



# HL IB Biology



## Evolution & Speciation

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Your notes

## Evolution

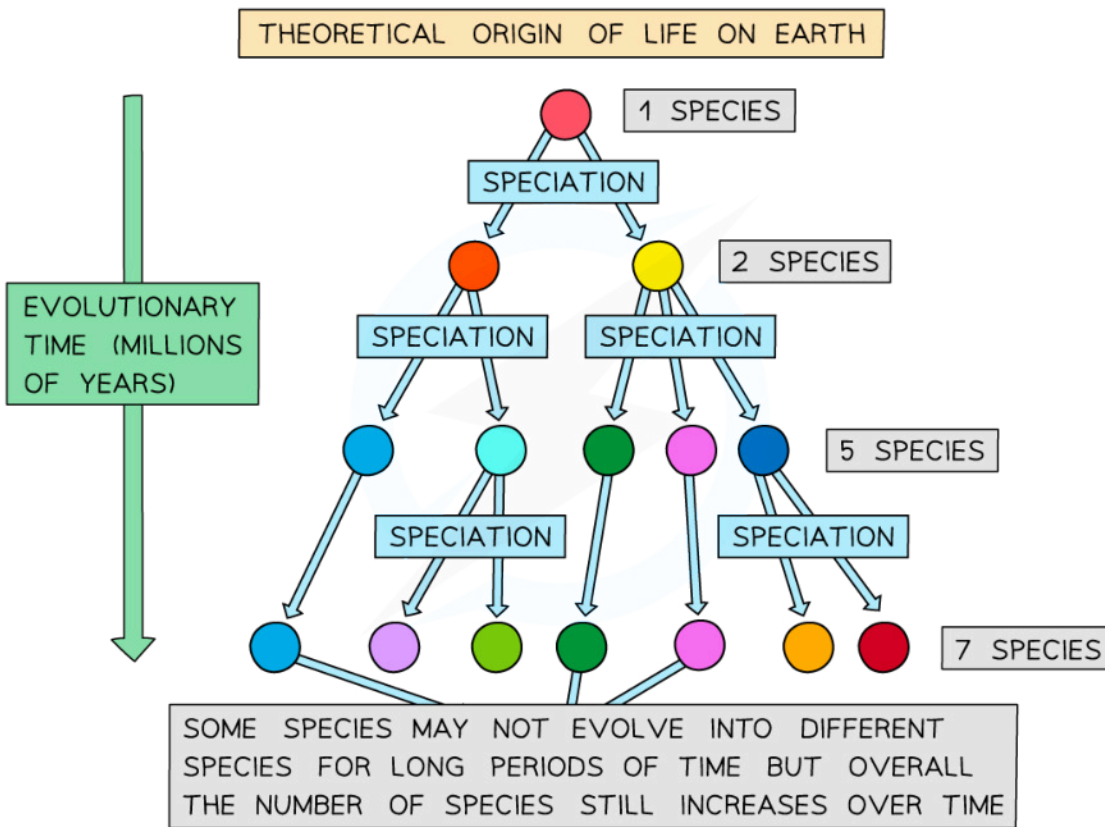
### Evolution

- 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



Your notes



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

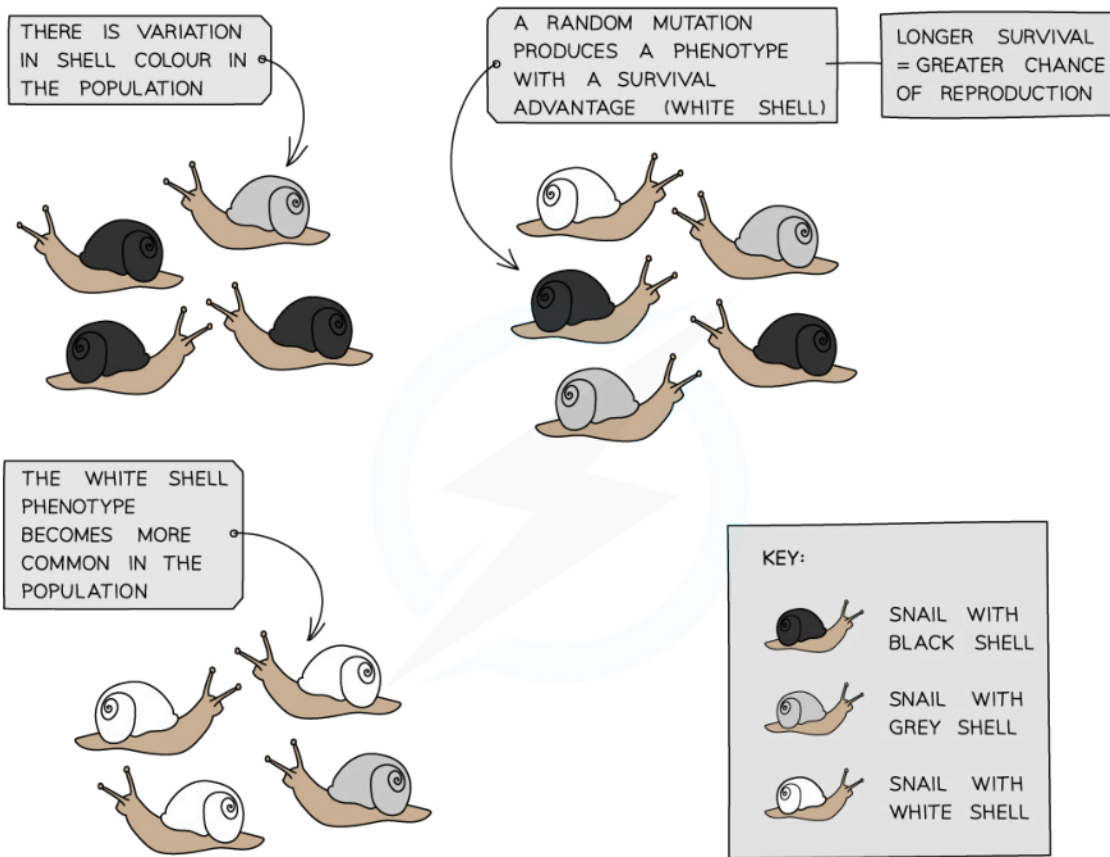
## Darwinian evolution

- 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

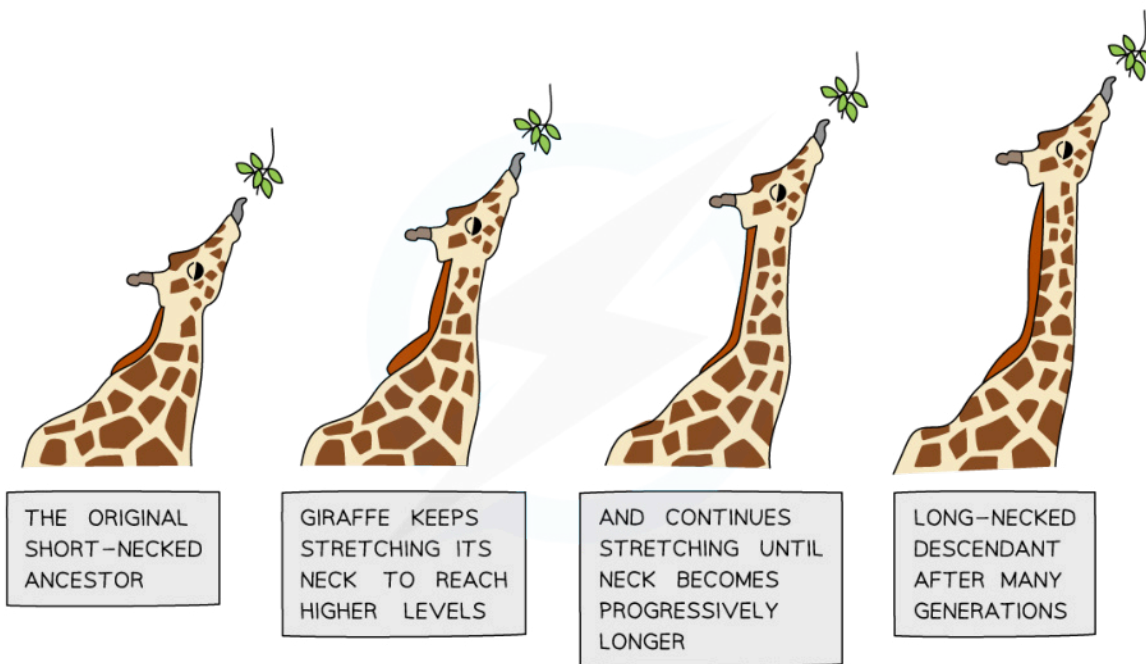
- Another theory of evolution, developed at the start of the 19th century (before Darwin announced his theory), was that of French scientists **Jean-Baptiste Lamarck**
- Lamarck's theory was based mainly on the idea that changes that occur in an organism **during its lifetime** can be inherited
  - Such 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:



Your notes

- 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

- 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'



Your notes



Your notes

## Evidence of Evolution

### 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



Your notes

SPECIES X GACTGGGATGAGCAACGGGCTGAAGGCACGTTTCCCAGGAAAGATCTGAACTGGCTGCATC  
 SPECIES Y GACTGGGATGAGCAACGGGCTGAAGGCACGTTTCCCAGGAAAGATCTGAACTGGCTGCGTC

SPECIES X TCCCTTTCCTCTGTCTCCAATCCTTCTCCCAGGATGGTGAAGGGGACCTGGTACCCAGT  
 SPECIES Y TCCCTTTCCTTTGTCTCCGTCCTTCTCCCAGGATGGTGAAGGGGGATGTAGTACCCCGT

SPECIES X GATCCCCACCCCAGGATCCTA---CAATCATGACTTACCTGCTAATAAAAACTCAATTGGA  
 SPECIES Y GATCCCCACCCCAGGATCCTAAATCAATCATGACTTACCTGCTAATAAAAACTCAATTGGA

SPECIES X AAAGTGA  
 SPECIES Y AAAGTGA

SUBSTITUTION FROM G IN SPECIES X TO A IN SPECIES Y

DELETION OF THREE BASES (TRIPLET CODE)

