Edexcel International A Level (IAL) Biology

Your notes

Environmental Biology

Contents

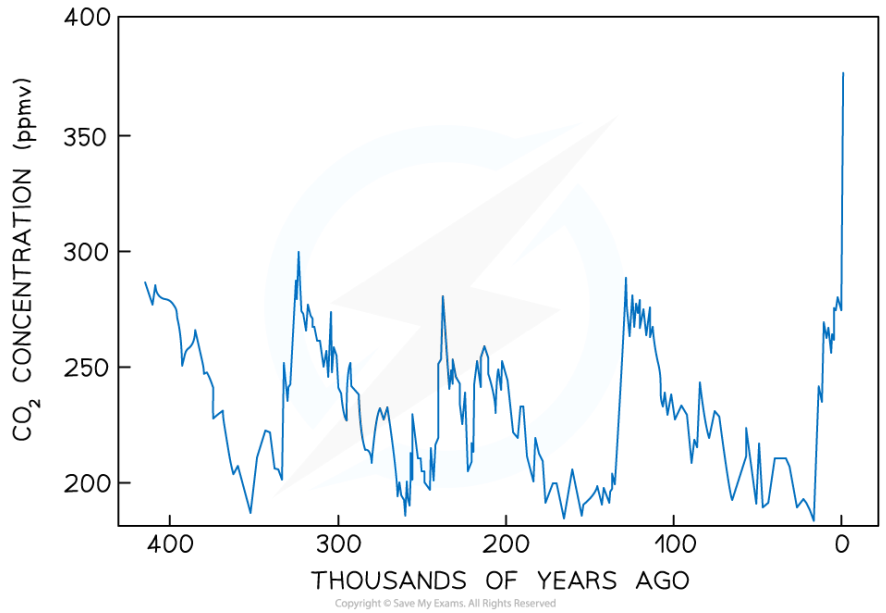
Your notes

Evidence for Climate Change

- The term **climate** refers to the **weather conditions** in a region over a **long period of time** i.e. several decades
- When the weather conditions in a region change significantly over a long period of time, this is **climate change**
  - The term climate change is most often used today to refer to **global warming** that is occurring as a result of human activities
- Scientists have long hypothesised that
  - Climate change in the form of **global warming is currently taking place**
  - **Human activities** that increase the concentrations of greenhouse gases in the atmosphere are **responsible for climate change**
- Several different types of evidence can be used to support these hypotheses
  - Records of **atmospheric carbon dioxide** levels
  - Records of **average global temperatures**
  - Records of changing plant communities gained from sampling of **pollen grains preserved in peat** over time
  - Records of **tree growth** gained by analysing the rings in the trunks of trees; known as **dendrochronology**

Atmospheric carbon dioxide

- Atmospheric carbon dioxide levels have **fluctuated throughout Earth's history** due to events such as volcanic eruptions and the weathering of limestone rocks
  - Scientists know this from having analysed the gas composition of **bubbles formed in ancient ice cores**
    - Ice is deposited as water freezes over time, so the deeper into the ice you go, the older it is
- Since the **industrial revolution**, however, atmospheric carbon dioxide levels have **risen to their highest in Earth's history**
  - Prior to the industrial revolution, the highest atmospheric carbon dioxide concentration was around 300 parts per million (ppm), and it is currently above 400 ppm



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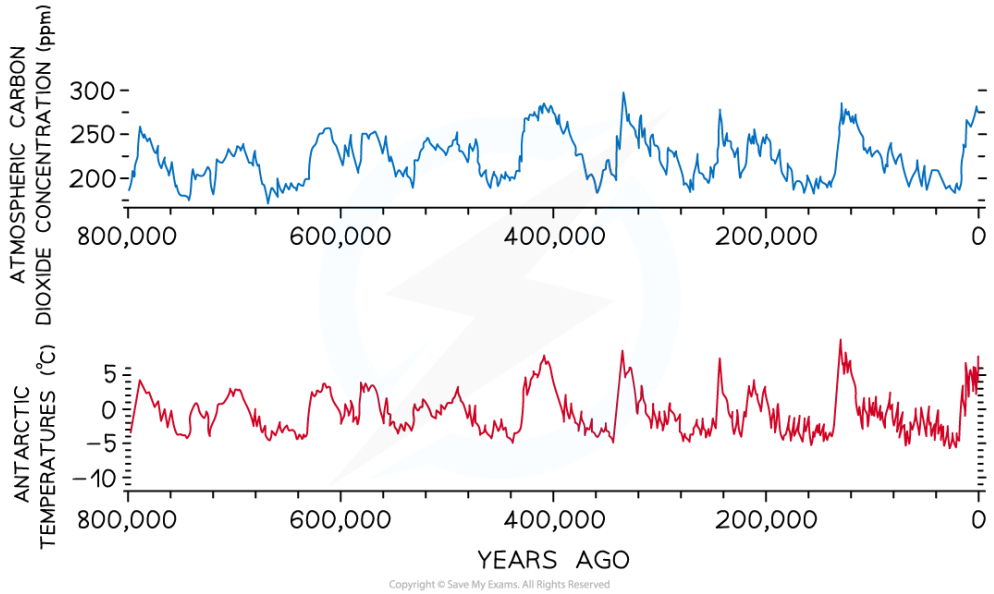
Atmospheric carbon dioxide levels have fluctuated throughout earth's history, but recent increases have been faster and greater than ever before

- Data show a **correlation** between changing atmospheric carbon dioxide levels and temperature over thousands of years
  - Note that carbon dioxide in the atmosphere is not thought to be the only factor affecting climate; it is known that events such as solar winds and sun spots can affect the climate on Earth, but scientists think that the effects of such events are small in comparison to that of atmospheric carbon dioxide
- **Correlation does not equal causation**, but together with what scientists know about carbon dioxide as a greenhouse gas, this is **strong evidence** that **carbon dioxide released by human activities since the industrial revolution is causing increasing global temperatures**



There is a correlation between atmospheric carbon dioxide concentrations and average antarctic temperatures over time

