Your notes

DP IB Environmental Systems & Societies (ESS): HL

3.1 Biodiversity & Evolution

Contents

Your notes

Biodiversity & Resilience

Understanding Biodiversity

Why is biodiversity important?

- 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 **habitats**, **species** and **genes** 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
  - This is because biodiversity allows them to resist changes in the environment and avoid ecological tipping points

Habitat diversity

- This is the range of different habitats within a particular ecosystem or biome
- If there is a large number of **different habitats** within an area, then that area has 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 is only one or two different habitats then an area has low biodiversity
  - Large sandy deserts typically have very low biodiversity
  - The conditions are basically the same throughout the whole area

Your notes

A coral reef is an example of an ecosystem with high biodiversity due to high habitat diversity (Photo by Francesco Ungaro on Unsplash)

Species diversity

- An ecosystem such as a tropical rainforest that has a very high number of different species would be described as species-rich
  - Species richness is the number of species within an ecosystem
- Species diversity looks at the number of **different species** in an ecosystem, and also the evenness of abundance across the different species present
  - The greater the number of species in an ecosystem and the more evenly distributed the number of organisms are among each species, then the greater the 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**

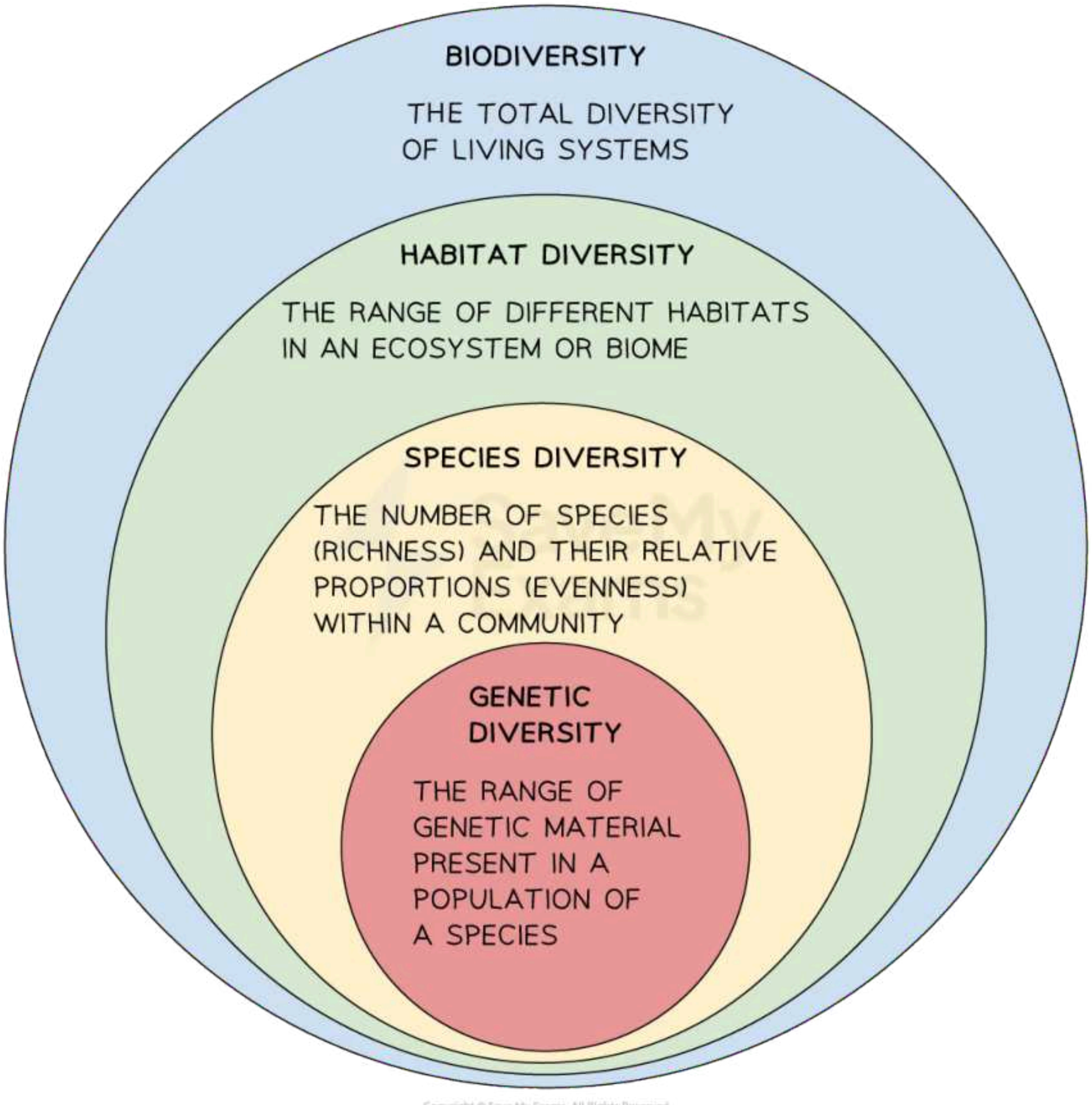
The lack of species diversity in the pine forests of Florida makes them vulnerable to collapse when pathogens enter the ecosystem (Photo by Worm Funeral on Unsplash)

Your notes

Genetic diversity

- Genetic diversity is the diversity of **genes** found within different individuals of a species
- Although individuals of the same species will have the **same set of genes**, these genes can take a variety of **different forms**
- This makes it possible for genetic diversity to occur **between populations** of the same species
- Genetic diversity **within a single population** also occurs
  - This diversity is important as it can help the population **adapt to**, and survive, **changes in the environment**
  - This could include changes in biotic factors such as new predators, pathogens and competition with other species
  - Or the changes could be abiotic factors like temperature, humidity and rainfall

Your notes



Biodiversity is a broad concept encompassing the total diversity of living systems, which includes habitat diversity, species diversity and genetic diversity

Evolutionary Processes

Your notes

Evolutionary Processes

- Biodiversity arises from evolutionary processes
  - Evolution is the cumulative change (i.e. the overall change over time) in the heritable characteristics of a population or species
  - Natural selection is the name of the mechanism that drives this evolutionary change
    - Natural selection occurs continuously and can take place over billions of years
    - The result of this process of natural selection is the biodiversity of life on Earth we see today

Natural Selection

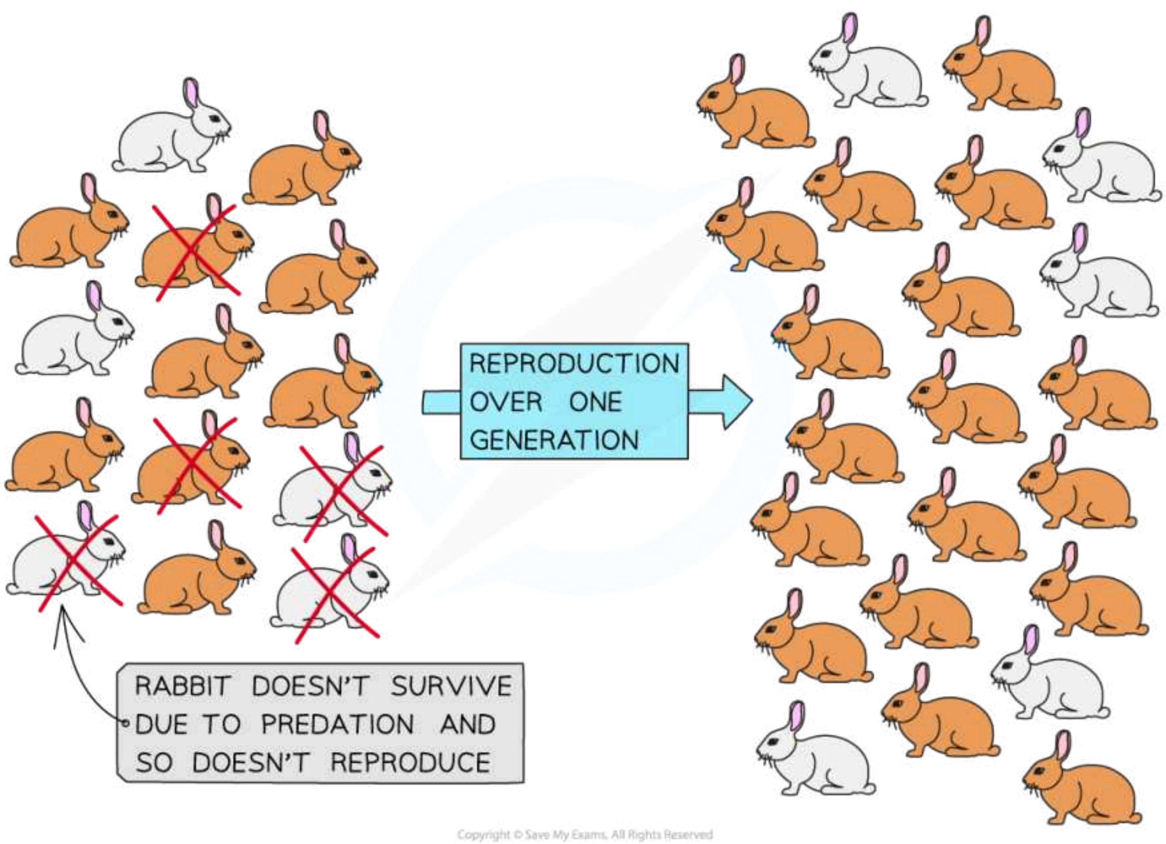
- In any environment, the individuals that have the best adaptive features are the ones most likely to **survive** and **reproduce**
- This results in natural selection:
  - Individuals in a species show a range of variation caused by **differences in genes** (genetic diversity)
  - When organisms reproduce, they produce more offspring than the environment is able to support
  - This leads to **competition** for food and other resources, which results in a "struggle for **survival**"
  - Individuals with **characteristics** most **suited** to the environment have a higher chance of survival and more chances to **reproduce**
  - Therefore, the genes resulting in these characteristics are **passed on** to **offspring** at a higher rate than those with characteristics less suited to survival
  - This means that in the next generation, there will be a greater number of individuals with the better adapted variations in characteristics
- This theory of natural selection was put forward by Charles Darwin and became known as "survival of the fittest"

Example of natural selection

- Imagine a population of rabbits shows variation in fur colour
- The rabbits have natural predators like foxes
  - This acts as a selection pressure

