HL IB Biology

Your notes

Evolution & Speciation

Contents

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Evolution

Your notes

Evolution

- Species **do not stay the same over time**; the species that we see around us today have developed over millions of years
  - This process of species change is known as **evolution**
- Evolution can be defined as:

Changes in the heritable characteristics of organisms over generations

- **Heritable** characteristics are those that can be **inherited by,** or **passed on to, the next generation**
  - Changes in characteristics that are not inherited, e.g. a plant having its leaves eaten, do not lead to evolution
  - Heritable characteristics are determined by the alleles of genes that are present in an individual
  - Alleles may change as a result of **random** mutation, causing them to become more or less advantageous
- Heritable characteristics that are **advantageous** are **more likely to be passed on** to offspring, leading to a **gradual change** in a species over time
  - This is the process of **natural selection**
- Changes in the heritable characteristics of organisms can also lead to the development of completely **new species**
- The formation of new species via the process of evolution has resulted in a **great diversity of species** on Earth
  - Theoretically, at the origin of life on Earth, there would have been just **one** single species
  - This species evolved into **separate new species**
  - These species would then have **divided** again, each forming new species once again
  - Over millions of years, evolution has led to countless numbers of these speciation events, resulting in the millions of species now present on Earth

Evolution diagram

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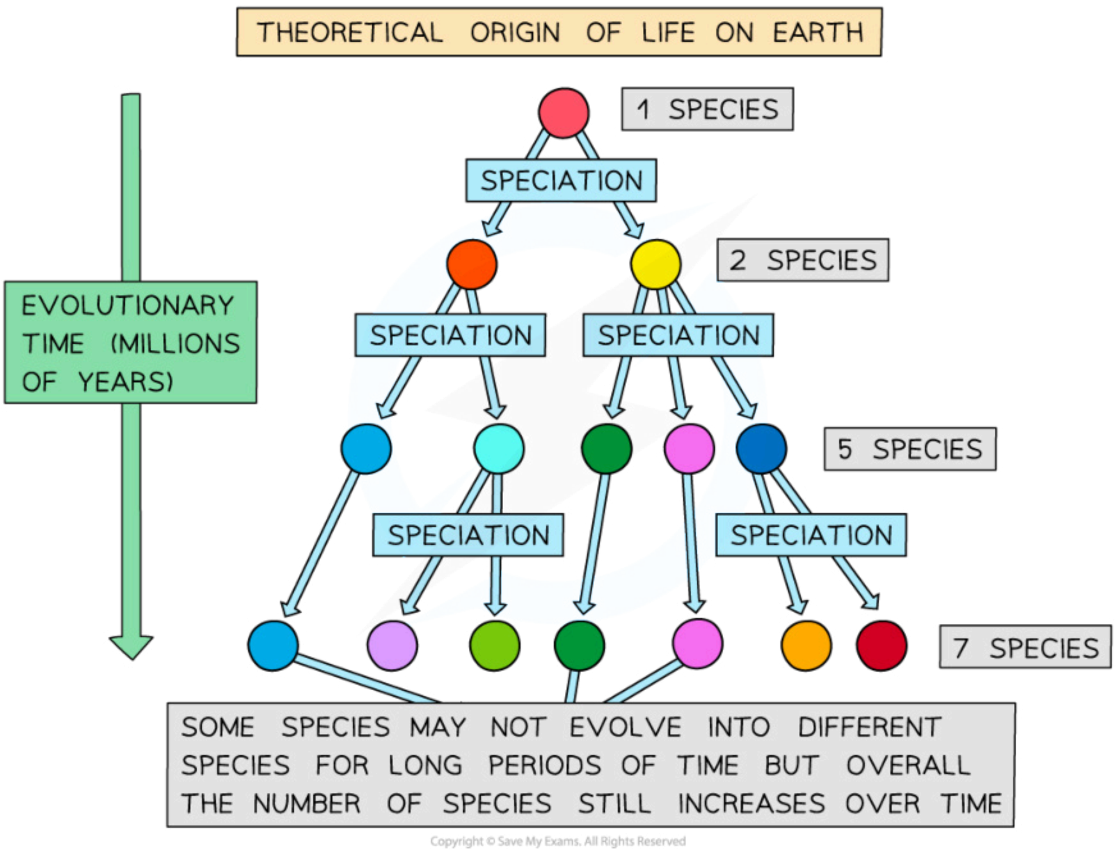

Evolutionary change over a long period of time has resulted in a great diversity of species

Darwinian evolution

- Charles Darwin, as a result of **observations** on a round-the-world expedition, and backed by years of experimentation and discussion, proposed the **theory of evolution by natural selection**
- Darwin's theory is as follows:
  - Individuals in a species show a wide range of **variation** due to **random mutations** in their DNA
  - Individuals within a population must compete for survival due to selection pressures
  - Individuals with characteristics most suited to the environment have a **higher chance of survival** and so are **more likely to reproduce**
  - Advantageous **alleles** are passed down to offspring
  - Over many generations the advantageous alleles become more frequent in a population
- Darwinian evolution by natural selection requires that characteristics are **heritable**

Natural selection diagram

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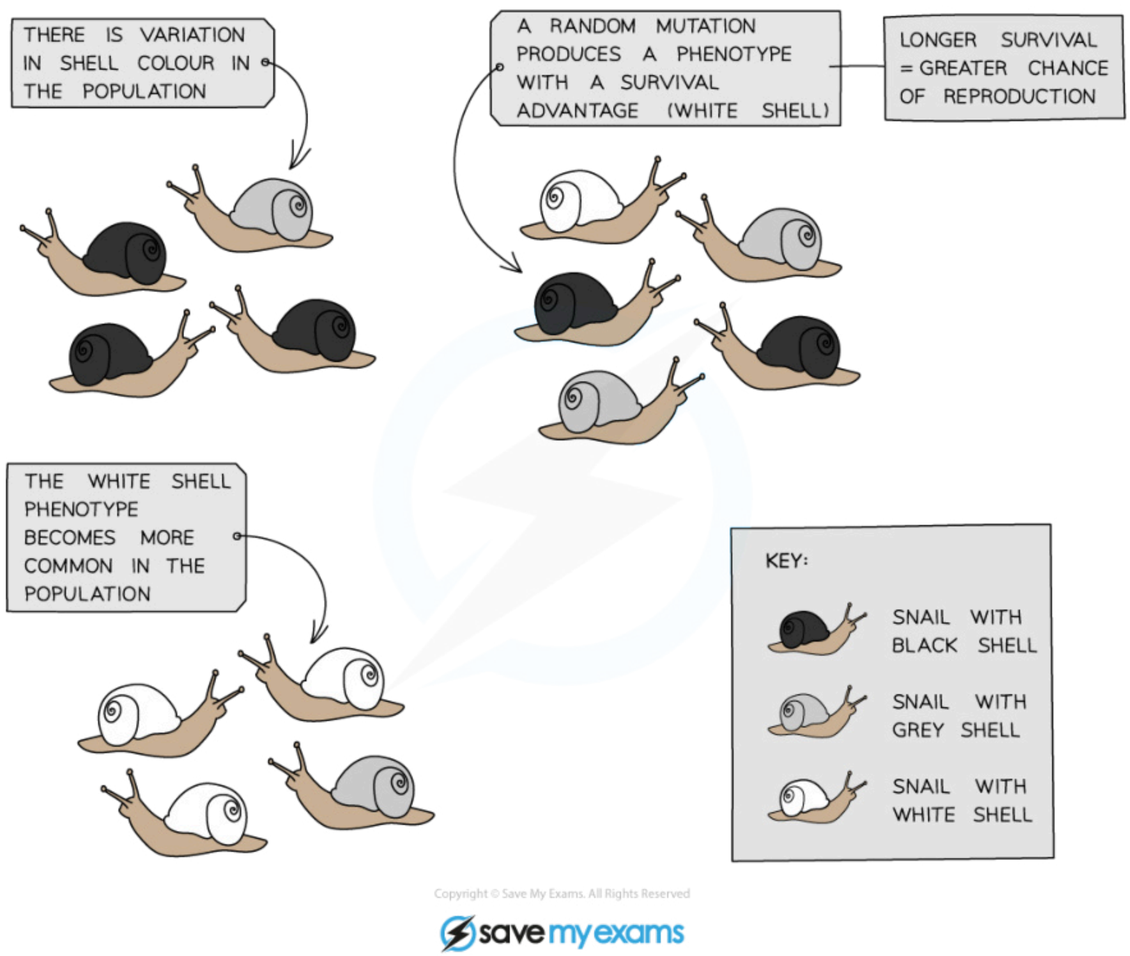

Natural selection acts on genetic variation in populations. Here the allele for white shells is advantageous, so becomes more frequent in the population over time.

