Advances in technology, such as **DNA sequencing**, have made it possible to **compare the genotypes** of organisms and **provide clarity** on the evolutionary relationships between them

Binomial system

- **Binomials** are the scientific names given to individual species
- It consists of the organism's **genus** and **species** name in modern Latin
  - The genus name is written first and is **capitalised**, while the species name comes second and is **not capitalise**d
  - **Both** parts of a binomial are **italicised**
- For example, the binomial for humans is *Homo sapiens* and the binomial for dogs is *Canis familiaris*
- Binomials are extremely useful for scientists as they allow for species to be **universally identified** - the binomial for a species is the same across the entire globe

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Five kingdoms

- Organisms can be placed into one of **five kingdoms**
- This is based on the general features that groups of organisms within these kingdoms **share**

Kingdom Prokaryotae (Monera)

- These are organisms that have **prokaryotic cells** which contain no nucleus
- They vary in size over a wide range, but are typically less than 5 μm
- Example: *Staphylococcus pneumoniae* is a bacteria species that causes pneumonia

Kingdom Protoctista

- All Protoctista are **eukaryotic,** and this broad group of cellular life encompasses all eukaryotic cells that do not belong to the other three eukaryotic kingdoms
- Members of this kingdom show great diversity in all aspects of life including structure, life cycle, feeding, trophic levels and modes of locomotion
- They usually live in **aquatic environments**
- Protoctists can exist as **single-celled organisms** or as a **group of similar cells**
- A group of Protoctista known as protozoa possess cells similar to animal cells
    - Their cells have **no cell wall**
- Another group of Protoctista known as algae possess cells similar to plant cells
    - Their cells have **cellulose cell walls and chloroplasts**
- *Stentor roseli* is a protoctist that has flagella all over its body which help it feed and move

Kingdom Fungi

- The oldest organism in the world is thought to be a fungus aged somewhere between 1500 - 10,000 years old
- All fungi are **eukaryotic** cells
- The cells of fungi:
    - Possess **non-cellulose cell walls** (often made of the polysaccharide **chitin**)
- Fungi are **saprotrophs:**
    - They obtain this energy and carbon by **digesting dead/decaying matter** extracellularly or from being **parasites** on living organisms
- Fungi **reproduce using spores** that disperse onto the ground nearby
- Fungi have a simple body form:
    - They can be unicellular (like the common baker's yeast *Saccharomyces cerevisiae)*

- Some consist of long threads called hyphae that grow from the main fungus body (mycelium)
- Larger fungi possess fruiting bodies that release large numbers of spores

- Examples: moulds, yeasts, mushrooms

Kingdom Plantae

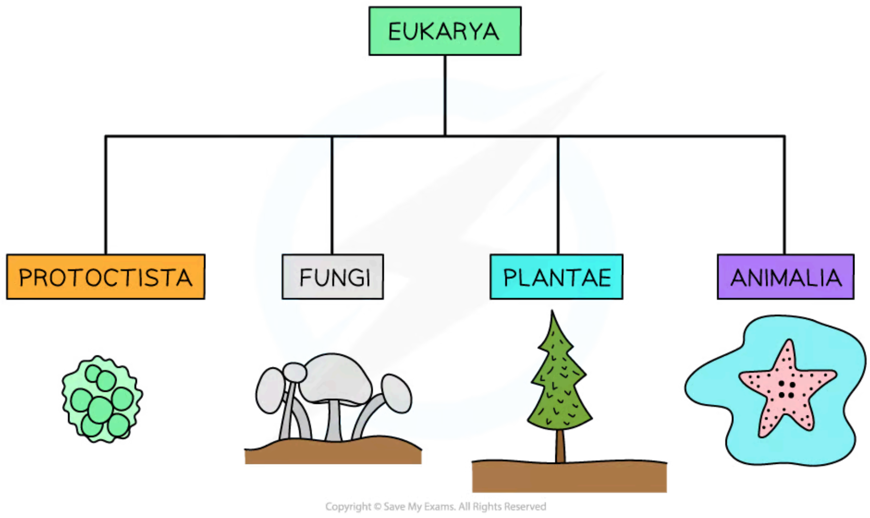
- Plants are **multicellular eukaryotic** organisms
- Plant cells:
  - All have **cell walls** composed of cellulose
  - Possess large (and usually permanent) **vacuoles** that provide structural support
  - Are able to differentiate into **specialized cells** to form **tissues and organs**
  - Possess **chloroplasts** (containing **chlorophyll**) that enable **photosynthesis** (not all plant cells have chloroplasts)
- They are **autotrophs**
  - This means they can synthesize their organic compounds and molecules for energy use and building biomass from inorganic compounds
- Examples: mosses, ferns, flowering plants

Kingdom Animalia

- Animals are also **multicellular eukaryotic** organisms
- Animal cells:
  - Are able to differentiate into **many different specialised cell types** that can form **tissues and organs**
  - Have **small temporary vacuoles** (for example, lysosomes)
  - Have **no cell walls**
- They are **heterotrophs**
  - They have a wide range of feeding mechanisms
- Examples: molluscs, insects, fish, reptiles, birds, mammals

Your notes

Your notes



The four kingdoms that fall under the domain Eukarya, representing the eukaryotes

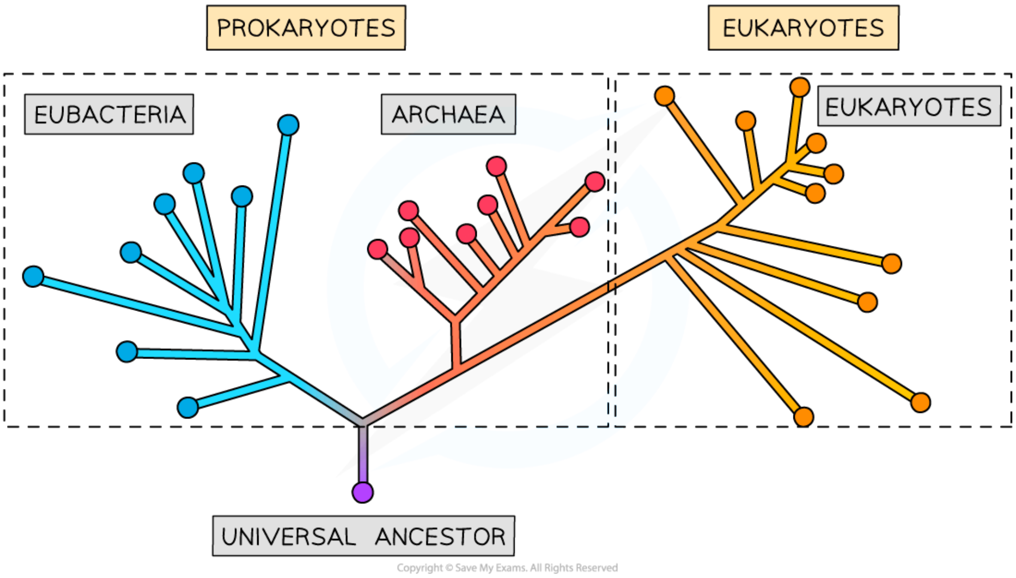
Examiner Tips and Tricks

The binomial for a species is always typed in italics or **underlined when handwritten**. The genus should always begin with a capital letter, and the species with a lower case letter.

Evidence for Taxonomy

- In the past, scientists encountered many difficulties when trying to determine the evolutionary relationships between species
- Using the physical features of species (such as colour/shape/size) has many limitations and can often lead to the wrong classification of species
- Advances in genome sequencing and immunology has allowed scientists to further investigate the evolutionary relationships between species
- This has led to many organisms being **reclassified** or changes being made to the **classification system structure**
- Scientific knowledge is **constantly changing**, as more technological advances are made
- One such example is the **three domain classification system**, which was based on new information obtained from molecular analysis of RNA genes in particular
  - Using this new information,scientists have realised that using cell type to classify organisms is insufficient, and that **prokaryotes** could be divided into two separate groups (domains)
  - The **three domains** are:
    - Archaea (prokaryotes)

- Bacteria (prokaryotes)
- Eukarya (eukaryotes)



The taxonomic classification system within the three domains

- This new classification system was based on **molecular phylogeny**
- **Phylogeny** investigates the evolutionary history of different groups of organisms and can specify how closely related they are
- Molecular phylogeny relies on similarities or **differences of molecules** (such as DNA, RNA or proteins) between groups of organisms to determine how closely related they are
- The **more similar** the molecules, the **more recent** the common ancestor is that they share
- Based on the evidence that molecular phylogeny provided, it was determined that the organisms in the kingdom **Prokaryotae** would be **reclassified** into two separate domains - the **Archaea** and **Bacteria**
- The evidence suggested that archaea and bacteria are **less closely related** to each other than scientists originally thought
- Organisms from the other four kingdoms where placed in another domain - **Eukaryota**