Your notes

- Rabbits with a white coat do not camouflage as well as rabbits with brown fur
  - This means 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 therefore have a selection advantage
  - This means they are more likely to survive to reproductive age and be able to pass on their genes to their offspring
- Over many generations, the frequency of the gene for brown fur will increase and the frequency of the gene for white fur will decrease

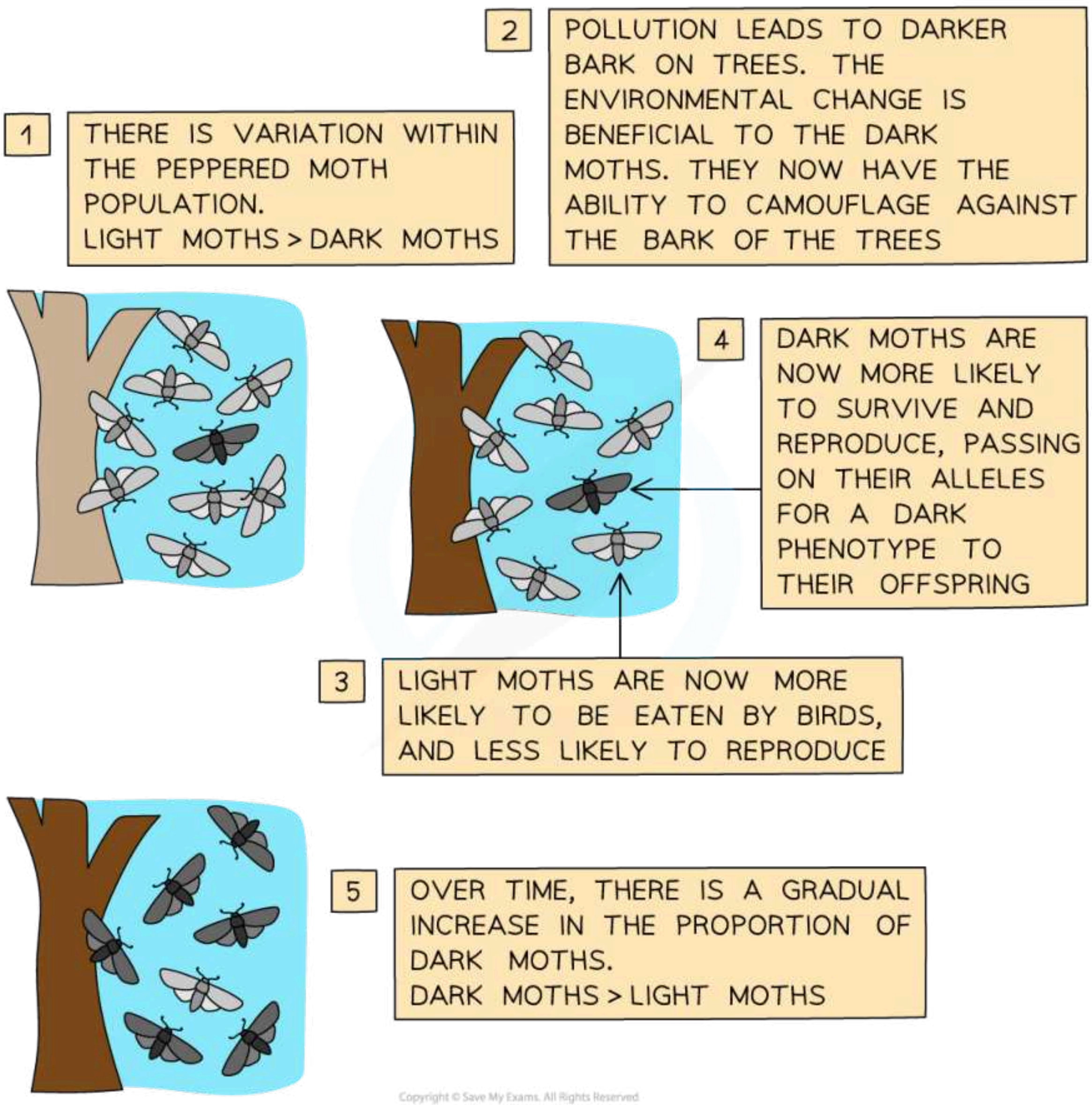


Selective pressures acting on a rabbit population for one generation—predation by foxes causes the frequency of rabbits with brown fur to increase and the frequency of rabbits with white fur to decrease

- Remember that organisms better suited to their environments are more likely to survive
  - However, this does not mean their survival is guaranteed
- Organisms that are less suited to an environment are still able to survive and potentially reproduce within it

Your notes

- However, their chance of survival and reproduction is lower than the individuals that are better-adapted
- Also, it is important to be aware that an environment, and the selection pressures it exerts on an organism, can change over time
  - When a change occurs then a different characteristic may become more advantageous
- Finally, remember that all organisms (not just animals) experience selection pressures as a result of the environment they are in



Another good example of natural selection is the evolution of the peppered moth

Speciation

Your notes

- Speciation is the generation of **new species** through evolution
- It occurs when populations of a species become **isolated** and adapt to their environments in different ways
- Over time, these populations become so different that they can **no longer interbreed** with each other to produce **fertile offspring**
- When they cannot interbreed in this way, they are considered **separate species**

Examiner Tips and Tricks

There are many examples of natural selection and you cannot possibly be familiar with all of them, however, they ALL follow the same sequence:

Based on the idea that within a species there is always variation due to chance mutations, some individuals will develop a characteristic that gives them a survival advantage that allow them to live longer, breed more, and be more likely to pass their genes on. Repeated over generations, the advantageous characteristic will become the norm within a population.

Assessing Biodiversity

Your notes

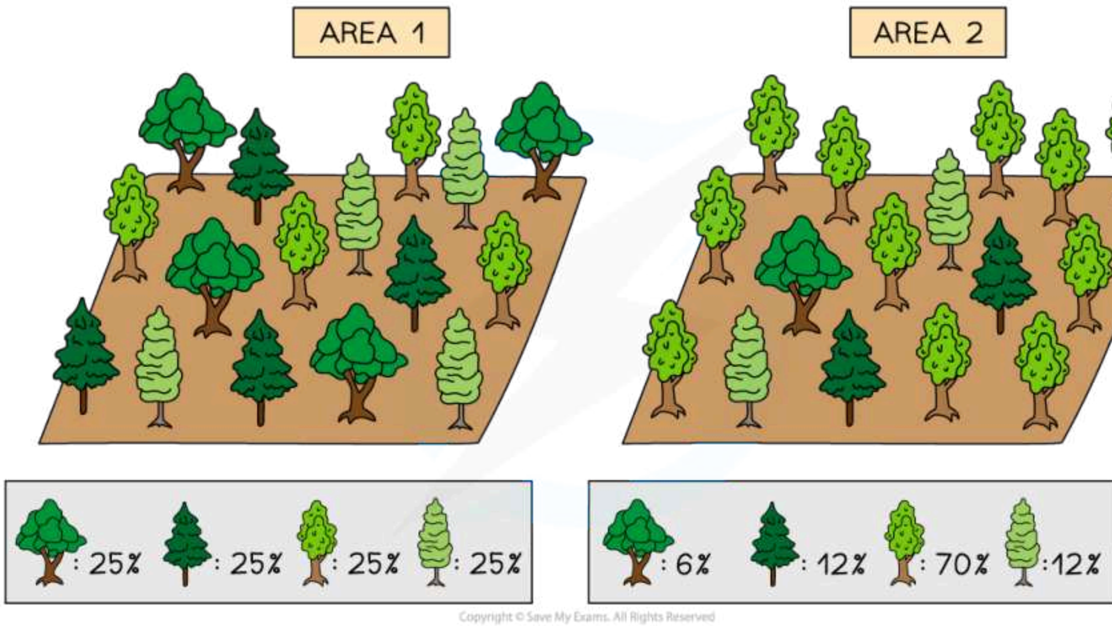
Species Diversity

- Species **richness** is the **number of species** in a community or defined area
  - In some cases, it can be a useful measure to compare the biodiversity of different areas
- However, in other cases, species richness can be a **misleading indicator** of diversity
  - This is because it does not take into account the **number of individuals of each species**
- Once the abundance of each 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 **species evenness**
    - Species evenness is the **evenness of abundance** across the different species (i.e. their **relative abundances**)

Species richness vs species diversity

- Species diversity is a much more **informative** measurement than species richness and conservationists often favour the use of species diversity as it takes into account both species richness and evenness
- For example:
  - Area 1 and Area 2 both contain four 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 evenness (and therefore a higher overall species diversity) than Area 2
  - This example illustrates the limitations of using just species richness on its own

Your notes



Area 1 and Area 2 have the same species richness but different species evenness. As it has a higher species evenness, the overall species diversity of Area 1 is higher than that of Area 2, as species diversity takes both richness and evenness into account

Simpson's Diversity Index

- Biological communities can be described and compared through the use of **diversity indices**
  - These are mathematical tools used to quantify the diversity of species within a community
- These indices provide a measure of the variety of species present, as well as their relative abundances
  - They can be used to **compare different communities** or to **track changes** in diversity **over time**
- A commonly used diversity index is **Simpson's index**

Calculating Simpson's diversity index

Worked Example

- A group of students used the kick sampling technique to collect, identify and count the invertebrates inhabiting a river
- Samples were obtained from different sites along the course of the river
- The data was used to calculate the Simpson's diversity index at two different river sites

Your notes

- This index of diversity is useful when comparing two similar habitats, or the same habitat over time
- The formula for calculating Simpson's Diversity Index, D, is:

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

- Where:
  - *D* = Simpson's diversity index
  - *N* = total number of individuals sampled
  - *n* = number of individuals of each species

Data Collection Table

Species	**Mean number of organisms per m^2 of river bed**	
	Site A	**Site B**
Mite	14	0
Snail	9	0
Leech	3	26
Worm	0	6
Flat worm	132	9
Mayfly nymph	43	0
Olive mayfly nymph	154	0
Midge Larva	0	10
Blackfly larva	77	0
Caddis larva	15	1
Fish	1	0
Freshwater shrimp	211	6
Water hog louse	0	40

Site A

Species	**Number (n)**	**n (n-1)**
Mite	14	182

Your notes

Snail	9	72
Leech	3	6
Worm	0	0
Flat worm	132	17 292
Mayfly nymph	43	1 806
Olive mayfly nymph	154	23 562
Midge Larva	0	0
Blackfly larva	77	5 852
Caddis larva	15	210
Fish	1	0
Freshwater shrimp	211	44 310
Water hog louse	0	0
Total	N= ∑n= 659	∑n(n-1)= 93 292

$$D = \frac{N(N-1)}{\Sigma n(n-1)} = \frac{659(658)}{93292} = 4.65$$

Site B

Species	**Number (n)**	**n (n-1)**
Mite	0	0
Snail	0	0
Leech	6	30
Worm	26	650
Flat worm	9	72
Mayfly nymph	0	0
Olive mayfly nymph	0	0
Midge Larva	10	90

Your notes

Blackfly larva	0	0
Caddis larva	1	0
Fish	0	0
Freshwater shrimp	6	30
Water hog louse	40	1 560
Total	N= ∑n= 98	∑n(n-1)= 2 432

$$D = \frac{N(N-1)}{\Sigma n(n-1)} = \frac{98(97)}{2432} = 3.91$$

- By comparing the diversity indices for Site A and Site B, we can see that Site B has a lower species diversity
  - The value of *D* will be higher where there is greater richness (number of species) and evenness (similar abundance)
  - The lowest possible value for *D* is 1

Examiner Tips and Tricks

Remember, this index of diversity is only useful when comparing two similar habitats, or the same habitat over time.