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





Your notes

## Selective Breeding

- 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

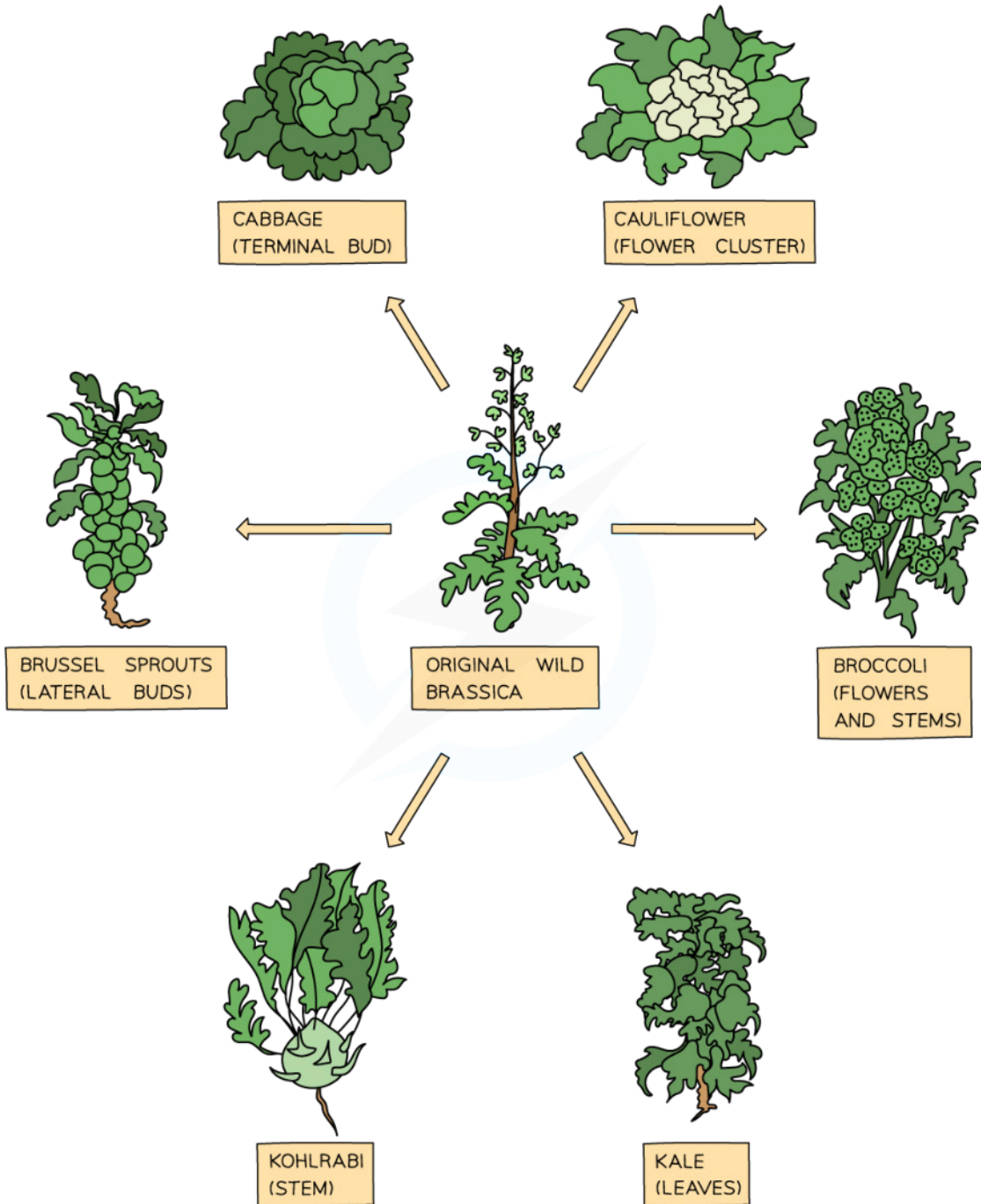
### The process of selective breeding

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



Your notes



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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

- **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

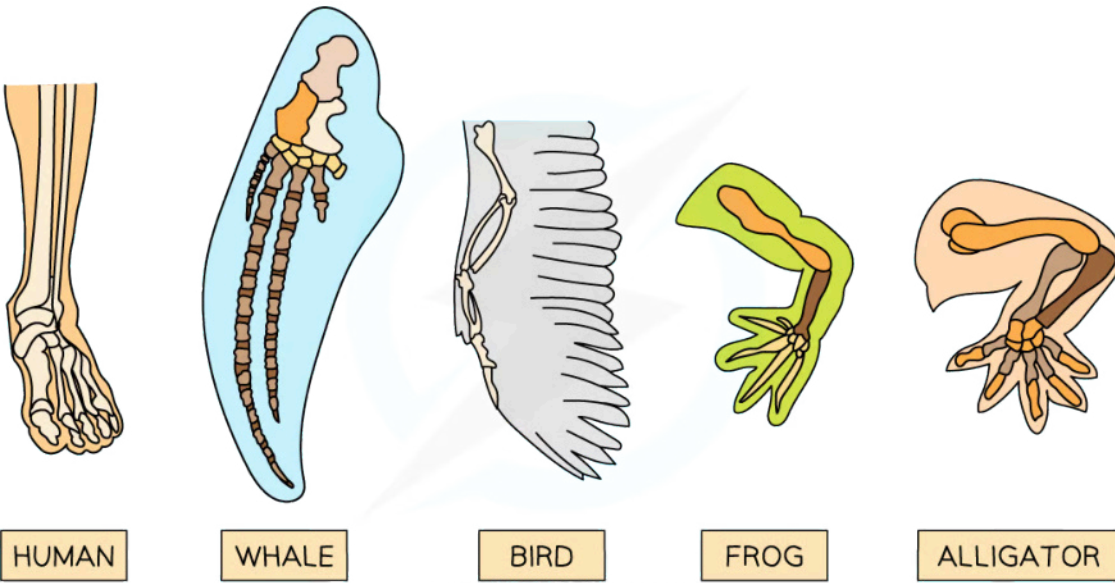
### A homologous structure: the pentadactyl limb