Lamarckian evolution

- Another theory of evolution, developed at the start of the 19th century (before Darwin announced his theory), was that of French scientists **Jean-Baptiste Lamarck**
- Lamarck's theory was based mainly on the idea that changes that occur in an organism **during its lifetime** can be inherited
  - Such changes are known as **acquired characteristics**
- His theory is as follows:
  - A characteristic that is used frequently by an organism becomes better and stronger, whereas a characteristic that isn't used gradually disappears
  - The beneficial **characteristics that are used frequently are passed to offspring**
  - For example, Lamarck suggested that:

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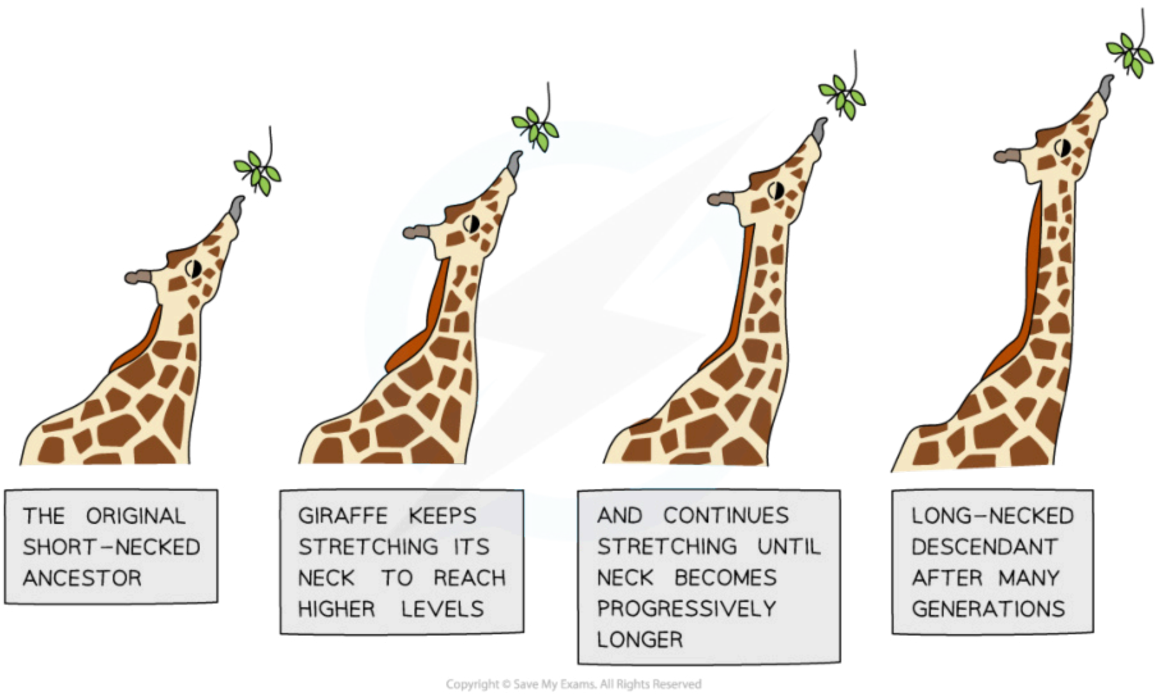
- Giraffes had a short-necked ancestor that would frequently stretch its neck to reach the high branches so it could feed on the leaves
- This repeated stretching could very slowly elongate the giraffe's neck and this **elongated neck would be passed to the giraffe's offspring**
- Over time and many generations, the giraffe would evolve to have the very long neck it has today

- Lamarck's ideas were incorrect because they lack the component of heritability; **acquired characteristics are not passed on to offspring**
  - The new science of epigenetics may provide an exception to this rule, but changes like these are unlikely to be major drivers of natural selection

Lamarckian evolution diagram



Lamarck proposed that characteristics acquired during an organism's lifetime could be passed on to offspring

NOS: The theory of evolution by natural selection predicts and explains a broad range of observations and is unlikely to ever be falsified

- Scientists can gather information about the world by **observing events**
- They formulate **theories** that seek to explain observed events
- The theory of natural selection **explains many observations**, and is **widely accepted** as a correct explanation of observed events; no other reasonable theories have ever been proposed, and so this theory is **likely to remain** as the scientific explanation for species change over time

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- It is worth noting that there are some minor aspects of Darwin's original theory that have been falsified since they were proposed:
  - 'Evolution by natural selection is always slow'
    - We know that, e.g. antibiotic resistance can evolve in bacteria very quickly
  - 'The fossil record cannot provide evidence for evolution'
    - There are multiple examples of fossils that appear to show intermediate species
- These errors have resulted in **updates** to Darwin's theory, but not to its falsification
- Due to the geological time periods over which evolutionary change has occurred, it is **not possible to formally prove** that natural selection has given rise to the species that we see today, hence the continued use of the term 'theory'

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Evidence of Evolution

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Sequence Data

- Sequence data can be obtained from:
  - DNA
    - The **base sequence of DNA** found in the nucleus, mitochondria and chloroplasts of cells can be determined
  - RNA
    - RNA is the product of transcription, and the **RNA base sequence** provides information about the DNA base sequences of genes that are expressed in a cell
  - Proteins
    - The **amino acid sequence** of expressed proteins can be determined
- Similarities between sequence data in different species suggest that **all species share a** common ancestor
- The sequences for comparison must come from the same part of the DNA, and are often taken from regions of DNA that are **highly conserved**, meaning that they have **changed very little over time**; this is important for several reasons:
  - **Like needs to be compared with like**; comparing two completely different regions of DNA will not yield useful information
  - There are likely to be relatively few differences, so **similarities and differences can be easily identified**
  - Conserved sequences are also more likely to exist in a **wide range of species**
- Examples of conserved sequences are those that **code for essential proteins**, e.g. haemoglobin, or enzymes involved in respiration

Comparing DNA sequences

- DNA is **extracted from cells**
  - DNA can be extracted from blood or skin samples from **living organisms** or from **fossilised remains**
- The extracted DNA is processed, analysed and the **base sequence** is obtained
- The base sequence is **compared to that of other organisms** to determine **evolutionary relationship**
  - The **more similarities** there are in the DNA base sequence, the **more closely related** members of different species are
  - E.g. in 2005 the chimpanzee genome was sequenced, and when compared to the human genome it was discovered that humans and chimpanzees share almost 99% of their DNA sequences, making them our closest living relatives
- Data from **multiple sources**, e.g. several different genes, are compared to increase the level of certainty
- The data gained from comparing sequence data can be used to build an **evolutionary tree**

Comparing DNA sequences diagram

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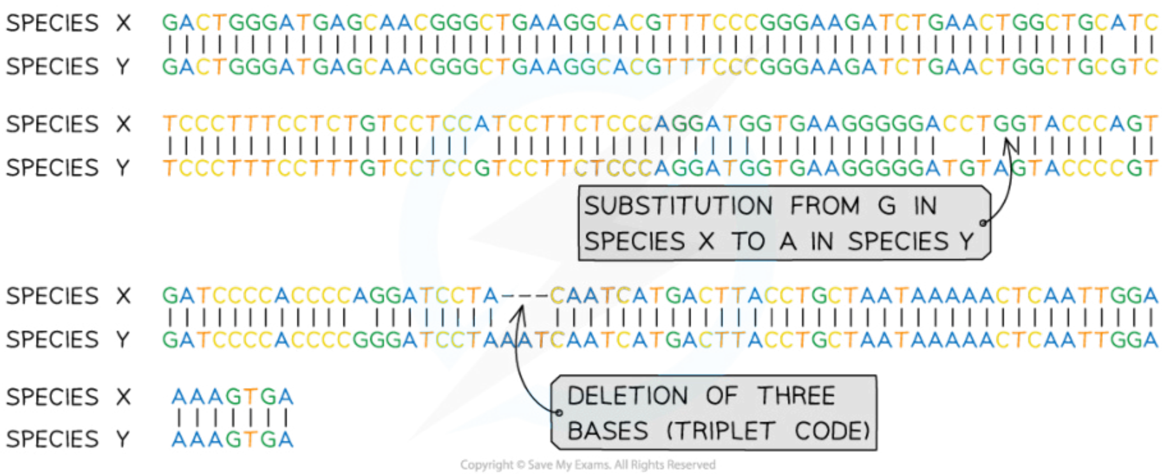

Similarities and differences between the DNA of two species provide information about their divergence from a common ancestor

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Selective Breeding

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- Selective breeding is a process in which **humans choose** organisms with **desirable characteristics** and **breed them together repeatedly** to increase the expression of these characteristics over **many generations**
  - The process of selective breeding has enabled humans to take advantage of **naturally occurring variation**, e.g.
    - Variation between individuals in plants means that some individuals may have a higher food yield or disease resistance
    - Variation between individuals in domestic animal varieties means that some individuals may have thick, heavy wool, or large volumes of milk production
  - Humans have been able to develop desirable crop and domestic animal varieties from individuals with desirable characteristics
- This practice is also known as **artificial selection**
  - It makes use of the **principles of** natural selection, but is carried out by humans
    - In natural selection, **advantageous** alleles are more likely to be passed on because they increase an organism's chances of survival
    - In artificial selection, or selective breeding, **desirable alleles** are more likely to be passed on because humans decide which individuals will be used for breeding
- Selective breeding involves **changes to** heritable **characteristics** over **many generations**, and so it is an example of **evolution in action**
  - Selective breeding leads to **faster change** than natural selection; this is because **only the selected individuals are allowed to breed** together, while in natural selection there will still be some breeding between individuals with less favourable alleles
- Selective breeding provides evidence that evolution occurs due to the **accumulation of small changes to the DNA** of organisms over time