You will be provided with the formula for Simpson's Index in the exam but you need to know how to use it to calculate Simpson's Diversity Index for example sets of data.

Your notes

Biodiversity Management

Biodiversity Management

Importance of biodiversity management

- Biodiversity refers to the variety of life on Earth, including ecosystems, habitats, species and genetic diversity
- Managing biodiversity is crucial for many reasons, including:
  - **Ecosystem stability**—biodiversity maintains ecosystem resilience to environmental changes
  - **Medicine and pharmaceuticals**—many medicines are derived from biodiversity, offering potential treatments for various diseases
  - **Cultural and spiritual significance**—biodiversity holds cultural and spiritual importance, preserving traditional knowledge
  - **Economic benefits**—biodiversity contributes to tourism and livelihoods, supporting local economies
  - **Climate regulation**—ecosystems help mitigate climate change by sequestering carbon dioxide
  - **Pollination and food security**—biodiversity, especially pollinators, is essential for crop pollination and food production.

Gathering Knowledge of Biodiversity

- Effective biodiversity management requires comprehensive knowledge at both global and regional levels

Global biodiversity data collection

- **International organisations**:
  - Organisations like the IUCN (International Union for Conservation of Nature) and WWF (World Wildlife Fund) gather data globally
    - For example, the IUCN Red List categorises species based on their extinction risk

Regional biodiversity data collection

- **National and local agencies**:
  - Government-funded agencies, such as Natural England in the UK, collect data on local species and habitats

Your notes

- For example, Natural England conducts surveys on bird populations to monitor their status
- **Citizen science**:
  - Involves public participation in scientific research
  - Volunteers collect data on local wildlife, which is then used by scientists
    - For example, the Big Butterfly Count in the UK engages the public in counting butterfly species
- **Voluntary organisations**:
  - NGOs like The Wildlife Trusts (UK) work on local biodiversity projects
    - For example, the Wildlife Trusts have a long-term hedgehog monitoring programme

Training for data collection

- **Indigenous people**:
  - Indigenous communities often possess detailed traditional knowledge of local ecosystems
  - Training helps integrate their knowledge with scientific methods
    - For example, indigenous rangers in Australia are trained to monitor and protect native species
- **Parabiologists**:
  - These are local people trained to assist in biological research
  - They bridge the gap between local communities and scientific researchers
  - They may be used to gather information for use in conservation management

Biodiversity management strategies

- There are many different biodiversity management strategies but the main categories are:
  - The creation of protected areas
  - The restoration of existing but damaged habitat
  - The implementation of sustainable management strategies
- **Protected areas**:
  - Creating parks, reserves and conservation areas
    - For example, the establishment of marine protected areas to safeguard coral reefs
- **Habitat restoration**:
  - Restoring degraded ecosystems to their natural state

Your notes

        - For example, rewilding projects involve the restoration of ecosystems by reintroducing native species to their original habitats
- **Sustainable practices**:
    - Encouraging sustainable agriculture, forestry and fishing
        - For example, certification schemes like Fair Trade promote sustainable farming practices

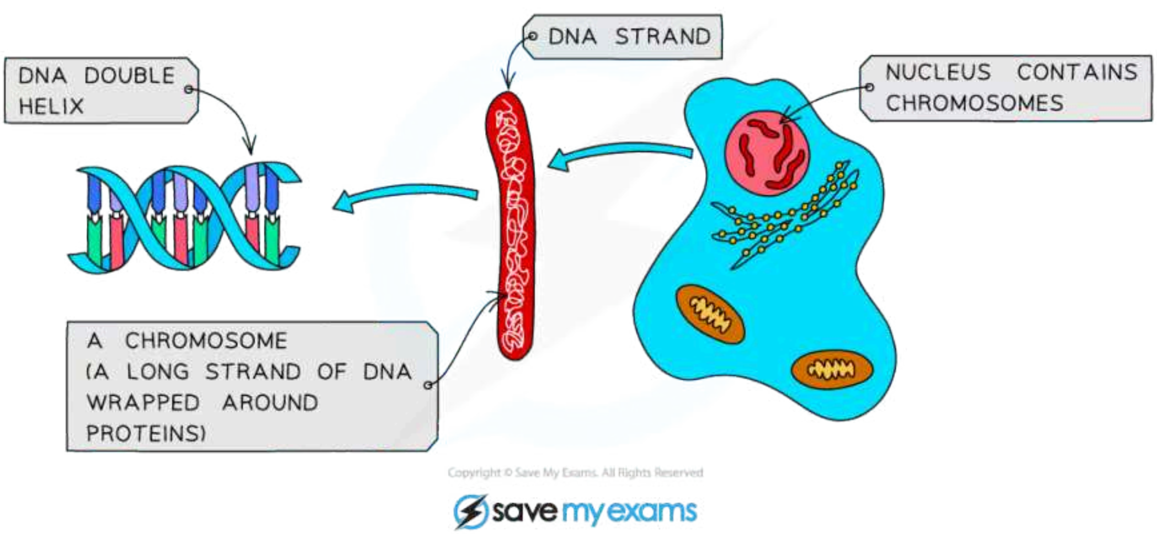
Genetic Diversity (HL)

Your notes

Genetic Diversity

DNA, chromosomes and genes

- **DNA** is the molecule that carries genetic information in all living organisms
- **Genes** are specific sequences of DNA that code for particular traits or proteins in an organism
  - Each gene controls a certain characteristic or function
- **Chromosomes** are long strands of DNA tightly coiled together
  - For example, humans have 46 chromosomes, arranged in 23 pairs
  - Each pair carries genes inherited from both parents
- The **genome** is the complete set of genes or genetic material in an organism
  - Every living thing has its own unique genome
- **Genetic diversity** refers to the variation in genes between individuals within a species
  - This diversity is very important for the survival and adaptation of populations in changing environments



Genes are short lengths of DNA that code for a protein—they are found on chromosomes

Your notes

How genetic diversity arises

Mutation and genetic diversity

- Mutations are **random changes** in the DNA sequence
  - They can occur naturally during cell division or due to environmental factors like radiation
- Mutations create **new versions** of genes known as **alleles**
  - These changes can introduce **new traits** into a population
  - For example, a new allele might provide resistance to a certain disease or the ability to digest a new food source
- Most mutations are **neutral**, meaning they have no effect on the organism
  - However, some can be **beneficial** (increasing survival chances) or **harmful** (leading to genetic disorders)
  - For example, in some human populations, a mutation in the **CCR5 gene** provides greater resistance to HIV infection

Sexual reproduction and genetic diversity

- Sexual reproduction **combines genetic material** from **two parents**
  - An individual's gametes are **genetically distinct** from each other
  - Depending on which gametes fuse together during fertilisation, the offspring created will always be genetically distinct
  - This results in offspring with a **unique set of genes**
- The genetic recombination that occurs during reproduction (i.e. the mixing of DNA from both parents) leads to **new combinations of alleles** in the offspring
  - For example, human siblings (except for identical twins) have different combinations of their parents' genes, leading to genetic variation within a family

Importance of genetic diversity

- **Survival and adaptation**:
  - High genetic diversity gives populations a greater ability to **adapt** to **changing environments**
  - If a new disease, new predator, new food source or climate change occurs, some individuals may have the right genetic traits to **survive**. For example:

    - In agriculture, maintaining genetic diversity in crops is important for resilience to pests and diseases
    - Some corals have specific genes that code for proteins helping them survive higher temperatures
    - Genetic diversity in these heat-tolerance genes can allow certain corals to withstand warming ocean temperatures, while others without these genes may bleach and die
- **Reduced risk of inbreeding**:
  - In populations with low genetic diversity, individuals are more likely to inherit harmful mutations due to inbreeding (mating between closely related individuals)
  - This can lead to genetic disorders or reduced survival rates
  - For example, cheetahs have low genetic diversity, making them more vulnerable to disease and reproductive issues

Your notes

Reproductive Isolation (HL)