- 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



Your notes



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



Your notes

## Convergent Evolution

### Convergent Evolution

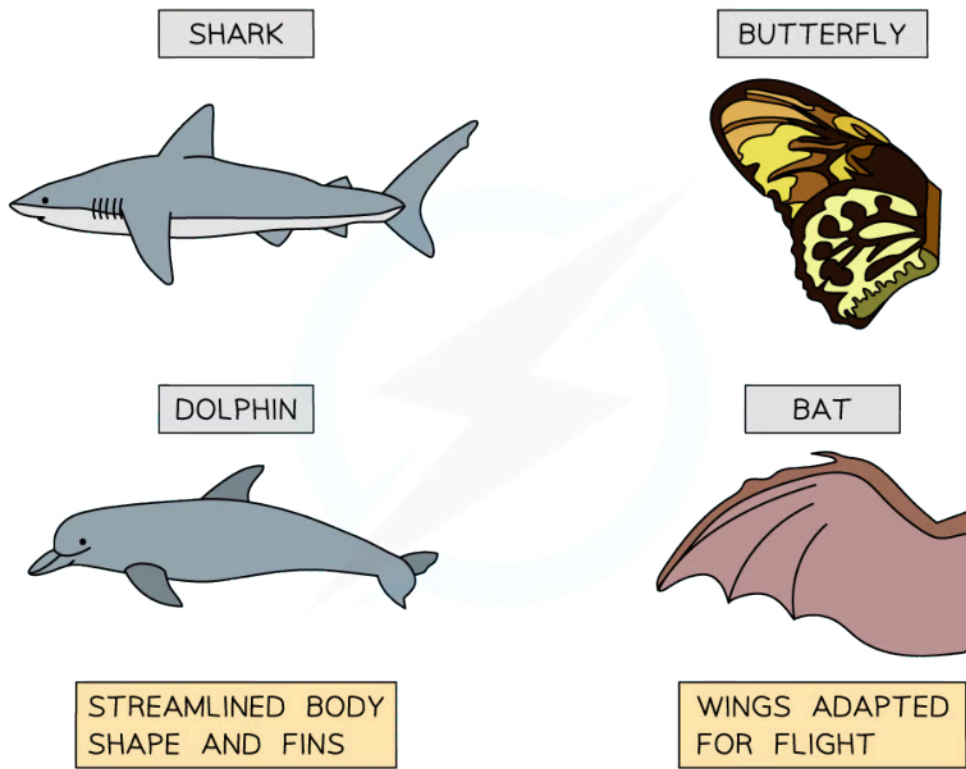
#### Convergent evolution

- **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



Your notes

## Speciation

### Speciation

#### Speciation increases diversity

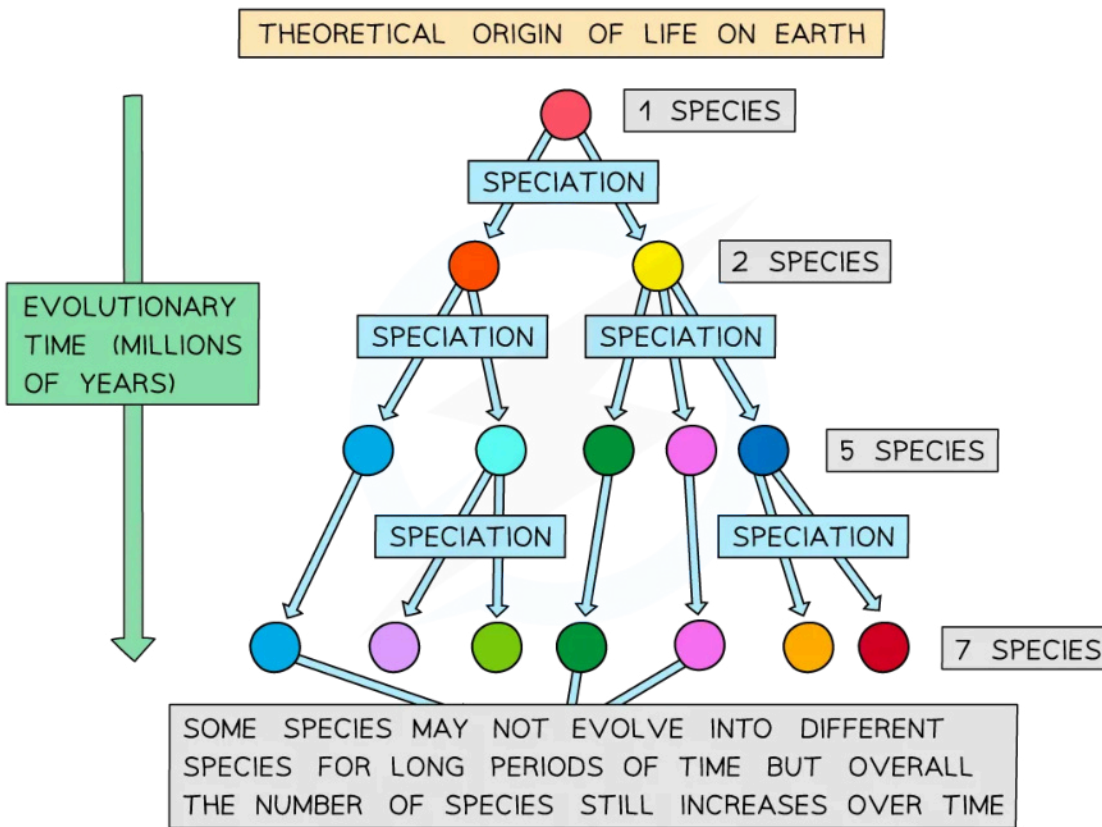
- The theory of evolution states that **species do not stay the same**, but change over time; this can lead to the process of **speciation**
- Speciation can be defined as  
**The development of new species from pre-existing species over time**
- Speciation has resulted in a **great diversity of species** 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