The process of selective breeding

1. The population shows **variation;** there are individuals with different characteristics
2. Breeders select **individuals with the desired characteristics**
3. Two selected individuals are **bred together**
4. The offspring produced reach maturity and are then **tested for the desirable characteristics;** those that display the desired characteristics to the greatest extent are selected for **further breeding**
5. The process is **repeated over many generations**; the best individuals from the offspring are continually chosen for breeding until all offspring display the desirable characteristics

Selective breeding diagram

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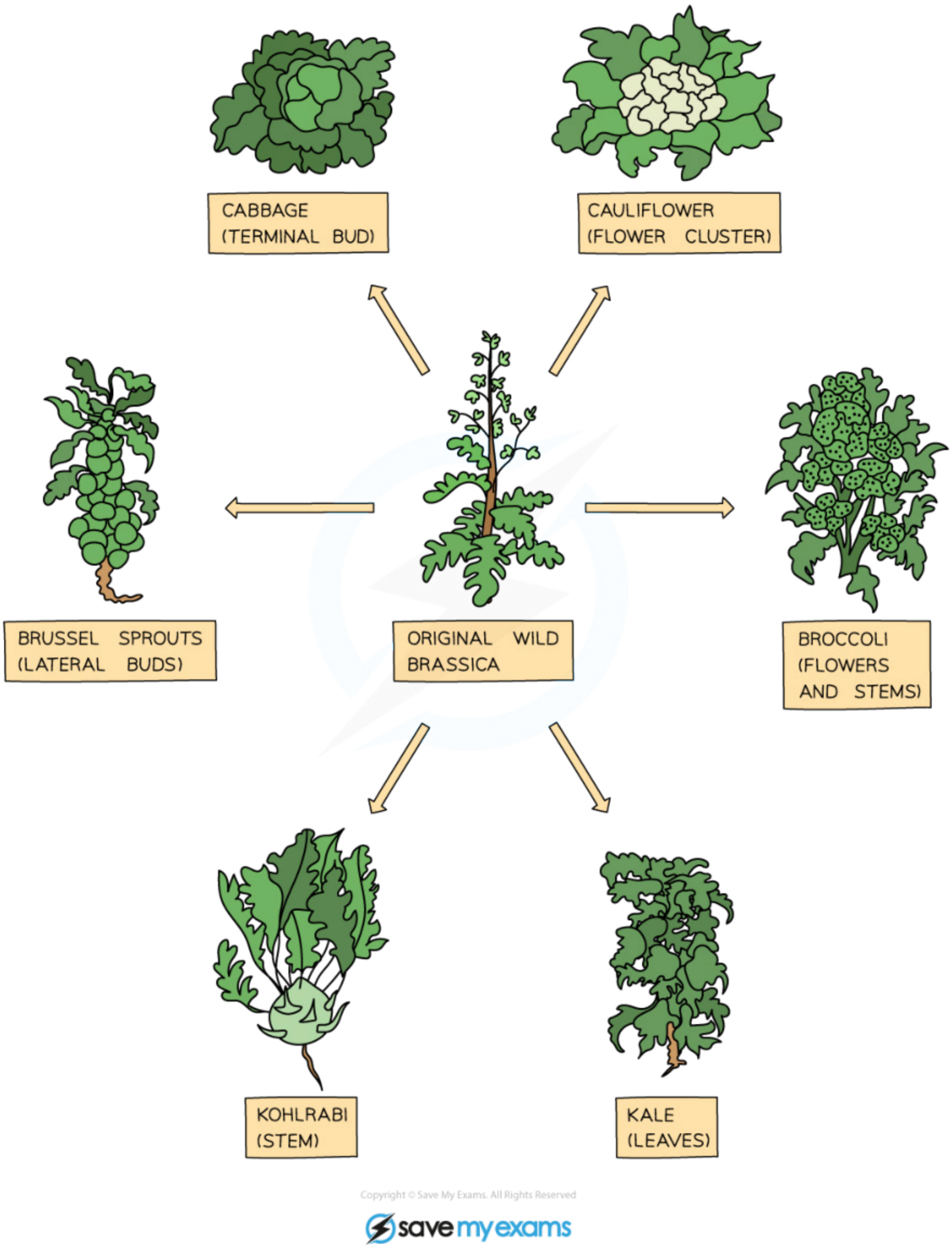

Variation in wild brassica plants allowed humans to selectively breed many of the crop plants that we eat today

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Homologous Structures

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- **Homologous structures** are body parts that may **look and function very differently** but share **structural similarities**
- The limbs of animals are a good example of this; animals have many different mechanisms of motion and limb use, but the **basic arrangement of bones** in many different types of limbs is **very similar**
  - E.g. The limbs of birds, bats, crocodiles, whales, horses, and monkeys are used very differently and are visually very different, but are structurally **very similar** to each other
- One explanation for the surprising similarities of these different limbs is that of **adaptive radiation;** the idea that organisms with homologous structures have all **evolved from a shared, common ancestor** but have **adapted to different environments** in the process
  - Note that adaptive radiation does not provide **proof** that these organisms have evolved from a common ancestor, but it is a good explanation for the existence of homologous structures

A homologous structure: the pentadactyl limb

- A **pentadactyl limb** is any limb that has **five digits**, i.e. five fingers or toes
- Pentadactyl limbs are present in **many species** from **many groups of organisms**, including mammals, birds, amphibians, and reptiles
- In different species, the pentadactyl limb has a **similar bone structure** but can enable an animal to move in a very different way
  - The **human foot** evolved for **upright walking** and **running**
  - **Whale flippers** enable them to **propel** themselves through a **marine environment**
  - **Bird wings** are usually highly adapted for **flight**
  - The **limbs of frogs** allow them to **walk, jump** and **swim**
  - **Alligator limbs** enable them to **walk** and **swim**
- Although the **individual bones** of the pentadactyl limb in these example animals are **very different shapes and sizes** due to their different mechanisms of **locomotion**, their **layout** is almost **exactly the same**

Homologous structures diagram

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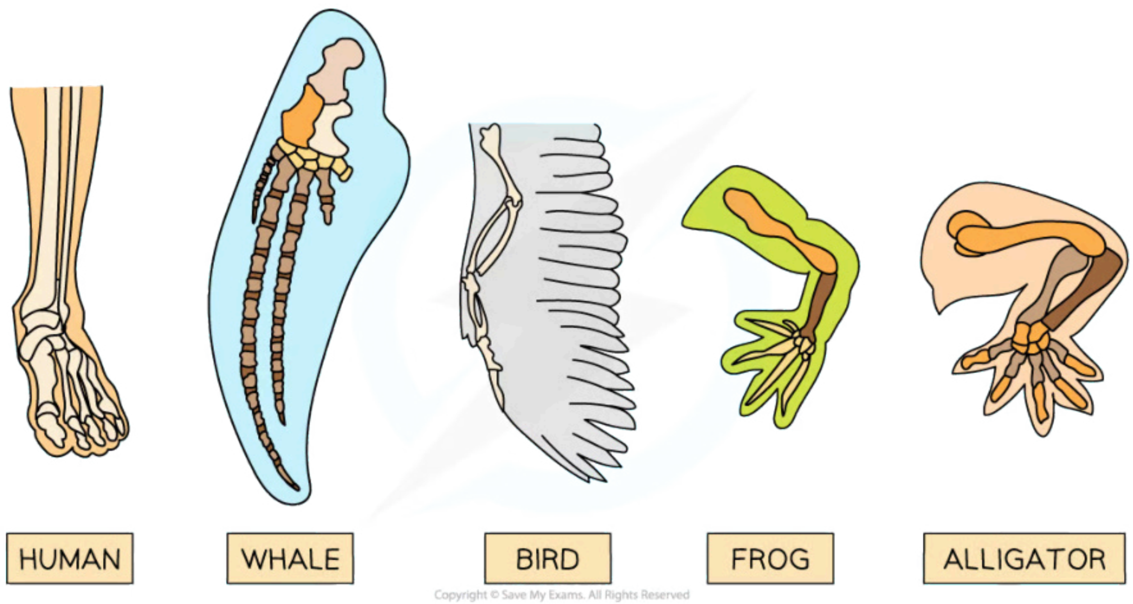

The pentadactyl limbs of humans, whales, birds, frogs, and alligators all have the same basic layout despite having evolved for different functions