Characteristics & Features of the Three Domains Table

Your notes

Feature	Archaea	Eubacteria	Eukaryotes
Cell type	Prokaryotic	Prokaryotic	Eukaryotic
Chromosome	Circular	Circular	Linear chromosomes + circular mtDNA and cpDNA
Cell membrane lipids	Glycerol–ether lipids	Glycerol–ester lipids	Glycerol–ester lipids
Ribosomes	70S ribosomes but small subunit is more similar to eukaryotic ribosomes	70S ribosomes	Larger 80S ribosomes in cytosol and 70S ribosomes in mitochondria and chloroplasts
Cell walls	Always present (without peptidoglycan)	Always present (with peptidoglycan)	Sometimes present (without peptidoglycan)
Histones	Yes	No	Yes
Introns	Sometimes	Rarely	Yes

Your notes

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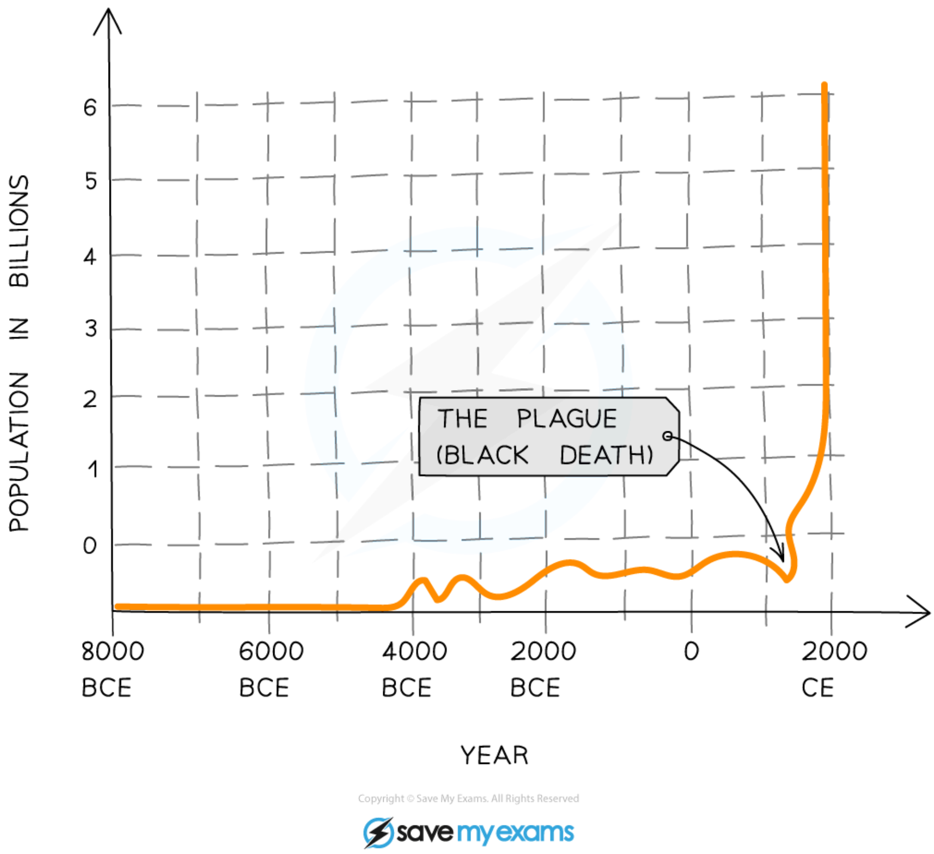
Human Impact on Variety of Life

- **Evolution** by the process of natural selection has increased the variety of life on Earth over time
- In recent times, however, **human activities** have threatened many species with extinction
- The global human population has been growing **exponentially** for the last 150 years
- There are many reasons for this exponential growth, including:
  - **Improved technology** leading to an **abundance of food** = increase in birth rate
  - **Improved medicine, hygiene and health care** = decrease in death rate



The human population is growing exponentially

- Humans use many **resources** from the Earth such as **land** (for settlements and agriculture), **water**, **wood** and **fossil fuels**
- As the human **population increases** and countries become more economically **developed**, our requirement for these **natural resources** also **increases**

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- This is having a **harmful effect** on many aspects of the environment, including **aquatic** and **terrestrial ecosystems**, and our **atmosphere** and **climate**
- The damage to these ecosystems is negatively impacting the **species** and **habitats** contained within them
- This means that a **conflict** exists between **human needs** and the **conservation of biodiversity**
- The **main factors affecting biodiversity** today are:
  - Habitat destruction
  - Overexploitation
  - Hunting
  - Agriculture
  - Climate change

Habitat destruction

- Many **human needs** lead to **natural environments** being **destroyed**
- When land is **cleared** for agriculture, industry, energy production, housing, transport, leisure facilities, waste disposal and water storage, this results in:
  - **Habitat loss** (plant and animals completely lose their habitats)
  - **Habitat fragmentation** (habitats are divided into small areas - populations living within these **separated habitat fragments** are more likely to suffer from **inbreeding** or **local extinction**)
- **Deforestation** is one of the most damaging forms of habitat destruction, as forest habitats often have the **highest levels of biodiversity**
- **Marine habitats** are also being destroyed, including:
  - **Coral reefs** (some people use dynamite as an extreme way to catch fish, which damages corals)
  - **Sea beds** (fishing practices such as trawling, where nets are dragged along the sea bed, destroy this important habitat)

Overexploitation

- Many of the natural resources exploited by humans are actually being **overexploited** (they are being used up **faster** than they can be replaced)
- For example, much deforestation is **unsustainable** as trees are **removed** but are **not replaced** by replanting. Even if they are replanted, the rate at which trees are being **removed** far **exceeds** the rate at which they are **growing back**
- **Fish stocks** are also being overexploited, which is also having a knock-on effect on organisms that feed on these fish species, such as marine mammals and seabirds

Hunting

- Hunting is another form of overexploitation, as many **wild, non-farmed species** of animals are being hunted and removed **more quickly** than their wild populations can be **replenished**
  - An example is the hunting of animals for 'bush meat' in developing countries (including the hunting of primates such as monkeys and chimpanzees, as well as other mammal and reptile species)

Agriculture

- After the second world war, there was a massive change in how food was produced
- There was a need to produce more food, at a quicker rate
- It was then that modern farming practices began:
  - Farms became more **specialised** so they grew only one crop or raised one type of livestock (monoculture)
  - There was a switch to growing **cereal crops** rather than vegetables
  - **Fields were made bigger** to accommodate machinery via the removal of hedgerows and stonewalls
  - More land was made **arable** by **draining wetland** and **filling in ponds**
  - The use of **fertilisers** and **pesticides** massively increased
- Most of these modern farming techniques have had a **major negative impact** on the level of biodiversity present in farmed areas
  - Monocultures support much **lower levels of biodiversity** compared to natural habitats or even natural grazing land (that has a large variety of plant species present which can support a much greater range and number of insect species and bird species)
  - **Hedgerows** represent an **important habitat** for many insects, small mammals and birds, which can nest there. As hedgerows are being increasingly removed, this habitat and the biodiversity it supports is lost
  - **Fertilisers** can **leach** into **waterways**, causing **eutrophication**, which can lead to the death of many **aquatic invertebrate** and **fish** species
  - **Pesticides** (e.g. insecticides) used on crops kill insect pests but also **kill many non-target species**, including important insect pollinators like bees

Climate change

- Human-caused climate change is causing **weather patterns** to **change** and the **frequency of extreme weather events**, such as hurricanes, typhoons, floods and droughts, to **increase**
  - It is feared that climate change is now occurring **too fast** for many species to be able to **adapt** to these changes, which could result in many species becoming **extinct** and a major decline in biodiversity

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- **Global warming** (a result of climate change) is causing many species to move towards the poles or to higher altitudes
    - However, these species may not be able to compete with, or may even out-compete, the species already present in these habitats, with either result leading to **decreased biodiversity**
    - Some species (such as plant species) may not be able to move or change their distributions fast enough to adapt to increasing temperature and may go extinct as a result
- Global warming (and the human-generated CO_2 that is the primary cause of this) is also threatening marine biodiversity:
    - **Increasing atmospheric CO_2** is leading to more CO_2 dissolving in seawater, **decreasing** its pH (known as **ocean acidification**). This is negatively affecting organisms that require **calcium carbonate** for shells (e.g. plankton and coral polyps)
    - Increased ocean temperatures have also led to an **increased frequency of coral-bleaching events**, where the tiny organisms that live inside corals and help keep them alive **leave** due to **temperature stress**. Without these organisms, the corals die and are broken down, eventually leading to the loss of whole coral reefs and as a result, the loss of the huge amount of biodiversity that depends on them

Your notes

Biodiversity & Endemism

- Biodiversity can be thought of as a study of all the **variation** that exists within and between all forms of life
- Biodiversity looks at the range and variety of genes, species and habitats within a particular region
- It can be assessed at three different levels:
  - The number and range of different ecosystems and habitats
  - The number of **species** and their relative abundance
  - The **genetic** variation within each species
- Biodiversity is very important for the **resilience of ecosystems;** in that it allows them to **resist changes** in the environment