Reproductive Isolation

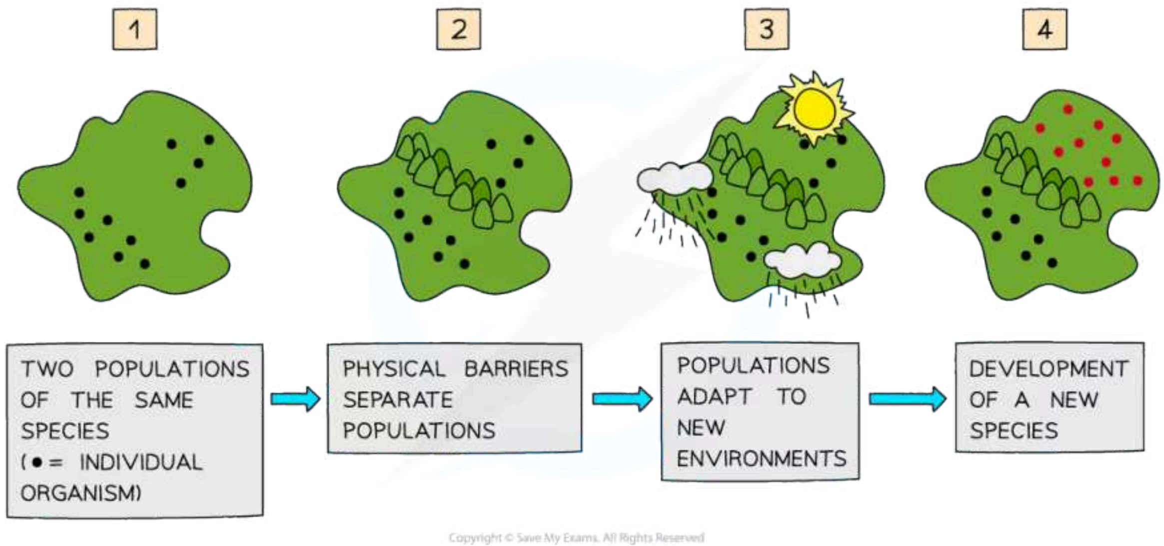
- Reproductive isolation occurs when **different populations** of a species can **no longer interbreed**
  - This **prevents gene flow** between the populations, i.e. they no longer interchange genes with each other during the production of offspring
  - This leads to the development of new species over time (**speciation**)
- It can occur due to **physical barriers** (geographical isolation) or differences in **behaviour** or **ecology** (behavioural or ecological isolation)

Types of reproductive isolation

Geographical isolation

- Geographic isolation occurs when physical barriers like rivers, mountains, or oceans **separate** populations
- This **prevents mating** between individuals from each population
  - Speciation happens because, over time, these populations **evolve differently** due to their unique environments
  - Random mutations within each population also change the alleles present in each population
  - When the genetic differences lead to an **inability** of members of the populations to **interbreed** and produce **fertile offspring**, speciation has occurred

Your notes

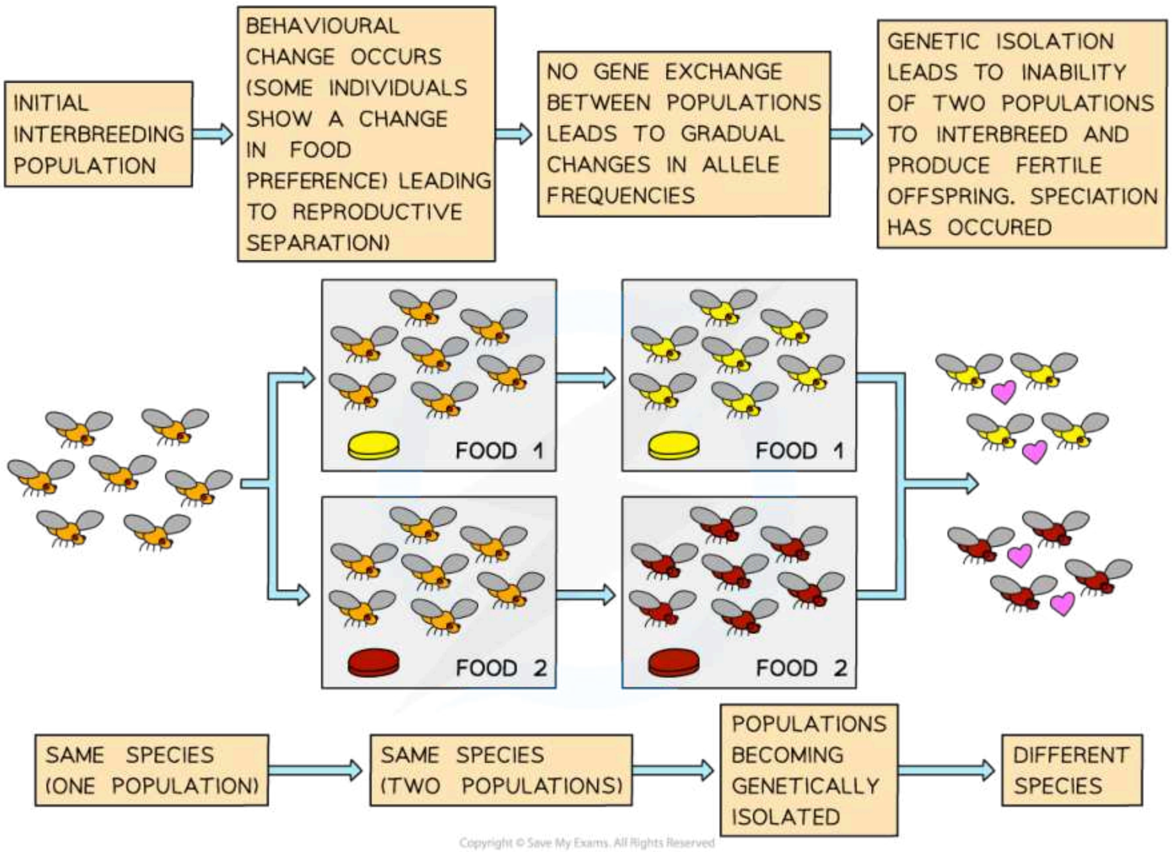


Speciation occurring due to geographical isolation of two populations of the same species

- **Example: bonobos and common chimpanzees**
  - Bonobos and common chimpanzees were once part of the **same species**
  - The **Congo River** in Africa separated the two populations, preventing interbreeding
  - Over time, the two populations developed different **physical** and **behavioural traits**, eventually becoming **distinct species**

Ecological and behavioural isolation

- Populations living in the **same area** (no geographic barriers) can become reproductively isolated if they occupy **different ecological niches** or develop **different behaviours**
- These differences prevent the populations from interbreeding, **even though they live close together**
  - In the example below, the insects often mate in the same location they feed
  - As some individuals start to change their food source, mating between the two groups of insects starts to decrease
  - Over time, two distinct populations form which no longer interbreed



Reproductive separation of two populations can lead to speciation

- **Example: apple maggot fly (*Rhagoletis pomonella*)**
  - Originally, the apple maggot fly laid its eggs on hawthorn trees in North America
  - When apple trees were introduced, some flies started laying eggs on apples
  - The two groups of flies have become behaviourally isolated because they now mate on different plants
  - This has led to the early stages of speciation
- Other examples of ecological or behavioural 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**:

Your notes

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

High rates of endemism on isolated islands

- **Endemism** refers to species that are found only in one **specific geographical area**, like an island
  - Islands, especially those **far from the mainland**, often have high rates of **endemic species** due to geographical isolation
  - For example, pygmy three-toed sloths are only found on a small island off the coast of Panama
- **Example: Hawaiian honeycreepers**
  - Hawaiian Honeycreepers are a group of birds found **only in the Hawaiian Islands**
  - There are many different species of honeycreepers, and each one has adapted to a **specific niche** within the environment
  - Some species are found on specific islands, while others may be spread across multiple islands, but all are **endemic** (found only in Hawaii)
  - The isolation of the islands created **unique conditions** for these birds to evolve separately, leading to many different species that exist nowhere else in the world

Examiner Tips and Tricks

Remember that speciation often takes a very long time to occur, even after reproductive isolation has occurred. Enough genetic differences between the populations need to accumulate before two new species are formed.

Make sure you're familiar with key terms like reproductive isolation, speciation, endemic species, and behavioural isolation.

Biodiversity Hotspots (HL)

Your notes

Biodiversity Hotspots

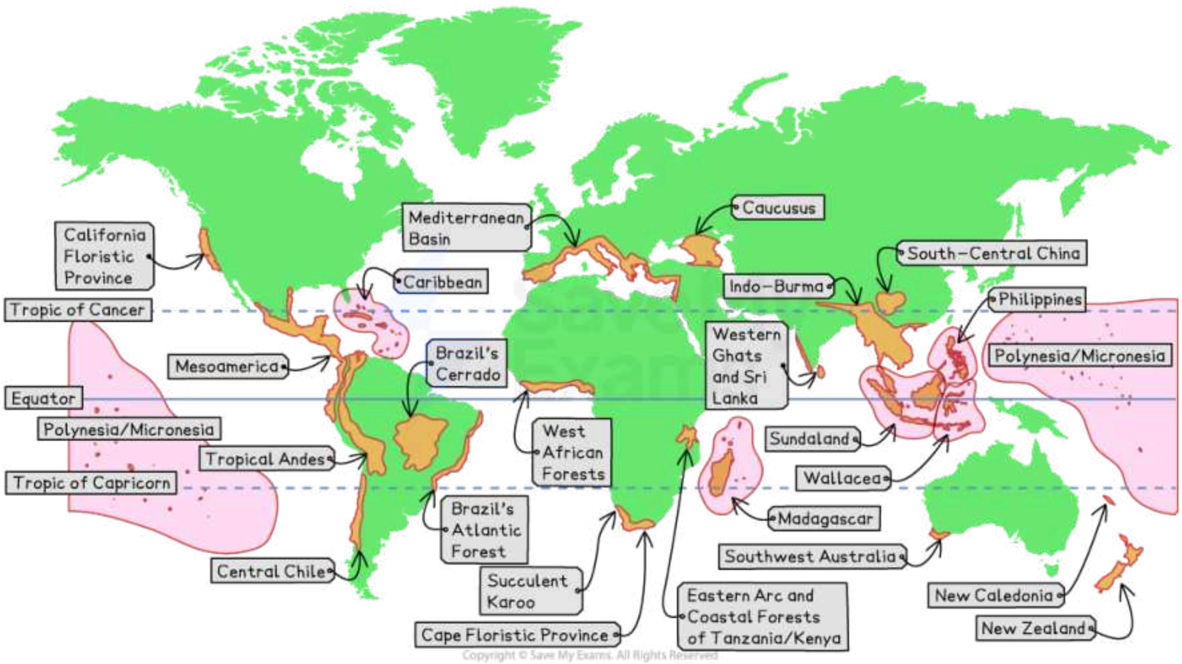
What are biodiversity hotspots?