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Convergent Evolution

Convergent Evolution

Convergent evolution

- **Analogous structures** are characteristics with **similar form and function, but with different evolutionary origin**
  - Such structures have historically caused some confusion for scientists working in the field of taxonomy
- While homologous structures provide evidence of shared ancestry, analogous structures come about as the result of **convergent evolution**
  - Analogous structures provide **evidence for the passing on of advantageous characteristics** during natural selection
- Convergent evolution can occur when two distantly related species live in habitats with similar selection pressures, meaning that similar characteristics provide a survival advantage
  - **Advantageous characteristics evolve separately**, rather than as the result of a single mutation
- Examples of similarities that have arisen due to convergent evolution include:
  - Dolphins and sharks
    - These are both groups of aquatic animals that **share a similar body shape**, but they in fact belong to different classes
      - Dolphins are mammals and sharks are fish
    - Their streamlined body shapes **evolved separately** rather than originating in one common ancestor
  - Cacti and euphorbia
    - These are two groups of desert plants recognisable by their spiny leaves and branching, succulent stems
    - They belong to different orders of plants
      - Cacti are found in the deserts of the Americas, while euphorbias are found in Africa
    - They evolved separately, but **adapted to similar environments**

Analogous structures diagram

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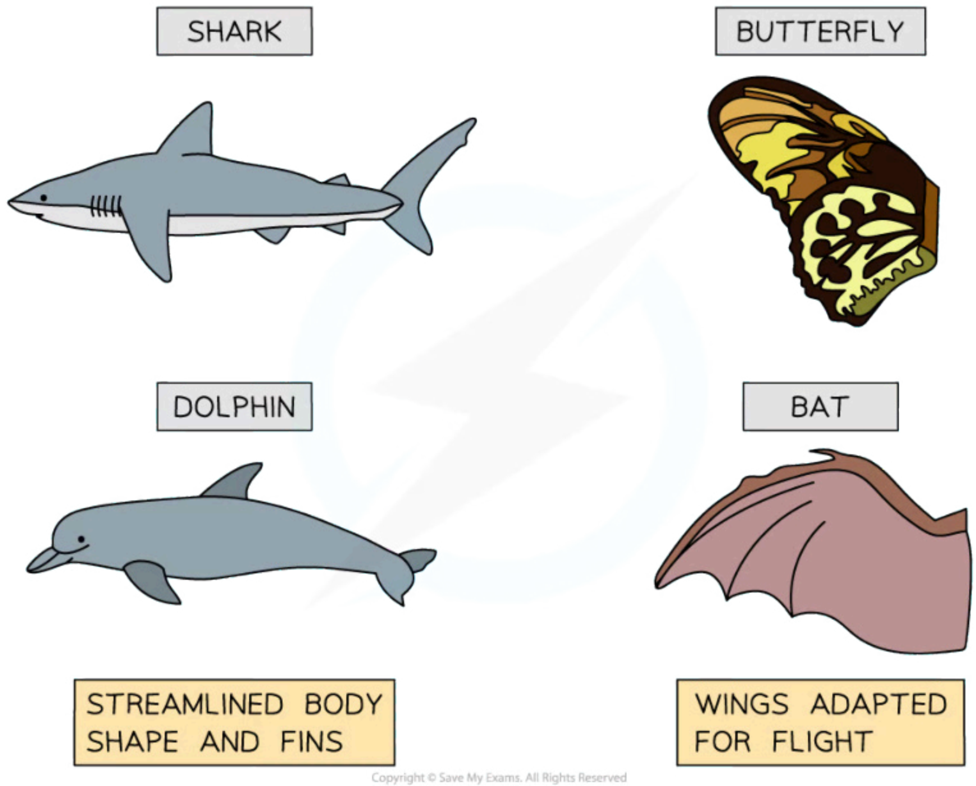

Analogous structures, such as body shape in sharks and dolphins, and wings in butterflies and bats, occur as the result of convergent evolution

Examiner Tip

Make sure that you learn **at least one example** of analogous structures

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Speciation

Speciation

Speciation increases diversity

- The theory of evolution states that **species do not stay the same**, but change over time; this can lead to the process of **speciation**
- Speciation can be defined as

The development of new species from pre-existing species over time

- Speciation has resulted in a **great diversity of species** on Earth
  - Theoretically, at the origin of life on Earth, there would have been just one single species
  - This species evolved into separate new species
  - These species would then have divided again, each forming new species once again
  - Over millions of years, evolution has led to countless numbers of these speciation events, resulting in the millions of species now present on Earth
- Speciation can occur when the exchange of genes, or **gene flow**, between populations of a species is prevented, e.g. due to them being separated on different islands
  - When gene flow stops, **genetic differences can accumulate** between the two populations
  - This may happen faster if different selection pressures are acting on the two populations
- A speciation split has occurred when the two populations **can no longer interbreed to produce fertile offspring**; at this point the two populations are said to be **reproductively isolated** from each other
  - Note that in order for speciation to have occurred, **there must be reproductive isolation**; gradual evolutionary change alone is not enough

Speciation diagram

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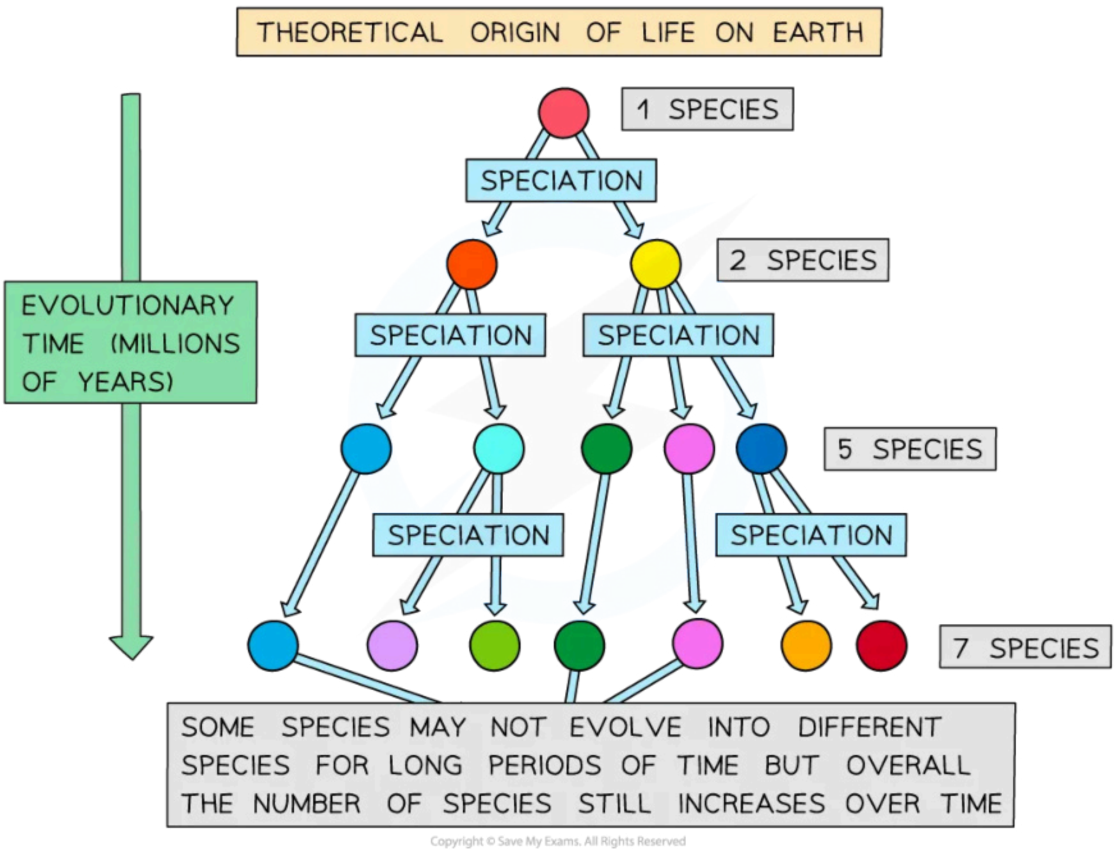

Speciation is thought to have given rise to the huge diversity of species on Earth

Extinction reduces diversity

- While speciation increases the number of species on Earth, not all of the species that have evolved over evolutionary time still exist today; many species have gone **extinct**, meaning that **they no longer exist**
  - E.g. The passenger pigeon and the woolly mammoth
- Extinction **reduces the number of species** on Earth

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Reproductive Isolation & Differential Selection

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Reproductive isolation

- Organisms that belong to the same species share the same characteristics and are able to **breed together to produce fertile offspring**
- **Reproductive isolation** occurs when changes in the alleles and phenotypes of some individuals in a species **prevent them from successfully breeding** with other individuals 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 may develop different mating or flowering seasons, becoming sexually active at different times of the year
  - Behavioural changes
    - Some individuals in a population may develop changes in their courtship behaviours, meaning they can no longer attract individuals of the opposite sex for mating
- These changes can occur as a result of **geographical isolation of populations**

Geographical isolation

- Reproductive isolation can occur when populations of a species become separated from each other by **geographical barriers**
  - The separated populations are said to be **geographically isolated** from each other
- Geographical barriers can include
  - Naturally occurring barriers such as a body of water, or a mountain range
  - Man-made barriers, such as a motorway
- Geographical isolation creates two populations of the same species between which **no gene exchange** can occur
- The two populations may be affected by **different selection pressures**, meaning that natural selection may act differently on the two populations
  - This is known as **differential selection**
- Over time, the two populations may become so different that they are **reproductively isolated**, and speciation has occurred