Ecosystem or habitat diversity

- This is the **range** of different ecosystems or **habitats** within a **particular area or region**
- If there is a large number of different habitats within an area, that area is likely to have **high biodiversity**
  - A good example of this is a coral reef. They are very complex with lots of microhabitats and **niches** to be exploited
- If there are only one or two different habitats within an area, that area is likely to have low biodiversity
  - Large sandy deserts typically have very **low biodiversity** as the conditions are basically the same throughout the whole area

Species diversity

- An ecosystem such as a tropical rainforest that has a very high number of different species would be described as being **species-rich**
  - **Species richness** is the **number** of species within an ecosystem
- Species diversity includes the number of different species in an ecosystem, and also the **abundance** across the different species present
  - The **greater the number of species** in an ecosystem, and the **greater the abundance** of individuals from each species, the greater the **species diversity**
  - For example, an ecosystem can have a large number of different species but some species may be very rare (may only have a few individuals) in that particular ecosystem. As a result, the ecosystem does not necessarily have high species diversity

- Ecosystems with **high species diversity** are usually **more stable** than those with lower species diversity as they are **more resilient** to environmental changes
    - For example in the Pine forests of Florida, the ecosystem is **dominated by one or two** tree species. If a pathogen comes along that targets one of the two dominant species of trees, then the whole population could be wiped out and the ecosystem it is a part of could collapse

Genetic diversity

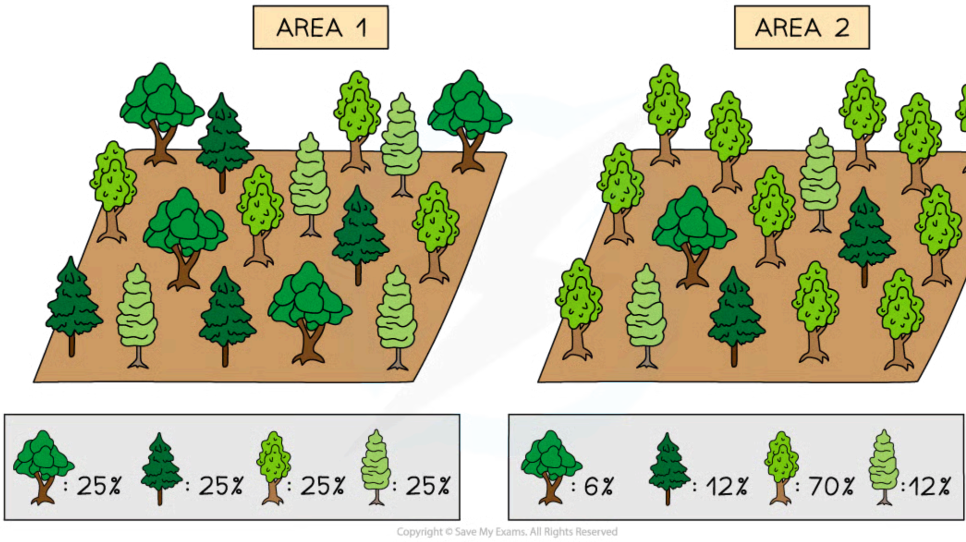
- The genetic diversity within a species is the **diversity of alleles and genes in the genome** of species
- Although individuals of the same species will have the same genes, they will not necessarily have the same **alleles** for each gene
- Genetic diversity is measured by working out the proportion of genes that have more than one form (allele) and how many possible alleles each gene has
- There can be genetic differences or diversity **between populations** of the same species
    - These differences may arise because the two populations occupy slightly different ranges in their habitat and so are subject to slightly different selection pressures that affect the allele frequencies in their populations
- Genetic diversity can also be observed **within a single population**
    - Genetic diversity in a species is important as it can help the population **adapt** to, and survive, **changes in the environment**
    - The changes could be in **biotic factors** such as new predators, pathogens and competition with other species
    - Or the changes could be through **abiotic factors** like temperature, humidity and rainfall
- Genetic diversity is **limited** in populations that are very **small** or **isolated**
    - **Inbreeding** in small, isolated populations leads to a **high proportion** of individuals being **homozygous** (e.g. AA to aa) for many genes, resulting in **lower genetic diversity**
    - This can mean that **genetic diseases** caused by **recessive alleles** can become **more common** in these populations

Endemism

- Certain species only occur in one particular area of the world - e.g. pygmy three-toed sloths which are only found on a small island off the coast of Panama
- These species are said to be **endemic** to that region and they do not naturally occur anywhere else
- Endemic species are particularly at risk of extinction due to their limited range

Species Richness & Heterozygosity Index

- The place where an organism lives is called its **habitat**
- Habitats can vary in size, with some being very large (e.g. grasslands) while others are very small (e.g. a puddle of water that formed after heavy rain)
- Measuring the **species diversity** within different habitats can be useful in making comparisons between them or when studying how habitats change over time
- One way to determine species diversity is to measure **species richness** in a habitat
- **Species richness** is the **number** of species within a community
  - A community is a group of populations of **different species** living in the same place at the same time that **interact with each other**
- Species richness is the simplest way to measure **species diversity**
- A community with a greater number of species will have a greater species richness score
  - For example, a tropical rain forest has a very high number of different species so it would be described as **species-rich**
- Species richness can be a **misleading** indicator of diversity as it does not take into account the **number of individuals** of each species
- **Species abundance** is a measure of the **relative number of individuals** in the different species within a given area
  - In the example below, Area 1 and Area 2 both contain 4 tree species
  - However, Area 2 is actually **dominated** by one species and in fact, one of the species is very **rare** (only one individual)
  - Although the two areas have exactly the same **species richness**, Area 1 has a **higher species abundance** (and therefore a **higher overall species diversity**) than Area 2
  - This example illustrates the limitations of using just species richness on its own
- Conservationists often favour the use of an **index of diversity** as it takes into account species number and evenness



Area 1 and 2 have the same species richness but different species abundance. Area 1 will have a higher overall species diversity as it has a higher species abundance. Species diversity takes both richness and abundance into account.

- Measuring the different levels of biodiversity within an ecosystem can be challenging
- Finding out which species live in an ecosystem and the size of the populations requires the **identification and cataloguing** of all organisms present to build a **species list**
- This is possible for areas that are very small or where the species are very large like trees
- However, for larger and more complex ecosystems like rainforests, it is simply **impossible** to find, identify and count every organism that exists there
- When this is the case, different **samples** of the area can be taken and used to make an **estimate for the total** species numbers in the area

Random sampling

- Some ecosystems are very complex with large numbers of different species of different sizes
- For the sake of logistics, **random sampling** is often used to estimate the **distribution** and **abundance** of species
    - The **distribution** of a species describes how it is spread throughout the ecosystem
    - The **abundance** of a species is the number of individuals of that species
- When carrying out sampling, square frames called **quadrats** can be used to mark off the area being sampled
    - Quadrats are square frames made of wood or wire
    - They can be a variety of sizes eg. $0.25m^2$ or $1m^2$
    - They are placed on the ground and the organisms within them are recorded