- Biodiversity hotspots are areas on Earth that contain a **large number of different species**, particularly those that are:
  - Rare
  - Endemic (found only in that area)
  - Endangered
- These regions are critical for **conservation** because they often have species that are not found anywhere else in the world
- Hotspots are regions of **high biodiversity**
  - However, they are also often the regions that are most under threat from human activities such as deforestation, pollution, and habitat destruction

Hotspot criteria

- To qualify as a biodiversity hotspot, an area must meet two main criteria:
  1. **High endemism**: the area must contain at least **1,500 species of vascular plants** that are **endemic**
  2. **Significant habitat loss**: the area must have lost at least **70% of its original natural vegetation**—this indicates that the region is under severe threat from human activities and is in urgent need of conservation
- These criteria, developed by ecologist Norman Myers and used by Conservation International, focus on areas of both high biodiversity and critical levels of habitat loss

Your notes



Map showing biodiversity hotspots across the globe

- The Amazon rainforest **does not currently qualify as a biodiversity hotspot** because it has **not yet met the second key criterion** for being classified as one
  - Although it is facing significant deforestation and other threats, the Amazon has not yet reached the 70% threshold of habitat destruction, though deforestation rates are increasing

Uneven distribution of biodiversity

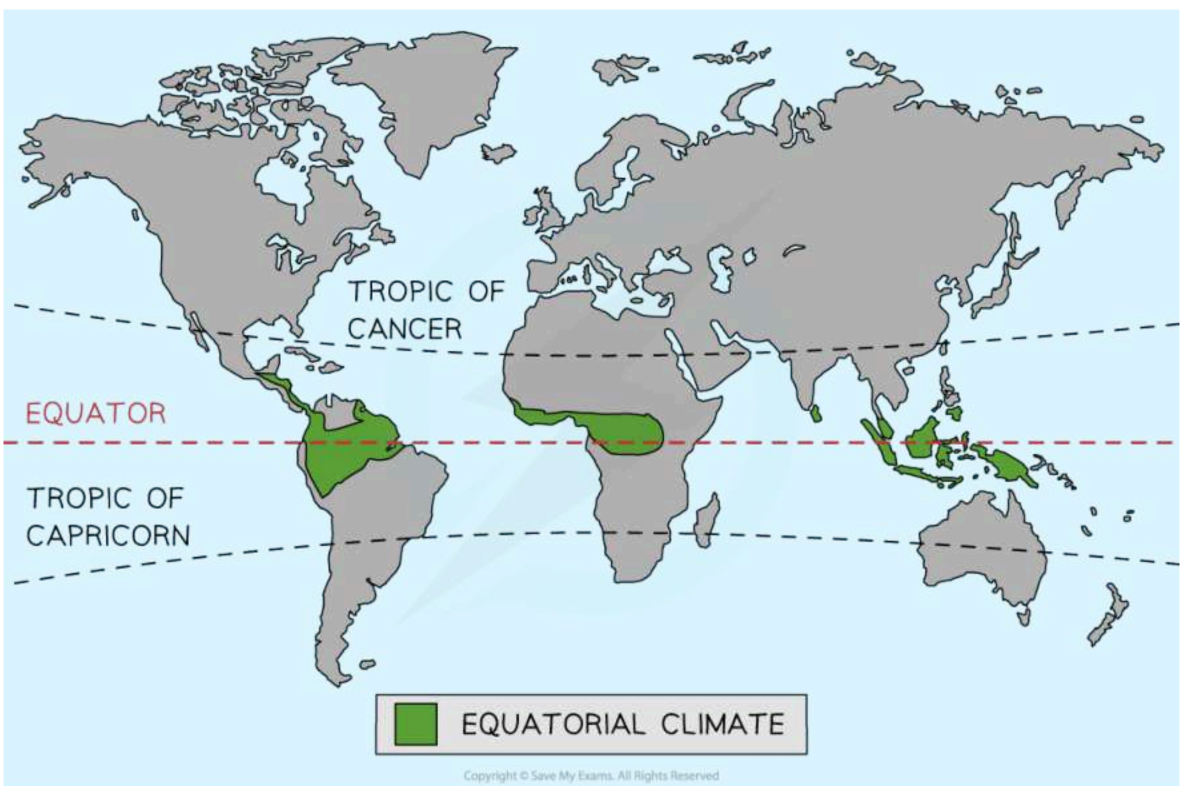
- Biodiversity is **not evenly spread across the planet**
  - Some areas, like the poles, have low biodiversity, while others, like tropical rainforests, have very high biodiversity
- Hotspots make up less than 3% of Earth's surface but contain more than half of the world's plant species and a large percentage of its animal species
- Hotspots are often located in areas with **unique climates and geographical features**, which allow species to evolve and adapt to specific niches

Hotspots in tropical biomes

- Many hotspots are in tropical biomes
  - Tropical biomes tend to have the highest levels of biodiversity

Your notes

    - The warm, wet conditions in tropical rainforests, for example, support a wide range of plants, insects, birds, and mammals
- Examples of tropical hotspots include:
    - The **Coral Triangle** in Southeast Asia, home to more than 600 species of reef-building corals
    - The **Madagascar** hotspot, where over 90% of the species are endemic
- Tropical biomes are mainly found in a band between 15° north and 15° south of the equator within the equatorial climate zone
- Covering only 6% of the Earth's surface, the main areas covered by tropical ecosystems are in the following countries:
    - **Amazon**: the largest remaining rainforest on Earth, usually associated with Brazil but covering parts of seven other countries in South America
    - **Central America**: including parts of Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama
    - **Central Africa**: including Cameroon, the Central African Republic, the Republic of Congo, the Democratic Republic of Congo (DRC), Equatorial Guinea and Gabon
    - **Indo-Malaysia**: including Malaysia, Indonesia and a number of other countries in South-East Asia



Distribution of the equatorial climate

Your notes

Examiner Tips and Tricks

Remember that a biodiversity hotspot must meet two criteria that require: having a certain number of endemic species and experiencing a certain level habitat loss. The Amazon rainforest is often mistakenly described as a biodiversity hotspot.

Human Impacts on Evolutionary Processes (HL)

Your notes

Human Impacts on Evolutionary Processes

- **Evolution** refers to the changes in the genetic diversity of populations over generations
  - Evolution is driven by the process of **natural selection**
  - Traits that help organisms survive and reproduce are passed on more frequently, allowing species to adapt to their environment
- Human activities have altered natural environments, creating new pressures on species and influencing evolutionary processes

How human activities are affecting evolution

Climate change

- Climate change, mainly caused by burning fossil fuels, is altering ecosystems and habitats
- For example, **warmer temperatures** are forcing some species to adapt quickly, such as Arctic animals like the **polar bear**
  - Polar bears are facing evolutionary pressure due to melting sea ice
  - They rely on sea ice to hunt seals, their main food source
  - As ice melts earlier in the year and forms later, polar bears have less time to hunt
  - This has led to:
    - **Smaller body size**: some polar bears are reaching smaller adult body size due to reduced food availability
    - **Shifts in hunting behaviour**: polar bears are increasingly forced to hunt on land, where food sources are less abundant, which could eventually lead to long-term evolutionary changes in their diet and behaviour
    - **Increased land travel**: some polar bears are adapting by moving over larger areas to find food, potentially favouring individuals that are better at long-distance travel
  - Climate change is driving both **behavioural** and **physical adaptations** in polar bears
  - As environments change rapidly, only individuals with **specific traits** may **survive**, causing evolutionary shifts in the population
    - This could lead to future evolutionary changes in polar bear populations

Your notes

Hunting, poaching, and harvesting

- Hunting and poaching puts direct pressure on specific species
  - This can lead to changes in the traits that help the individuals of these species to survive
- For example, in **Gorongosa National Park, Mozambique**, poaching for ivory during the civil war led to an **increase** in **tuskless elephants**
  - Poachers were less likely to kill elephants without tusks
  - Over time, tuskless elephants have become more common due to this selective pressure
  - As a result of human actions driving natural selection, the tuskless trait has become more common
- In some fish populations, overfishing of large fish has led to a population dominated by smaller individuals, as larger fish are more likely to be caught

Creation of new habitats and fragmentation

- Human activities like urbanisation and agriculture lead to habitat fragmentation and the creation of new environments
  - This puts pressure on native species to **adapt** or **move away**
  - Urban areas favour species that can adapt to human environments, such as pigeons and rats, which evolve to thrive in cities
  - These species may evolve traits such as greater tolerance to pollution or greater ability to find food in human-dominated areas

Examiner Tips and Tricks

Try to familiarise yourself with some other examples of humans influencing evolution in other species. For example, pesticide-resistant insects: the overuse of pesticides in agriculture has led to the evolution of pest species that are resistant to these chemicals, making pest control more difficult. Similarly, overuse of antibiotics in humans and livestock has led to the evolution of antibiotic-resistant bacteria (e.g. MRSA), which are harder to treat.

Artificial Selection

What is artificial selection?

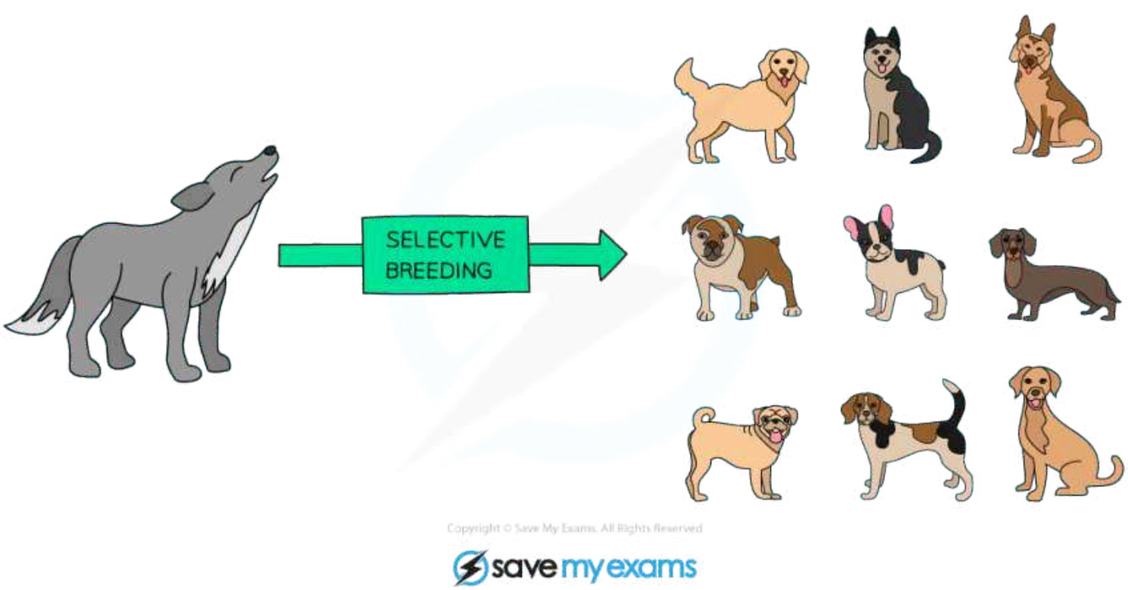
- Artificial selection is the process by which **humans deliberately choose** specific plants or animals to breed based on **desirable traits**