Geographical isolation diagram

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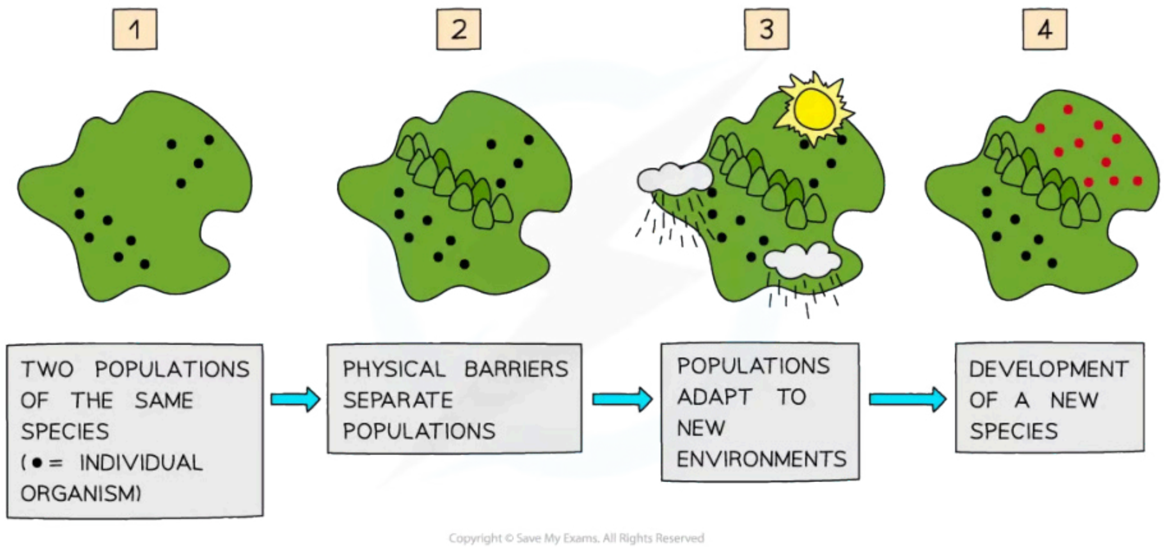

A mountain range can lead to geographical isolation, and eventually reproductive isolation

Bonobos & chimpanzees

- An example of a speciation event that has resulted from geographical isolation is the evolution of bonobos (*Pan paniscus*) and chimpanzees (*Pan troglodytes*)
- Chimpanzees are found to the north of the Congo river, and bonobos to the south
  - This suggests that at some point in their evolutionary past the river caused two populations of their ancestor species to become **geographically isolated**
  - **Different selection pressures** would have acted on the two populations, so **differential selection** occurred, resulting in differences between the two populations, e.g.
    - Chimpanzees tend to be more behaviourally aggressive than bonobos; this could have arisen due to more intense competition for resources
    - Chimpanzees have male-dominated social structures while bonobos have dominant females
  - Eventually the two groups became **reproductively isolated**, and were two separate species

Examiner Tip

Be careful not to confuse geographical isolation with reproductive isolation. Geographical isolation **prevents gene flow**, but may be temporary (i.e. if the two populations came back together again then successful breeding could occur) while reproductive isolation means that **speciation has occurred** and that the two species **can no longer breed together successfully**, even if they live in the same habitat.

Note that you **do not** need to use binomial Latin names in an exam, e.g. it is fine to refer to bonobos rather than *Pan paniscus*

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Types of Speciation (HL)

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Sympatric & Allopatric Speciation

Types of speciation

- **Evolution** causes **speciation**: the formation of **new species** from pre-existing species over time
- There are two different situations in which speciation can take place:
  - Two populations of a species are **geographically isolated**; speciation that occurs as a result of this is known as **allopatric speciation**
  - Two populations of species are living in the **same area**; this type of speciation is known as **sympatric speciation**

Allopatric speciation

- Allopatric speciation occurs as a result of **geographical isolation**
  - It is the most common type of speciation
- Allopatric speciation occurs when populations of a species become **separated** from each other by **geographical barriers**
  - The barrier could be **natural**, e.g. a body of water or a mountain range
  - It can also be man-made, e.g. a motorway
- This creates two populations of the same species between which no **gene flow** is taking place
- Allele frequencies in the gene pools of the two populations may change in different ways due to
  - Different **selection pressures** acting on them
  - The **accumulation of random changes** in allele frequencies, known as genetic drift
- Changing allele frequencies will lead to changes in the phenotypes of the two populations
- If enough allele frequency differences arise between the two populations then they will eventually be reproductively isolated, and can be said to be **separate species**

E.g. Allopatric speciation in trees

- A population of trees exists in a mountainous habitat
- A new mountain range forms that **divides the species** into **two geographically isolated populations**
- The geographical barrier prevents the two populations from **interbreeding** so there is **no gene flow** between them
- The two populations experience **different environments**, so **differential selection** occurs
- Different alleles are therefore more likely to be **passed on** in each population
- Different alleles become **more frequent** in each population
- Over thousands of years the divided populations **form two distinct species** that are **reproductively isolated**

Allopatric speciation diagram

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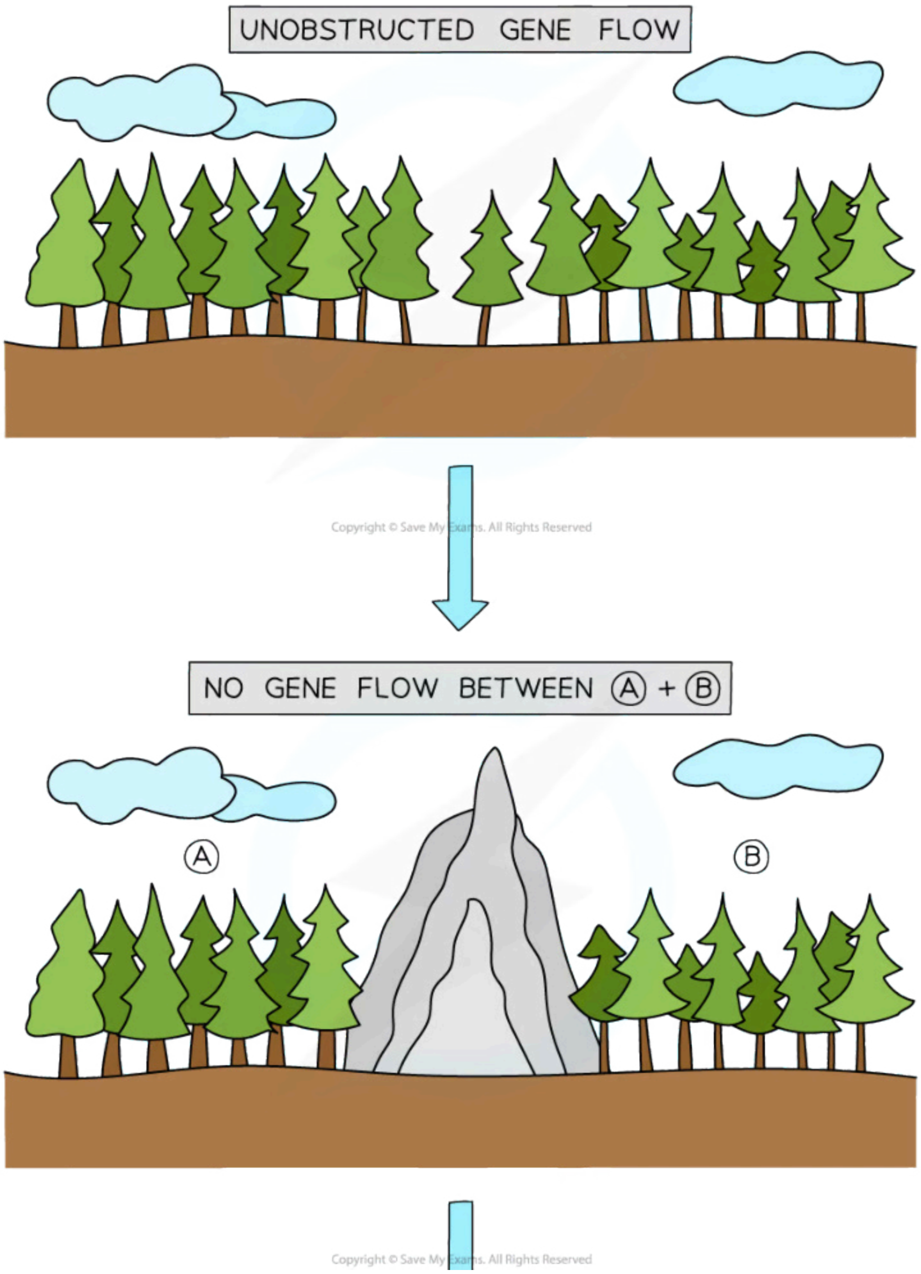