Your notes



*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





Your notes

## Reproductive Isolation & Differential Selection

### 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**

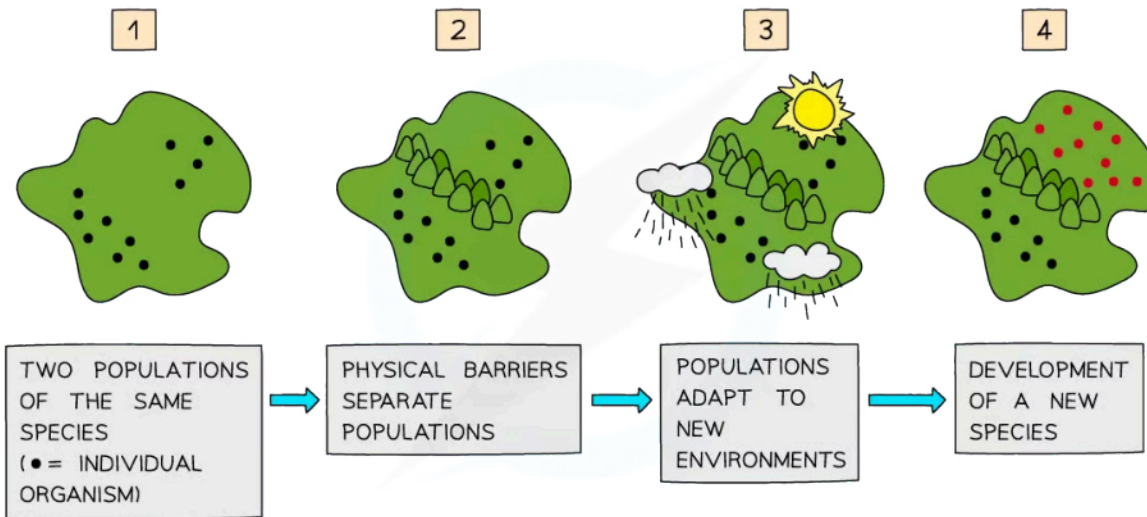
### Geographical isolation

- 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**
  - **Differential 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*



Your notes

## Types of Speciation (HL)

### 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**

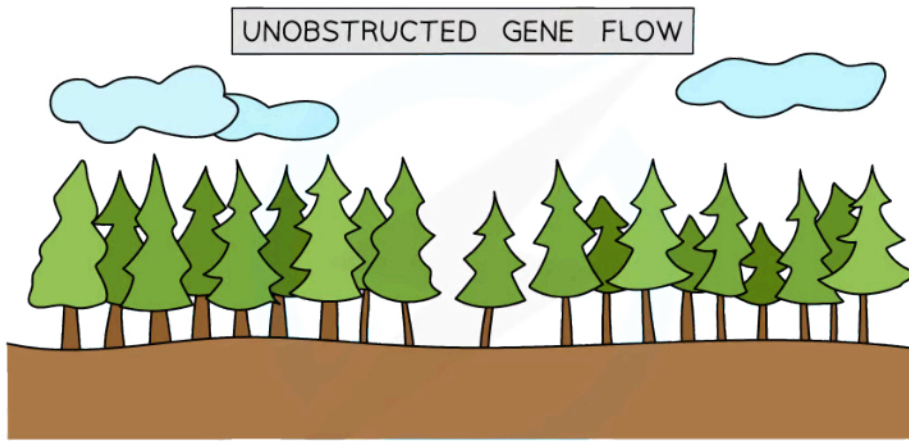
#### E.g. Allopatric speciation in trees

- 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**

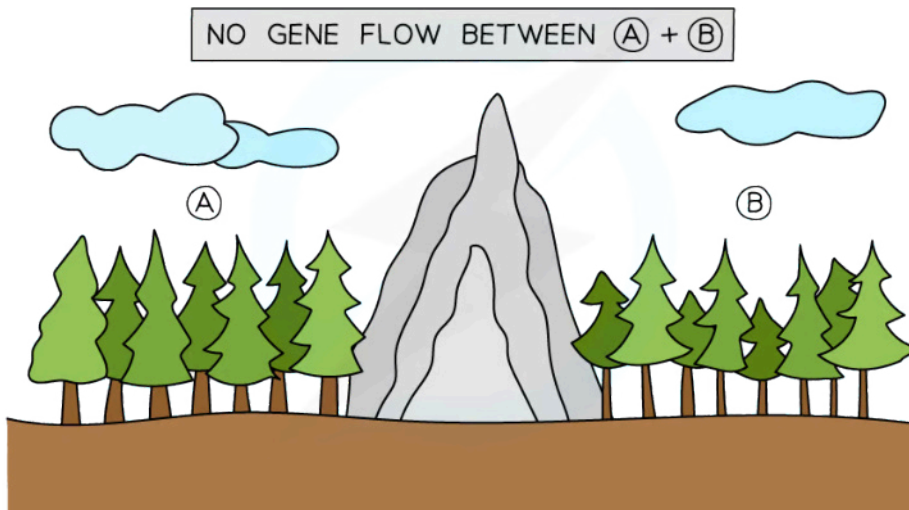
#### Allopatric speciation diagram



Your notes



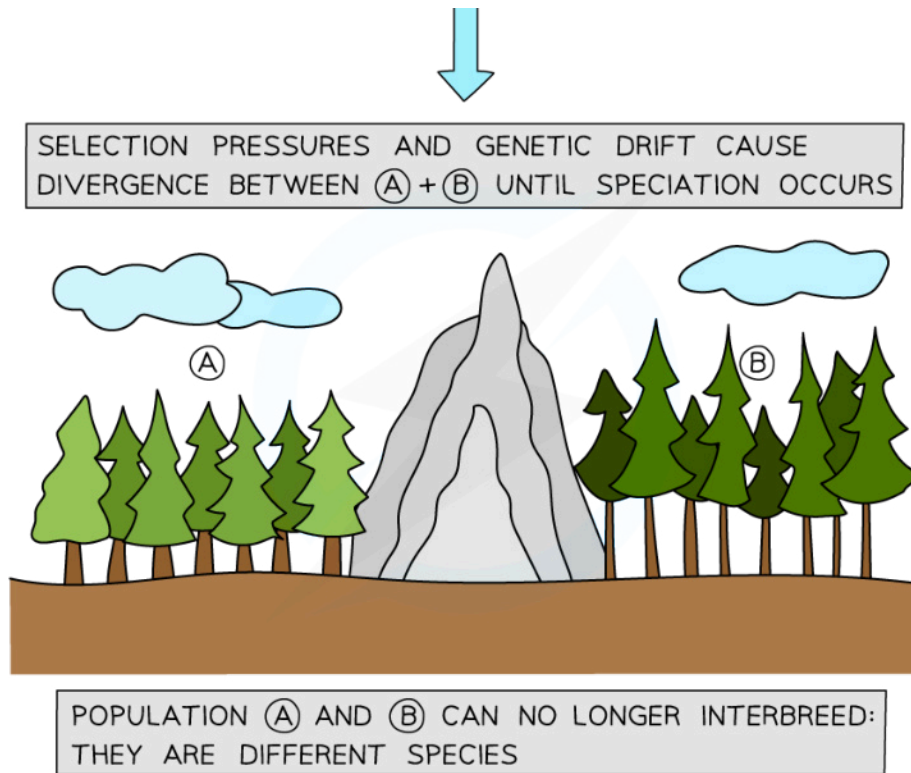
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*The natural geographical barrier of a mountain range can lead to allopatric speciation in trees*