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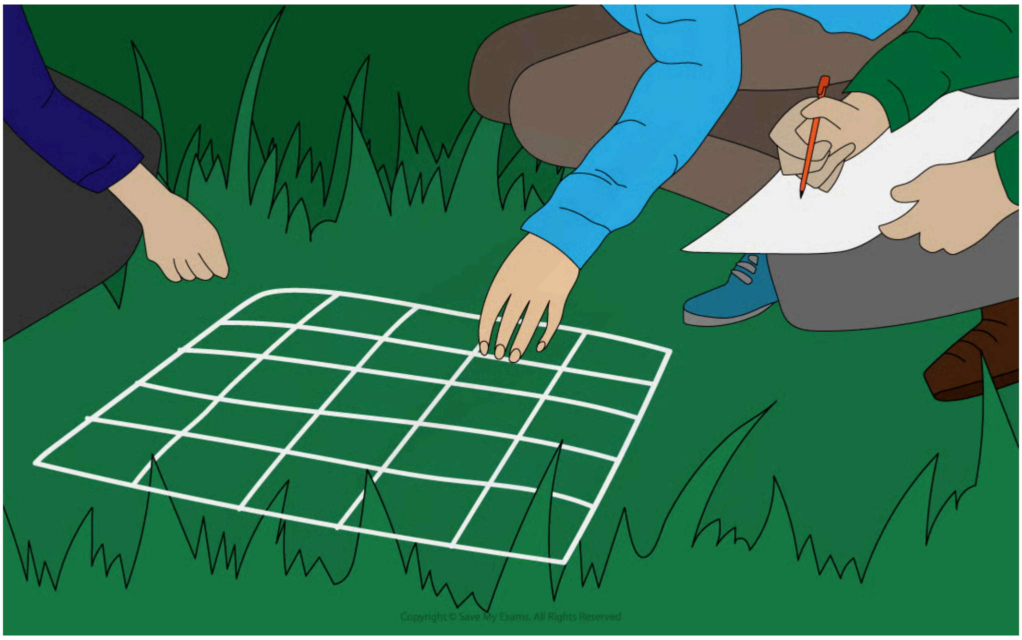
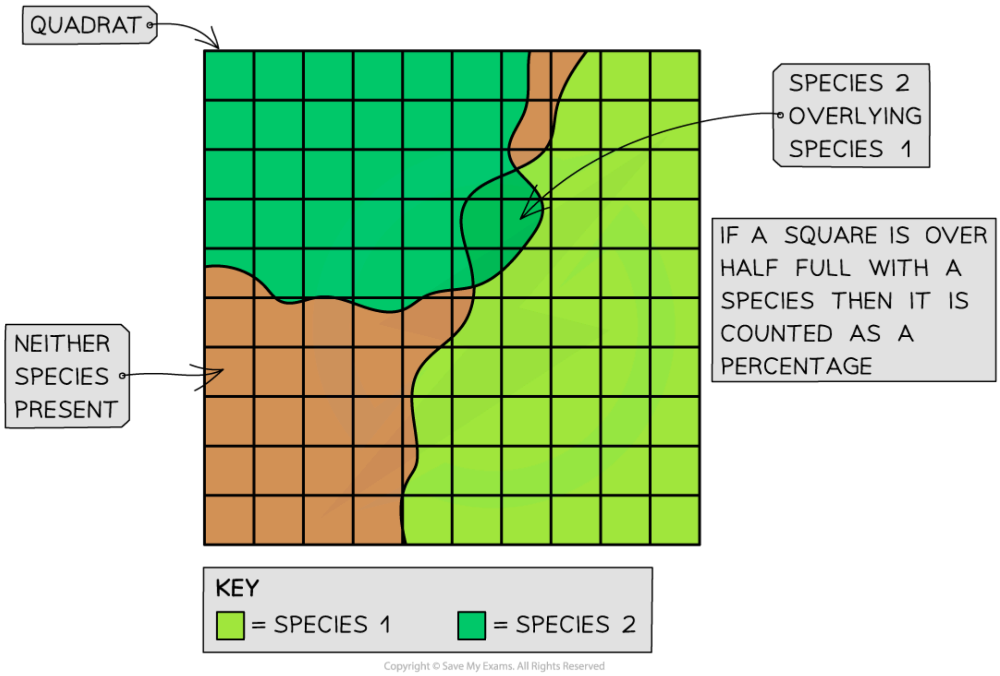
- They can be used to measure the distribution and abundance of **plants**



Using a quadrat to investigate population size or distribution

- Quadrats of different sizes can be used depending on what is being measured and what is most suitable in the space the samples are being made in
- Quadrats must be laid **randomly** in the area to **avoid sampling bias**
  - This random sampling can be done by converting the sampling area into a **grid format** and labelling each square on the grid with a number
  - Then a random number generator is used to pick the sample points
- Once the quadrat has been laid on the chosen sample point the **abundance** or **percentage cover** of all the **different species** present can be recorded

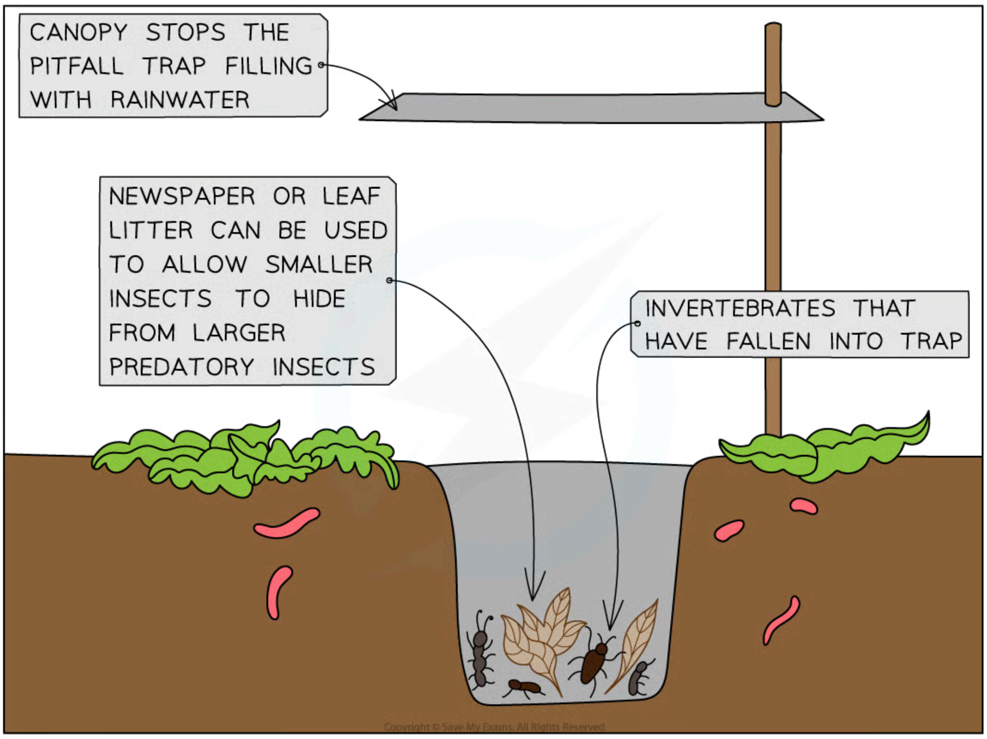
Your notes



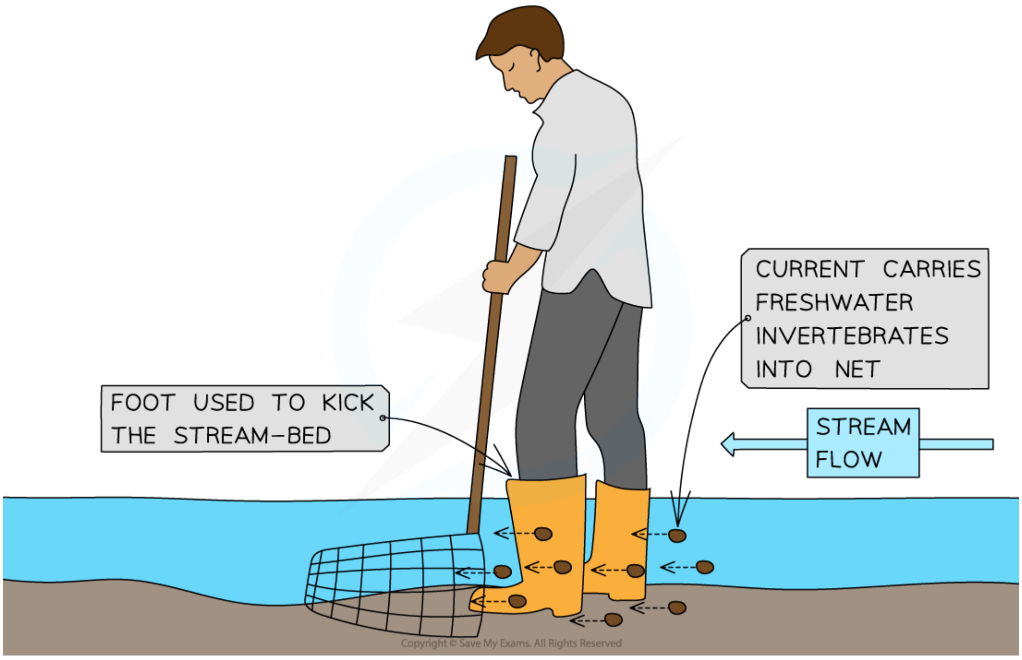
Using a quadrat to investigate the percentage cover of two species of grass. Some squares may be lacking any species while other squares may have multiple species in them – this means that the total percentage cover may sometimes be over or under 100%

- Quadrats are suitable for sampling **plants**
- For many **animal species**, however, it is not possible to use quadrats to measure their distribution and abundance
- In these cases, **other techniques** involving other items of **equipment** are necessary, including:
  - **Sweeping nets**: these are large, strong nets with a fine material (very small holes) that are used to catch flying insects and insects that live in long grass by sweeping the net back and forth through the grass
  - **Pitfall traps**: these are cans or jars that are buried in the ground that are used to catch ground-dwelling (often nocturnal) insects and other invertebrates as they fall into the trap
  - **Kick-sampling**: this technique is used to catch freshwater invertebrates living in streams or rivers. A net in placed on the stream-bed so that the water is flowing into it and the stream-bed just above the net is churned up by the scientist (using their foot) for a set period of time. The invertebrates are carried by the stream into the net
- Take as **many samples** as possible to get a more accurate indication of the entire habitat
- The results can be used to **estimate** the total number of individuals or species richness in the habitat
- It is important to use the **same sampling method** when gathering data to compare different habitats with one another

Your notes



Example of how a pitfall trap can be used



Example of how kick-sampling is done

Measuring genetic diversity within a species

- Genetic diversity refers to the **different alleles** that occur within the gene pool of a species or a population