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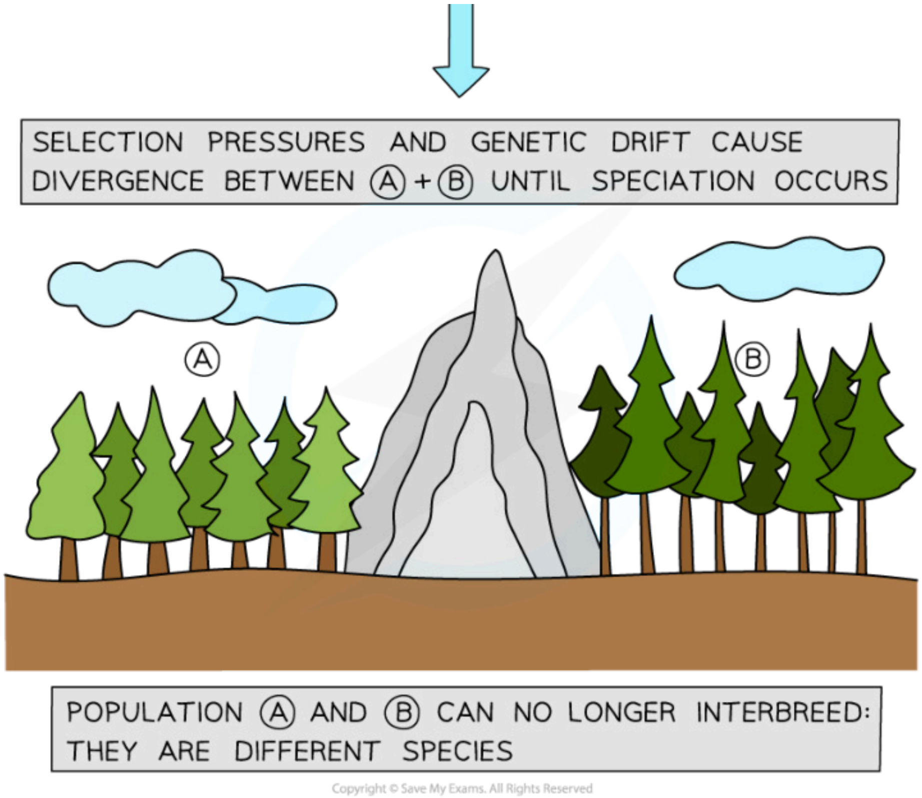

The natural geographical barrier of a mountain range can lead to allopatric speciation in trees

Sympatric speciation

- Sympatric speciation takes place with **no geographical barrier**
- Isolation instead occurs when random changes in the **alleles**, and therefore **phenotypes**, of some individuals in a population **prevent** them from successfully **breeding** with other individuals in the population
- Examples of phenotype changes that can lead to reproductive isolation include
  - **Seasonal changes**
    - Some individuals in a population may develop **different mating** or **flowering** seasons to the rest of the population, i.e. their **reproductive timings** no longer match up
    - This is known as **temporal isolation**
  - **Behavioural changes**
    - Some individuals in a population may develop changes in their **courtship behaviours** meaning they can no longer **attract** individuals of the opposite sex for **mating**, i.e. their methods of attracting a mate are no longer effective
    - This is known as **behavioural isolation**
- The populations may still **live in the same habitat** but they **do not interbreed**
- The **lack of gene flow** between the two populations means that allele frequencies in the gene pools of the two populations may change in different ways
- **Changing allele frequencies** will lead to **changes in the phenotypes** of the two populations

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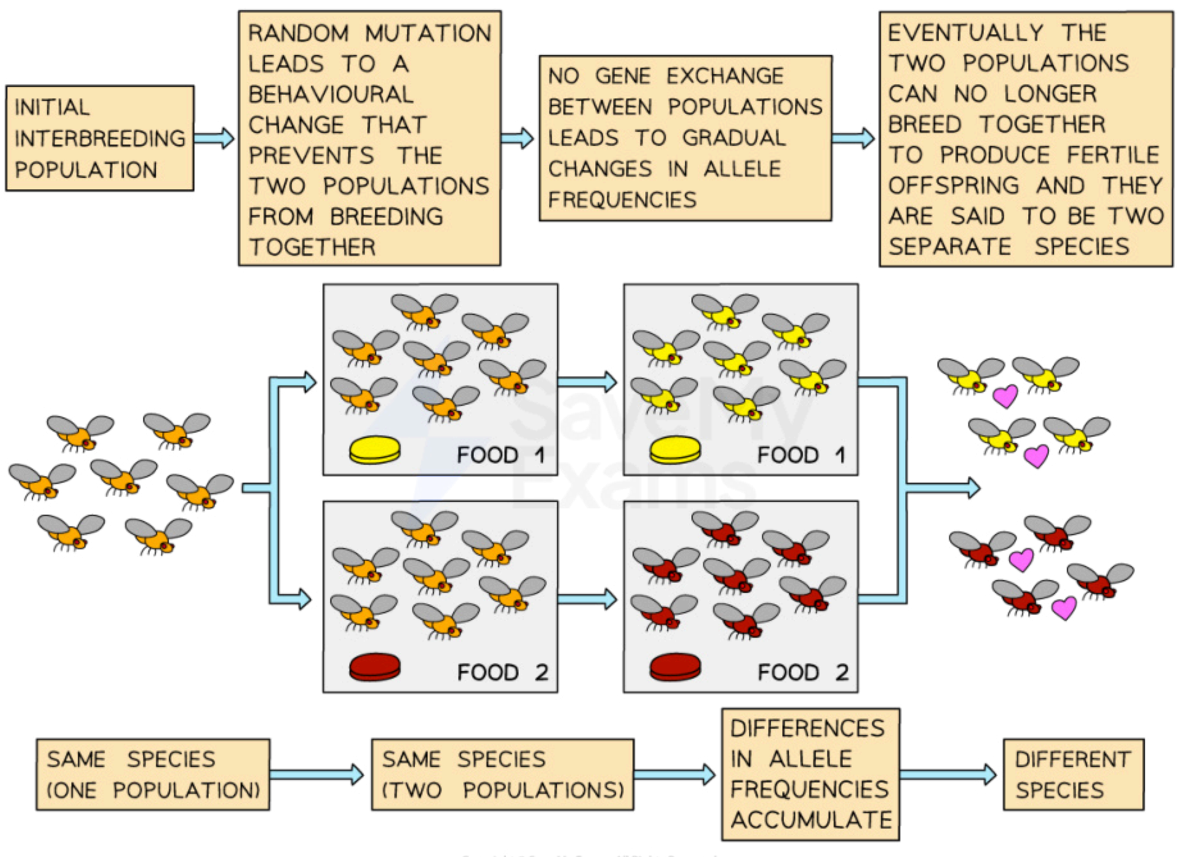
- If enough allele frequency differences arise between the two populations then they will become **reproductively isolated** and will be **two separate species**

E.g. sympatric speciation in fruit flies

- A population of fruit flies exists in a laboratory
- A random allele change resulting from random mutation **divides the species** into **two populations**
  - The allele changes leads to a change in phenotype, e.g. food preference
- The difference in phenotype prevents the two populations from **interbreeding** so there is **no gene flow** between them
- Different alleles are therefore **passed on** in each population
  - This could be due to difference in selection pressure, e.g. certain enzymes are advantageous for the digestion of different foods or due to random passing on of different alleles
- Different alleles become **more frequent** in each population
- Over time the divided populations **form two distinct species** that can no longer interbreed to produce fertile offspring



Phenotypic changes resulting from random mutations prevent gene flow between two populations of fruit flies which may lead to sympatric speciation

Your notes

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Examiner Tip

As with geographical isolation on the previous page, be careful not to mix up the **reason for gene flow prevention**, e.g. temporal or behavioural isolation, with the **resulting** reproductive isolation. This can be confusing due to the similarities in terminology.

Your notes

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Your notes

Preventing Hybridisation

- The definition of a species states that

A species is a group of organisms with similar characteristics that can interbreed to produce fertile offspring

- There are several reasons why individuals of different species cannot breed together to produce fertile offspring, e.g.
  - Incompatible chromosome numbers
  - Incompatible courtship behaviours
- The term **'hybrid'** refers to the offspring of individuals of two different species
  - **Hybridisation** is the mechanism by which hybrids are produced, i.e. the mating, fertilisation, and development processes
- Hybrids are **rare**, and are usually **infertile**

Barriers to hybridisation: incompatible chromosomes

- The fusion of gametes from **different species** often leads to **non-viable zygotes**; this can occur if the **chromosomes of the different species do not match**
  - The gene at a particular locus on a particular chromosome needs to be the same in both chromosomes in a homologous pair
- Viable zygotes can sometimes occur, but such zygotes usually develop into **infertile hybrids**
  - Different species often have **different chromosome numbers**, resulting in gametes with different numbers of chromosomes
  - The new diploid cells formed during fertilisation contain an **uneven number of chromosomes** which are unable to pair up in homologous pairs
  - These individuals will be unable to carry out **meiosis** and so will be infertile
- A well-known example of this is the mating of a horse and donkey to produce a mule:
  - Mule chromosomes cannot pair up during meiosis, so mules cannot produce gametes of their own