- For example, farmers might breed crops with higher yields or livestock that grow quickly
- This process is known as **selective breeding**
- Humans have been selectively breeding organisms for thousands of years, long before scientists understood the genetics behind it

- Artificial selection is different to **natural selection**, where **environmental pressures** determine which traits become more common in a population over time
  - Natural selection is not directed by humans (it is **not deliberate**)

Selective breeding in animals

- Humans selectively breed animals for a variety of traits, including:
  - Cows, goats and sheep that produce a higher yield of milk or meat
  - Chickens that lay large eggs
  - Domestic dogs that have a gentle nature
  - Sheep with good quality wool
  - Horses with fine features and a very fast pace
- An example of an animal that has been selectively bred by humans in many ways to produce breeds with many different characteristics is the domestic dog, all breeds of which are descended from wolves



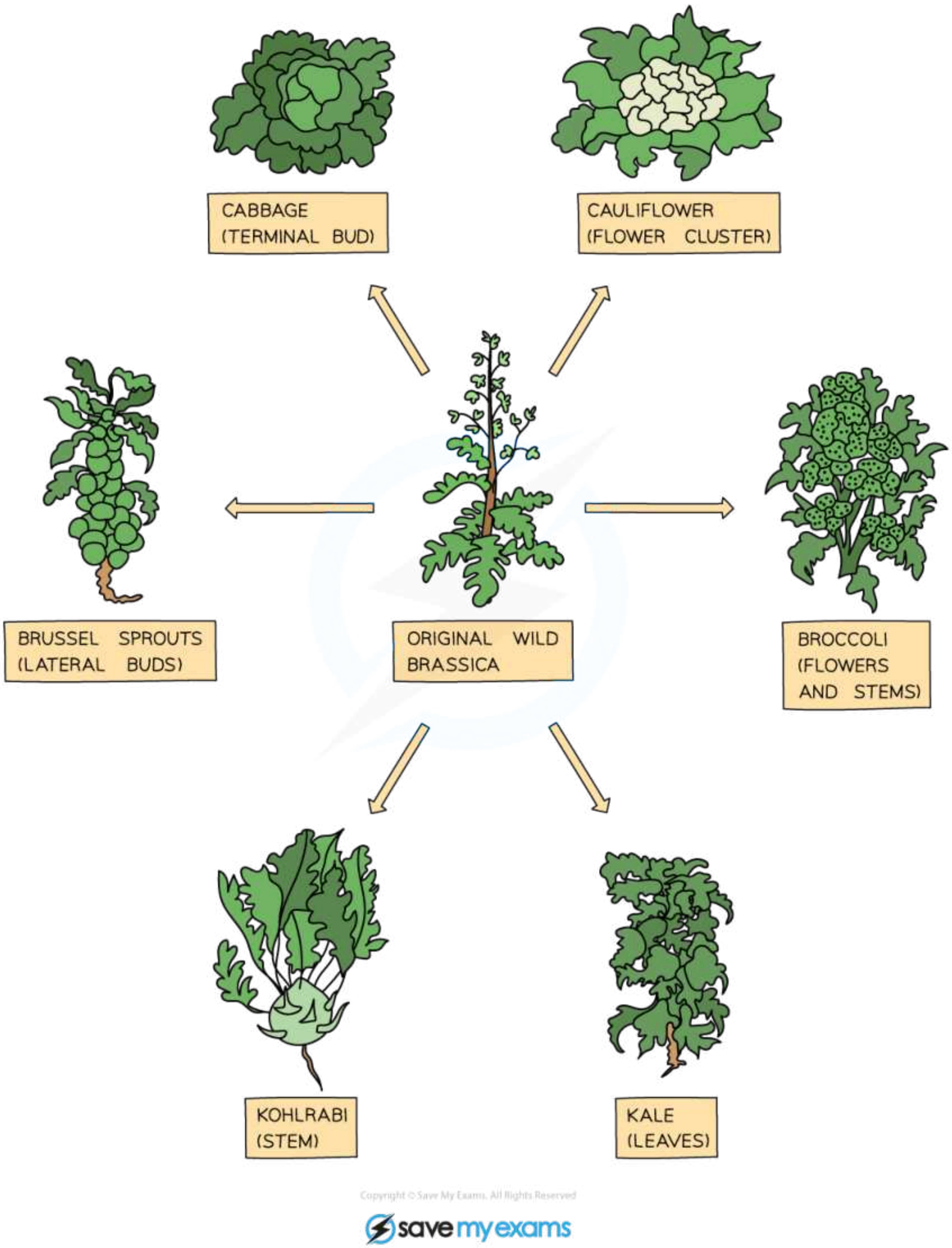
Selective breeding has produced many different breeds of domestic dog

Selective breeding in plants

- Humans selectively breed plants to develop a variety of traits, including:
  - Disease resistance in food crops
  - Increased crop yield
  - Hardiness to weather conditions (e.g. drought tolerance)
  - Better tasting fruits
  - Large or unusual flowers
- An example of a plant that has been selectively bred in multiple ways is wild brassica, which has given rise to cauliflower, cabbage, broccoli, Brussels sprouts, kale and kohlrabi

Your notes

Your notes



An example of selective breeding in plants

Your notes

How does artificial selection reduce genetic diversity?

- When breeders choose individuals with specific traits to reproduce, only the genes for those traits are passed on
  - This reduces the overall number of different genes in the population, making the gene pool smaller
- This **reduction in genetic diversity** can make populations more **vulnerable** to diseases and environmental changes
  - For example, many commercial crops like **bananas** and **potatoes** have **very low genetic diversity** (they are all very genetically similar), making them vulnerable
  - Panama disease has devastated many banana plantations
- With less genetic variation, populations lack the flexibility to adapt to changes
  - This can reduce their **resilience** to challenges like climate change or new pests and diseases

Economic and environmental implications

- **Economic value**:
  - Artificial selection can increase crop yields and livestock productivity, providing short-term economic benefits
    - For example, **dairy cows** have been selectively bred to produce more milk, benefiting the dairy industry
- **Environmental vulnerabilities**:
  - The lack of genetic diversity can make artificially selected breeds more vulnerable to sudden environmental changes
  - This can lead to crop failure or large-scale livestock deaths
  - This can have significant long-term economic costs
    - For example, the **Irish potato famine** in the 1840s was made worse because people depended on a single potato variety that was vulnerable to potato blight disease

The Geological Timescale (HL)

Your notes

The Geological Timescale

- The geological timescale provides a framework for understanding Earth's **4.5 billion-year** history
- It helps scientists study how life has evolved in response to **changing environments** over long periods
  - The timescale is essential for understanding the history of the planet and the organisms that have lived on it

Role of fossils in evolution

- Fossils are the **preserved remains** or **traces** of ancient organisms
- They are important sources of evidence for understanding how life has changed over time
- By studying fossils, scientists can track the evolution of species and identify when different groups **first appeared** or **went extinct**
  - For example, the transition from fish to amphibians can be traced through fossil evidence, showing how certain traits evolved to adapt to land environments

Structure of the geological timescale

- The geological timescale is divided into **eons**, **eras**, **periods**, and **epochs**
- Each level represents significant stages in Earth's geology and life and changes in these time frames are marked by **major geological and biological events**

Eons

- There are four main eons in Earth's history:
  - **Hadean Eon** (4.5 to 4 billion years ago): The formation of Earth, with a molten surface and no life
  - **Archean Eon** (4 to 2.5 billion years ago): The appearance of the first simple life forms, such as bacteria
  - **Proterozoic Eon** (2.5 billion to 541 million years ago): Development of more complex life, including multicellular organisms
  - **Phanerozoic Eon** (541 million years ago to present): Marked by an abundance of fossils and the rapid evolution of life forms

Eras

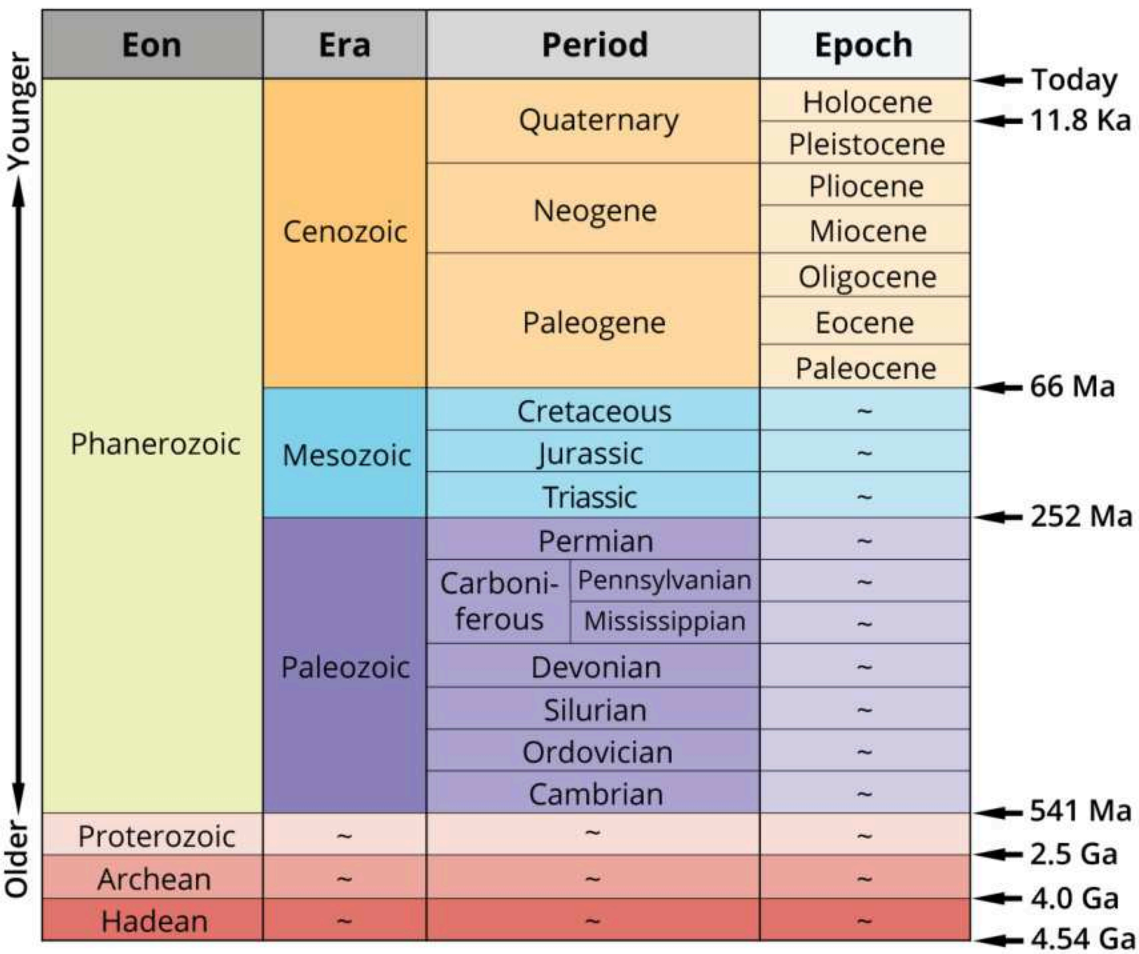
- The Phanerozoic Eon is divided into three eras:

Your notes

- **Paleozoic Era** (541 to 252 million years ago): Development of diverse marine life and the colonisation of land by plants and animals
- **The Mesozoic Era (252–66 million years ago),** also known as the age of reptiles, which included dinosaurs, was notable for its significant changes in flora and fauna
- **Cenozoic Era** (66 million years ago to present): The age of mammals and birds, leading to the rise of humans

Periods and Epochs

- Significant events further divide each era into periods and epochs:
  - For example, the **Cretaceous Period** (145 to 66 million years ago) ended with the mass extinction of dinosaurs
  - The **Pleistocene Epoch** (2.6 million to 11,700 years ago) saw the rise of ice ages and the evolution of modern humans



The geological timescale. Image by Jonathan R. Hendricks. CC BY-SA 4.0

Your notes

Major geological and biological events

- Changes in the geological timescale are often linked to major events
  - **Mass extinctions**: These events, such as the Permian-Triassic extinction (around 252 million years ago), greatly reduced biodiversity and allowed new species to evolve
  - **Environmental changes**: Shifts in climate, land formation, and ocean currents influenced how life adapted and evolved

Examiner Tips and Tricks

You don't need to memorise the names of every individual level or stage of the geological timescale. However, you should remember:

- The order of divisions in the geological timescale: eons > eras > periods > epochs
- These stages mark major geological and biological events that influenced the evolution of life on Earth

Your notes

Mass Extractions (HL)

Mass Extinctions

What is a mass extinction?

- Mass extinction is a widespread and rapid decrease in the diversity of life on Earth
  - It happens when a significant proportion of Earth's species die off in a **relatively short period of time**
  - At least **75% of species** are wiped out in a mass extinction event
- There have been **five major mass extinctions** in Earth's history
  - Each has significantly reshaped life on the planet

The five major mass extinctions

1. Ordovician–Silurian Extinction (approx. 444 million years ago)

- This was the first mass extinction
- It mainly affected marine life, as most species lived in the oceans at the time
  - Around **85% of marine species** became extinct
  - Possible causes include:
    - **Climate change** (glaciation and global cooling)
    - **Sea level drop**, which reduced habitat space for marine species

2. Late Devonian Extinction (approx. 375 million years ago)

- This event took place over millions of years and impacted marine ecosystems
  - **75% of all species** died out, including many species of corals and fish
  - Possible causes include:
    - **Volcanic activity**, leading to climate change
    - **Decreased oxygen levels** in oceans (hypoxia)

3. Permian–Triassic Extinction (approx. 252 million years ago)

- Known as the '**Great Dying**', it was the most severe mass extinction.

- **96% of marine species** and around **70% of land species** became extinct
- Possible causes include:
  - **Massive volcanic eruptions** in what is now Siberia
  - The volcanic activity released huge amounts of **carbon dioxide**, causing **global warming** and **ocean acidification**
  - Some scientists suggest this event was made worse by **methane gas** being released from melting ice

4. Triassic–Jurassic Extinction (approx. 201 million years ago)

- This extinction was followed by the dominance of **dinosaurs**
  - Around **80% of all species** died out
  - Possible causes include:
    - **Volcanic activity** linked to the breakup of the supercontinent **Pangaea**
    - Resulting **climate changes** and sea-level rises

5. Cretaceous–Paleogene Extinction (approx. 66 million years ago)

- This is the most famous mass extinction, known for the extinction of the **dinosaurs**
  - Around **75% of species** became extinct, including all non-avian dinosaurs, pterosaurs, and ammonites
  - Possible causes include:
    - A large **meteorite impact** in what is now the **Yucatán Peninsula** in Mexico (Chicxulub crater)
    - This caused fires, tsunamis, and dust clouds that blocked out sunlight, disrupting the climate
    - Massive volcanic activity in India, causing short-term global cooling and acid rain, may have contributed

What causes mass extinctions?

Tectonic plate movements

- Tectonic plates are large slabs of Earth's crust that move over time, reshaping continents and oceans
- When plates move, they can cause **habitat loss** by altering land masses and changing ecosystems.
  - **Formation of supercontinents** like **Pangaea** combined previously separated land masses, reducing coastal areas and shallow seas, which are rich in biodiversity
  - This led to widespread species loss, particularly in marine environments

Your notes

Your notes

- Plate movements can also trigger **volcanic activity** and earthquakes
  - These events can significantly impact life by destroying habitats and releasing gases into the atmosphere

Super-volcanic eruptions

- Super-volcanoes release massive amounts of **ash**, **lava**, and **gases** (such as sulphur dioxide and carbon dioxide) into the atmosphere
- This can block sunlight, leading to a temporary **cooling of the Earth** known as a 'volcanic winter'
  - The **reduced sunlight** can cause **plants** to die off, disrupting food chains and leading to the collapse of entire ecosystems
  - The **Siberian Traps** eruptions at the end of the Permian period released enough gases and ash to cause global temperatures to plummet and acidify the oceans

Climate changes

- Mass extinctions can be caused by both **global cooling** (ice ages) and **global warming** (greenhouse effects)
- Global cooling can reduce biodiversity by shrinking marine habitats and lowering temperatures beyond the tolerance of many species
  - The **Ordovician-Silurian extinction** was triggered by an ice age, which reduced shallow marine habitats
- **Global warming** can lead to increased temperatures, habitat destruction, and **ocean acidification**
  - Warming can cause polar ice caps to melt, raising sea levels and altering ecosystems

Sea-level changes

- **Fluctuating sea levels** can drastically reduce or expand habitats, particularly for marine species
- **Sea-level decline** can expose shallow seas and coastal habitats, reducing the space available for organisms that rely on these environments
  - This is particularly destructive to **coral reefs**, mangroves, and other coastal ecosystems, which are biodiversity hotspots
- **Sea-level rise** can flood terrestrial areas, displacing land species and altering ecosystems

Meteorite impact

- Large meteorites or asteroids crashing into Earth can cause massive destruction on a global scale
- Upon impact, meteorites create **shockwaves** and **fires**, but the more long-term damage comes from **dust and debris** thrown into the atmosphere

    - This debris can block sunlight for months or even years
    - This cools the planet and disrupts photosynthesis, leading to a breakdown of food chains

Rapid speciation after mass extinctions

- **Speciation** is the process by which new species evolve
    - After a mass extinction, many ecological **niches** become available due to the extinction of species
    - Surviving species often undergo **rapid evolution** to fill these empty niches
    - This is the reason why periods of **rapid speciation** frequently follow mass extinctions
        - For example, after the Cretaceous-Paleogene extinction, **mammals** diversified and evolved into many new species, leading to the eventual rise of humans

The sixth mass extinction (anthropogenic extinction)

- **Anthropogenic** means caused by humans
- Scientists believe a sixth mass extinction has begun, driven by human activities including:
    - **Habitat destruction**, such as deforestation and urbanisation
    - **Climate change** caused by burning fossil fuels is altering habitats and weather patterns
    - **Overfishing**, **hunting**, and **pollution** (e.g. plastic pollution, pesticides) are further threats to biodiversity

Examiner Tips and Tricks

Make sure you are able to explain how different factors (volcanic eruptions, sea-level changes, etc.) contribute to mass extinctions.

Your notes

The Anthropocene (HL)

Your notes

The Anthropocene

What is the Anthropocene?

- The Anthropocene is a **proposed geological epoch**
  - Scientists have suggested that **humans** have become a **dominant force** shaping the Earth's environment and climate
- The Anthropocene is not yet an officially recognised epoch
  - However, it still highlights the extent to which **human activities**, like industrialisation, deforestation, and urbanisation, are driving:
    - **Rapid environmental change**
    - **Species extinction**
- Human impacts are so significant that they are leaving **permanent records** on Earth's **geology**, **atmosphere**, and **ecosystems**

Debate over the Anthropocene

- There is **debate** among scientists about whether the Anthropocene should be considered separate from the current **Holocene** epoch, which began around 11,700 years ago after the last Ice Age
  - Some scientists argue that human impacts are significant enough to define a new epoch
  - Others believe these changes (e.g. in climate) are part of the **natural variability** of the Holocene
- The **starting point** of the Anthropocene is also debated, with different proposals for when it began