## 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

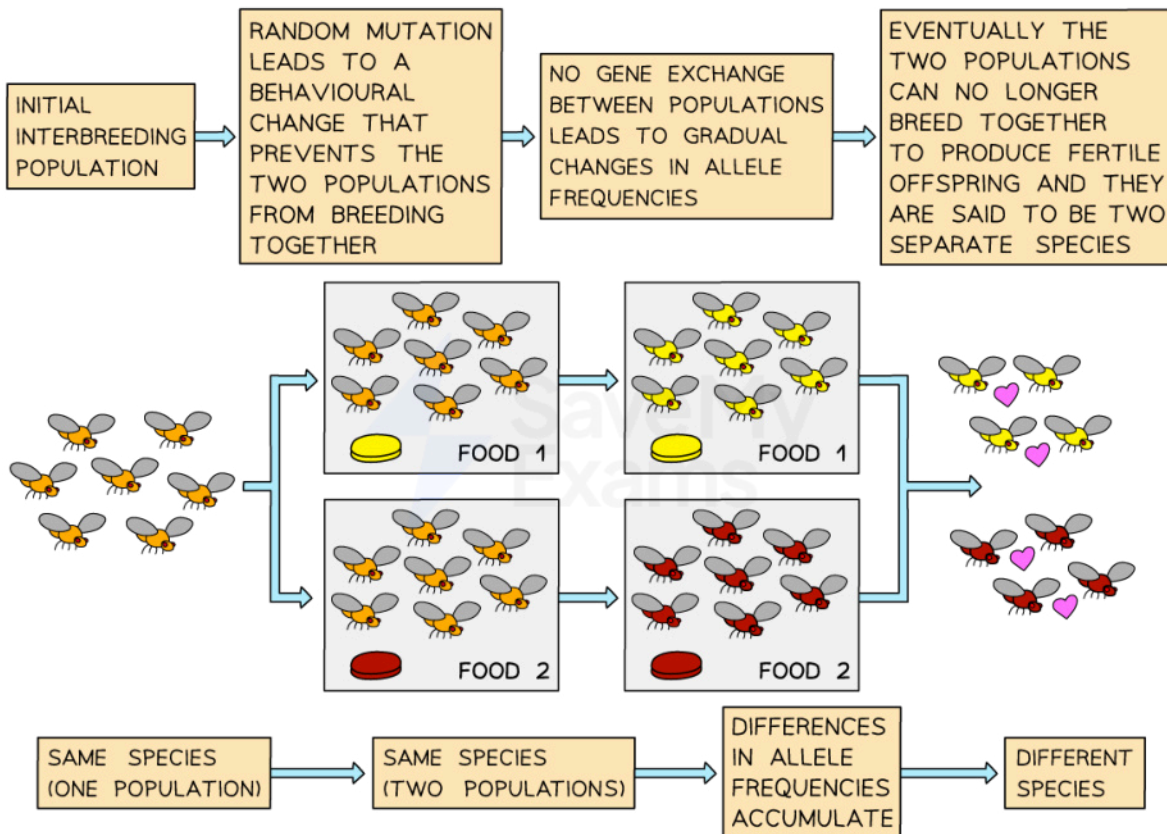


Your notes

- 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 change 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



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



 **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



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

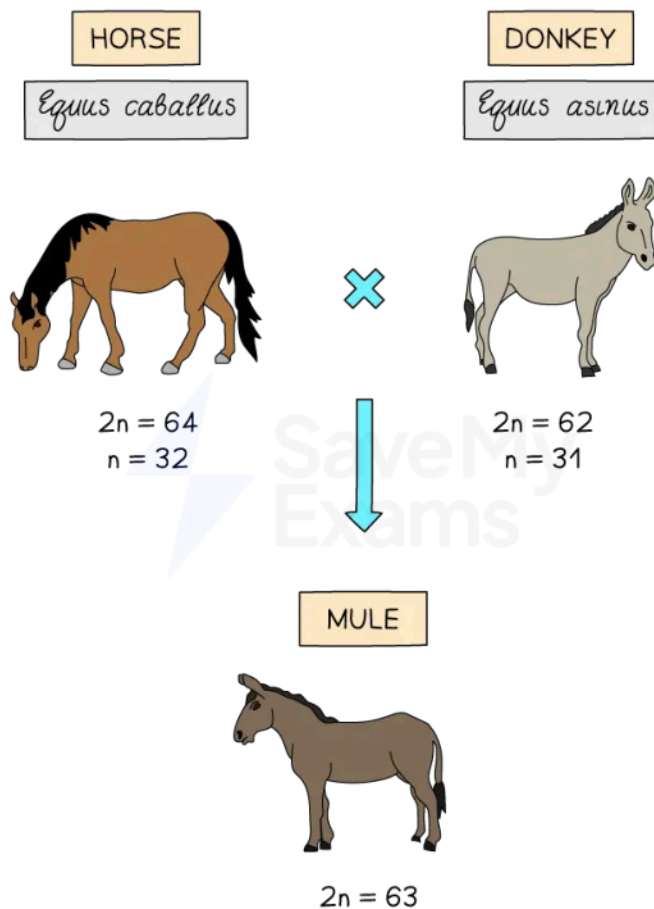
- The fusion of gametes from **different species** often leads to **non-viable zygotes**; this can occur if the **chromosomes of the different species do not match**
  - The gene at a particular locus on a particular chromosome needs to be the same in both chromosomes in a homologous pair
- Viable zygotes 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