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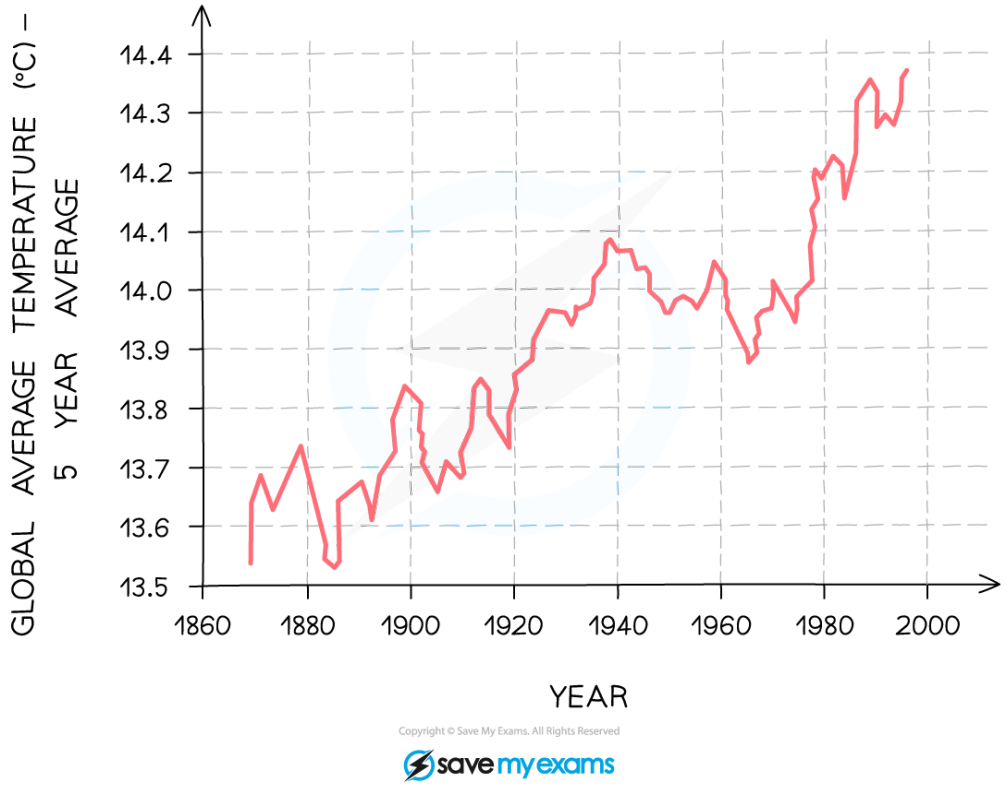
Average global temperatures

- **Thermometers** can be used to measure air temperature, and thermometer records from **different places** around the world over **extended periods** of time can be put together to show **average global temperature change over time**
- Records from the mid-1800s show an overall **trend of increasing average global temperatures**
  - There are some short time periods within this window during which temperatures have declined, but the overall trend is upwards
- The time period since the mid-1800s **corresponds with the time during which humans have been burning fossil fuels** and therefore releasing carbon dioxide into the atmosphere



Average global temperature records show some temperature fluctuations but an overall trend of increasing temperatures over time

Pollen grains preserved in peat bogs

- Under waterlogged and acidic conditions partly decomposed **dead plant matter accumulates** and becomes **compacted** under its own weight over time; this compacted, partially decomposed plant matter forms **peat**

- The place where peat accumulates is known as a **peat bog**, or **peatland**

- Peat **builds up in layers**, meaning that layers of peat at the top of a bog are recently formed and the **peat become older as you dig down** into a bog
- **Peat cores** can be taken from a bog and the **layers can be analysed** to assess the pollen grains that have become trapped in the peat
- Pollen grains from peat samples can be observed under a microscope, and because the pollen grains of each plant species are unique to that plant, the **plant species that were growing around the bog at different points in time can be identified**
- Different plant species grow under different climatic conditions, so the **plants present at different times** can be used a **measure of the climate at that time**
    - E.g. an increase in the number of plant species that grow better in warmer climates combined with a decrease in the number of plant species that grow better in cooler climates **indicates a gradual warming of the climate**

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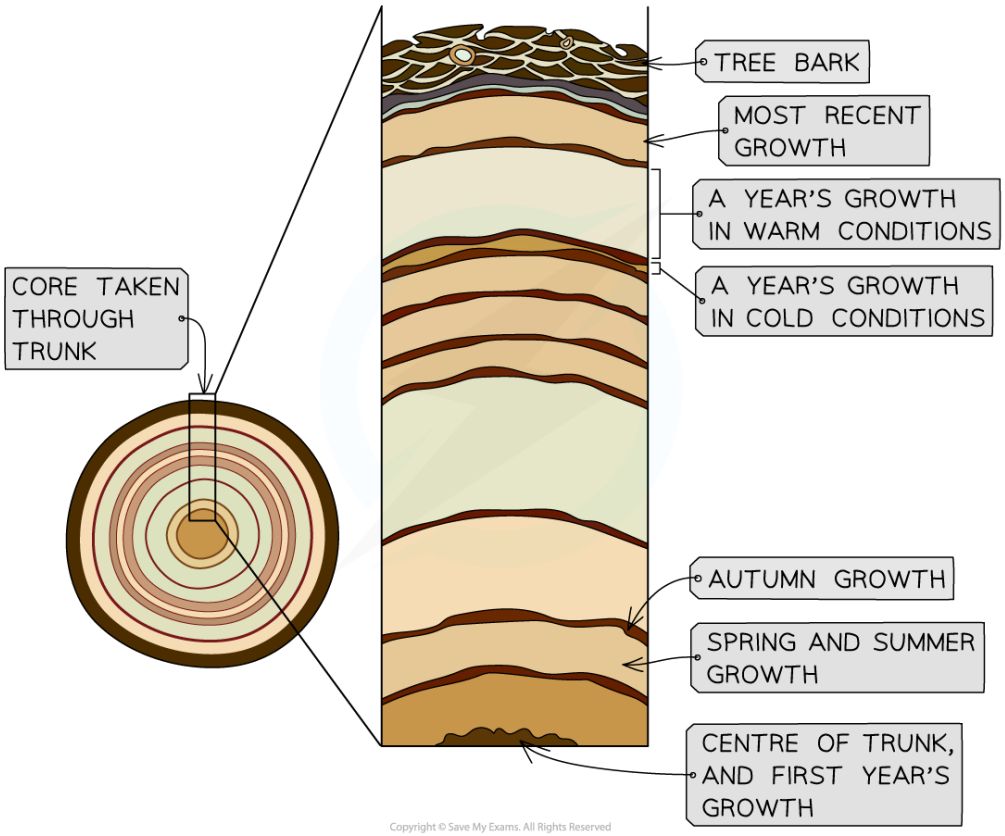
Dendrochronology