- The **greater** the allele variety within a species, the **higher** the genetic diversity will be
- Measurements of genetic diversity is useful to investigate changes occurring in a population over time or when comparing two species with one another
- To measure genetic diversity two factors can be considered:
  - **Phenotype**
  - **Genotype**
- The **phenotype** of an organism refers to its **observable features**
- **Different alleles** are responsible for the **variety of phenotypes** that can be observed within a species
- **Therefore,** the greater the variety of phenotypes within a species, the higher the genetic diversity
- An organism's genotype is determined by the **different alleles** that are found within the cells
- Different alleles will have a different order of bases in the DNA molecules
- These base orders can be determined by sequencing the DNA of individuals in a species
- The **higher** the number of **different alleles** for a characteristic, the **greater** the **genetic diversity** within that species
- Another way to determine the genetic diversity within a species is to use the **heterozygosity index**

Heterozygosity index

- Organisms that have two different alleles at a particular gene locus are known as **heterozygotes**
- The **higher** the proportion of heterozygotes in a population, the **greater** the genetic diversity of that population will be
- We can use the following formula to calculate the **heterozygosity index** (H):

$$H = \frac{\text{number of heterozygotes}}{\text{number of individuals in the population}}$$

Worked Example

In pea plants the gene controlling seed shape exist in two forms: Allele **R** codes for round seeds and is dominant over allele **r** which codes for wrinkled seeds. It is found that within a population of 620 pea plants, there are 350 heterozygous (**Rr**) individuals.

Calculate the heterozygosity index for the pea plants at the locus for seed shape.

Your notes

Answer:

The formula is:

$$H = \frac{\text{number of heterozygotes}}{\text{number of individuals in the population}}$$

$$H = \frac{350}{620}$$

$$H = 0.56$$

- It is possible to determine the value for H at many loci, then calculate an **average** value
- This value can then be used as an **estimation** of the genetic diversity of the entire genome of the population

Your notes

Your notes

Comparison of Biodiversity Indicies

- Once the abundance of different species in an area has been recorded, the results can be used to calculate the **species diversity** for that area
  - Species diversity looks at the number of different species in an area but also the **abundance** across the different species
- An **index of diversity** is a measurement that describes the relationship between the number of species present and how each species contributes to the total number of organisms that are present in that community

The index of diversity formula

- The formula is:

$$D = \frac{N(N-1)}{\Sigma n(n-1)}$$

- Where:
  - *n* = total no. of organisms for a single species in the community
  - *N* = total no. of organisms in the community
  - **Σ** = sum of
- The **larger the number** obtained, the **higher the level of diversity**

Calculating the index of diversity

- To calculate:
  - **Step 1:** Calculate N(N-1) to find *value A*
  - **Step 2:** Calculate n(n-1) for **each species** and add all these numbers together to find *value B*
  - **Step 3:** Divide *value A* by *value B*

Worked Example

Samples of different insect species in a back garden were collected using sweep nets and identification keys. Use the data recorded to calculate the index of diversity.

Your notes

Species	Number of individuals (n)
Northern brown argus butterfly	7
Ladybird	34
Forester moth	6
Wasp	21
Grass spider	12
Bee	37
Hornet	7
Fly	19
Highland Midge	59

The total number of organisms(**N**) in this community would be: 7 + 34 + 6 + 21 + 12 + 37 + 7 + 19 + 59 = **202**

The formula is:

$$D = \frac{N(N-1)}{\Sigma n(n-1)}$$

Answer:

Step one: Calculate N(N-1) to find *value A*

$$N(N-1) = 202(202-1)$$

$$N(N-1) = 202(201)$$

$$N(N-1) = 40602$$

Step two: Calculate n(n-1) for each species and add all of these numbers together to find *value B*

See table below

Species	Number of individuals (n)	n−1	n(n−1)
Northern brown argus butterfly	7	6	7 × 6 = 42
Ladybird	34	33	34 × 33 = 1122
Forester moth	6	5	6 × 5 = 30
Wasp	21	20	21 × 20 = 420
Grass spider	12	11	12 × 11 = 132
Bee	37	36	37 × 36 = 1332
Hornet	7	6	7 × 6 = 42
Fly	19	18	19 × 18 = 342
Highland Midge	59	58	59 × 58 = 3422
Total no. of organisms (N)	202	Σn(n−1) = 6884	

Step three: Divide *value A* by *value B* to calculate the index of diversity (D)

$$D = 40602 \div 6884$$

$$D = 5.90$$

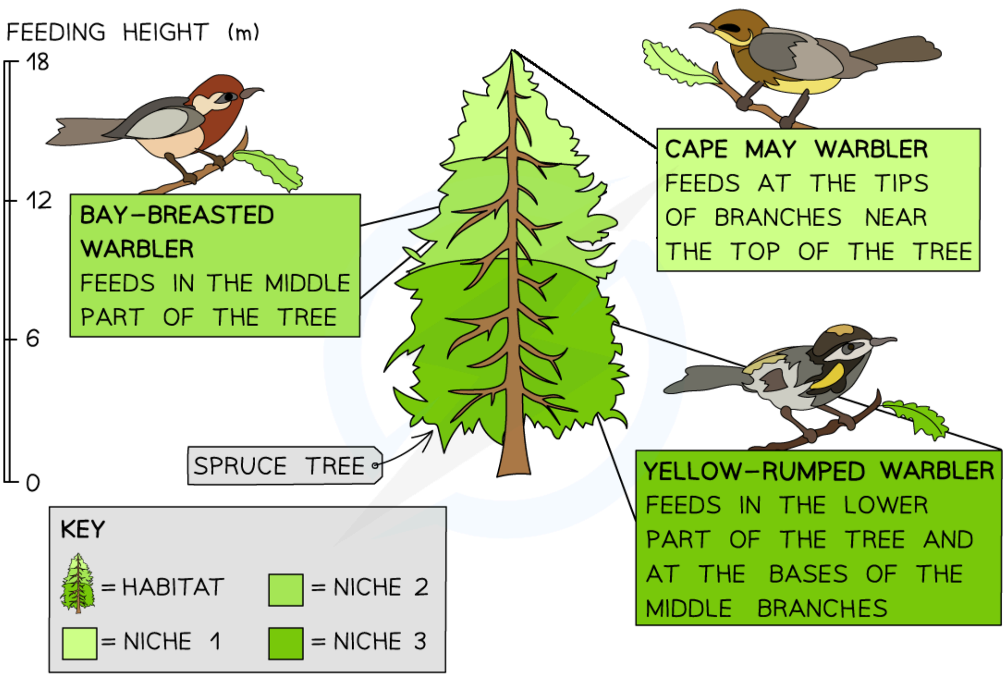
- The **higher** the value of D, the **greater** the level of biodiversity in that area
- It is useful to **compare** the species diversity in different habitats by calculating the diversity index for each of them

Examiner Tips and Tricks

Even though you are not expected to memorise the formulae for calculating the heterozygosity index and index of diversity, you will be expected to know how to use them and understand what the values mean that you calculate with them.

Niche

- The place where a species lives within an ecosystem is its **habitat**
- The role that a species plays within its habitat is known as its **niche**, including:
  - The **biotic interactions** of the species (e.g. the organisms it feeds on and the organisms that feed on it)
  - The **abiotic interactions** (e.g. how much oxygen and carbon dioxide the species exchanges with the atmosphere)
- A niche can only be occupied by **one** species, meaning that every individual species has its own **unique** niche
- If two species try to occupy the **same niche**, they will **compete** with each other for the **same resources**
  - One of the species will be **more successful** and **out-compete** the other species until only **one** species is left and the other is either forced to occupy a new, slightly different niche or to go extinct from the habitat or ecosystem altogether
- For example, the three North American warbler species shown below all occupy the **same habitat** (spruces and other conifer trees) but occupy **slightly different niches** as each species feeds at a **different height** within the trees
  - This **avoids competition** between the three species, allowing them to **co-exist** closely with each other in the **same habitat**



Although it appears as though these birds share the same niche, they spend their time eating in different parts of spruces and other conifer trees

Adaptations to abiotic and biotic conditions

- Adaptations are features of organisms that **increase** their chances of **surviving** and **reproducing**. These adaptations can be:
  - **Anatomical**, which refers to structural features such as horns, claws or feathers, that increase an organism's chances of survival
  - **Behavioural**, which refers to behaviours such as courtship of defensive behaviours, that increase an organism's chances of survival
  - **Physiological**, which refers to processes inside the body, such as venom production or the ability to digest cellulose, that increase an organism's chances of survival
- A species must be adapted to both the **biotic** and **abiotic** factors within its habitat in order to use this habitat in a way no other species can (i.e. in order to occupy its unique niche)
- Examples of adaptations to **biotic conditions** could include:

Adaptations to Biotic Factors Table

Organism	Adaptation	Type of adaptation
Sea otter	Using rocks to break open shellfish allows them to access a valuable food resource	Behavioural
Male frog	Using throat pouches to produce distinct mating calls allows them to attract a mate from the same species	Anatomical and behavioural
Bacteria	Some species produce antibacterial chemicals to out-compete other species of bacteria in the same area, allowing them great access to resources	Physiological

- Examples of adaptations to **abiotic conditions** could include:

Adaptations to Abiotic Factors Table

Your notes

Organism	Adaptation	Type of adaptation
Otter	Webbed paws allow them to live and hunt both on land and in water	Anatomical
Seal	A thick layer of blubber allows them to keep warm in very cold environments	Anatomical
Hedgehog	Hibernating over winter (lowering their rate of metabolism) allows them to conserve energy during the coldest months when food is scarce	Behavioural and physiological

Changes in Allele Frequency

Hardy-Weinberg Principle

- The Hardy-Weinberg principle states that if certain conditions are met, the **allele frequencies of a gene within a population will not change from one generation to the next**
- There are several **conditions or assumptions** that must be met for the Hardy-Weinberg principle to hold true:
  - **Mating** must be **random** between individuals
  - The population is **infinitely large**
  - There is **no migration, mutation** or **natural selection**
- The Hardy-Weinberg **equation** allows for the **calculation of allele and genotype frequencies** within populations
- It also allows for predictions to be made about how these frequencies will change in future generations
- If the allele frequencies in a population **change over time**, then it means that migration, mutation or natural selection has happened

Hardy-Weinberg calculations

- If the phenotype of a trait in a population is determined by a single gene with only two alleles (we will use **B / b** as examples throughout this section**)**, then the population will consist of individuals with three possible genotypes:
  - **Homozygous** dominant (**BB**)
  - **Heterozygous** (**Bb**)
  - Homozygous recessive (**bb**)
- When using the Hardy-Weinberg equation, the **frequency of a genotype** is represented as a **proportion** of the population
  - For example, the **BB** genotype could be 0.40
  - Whole population = 1
  - The letter ***p*** represents the frequency of the dominant allele (**B**)
  - The letter ***q*** represents the frequency of the recessive allele (**b**)
  - As there are only two alleles at a single gene locus for this phenotypic trait in the population:

$$p + q = 1$$

- The chance of an individual being homozygous dominant is p^2
    - In this instance, the offspring would inherit dominant alleles from both parents ($p \times p = p^2$)
- The chance of an individual being heterozygous is $2pq$
    - Offspring could inherit a dominant allele from the father and a recessive allele from the mother ($p \times q$) **or** offspring could inherit a dominant allele from the mother and a recessive allele from the father ($p \times q$) = $2pq$
- The chance of an individual being homozygous recessive is q^2
    - In this instance, the offspring would inherit recessive alleles from both parents ($q \times q = q^2$)
- As these are all the possible genotypes of individuals in the population, the following equation can be constructed:

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

Your notes

Worked Example

In a population of birds, 10% of the individuals exhibit the recessive phenotype of white feathers. Calculate the frequencies of all genotypes.

Solution:

- We will use **F / f** to represent dominant and recessive alleles for feather colour
- Those with the recessive phenotype must have the homozygous recessive genotype, **ff**
- Therefore **q^2 = 0.10** (as 10% of the individuals have the recessive phenotype and **q^2** represents this)

To calculate the frequencies of the homozygous dominant (p^2) and heterozygous ($2pq$):

Step 1: Find q

$$\sqrt{q^2} = \sqrt{0.1} = 0.32$$

Step 2: Find p (the frequency of the dominant allele F). If q = 0.32, and p + q = 1

$$p + q = 1$$

$$p = 1 - 0.32$$

$$p = 0.68$$

Step 3: Find p^2 (the frequency of homozygous dominant genotype)

$$0.68^2 = 0.46$$

$$p^2 = 0.46$$

Step 4: Find 2pq = 2 x (p) x (q)

$$2 \times (0.68) \times (0.32)$$

$$= 0.44$$

Step 5: Check calculations by substituting the values for the three frequencies into the equation; they should add up to 1

$$\boldsymbol{p}^2 + \boldsymbol{2pq} + \boldsymbol{q}^2 = 1$$

$$0.46 + 0.44 + 0.10 = 1$$

In summary:

- Allele frequencies:
    - p = **F** = 0.68
    - q = **f** = 0.32
- Genotype frequencies:
    - p^2 = **FF** = 0.46
    - q^2 = **ff** = 0.10
    - $2pq$ = **Ff** = 0.44

Examiner Tips and Tricks

When you are using Hardy-Weinberg equations, start your calculations by determining the proportion of individuals that display the **recessive phenotype** - you will always know the genotype for this: **homozygous recessive**. Remember that the dominant phenotype is seen in both homozygous dominant, and heterozygous individuals. Also, don't mix up the Hardy-Weinberg equations with the Hardy-Weinberg principle. The **equations** are used to **estimate** the allele and genotype **frequencies** in a population. The **principle** suggests that there is an **equilibrium** between allele frequencies and there is no change in this between generations.

Reasons for Changes in Allele Frequency

Mutations

- Organisms of the same species will have very similar genotypes, but two individuals (even twins) will have differences between their DNA base sequences
- Considering the size of genomes, these differences are small between individuals of the same species
- The small differences in DNA base sequences between individual organisms within a species population is called **genetic variation**
- Genetic variation is **transferred** from one generation to the next and it **generates phenotypic variation** within a species population
- The primary source of genetic variation is **mutation** (changes in the DNA base sequence)

Your notes

- Mutation results in the **generation of new alleles**
  - The new allele may be advantageous, disadvantageous or have no apparent effect on phenotype
  - New alleles are not always seen in the individual that they first occur in
  - They can remain hidden (not expressed) within a population for several generations before they contribute to phenotypic variation

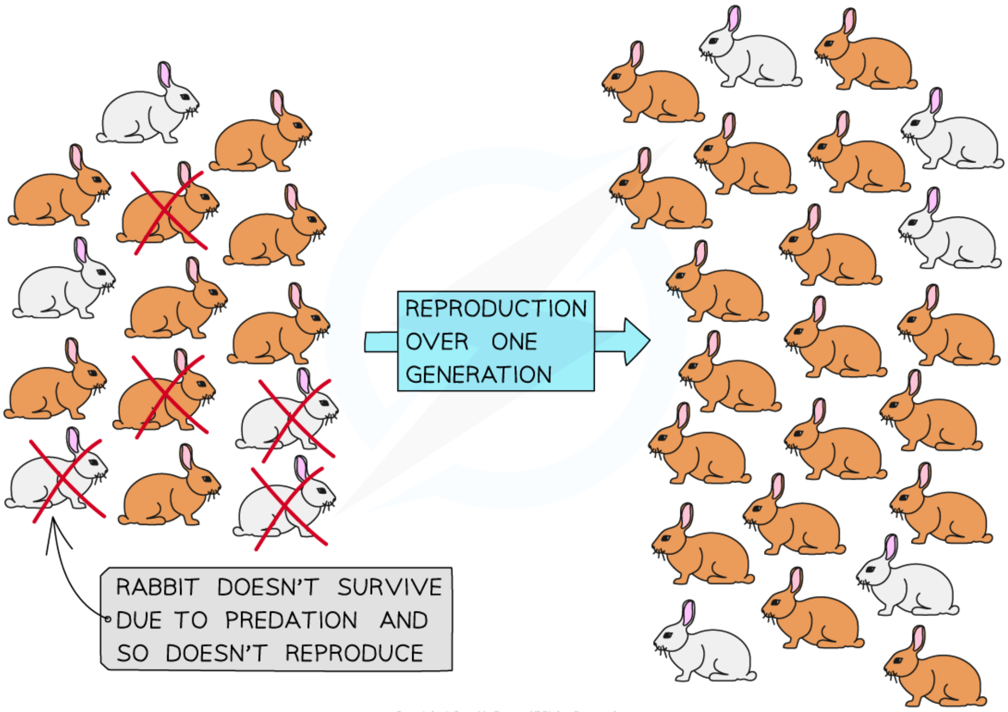
Natural selection

- **Variation** exists within a species population
- This means that some individuals within the population possess **different phenotypes** (due to genetic variation in the alleles they possess; remember members of the same species will have the same genes)
- Environmental factors affect the chance of survival of an organism; they, therefore, act as a **selection pressure**
- Selection pressures **increase the chance** of individuals with a **specific phenotype** surviving and reproducing over others
- The individuals with the favoured phenotypes are described as having a higher **fitness**
  - The fitness of an organism is defined as its ability to **survive** and **pass on its alleles** to offspring
  - Organisms with higher fitness possess **adaptations** that make them **better suited to their environment**
- When selection pressures act over several generations of a species, they can cause a change in the **allele frequency** and the **phenotype frequency** in a population through **natural selection**
  - Natural selection is the process by which individuals with a fitter phenotype are more likely to survive and pass on their alleles to their offspring so that the **advantageous alleles increase in frequency over time and generations**