Hybrid sterility diagram

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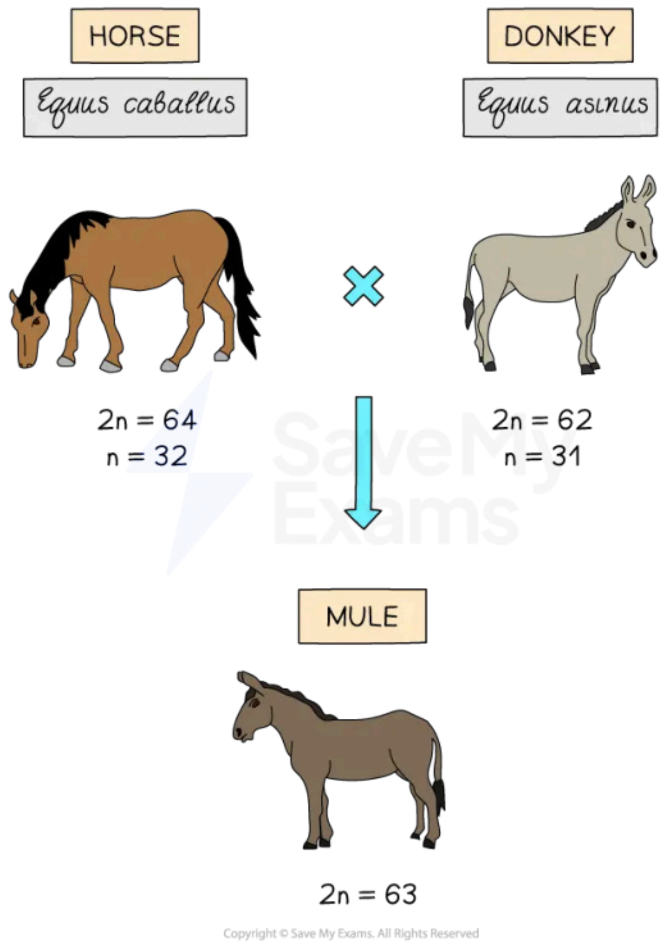

Mules have an odd number of chromosomes so cannot carry our meiosis and are sterile

Barriers to hybridisation: incompatible courtship behaviours

- In some species the process of successful breeding can be preceded by some form of **courtship behaviour**
- Courtship behaviour in animals is a **ritual** that eventually results in mating and reproduction
  - It can be a very simple process that involves a small number of visual, chemical or auditory stimuli
  - It can also be a highly complex sequence of behaviours involving two or more individuals, using several modes of communication
    - Many birds of paradise have intricate and impressive courtship rituals
- If the **courtship rituals of two individuals do not match**, then no mating will occur and hybridisation will be prevented

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Adaptive Radiation (HL)

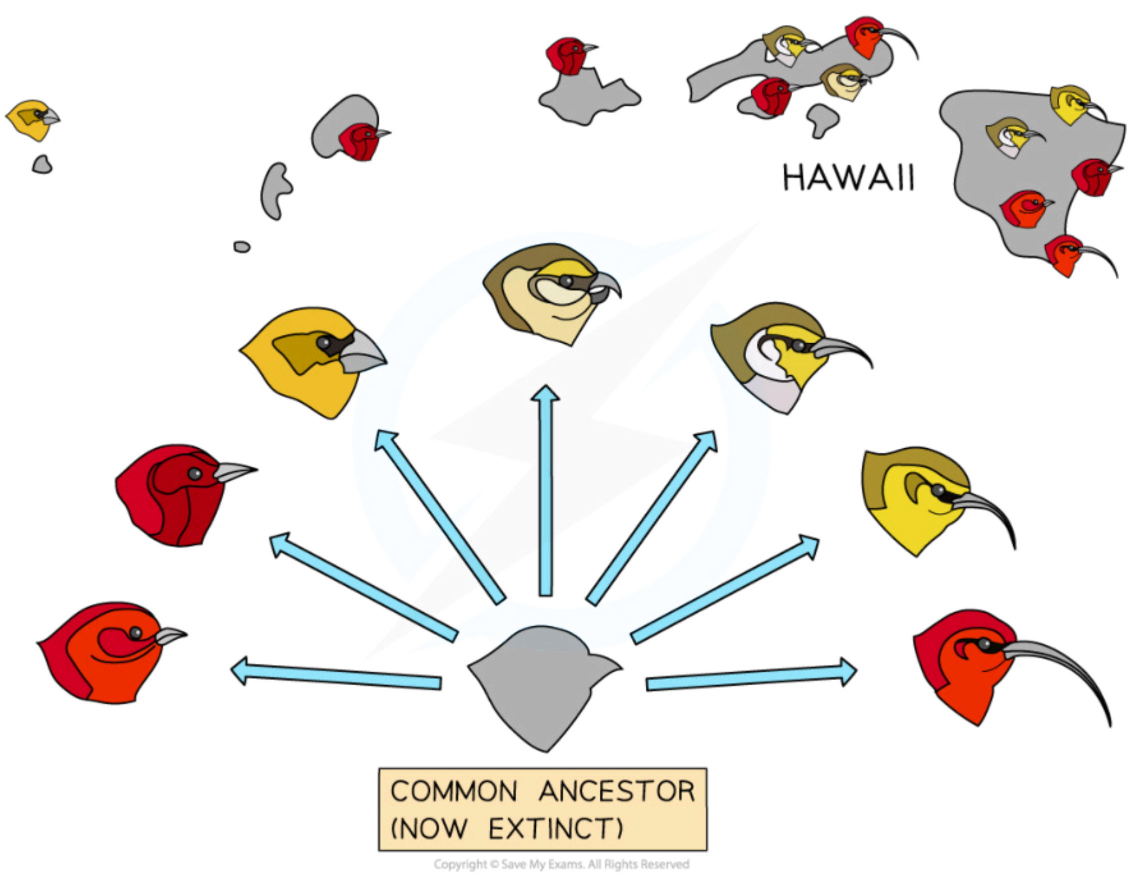
Your notes

Adaptive Radiation

Adaptive radiation

- Natural selection can result in the **rapid evolution of multiple species** from a common ancestor
  - This is known as **adaptive radiation**
- These new species are likely to have **some similar features** due to their shared ancestry
- The **differences that arise** between the new species often enable them to live **together in one habitat** because they are able to fill **different ecological niches**
  - An organism's ecological niche is its **role within its ecosystem**, e.g. the food that it eats, the environmental conditions that it requires, the predators that it provides food for, etc.
- Examples of groups of species that show adaptive radiation include
  - Darwin's finches; many species of small birds observed by Darwin in the Galapagos islands
  - Hawaiian honeycreepers; a group of more than 50 bird species found in the Hawaiian archipelago

Adaptive radiation example diagram



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Adaptive radiation is thought to have given rise to the many species of Hawaiian honeycreeper. Some of these species are able to co-exist on the same island due to filling different niches.

Your notes

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Speciation in Plants (HL)

Your notes

Speciation in Plants

- In most situations **speciation is a slow process**; this is due to the slow rate at which allele changes accumulate
- In some plant species speciation can happen **within a single generation**; this is known as **abrupt**, or **instant**, **speciation**
- Abrupt speciation in plants can occur because plant cells are able to remain viable even when they are **polyploid**
  - Polyploid cells have **more than two sets of chromosomes**, e.g.
    - 3n = triploid
    - 4n = tetraploid
  - This is in contrast to normal body cells which are **diploid** (2n), and gametes which are **haploid** (n)
- Polyploidy can arise when an individual gains more than two sets of chromosomes from:
  - within a single species; this is **autopolyploidy**
  - two different species; this is **allopolyploidy**
- Polyploid varieties of plant appear to be successful, and it is thought that this could be due to advantages such as:
  - polyploidy may allow hybrids that would otherwise be infertile to carry out meiosis due to their additional chromosomes
  - polyploid plants are often larger and more vigorous than their diploid parents
  - having more copies of each gene reduces the impact of any negative mutations that may arise as harmful alleles are masked

Autopolyploidy

- Autopolyploid **4n** individuals can arise **within** a 2n plant population:
  - During meiosis the separation of **homologous pairs** does not occur correctly, meaning that **one daughter cell may contain two sets of chromosomes**
    - The failure of chromosomes to separate during meiosis is known as chromosome nondisjunction
  - The resulting **diploid (2n) gamete** can then fuse with a normal gamete to produce a 3n zygote, or with **another diploid gamete** to produce a **4n zygote**