- Tree trunks **grow in diameter** each growing season as they produce more vascular tissue
- This vascular tissue grows in a **ring** around the outside of the trunk
- **Light coloured rings** are produced by fast growth during **warmer spring and summer months** and **dark coloured rings** form as a result of **slow autumn growth**, meaning that one light ring and one dark ring together represent a full year's growth in a tree
- Trees grow faster when conditions are warmer, so the **rings that form during warm years are wider** than the rings that form during cool years
- Analysis of the width of tree rings can provide a **measure of climate during each year of growth**
    - Taking cores from the trunks of older trees can provide samples that go back over hundreds of years



Dendrochronology uses the growth in a tree trunk each year as a measure of climate

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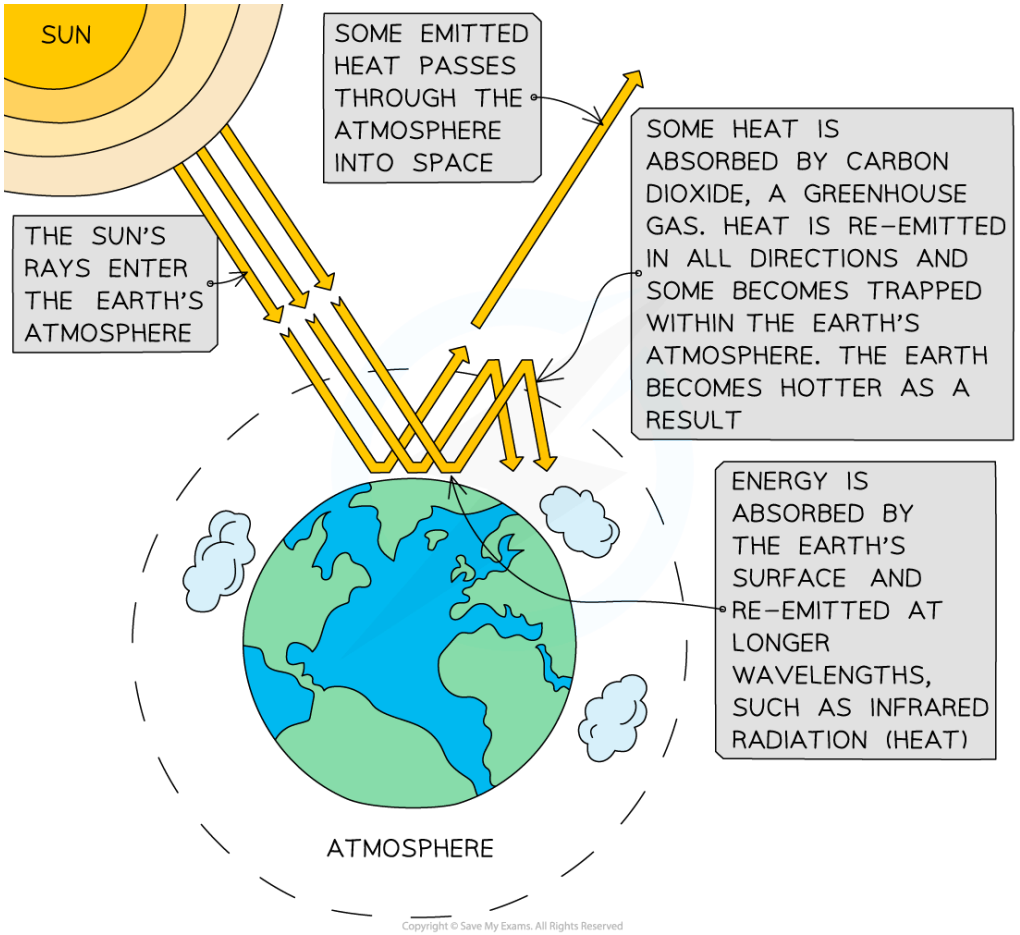
Anthropogenic Climate Change

- When **radiation from the sun** hits the earth, it is **radiated back** from the earth's surface
- A **greenhouse gas** is a gas that **absorbs** this re-radiated radiation, **trapping it in the earth's atmosphere** so that it is not lost to space
  - Greenhouse gases in the atmosphere have a similar effect to the glass in a **greenhouse**, hence the term **greenhouse gas**, and their effect being known as the **greenhouse effect**
- The greenhouse effect is important to ensure that Earth is **warm enough for life**; if it were not for the insulating effect of greenhouse gases, Earth would see similar dramatic **temperature fluctuations** to its neighbouring planets
  - Temperatures on Mars range between 20°C and –153°C
- There are many greenhouse gases including
  - **Carbon dioxide**
  - **Methane**
- It is thought that increasing levels of carbon dioxide and methane are entering the atmosphere **as a result of human activities**, leading to increased rates of atmospheric warming
  - The atmospheric warming, and therefore the changing climate, for which humans are thought to be responsible is known as **anthropogenic climate change**



Greenhouse gases absorb radiation re-emitted from the earth's surface, trapping it in the atmosphere

Carbon Dioxide

- Atmospheric carbon dioxide levels have **fluctuated throughout Earth's history** due to events such as volcanic eruptions and the weathering of limestone rocks
- Since the **industrial revolution**, however, atmospheric carbon dioxide levels have **risen to their highest in Earth's history**
- The industrial revolution began in the late 1700s when the **combustion of fossil fuels** to power **factories, transport**, and **homes** became commonplace
  - Fossil fuel combustion releases **carbon dioxide**
- A clear correlation can be seen between increasing **levels of carbon dioxide since the industrial revolution** and **increasing global temperatures**, providing evidence for the role of human activities in causing global warming
  - Note that a **correlation alone is not enough to prove causation**, but this evidence can be taken alongside what we know about greenhouse gases and other evidence to provide a growing body of proof

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- In addition to the burning of fossil fuels, carbon dioxide is also released into the atmosphere when **natural stores of carbon are damaged or destroyed** by human activities
  - These carbon stores are known as **carbon sinks**
  - Carbon sinks include trees, soils, peat bogs, and the oceans
    - Deforestation, soil degradation, peat harvesting, and ocean warming all contribute to the addition of carbon dioxide to the atmosphere