Your notes



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*Mules have an odd number of chromosomes so cannot carry out 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



Your notes

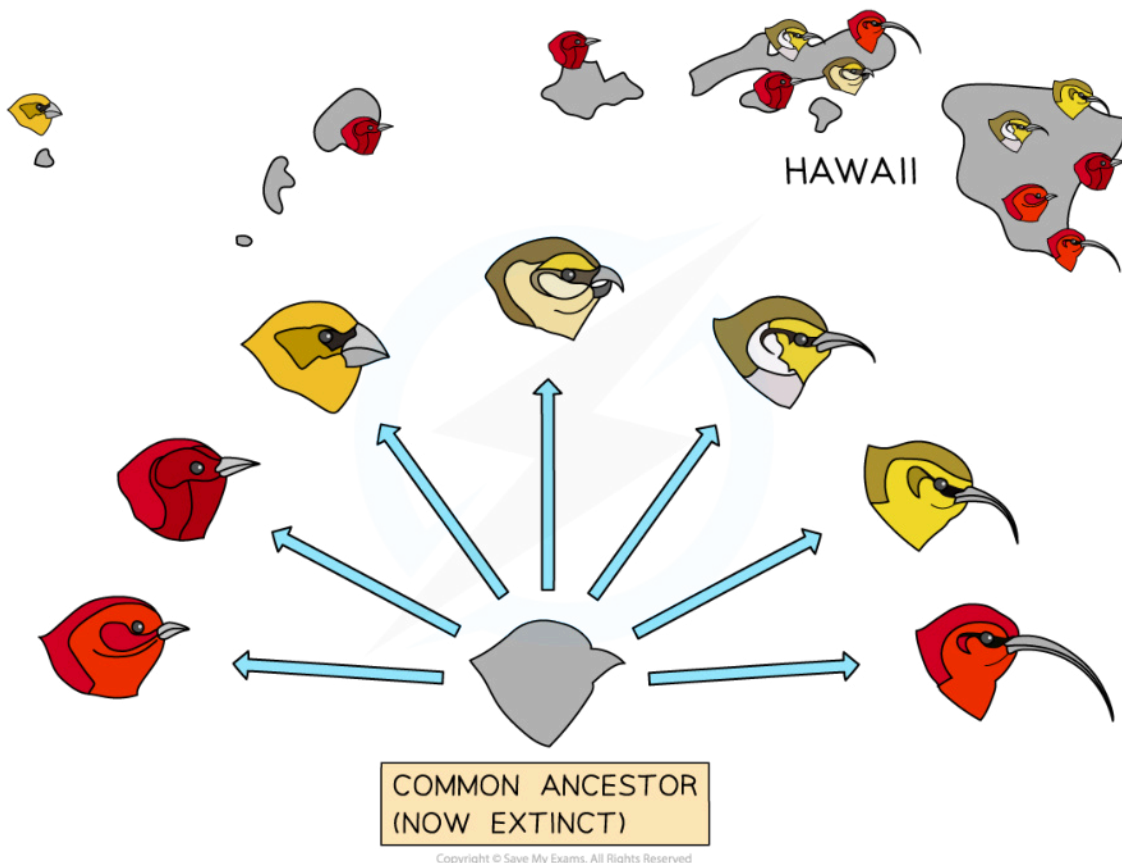
## Adaptive Radiation (HL)