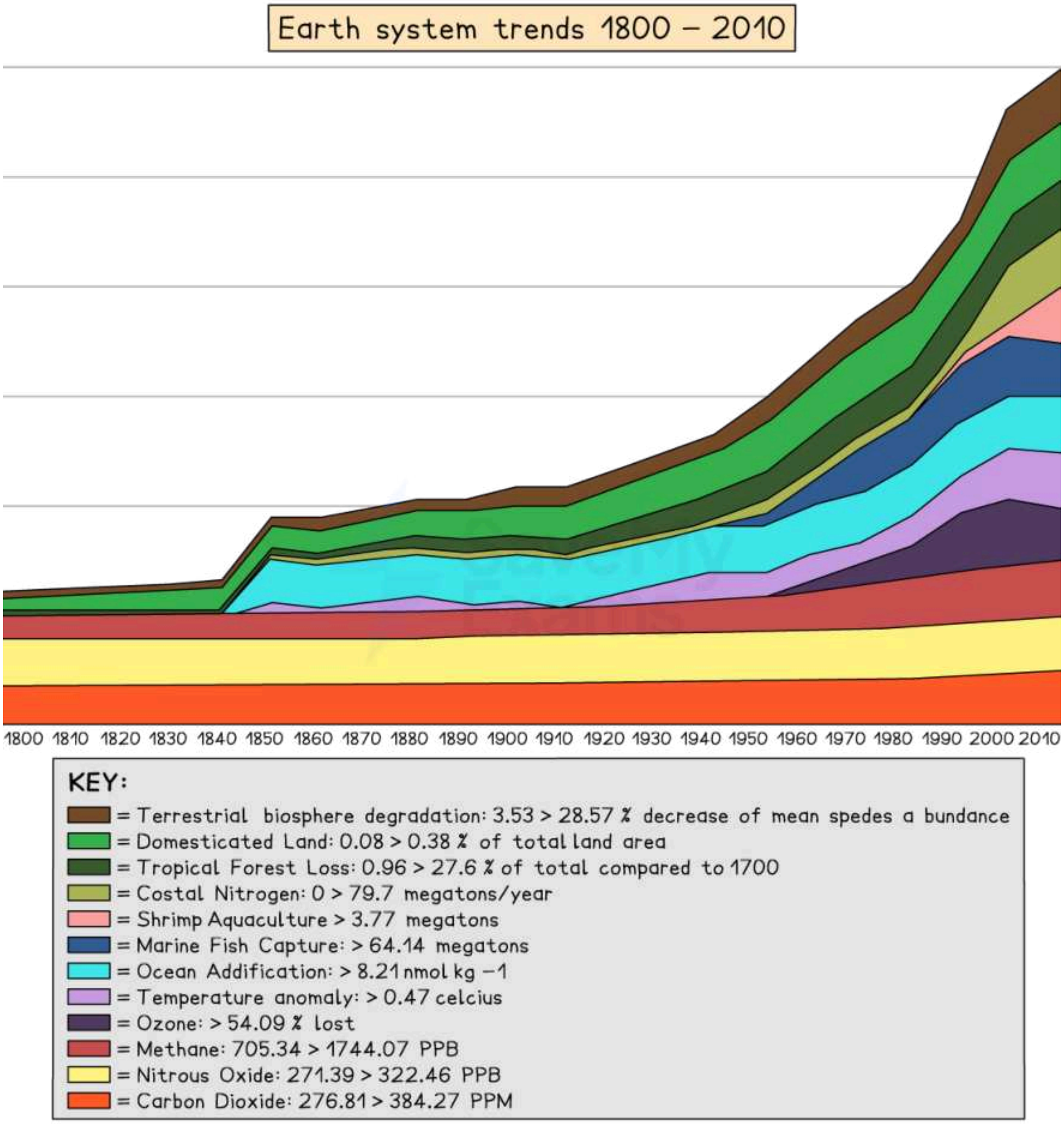
Proposed start dates for the Anthropocene

- **1610 carbon dioxide dip**:
  - One proposed marker is a dip in carbon dioxide levels around 1610, following the arrival of Europeans in the Americas
  - This drop in CO_2 is believed to be caused by the **decline of Indigenous populations** due to European diseases, warfare, and slavery, which led to the **reforestation** of previously farmed lands in the Americas
  - These new forests **absorbed more CO_2**, leading to a detectable drop in the atmosphere

Your notes

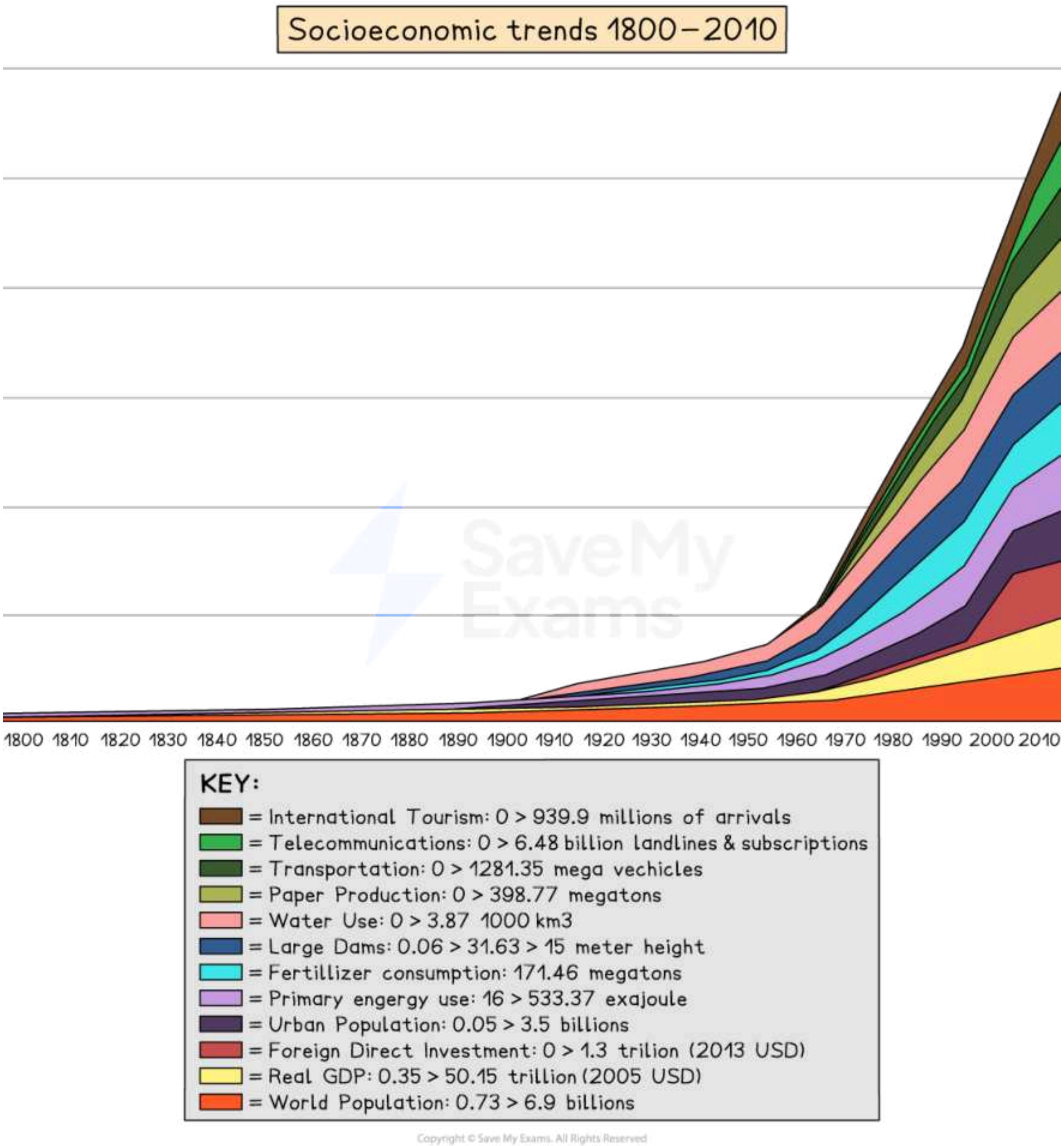
- This is sometimes referred to as the **"Orbis spike"** and is considered one potential starting point for the Anthropocene
- **1950 spherical fly ash particles**:
  - Another suggested marker is the appearance of spherical fly ash particles in the geological record, beginning around 1950
  - These particles were created by the **burning of fossil fuels** in coal-fired power plants
  - The particles have since spread globally, leaving a clear, human-made trace in the Earth's sediments
  - The 1950s also saw the beginning of the **"Great Acceleration"**, when human impacts on the environment, such as pollution and greenhouse gas emissions, increased dramatically
- **1964 carbon-14 markers**:
  - The 1964 spike in carbon-14 in the atmosphere, caused by **nuclear weapons testing**, is another potential marker
  - Nuclear tests, particularly those conducted during the Cold War, released radioactive isotopes like carbon-14 into the atmosphere
  - These isotopes settled into the Earth’s soils and sediments, creating a distinct signal in the geological record

Your notes



Earth system trends of the "Great Acceleration" of the Anthropocene from 1800 to 2010

Your notes



Socioeconomic trends of the "Great Acceleration" of the Anthropocene from 1800 to 2010

Human impact on the planetary scale

- Human activity is having a **planetary effect** on Earth's environment
  - This effect will be detectable in the geological record for millions of years.

- This means future geologists could look at Earth's layers and see clear evidence of our presence (a bit like how we study fossil records to understand ancient life forms)

Further evidence for the Anthropocene

1. **Chemical pollution accumulating in geological strata**:
   - Human-made chemicals, such as plastics, pesticides, and industrial waste, are accumulating in soils and sediments around the world
   - **Microplastics** are a clear example of human pollution that will be preserved in the Earth's strata far into the future
2. **Mixing of native and non-native species**:
   - Human activities have led to the mixing of native and non-native species through processes like **global trade** and **introduction of invasive species**
   - Species that do not naturally interact now share ecosystems
   - In the future, this mixing will be evident in the fossil record
3. **Modification of terrestrial and marine sedimentary systems**:
   - Human activities, such as **agriculture**, **deforestation**, and **urbanisation**, are altering Earth's natural sedimentary systems
   - These changes lead to:
     - **Increased soil erosion** (large-scale agriculture and deforestation often leads to soil erosion, where topsoil is worn away by wind or water)
     - **Changes to river flows and coastal ecosystems** (building cities and roads changes the natural landscape, blocking rivers and coastlines, which affects sediment flow and can lead to unnatural sediment build-up in some areas and erosion in others)
4. **Minerals created by human activity**:
   - Humans are creating new types of **minerals** and **materials** that do not exist naturally
     - E.g. **concrete**, **plastics**, and **metal alloys**
   - These human-made materials will persist in the geological record for millions of years, providing clear evidence of our influence on the planet

Examiner Tips and Tricks

Your notes

Be careful—some students confuse the Holocene with the Anthropocene. Be sure to differentiate between the two, with the Anthropocene being marked by human impacts.

Make sure you can discuss various types of evidence for these human impacts and how these will be preserved in the geological record.

Your notes