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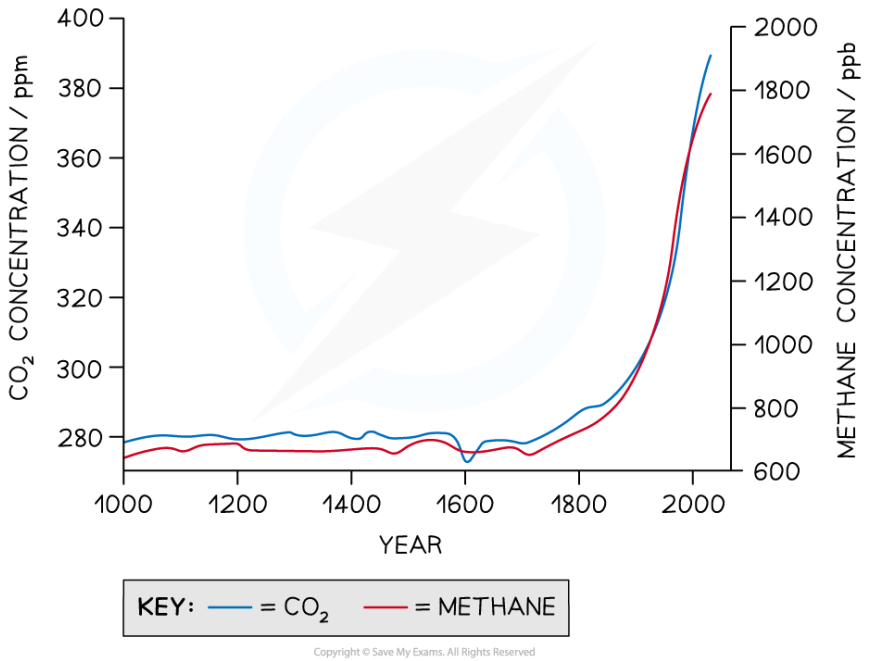
Methane

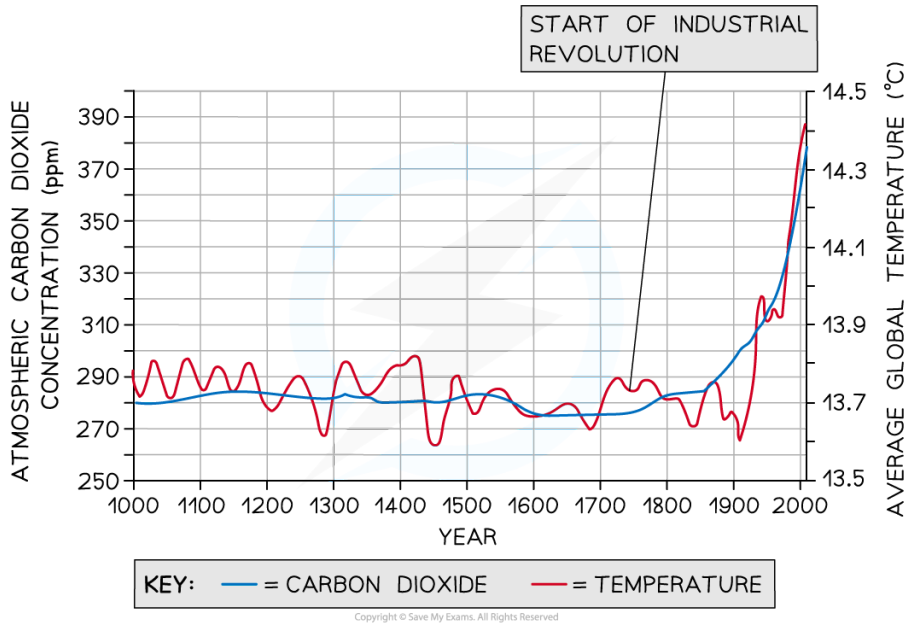
- **Methane** (CH_4) is a simple **hydrocarbon**
- It is present as a **gas** in the atmosphere, and underground, and is the main component of **natural gas** fossil fuel
- Methane can be produced by **naturally occurring processes** in some types of bacteria, but levels have risen significantly in the last 150 years due to human activities
- Methane can be produced by several human activities
  - Methane is released from the **guts of ruminant mammals** such as cattle
    - While this is clearly not a direct human activity(!) the intensive farming of such animals has greatly increased their contribution to atmospheric methane
  - **Landfill sites** release methane when organic matter such as food waste decomposes
  - **Extraction of fossil fuels from underground** releases methane
  - Anaerobic bacteria in waterlogged **rice paddy fields** release methane
- In addition to the list above, the warming of the poles that results from global warming also leads to the **release of methane from natural stores** such as permafrost
  - Permafrost is ground that remains frozen all year round



Atmospheric concentrations of both carbon dioxide and methane have increased since the industrial revolution due to human activities. Note that ppm = parts per million and ppb = parts per billion.

Worked Example

The graph below shows changes in average global temperatures and atmospheric carbon dioxide concentrations since the year 1000; describe the data and explain what can be concluded from the graph



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Answer:

- **Descriptions** of data must include any **trends**, as well as any sections of **data that don't fit with the trend**
  - Descriptions of data should also include **numbers to support the description**
  - Be careful that any **conclusions** reached are taken **directly from the data** and **do not go beyond** what the data show

Step 1: Describe the data

Atmospheric carbon dioxide levels and average global temperatures have both increased since the year 1000

Atmospheric carbon dioxide concentration has increased from around 280 ppm to around 380 ppm

Average global temperatures have increased from around 13.8 °C to around 14.4 °C

Average global temperatures have fluctuated, showing periods of decrease e.g. during the 1400s and periods of increase e.g. during the early 1700s

Atmospheric carbon dioxide levels and average global temperatures were both reasonably constant between the years 1000 and the mid-1800s/1900, and then both show a steep increase between 1900 and 2000

Step 2: State what can be concluded

There is a correlation between atmospheric carbon dioxide concentration and average global temperature

Both atmospheric carbon dioxide concentration and average global temperature increase from the industrial revolution onward

Average global temperatures fluctuate at times when atmospheric carbon dioxide concentrations are relatively constant

Note that you cannot conclude a causal relationship from this data alone; in fact the fluctuations in temperature when carbon dioxide levels are constant suggest that there are other factors involved

Examiner Tips and Tricks

Note that the greenhouse effect, global warming and climate change are terms that are often used interchangeably, but in fact they have slightly different meanings:

- **Global warming** refers to the rise in global temperatures mainly due to the increasing concentrations of greenhouse gases in the atmosphere.
- **Climate change** refers to the increasing changes in the measures of climate over a long period of time – including precipitation, temperature, and wind patterns. These are often a consequence of global warming.

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- **The greenhouse effect** is a naturally occurring event, constantly occurring due to the atmosphere and sunlight.