Autopolyploidy diagram

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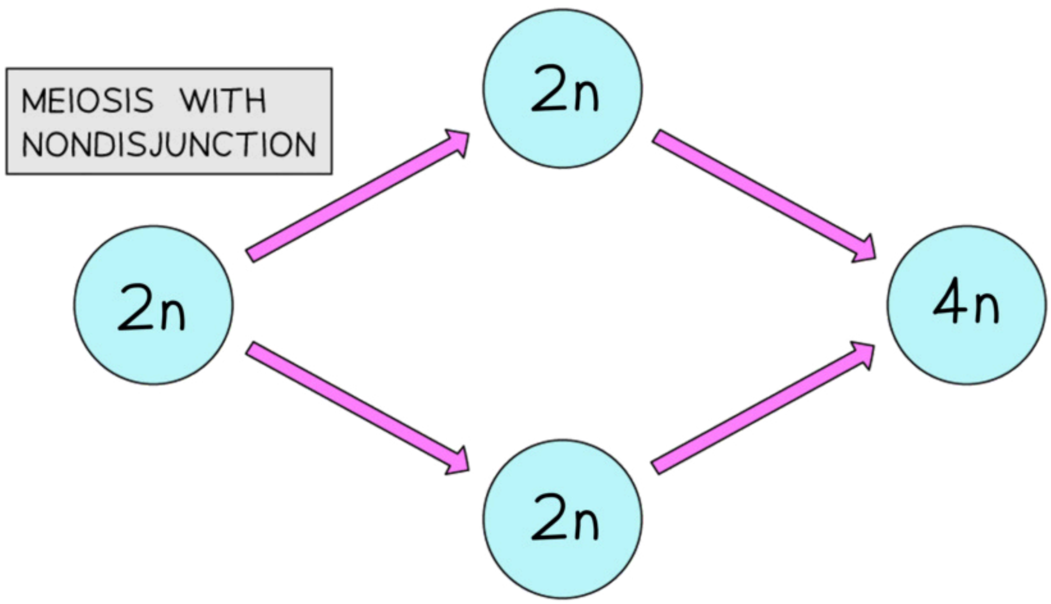

4n individuals can arise within a plant population of 2n individuals; this is autopolyploidy

Allopolyploidy

- To generate allopolyploidy the diploid gametes from individuals of **different species** fuse together to produce a polyploid zygote
  - Individuals from two different species breeding together is known as **hybridisation**
  - The resulting zygote is a **polyploid hybrid**

Allopolyploidy diagram

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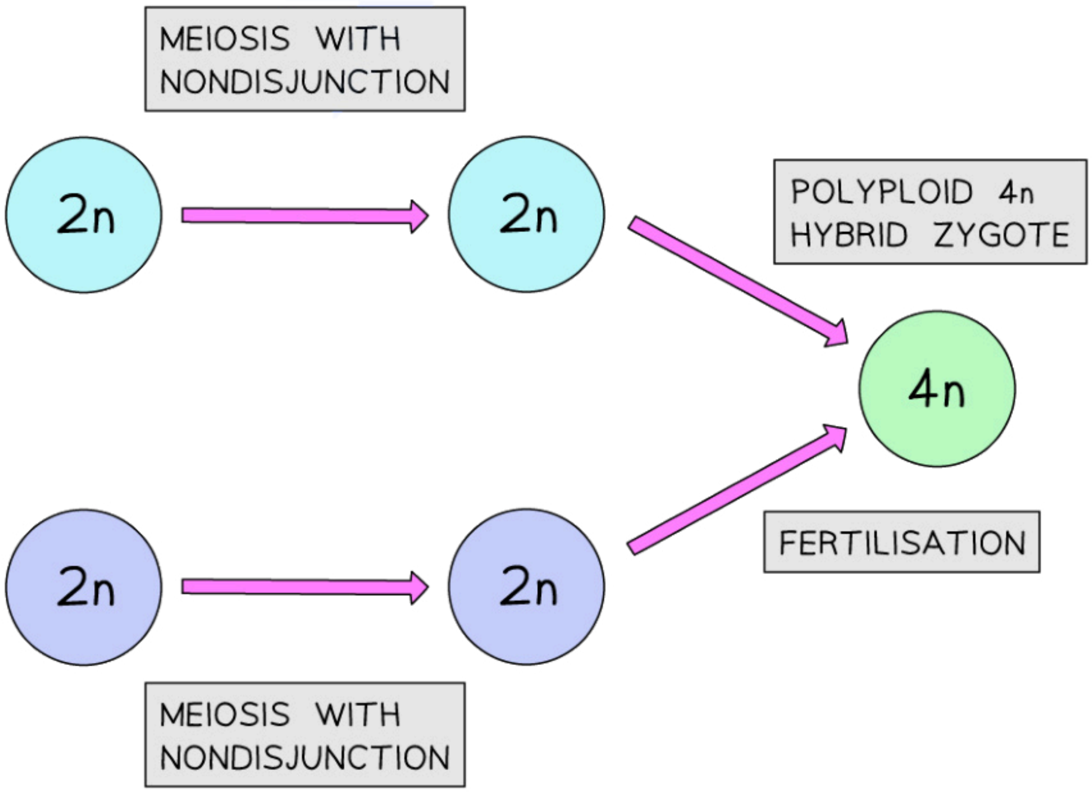

Meiosis with nondisjunction in individuals from two different species can result in 2n gametes, which can result in a 4n hybrid zygote if fertilisation occurs

Speciation due to polyploidy

- Any 4n individuals in a population will produce **2n gametes**, so will be **unable to breed** with 2n individuals in the original population to produce **fertile offspring**:
  - A 2n gamete fusing with a normal n gamete will result in a 3n zygote
  - An individual developing from a 3n zygote will be **infertile**
- A population that is unable to breed with its parent population to produce fertile offspring can be said to be a new species, meaning that **speciation** has taken place

Speciation due to polyploidy diagram

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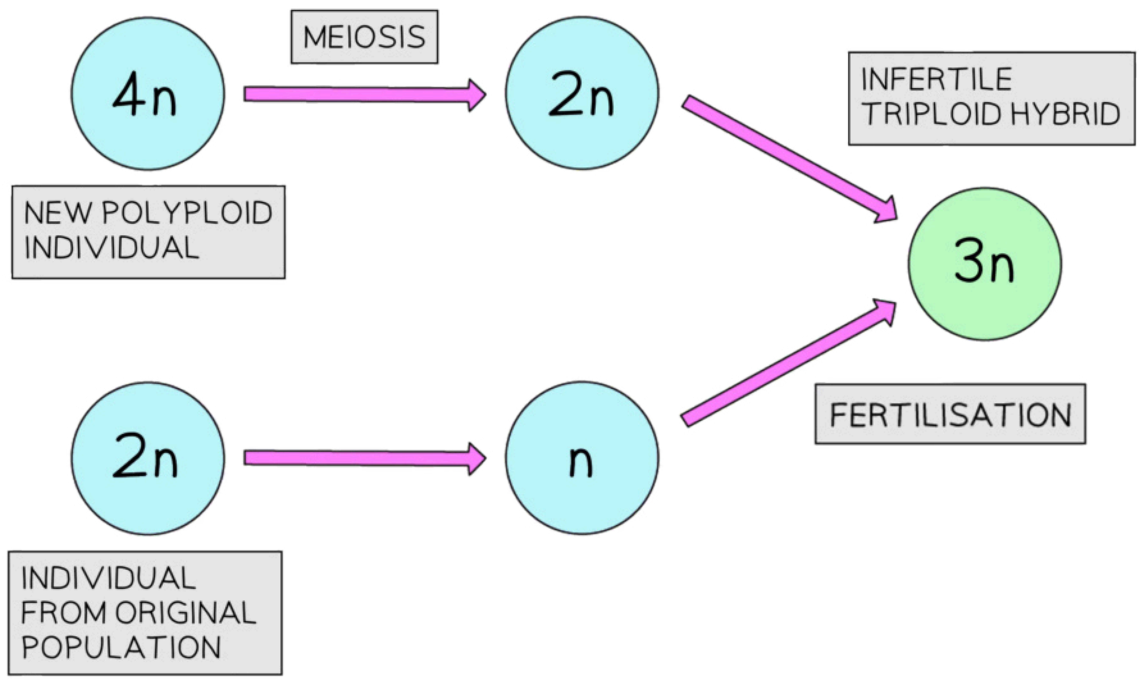

Polyploid individuals cannot breed with individuals from the parent population to produce fertile offspring, so can be said to be a new species

Examples of polyploidy: *Persicaria*

- The plant genus Persicaria, commonly known as smartweeds, contains a range of ploidy types
  - *Persicaria foliosa* is diploid (2n)
  - *Persicaria japonica* is tetraploid (4n)
  - *Persicaria puritanorum* is hexaploid (6n)
- It is thought that tetraploid species could have arisen by **allopolyploidy** between two diploid species, and that hexaploid species could have arisen by a hybridisation event between a diploid and a tetraploid species

Examples of polyploidy: *Fallopia*

- The genus *Fallopia*, commonly known as knotweeds, also contain polyploid species
  - *Fallopia japonica* (japanese knotweed) is octoploid (8n)
  - *Fallopia sachalinensis* (giant knotweed) is tetraploid (4n)
  - *Fallopia xbohemica* (bohemian knotweed) is hexaploid (6n)
- Bohemian knotweed is a **polyploid hybrid** of japanese and giant knotweed
  - Japanese and giant knotweed would have undergone **normal meiosis** in this instance to produce 4n and 2n gametes
- Japanese knotweed is a famously invasive species, and its polyploid nature is thought to aid its vigorous growth

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- Bohemian knotweed is thought to be even more vigorous

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Japanese knotweed is highly invasive. It is an example of a polyploid species.

Examiner Tip

Note that you **do not** need to refer to examples by their binomial Latin names in an exam, e.g. it is fine to refer to *Fallopia japonica* as japanese knotweed.

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