### 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



*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



Your notes

## Speciation in Plants (HL)

### 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

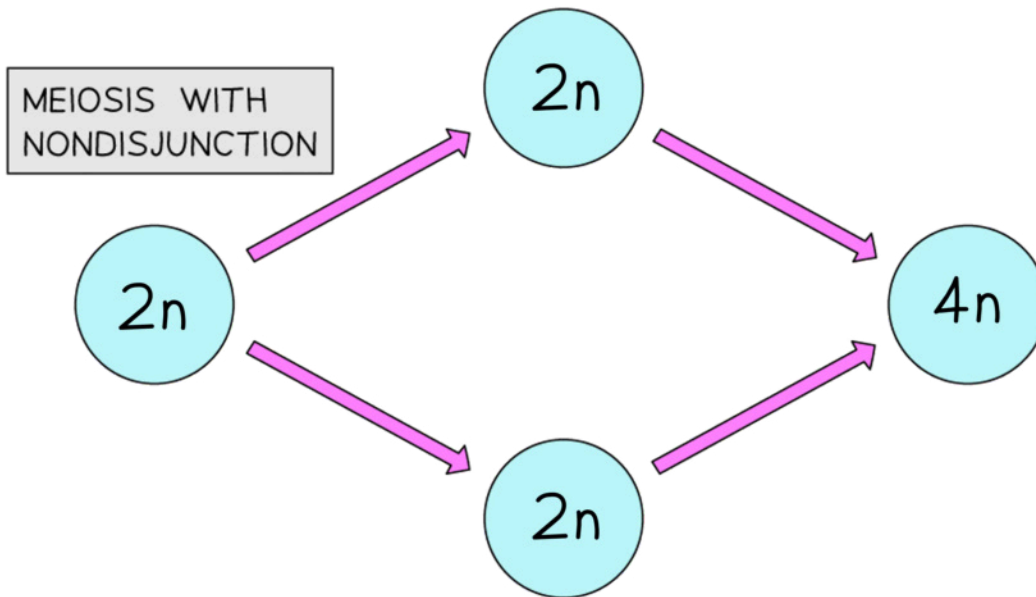
### Autopolyploidy

- 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



Your notes



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

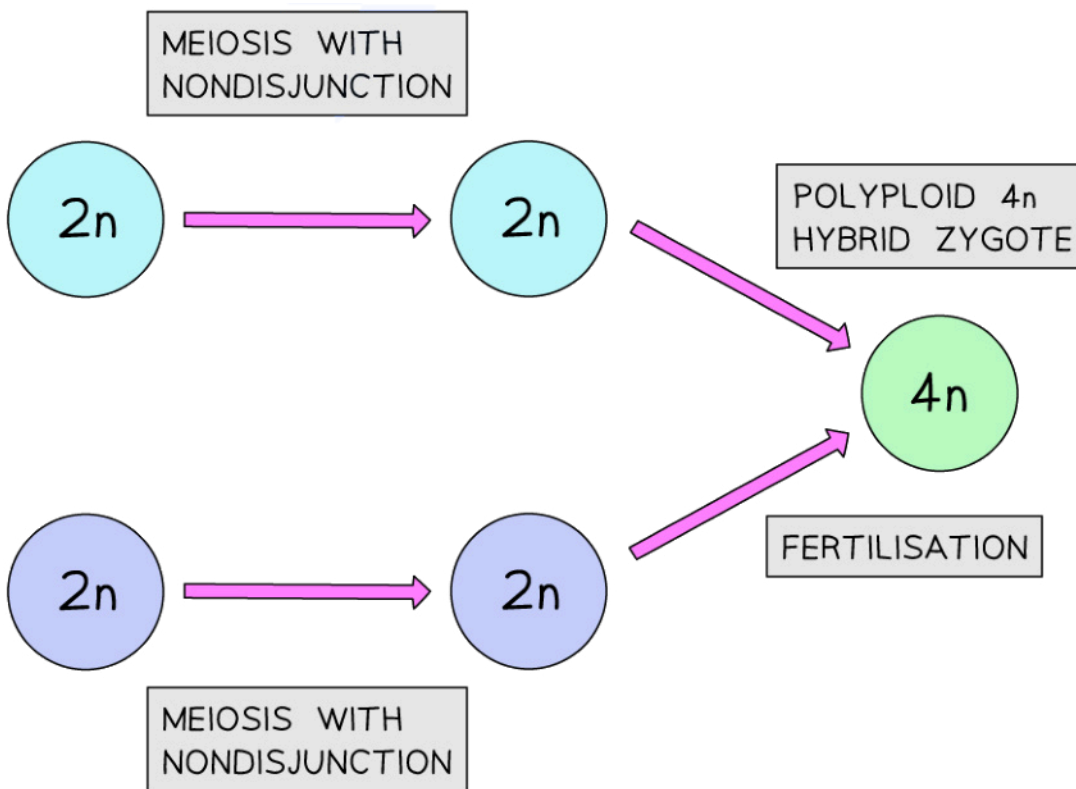
## Allopolyploidy

- 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



Your notes



*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*

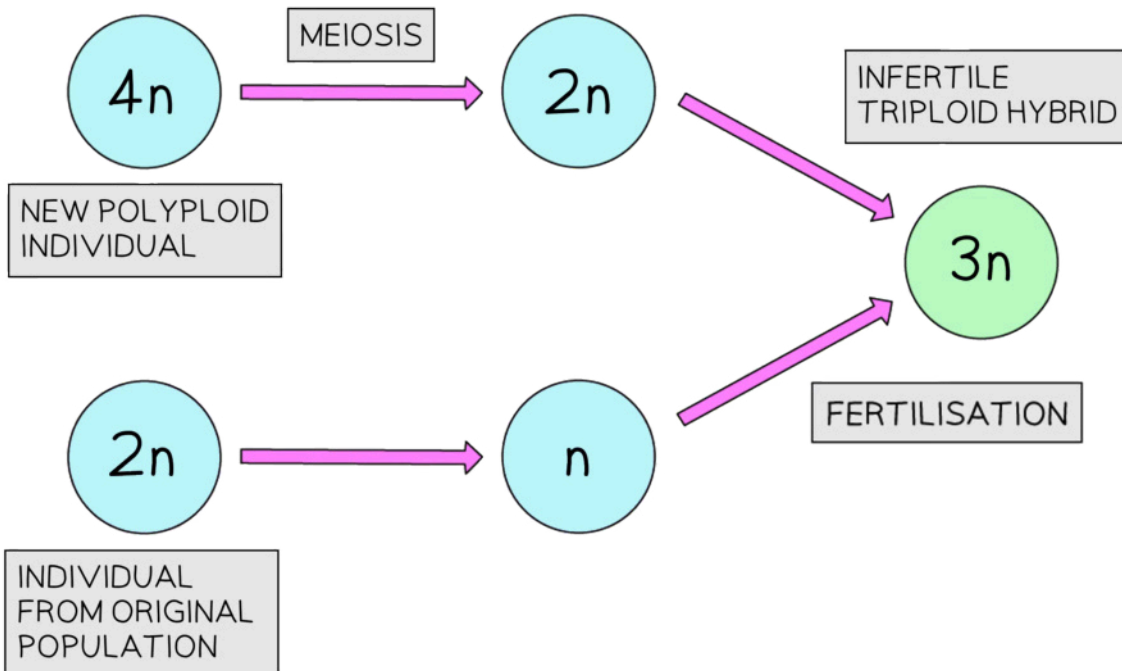
### Speciation due to polyploidy

- 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



Your notes



**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



- Bohemian knotweed is thought to be even more vigorous



W. Carter, CCO, via [Wikimedia Commons](#)

*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.



Your notes