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The Carbon Cycle

- The atmospheric carbon dioxide that contributes to the greenhouse effect is part of the global carbon cycle
- The term **carbon cycle** refers to the many processes by which carbon is transferred and stored, e.g.
  - Carbon is found in the biomass of living organisms e.g. in **carbohydrates** and **proteins**
  - Carbon is transferred when one organism **consumes and digests** another
  - Carbon is found in the **atmosphere** as **carbon dioxide** and in the **oceans** as e.g. **hydrogen carbonate ions**

The carbon cycle

- The following events occur during the carbon cycle
  - Carbon is present in the **atmosphere** in the form of **carbon dioxide**
  - Carbon dioxide is removed from the atmosphere by **producers** during **photosynthesis**
    - Producers incorporate carbon into their biomass in the form of **carbohydrates** and other biological molecules
  - Carbon is transferred to and between consumers as a result of **feeding**
  - Carbon is transferred back into the atmosphere by both plants and animals as a result of **respiration**
    - Respiration releases carbon dioxide as a product
  - Carbon dioxide can also be removed from the atmosphere by **dissolving in the oceans**
  - **Dissolved carbon** can be taken in by marine plants when they **photosynthesise** or by other marine organisms as they **build calcium carbonate exoskeletons**
  - When living organisms die their tissues are broken down by **decomposers** such as bacteria and fungi
    - When these organisms **respire**, they too **release carbon dioxide** back into the atmosphere
  - Any living tissue that is not fully decomposed can go towards the **formation of peat or fossil fuels** over millions of years; carbon can be stored in these **sinks** for long periods
  - The **combustion** of peat and fossil fuels releases carbon dioxide back into the atmosphere

- The combustion of biomass such as wood also returns carbon to the atmosphere

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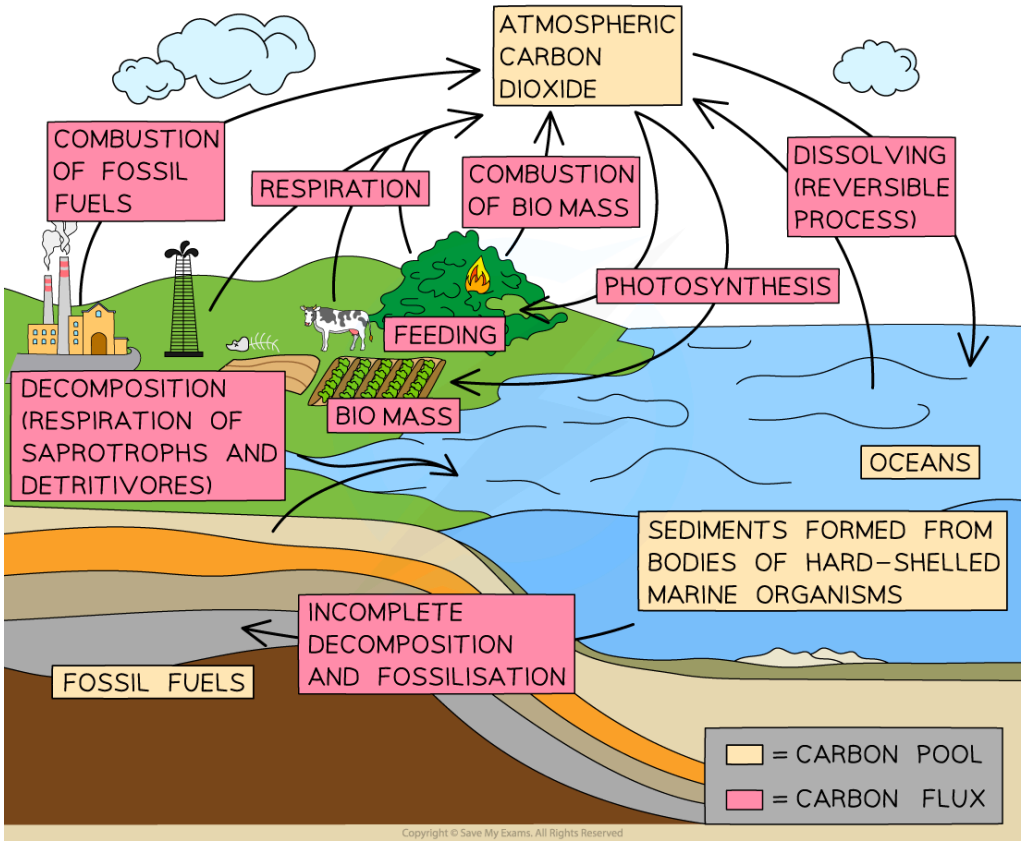

The carbon cycle includes the locations in which carbon is stored, shown here as 'carbon pools', and the processes by which it is transferred, shown here as 'carbon fluxes'

Carbon Cycle & Environmental Management

- A good understanding of the carbon cycle is essential in the fight against global warming
  - It is possible to see the points at which carbon enters the atmosphere; **reducing the carbon transfer** at these points will prevent further increases in atmospheric carbon dioxide e.g.
    - Reducing the **combustion of fossil fuels**
    - Reducing the **combustion of biomass**
    - Reducing **disturbance of carbon pools** such as soils and peat bogs
  - We can also see the points at which carbon is removed from the atmosphere; **increasing the transfers** here could help to reduce the greenhouse effect e.g.
    - Increasing **rates of photosynthesis** by planting trees

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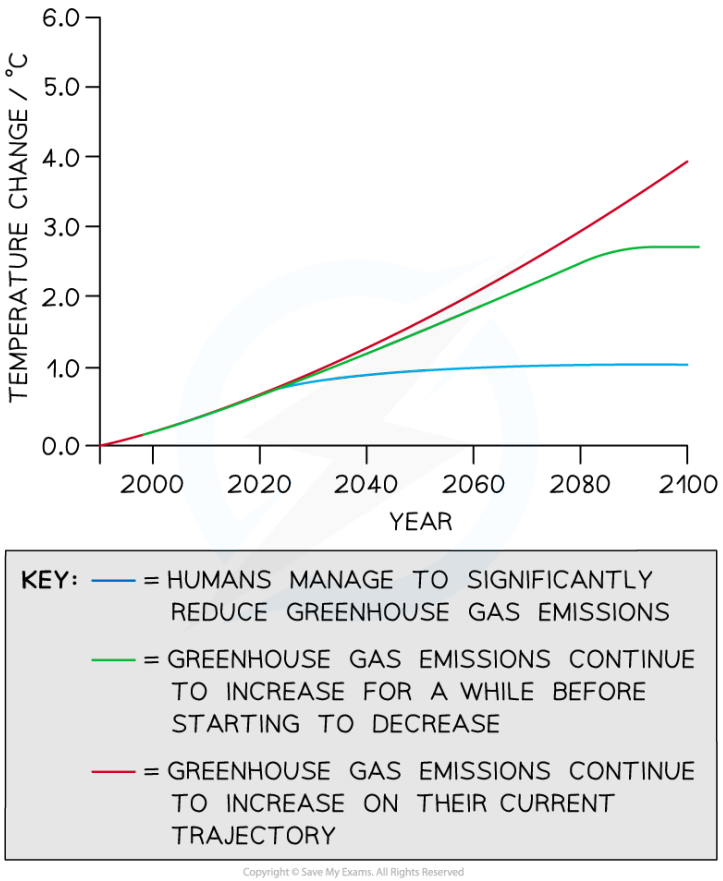
Models for Predicting Climate Change