An example of natural selection in rabbits

- **Variation in fur colour** exists within rabbit populations
- At a single gene locus, normal **brown fur** is produced by a dominant allele whereas **white fur** is produced by a recessive allele in a homozygous individual
- Rabbits have natural predators like foxes which act as a selection pressure
- Rabbits with a white coat do not camouflage as well as rabbits with brown fur, meaning predators are more likely to see white rabbits when hunting
- As a result, rabbits with white fur are less likely to survive than rabbits with brown fur
- The **rabbits with brown fur** have a selection advantage, so they are **more likely to survive** to reproductive age and be able to pass on their alleles to their offspring

- **Over many generations,** the **frequency** of **alleles** for **brown** fur will **increase** and the frequency of alleles for white fur will decrease



Selective pressure acting on a rabbit population for one generation. Predation by foxes causes the frequency of brown fur alleles in rabbits to increase and the frequency of white fur alleles in rabbits to decrease

Reproductive Isolation

- Organisms that belong to the **same species** share the **same characteristics** and are able to produce **fertile offspring**
- Reproductive isolation occurs when changes in the **alleles** and **phenotypes** of some individuals in a population **prevent** them from successfully **breeding** with other individuals in the population that don't have these changed alleles or phenotypes
- Examples of allele or phenotype changes that can lead to reproductive isolation include:
  - **Seasonal changes** - some individuals in a population may develop different **mating** or **flowering** seasons (becoming sexually active at different times of the year) to the rest of the population (i.e their **reproductive timings** no longer match up)
  - **Mechanical changes** - some individuals in a population may develop changes in their **genitalia** that prevent them from **mating** successfully with individuals of the opposite sex (i.e. their **reproductive body parts** no longer match up)
  - **Behavioural changes** - some individuals in a population may develop changes in their **courtship behaviours**, meaning they can no longer **attract** individuals of the

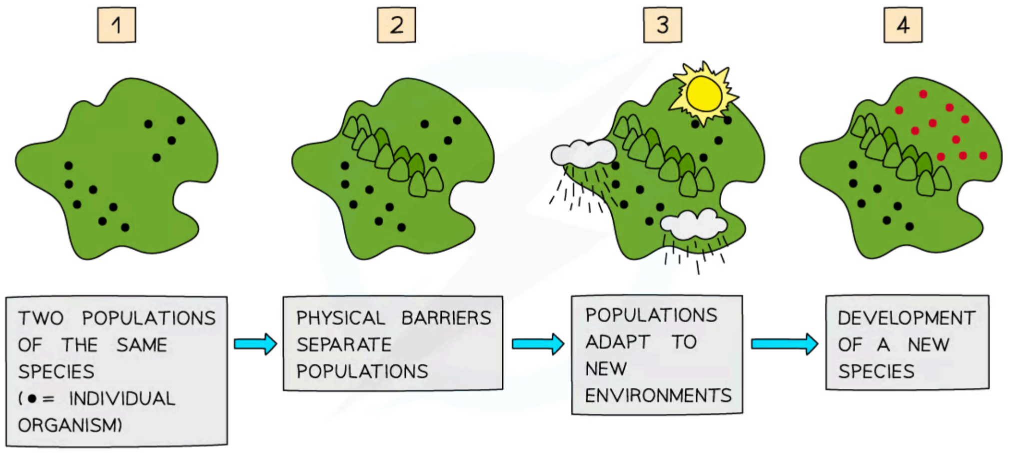
Your notes

opposite sex for **mating** (i.e. their methods of attracting a mate are no longer effective)

- These changes could be brought about due to **geographical barriers** isolating populations or **random mutations** producing new, different alleles in a population

Speciation

- Speciation can occur when populations of a species become **separated** from each other by **geographical barriers**
  - The barrier could be **natural** like a body of water, or a mountain range
  - It can also be **man-made**, like a motorway
- This creates two populations of the same species who are **reproductively isolated** from each other, and as a result, **no genetic exchange** can occur between them
- If there are sufficient **selection pressures** acting to change the **gene pools** (and allele frequencies) within both populations then eventually these populations will **diverge** and form **separate species**
  - The changes in the alleles/genes of each population will affect the **phenotypes** present in both populations
  - **Random mutations** within each population will also change allele frequencies in each
  - Over time, the two populations may begin to **differ** physiologically, behaviourally and anatomically (structurally)
- This type of speciation is known as **allopatric speciation**

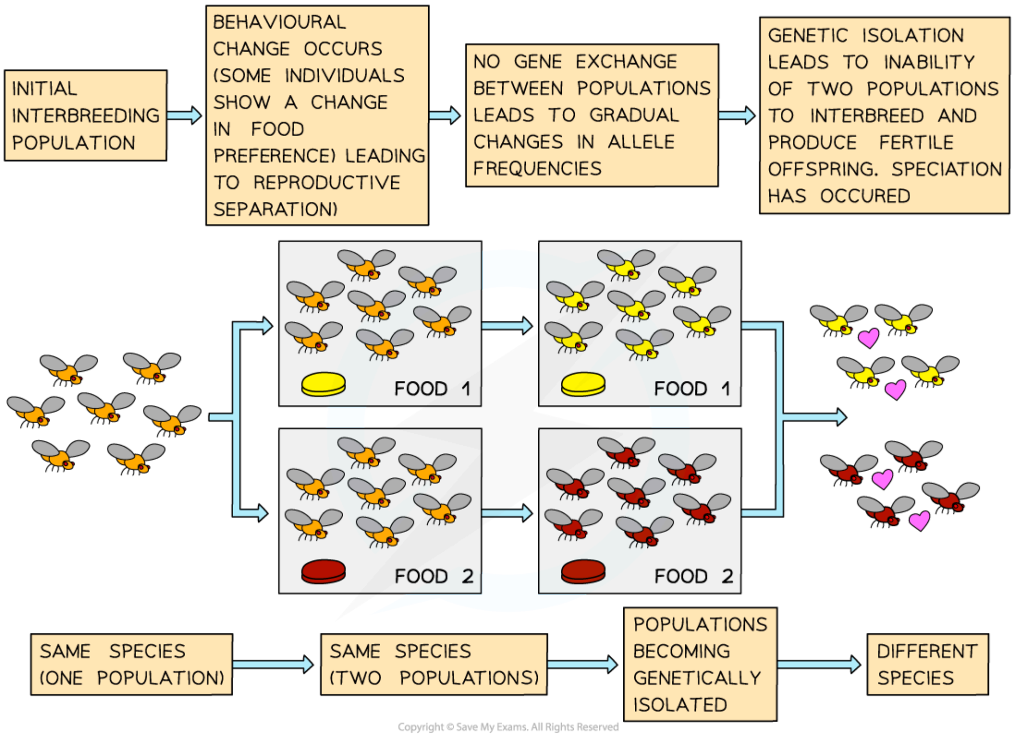


Allopatric speciation occurring due to geographical isolation of two populations of the same species

- Sometimes populations of the same species live in the **same geographical area** but they become separated from each other by **ecological** or **behavioural** means

- An example of ecological separation is populations that live in different environments within the same area e.g. plants growing in soil with different pH levels may flower at different times from each other causing reproductive isolation

- This type of speciation that occurs without the presence of a geographical barrier is known as **sympatric speciation**

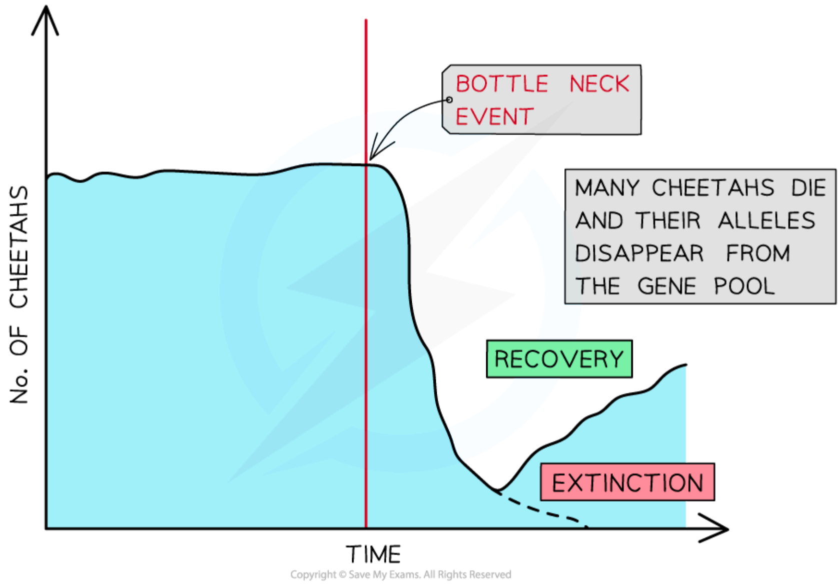


Reproductive separation due to behavioural changes that resulted in sympatric speciation occurring