- It is possible to use existing data relating to global warming to **make predictions about global temperatures** in the future
  - Using data in this way is known as **extrapolating from data**
  - Extrapolated data can be used to **produce models** that show how the climate may change in the future
- Global warming predictions can be used to
  - **Plan** for the future e.g.
    - Building flood defences
    - Funding scientific research into climate change technologies
  - Encourage people to **change their activities** e.g.
    - Reduce the burning of fossil fuels
    - Increase the use of renewable energy sources such as solar and wind energy
    - Reduce meat consumption
- The Intergovernmental Panel on Climate Change, or IPCC, is a group of climate scientists around the world that has used existing data to **extrapolate** how global temperatures might change in the future under **different human activity scenarios** e.g.
  - If humans manage to immediately begin reducing fossil fuel use, global temperature change could be limited to around 2°C hotter than pre-industrial times
  - If humans do nothing to change their fossil fuel use, global temperature increase may exceed 4°C
- The IPCC data can be added to other computer models on climate change to see how different parts of the world might be affected under the different scenarios



Future predictions of temperature change can be modelled on a range of scenarios

Limitations of Climate Change Prediction Models

- There are **limitations to models based on extrapolated data**
  - The IPCC has produced models based on several emissions scenarios, and we **do not know which of these scenarios is most likely**
    - I.e. we don't know how successful humans will be at cutting greenhouse gas emissions
  - We do not know whether **future technologies** will be successful at removing greenhouse gases from the atmosphere e.g. carbon capture technologies may or may not be effective
  - It is unknown **exactly how** atmospheric gas concentrations might affect global temperatures
  - Global **climate patterns are complex** and therefore predictions are difficult
    - It is possible that a certain **tipping point** in global temperatures could lead to a sudden acceleration in global warming e.g. permafrost melting may cause a sudden increase in atmospheric methane

Your notes

- Permafrost is ground that is frozen all year round

- We don't know exactly how **factors other than human activities** may affect climate in the future e.g. a volcanic eruption could increase ash in the atmosphere, reflecting radiation back into space and cooling the earth

Your notes

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How Climate Change Affects Species

- **Greenhouse gases** absorb infrared radiation emitted by the earth, causing the atmosphere to warm
- The **higher the concentration** of greenhouse gases in the atmosphere, the **more infrared radiation is absorbed**, and the **warmer the atmosphere** will become
- Increased atmospheric warming has had, and will have, multiple **impacts on climate patterns,** e.g.
  - **Weather events becoming more extreme** e.g. hotter, longer, heatwaves, and more violent storms
  - **Changes to ocean currents** leading to altered local climates e.g. the Gulf stream that currently brings warm water to the west coast of the UK might change direction, causing parts of the UK's climate to cool
  - Warmer air can hold more moisture, leading to **changes in patterns of rainfall**; more, heavier rainfall in some places could lead to reduced rainfall in other locations
- **Evidence** for some of these changes in climate patterns **can already be seen** in many parts of the world
  - Warming climates cause animals to **move towards the poles** or to **higher altitudes**
    - A concern is that these species may not be able to compete with, or may even out-compete, the species already present in these habitats, with either result leading to **decreased biodiversity**
    - Some species, such as plant species, may not be able to move or change their distribution fast enough to adapt to changing temperatures and may **become extinct** as a result
  - **Water availability** in some habitats is changing
    - Changes to rainfall patterns can be devastating to species that **rely on seasonal rains** for their survival e.g. some desert plants rely on rains that may come only once a year and climate change may mean that such seasonal events occur less frequently or stop altogether
    - Some species may **no longer be able to survive** in their habitat due to a lack of rainfall; such species may migrate to a new habitat or may become extinct
  - **Seasonal cycles** are changing e.g.
    - Plant species are producing flowers earlier in the year
    - Animals are producing young earlier in the year
    - Bird migratory patterns may lose their synchronisation with their habitats, leading to a change in migration patterns

- E.g. earlier plant growth leads to alterations in invertebrate life cycles, meaning that when a bird species arrives for its summer migration their usual food source is not available

- **Polar ice** and **glaciers are retreating**; it is thought that there may soon be no summer ice in the arctic if rates of warming there continue
  - The loss of glacier ice from mountain ranges may affect the water supplies of many people and surrounding wildlife
- **Sea levels have been rising** faster in recent years, putting many more people and animals at risk of being flooded out of their homes
  - Sea levels are rising due to the expansion of warmer water and due to melting polar ice

Your notes

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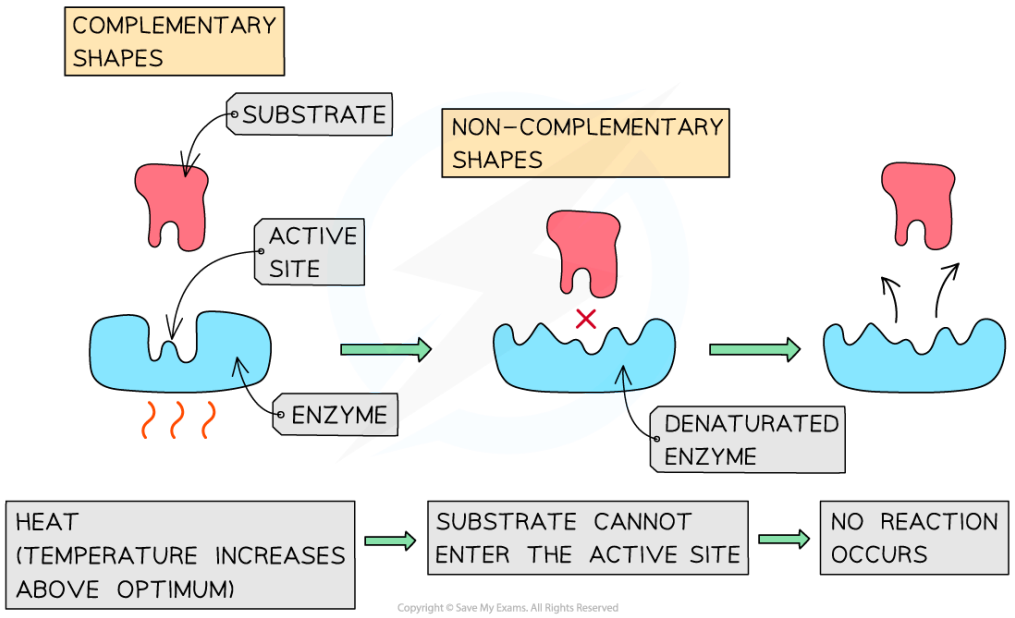
The Effect of Temperature on Enzyme Reactions

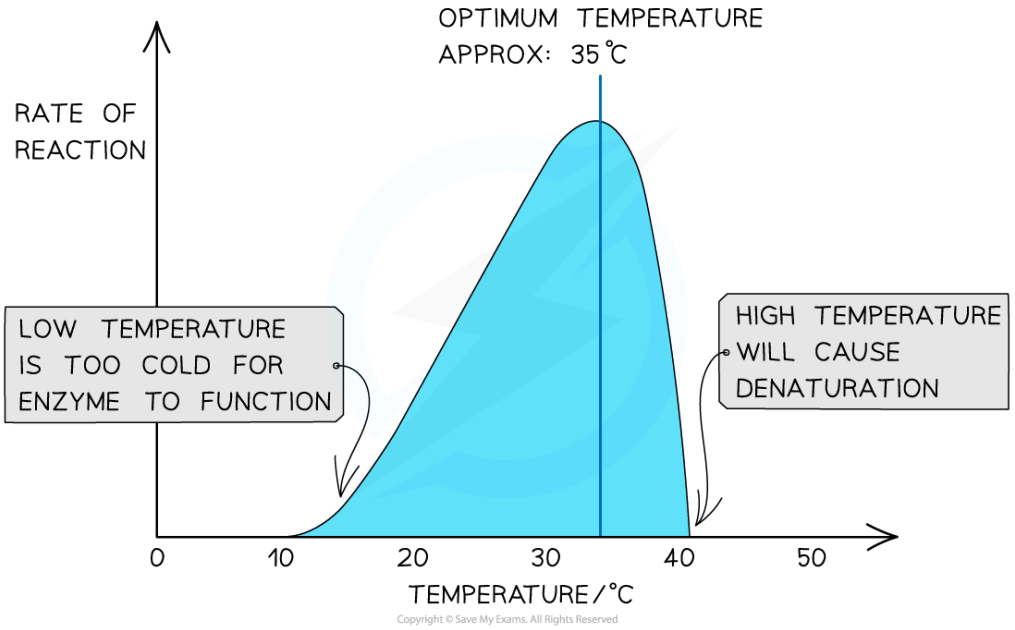
- Changing air temperature can have a **significant impact on the** metabolism of living organisms due to the effect of **temperature on enzyme activity**
- Enzymes have a specific **optimum temperature**
  - This is the temperature at which they catalyse a reaction at the **maximum rate**
- **Lower temperatures** either **prevent** reactions from proceeding or **slow them down**
  - Molecules move relatively **slowly** as they have **less** kinetic energy
  - Less kinetic energy results in a **lower frequency** of **successful collisions** between substrate molecules and the active sites of the enzymes which leads to less frequent **enzyme-substrate complex** formation
  - Substrates and enzymes also collide with **less energy**, making it less likely for bonds to be formed or broken
- **Higher temperatures** cause **reactions** to **speed up**
  - Molecules move **more quickly** as they have **more kinetic energy**
  - Increased kinetic energy results in a **higher frequency** of **successful collisions** between substrate molecules and the active sites of the enzymes which leads to more frequent **enzyme-substrate complex** formation
  - Substrates and enzymes also collide with **more energy**, making it more likely for bonds to be formed or broken

Denaturation

- If temperatures continue to increase **past a certain point**, the rate at which an enzyme catalyses a reaction **drops sharply** as the enzymes begin to **denature**
  - The increased **kinetic energy** and **vibration** of an enzyme puts a **strain** on its bonds, eventually causing the **weaker hydrogen and ionic bonds** that hold the enzyme molecule in its **precise shape** to start to **break**
  - The breaking of bonds causes the tertiary structure of the enzyme to **change**
  - The **active site** is **permanently damaged** and its shape is no longer **complementary to the substrate**, preventing the **substrate** from **binding**
  - **Denaturation** has occurred if the substrate can no longer bind



At high temperatures enzymes can denature



The rate of an enzyme catalysed reaction is affected by temperature. Note that 35 °C is not the optimum temperature for all enzyme-controlled reactions.

Calculating the temperature coefficient

- The **temperature coefficient**, represented by Q_{10}, calculates the increase in rate of reaction when the temperature is increased by 10 °C
- Q_{10} can be calculated using the following equation

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Q_{10} = rate at higher temperature ÷ rate at lower temperature

- A Q_{10} value of 2 indicates that the reaction rate doubles with an increase in temperature of 10 °C, while a value of 3 indicates that it trebles with every 10 °C increase

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Worked Example

In an enzyme catalysed reaction the rate of reaction can measured by recording the volume of product produced per unit time at different temperatures.

At 30 °C 3.5 cm^3 s^{-1} of product was recorded and at 40 °C 6.8 cm^3 s^{-1} was recorded. Calculate Q_{10} for this reaction.