Population bottlenecks

- A large population is required for the maintenance of a diverse gene pool
- Sometimes dramatic events occur (such as natural disasters or disease) that **decrease the size** of a population dramatically
- This is known as a **population bottleneck**
- It can lead to a **significant decrease** in the size of the **gene pool** of the population and will have a dramatic effect on the **allele frequencies** as a result thereof
- The remaining population will be **more susceptible** to the loss of alleles and the effects of mutations will be **magnified** in the new population
    - An example is the **cheetah** which survived a near-extinction event in the past
    - Only a few individuals remained and as a result the genetic diversity of all living cheetahs are very low
    - This makes them very vulnerable to disease or environmental changes

Your notes

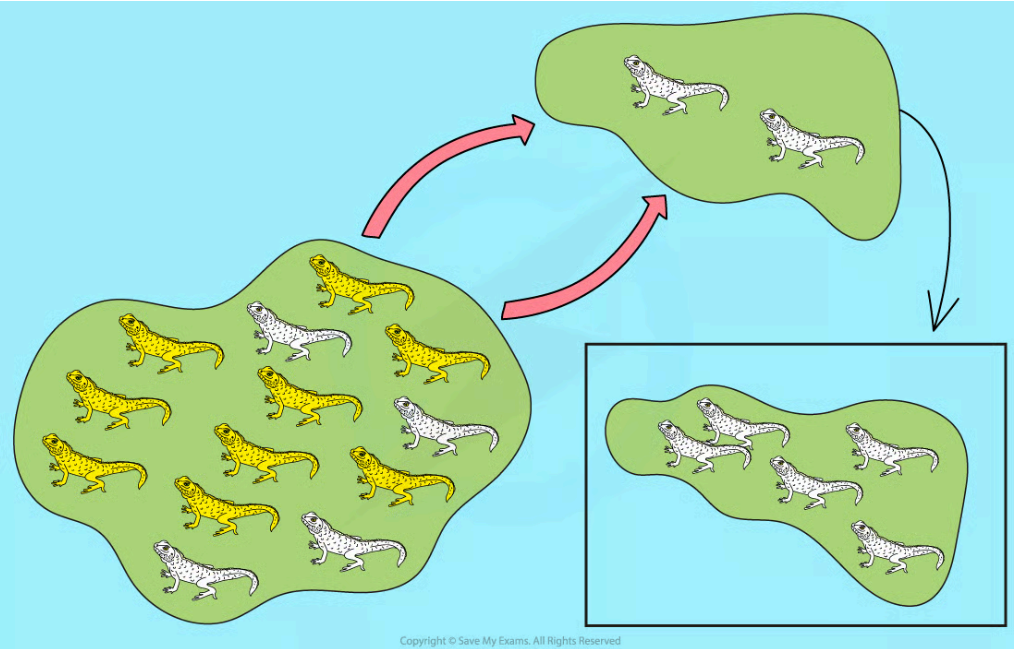


A population bottleneck in the past has dramatically decreased the genetic variation in cheetahs populations

The Founder effect

- This refers to the **loss of genetic variation** if a new population is formed by a **small number of individuals** that left the main population
- Since the **initial gene pool is small**, it is unlikely that it will contain the genetic variation of the original population that the individuals came from
- Should any of these individuals carry **unusual mutations** in their genome, these will appear **more frequently** in the new population
    - An example of this is the unusually high occurrence of **Ellis-van Creveld syndrome** (a type of dwarfism) among the **Amish** community in the USA
    - This was the result of a few individuals that were **heterozygous** for the recessive allele that formed part of the founding Amish population

Your notes



The Founder effect can amplify the occurrence of genetic mutations in a population due to the small gene pool of the founding members

Your notes

Your notes

Conservation of Endangered Species

- When species go extinct it leads to an overall **decrease in biodiversity**
- In recent times many species have already gone extinct, while others are **endangered**
- An endangered species is a **species that is being threatened with extinction**
- It is therefore important that these species are **conserved** to prevent them from going extinct
- Conservation of endangered species can be approached in several different ways
- Ideally a species should be **kept in their natural habitat**, as all the support systems they need to maintain life already exist there
  - National parks and marine parks are examples of conservation methods that do this
- When it is not possible to do this endangered species can be captured and placed in **captivity** for conservation efforts
  - **Zoos** and **botanic gardens** take part in conservation programmes
- Scientists have also come up with several methods to try and ensure the **long-term survival** of endangered species through frozen zoos and seed banks
- **Conservation** of species refers to **protecting** and **managing** them for future generations

Seed banks

- A **seed bank** is a facility that conserves plant diversity by drying and storing seeds in a temperature-controlled environment
- Usually, seeds of the same species are collected from different sites to **maintain genetic diversity**
- If the plant species goes extinct then the seeds can be used to grow them again
- Seeds can only be stored for so long. After a certain period of time the stored seeds are grown into plants and fresh seeds for storage are taken from those plants
- The **Svalbard Global Seed Vault** in Norway has almost 1 million species of plant seed. It is located in the Arctic Circle, within ideal environmental conditions
- Many organisations send seeds from crop plants to be stored there for safekeeping
- Some plants have **seeds that can not be frozen** such as coffee and cocoa plants
  - In order to preserve the genetic diversity of these plants successive generations must be grown or tissue cultures taken
- There are **advantages** and **disadvantages** of using seed banks
- Seed banks make valuable contributions to **scientific research**

- It provides an opportunity to investigate how to **successfully grow** plants from seeds
- They **provide a stock** of endangered plants that could be useful to humans (e.g. medicinal plant species, crop plant species) taking pressure off of wild populations

- It is important to note, however, that data gathered from seed banks may not be representative of wild populations due to the small, genetically limited, sample size
- Seed banks also educate people about endangered species and increase interest in conserving these species
    - For example, people can be trained to set up local seed banks, which involves the community

Advantages & Disadvantages of Seed Banks Table

Advantages	Disadvantages
◦ More cost effective to store seeds rather than fully grown plants ◦ Seeds take up less space, so more can be stored than for fully grown plants ◦ Less labour intensive ◦ Seeds can be stored anywhere in the world, as long as it's cool and dry ◦ Seeds are less vulnerable to disease, natural disaster or vandalism	◦ Testing seeds for viability is expensive and time–consuming ◦ The cost would be too high to store all types of seeds and test them for viability ◦ It will be challenging to collect seeds from plants growing in remote habitats

Zoos

- **Zoos** can also contribute to the conservation of endangered animal species
- **Captive breeding** programmes can breed individuals of a species so their offspring can be **released into the wild**
- Zoos are an invaluable resource for **scientific research**
    - Scientists are able to closely study animal's **genetics**, **behaviours** and **habitat needs**
- There are some **problems with zoos** and their role in conservation:
    - Captive breeding of small species populations can **reduce genetic diversity**
    - Certain animal species will **not breed in captivity**
    - Not all zoos can provide **adequate habitats** for animals with specific needs
    - Many people question the **ethics** of keeping animals in **captivity**
- There are stories of both **success and failure** when it comes to zoos and conservation:

Your notes

- The oryx is an antelope-like species that was saved from extinction and reintroduced into the wild in Africa thanks to zoos and captive breeding programmes
- Pandas have been in captive breeding programs for over 60 years and not a single panda has been reintroduced into the wild

- Zoos make a valuable contribution to **scientific research** in a variety of ways:
  - They provide information about the **specific needs** (behavioural, physiological, nutritional) of different animal species, which **aids conservation efforts in the wild**
  - They can carry out studies that would be very difficult to do in **wild populations**
- Animals in zoos **may not behave the same** way they would in the wild, so this raises questions about the **reliability of the data** from some **zoo-based studies**
- Zoos contribute to **educating people** about endangered species by bringing them close to these organisms and **increasing public enthusiasm** for, and **public engagement** with, conservation efforts

Advantages & Disadvantages of Zoos Table

Advantages	Disadvantages
∘ Invaluable resource for scientific research (scientists are able to closely study the genetics, behaviours and habitat needs of captive animals) ∘ This provides greater understanding of species' needs and aids conservation efforts in the wild ∘ Scientists can carry out studies that would be very difficult to do in wild populations ∘ Zoos contribute to educating the public about endangered species and conservation efforts	∘ Captive breeding of small species populations can reduce genetic diversity ∘ Certain animal species will not breed in captivity ∘ Not all zoos can provide adequate habitats for animals with specific needs ∘ Zoo animals may not behave the same way they would in the wild, so scientific data from zoo–based studies may not be reliable

Reintroduction back into the wild

- Plants and animals from these facilities can be released back into their natural habitat, which holds certain **benefits**:
  - This will help **prevent** them from **going extinct** in the wild
  - **Organisms that rely** on these plants and animals for food or habitat may also benefit from their presence
  - This contributes toward **restoring lost or degraded habitats**
- Reintroduction may have some **negative effects** too:

- These organisms may carry **new diseases** that will harm other organisms living in that habitat
- Reintroduced animals may **lack the ability** to **find food** or **communicate** effectively with members of their own species

Your notes