Answer:

Step 1: Write out the relevant equation

Q_{10} = rate at higher temperature ÷ rate at lower temperature

Step 2: Substitute numbers into the equation

$Q_{10} = 6.8 \div 3.5$

Step 3: Complete calculation

$Q_{10} = 1.94$

This value is close to 2, indicating that the rate of reaction has almost doubled

Enzyme activity and living organisms

- Changes to enzyme activity that result from changing global temperatures can affect living organisms
- Some chemical reactions take place **faster at higher temperatures**
  - Photosynthesis is essential for **converting carbon dioxide into carbohydrates,** the process which **produces food for producers and other organisms** higher up the food chain; it relies on the function of proteins in the electron transport chain and that of **enzymes** such as rubisco
    - E.g. blue-green algae, also known as cyanobacteria, photosynthesise at a higher rate in warmer water due to increased enzyme activity; this increases the formation of potentially harmful algal blooms
- Some chemical reactions are **slowed down** at higher temperatures
  - At high temperatures plants carry out a reaction called **photorespiration** at a faster rate; this reaction uses the enzyme rubisco and so **slows down photosynthesis**
    - This can **reduce crop yields** as temperatures rise
  - Some fish eggs have been shown to develop **more slowly at higher temperatures**

- Many species' successful egg development is dependent on temperature, with impacts such as
  - Extreme temperature fluctuations can **reduce hatching rates** in some invertebrates
- The sex of the young inside the egg of some species is determined by temperature, so **increasing temperatures can affect the sex ratios** in a species
  - E.g. in alligators
- Species may have to change their distribution in response to changing temperatures in order to survive
  - Species may **migrate to higher altitudes** or **further from the equator** to find cooler temperatures

Your notes

Your notes

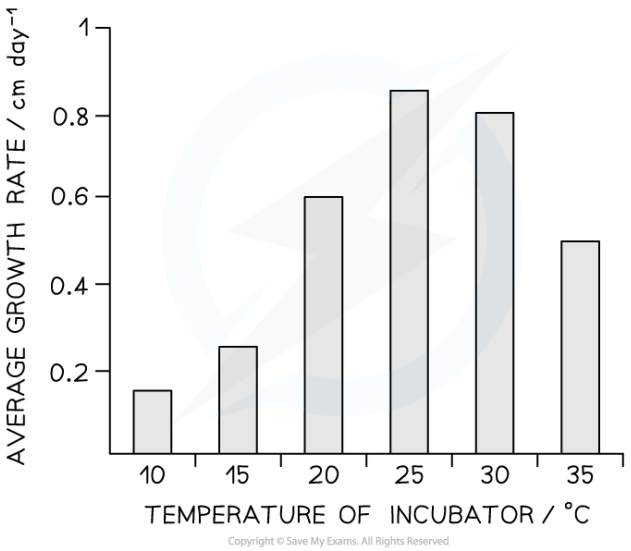
Effect of Temperature on Development

- Evidence from the natural world indicates that **global warming affects the development of living organisms**
- It is possible to investigate the effect of temperature change on development in the laboratory
  - This enables the **elimination of other factors** that might influence development e.g. light intensity or food availability
- It is possible to investigate the effect of temperature on
  - Seedling growth rate
  - Rate of hatching in brine shrimps

Temperature and seedling growth rate

1. Plant seeds of the same plant variety in several pots or trays of compost
   - Ensure that all seeds are kept in **identical conditions** at this stage
2. Allow the seeds to germinate and produce some initial days of growth
3. Measure the initial height of every seedling
4. Place each pot or tray into an incubator at a different temperature for the same amount of time e.g. 5 days
   - During this time ensure that **all factors other than temperature are kept the same** e.g. soil moisture, soil pH, light intensity
5. After the allotted time remove the seedlings from the incubators and record the final height of every seedling
6. Use the measurements and the following formula to calculate the average growth rate of seedlings in each incubator per day

average growth rate = average change in seedling height for incubator ÷ days of incubation



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Seedling growth rate increases as temperature increases up to 25 °C, after which growth rate decreases. This could be due to cellular enzymes denaturing at high temperatures.

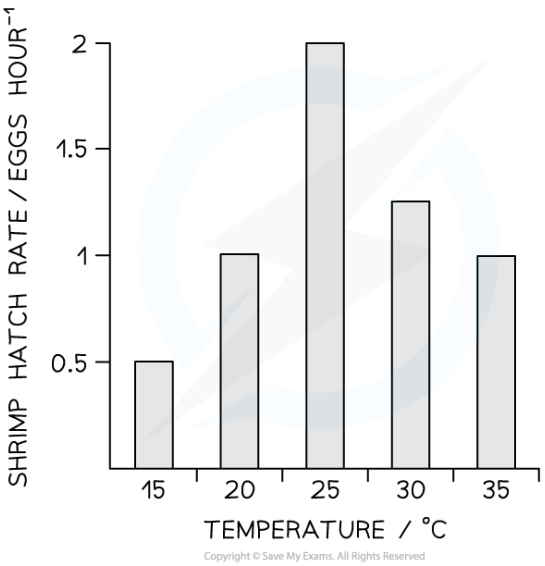
Temperature and brine shrimp hatching

1. Place an equal number, e.g. 40, of brine shrimp eggs into a series of water baths at different temperatures
    - Water baths should contain non-chlorinated water with 2 g of salt added per 100 cm^3
    - A magnifying lens may be needed to count the eggs
    - A wet piece of paper can be used to pick up and transfer the eggs to the water bath
    - Ensure that **all factors other than temperature are kept the same** between water baths e.g. age of shrimp eggs, water pH, water volume, dissolved oxygen concentration
2. Observe and record the number of brine shrimps that hatch at set time intervals e.g. every 12 hours
    - A bright lamp can be used to illuminate the water bath and count the hatchlings
3. Use the number of eggs hatched to calculate the hatching rate per hour

hatching rate = number of hatched shrimp eggs ÷ hours in water bath

- Note that brine shrimps are living organisms and so **welfare considerations** should be taken into account when using them for experimental purposes
    - Hatched shrimps should be **returned to a suitable environment** that replicates their natural habitat at the end of the experiment
    - Any handling and transfer of hatched shrimps should be carried out **gently and quickly**
    - Dangerously **high temperatures should not be used**

- Any bright lamp used for observation should be **switched off** when not in use



Shrimp hatch rate increases as temperature increases up to a temperature of 25 °C, after which hatch rate decreases

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Your notes

Mutation, Natural Selection & 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**

Natural Selection

- **Natural selection** can be defined as **the process by which organisms that are better adapted to their environment survive, reproduce, and pass on their advantageous alleles, causing advantageous characteristics to increase in frequency within a population**
- Natural selection involves the following stages
  - Variation exists between individuals in a population
    - Natural selection can only take place if variation is present
    - **Variation** results from small differences in **DNA base sequences** between individual organisms within a population
    - Sources of variation include
      - Mutation
      - Meiosis
      - Random fertilisation during sexual reproduction
  - In any habitat there are **environmental factors** that **affect survival chances**
    - E.g. predation, competition for food, and disease


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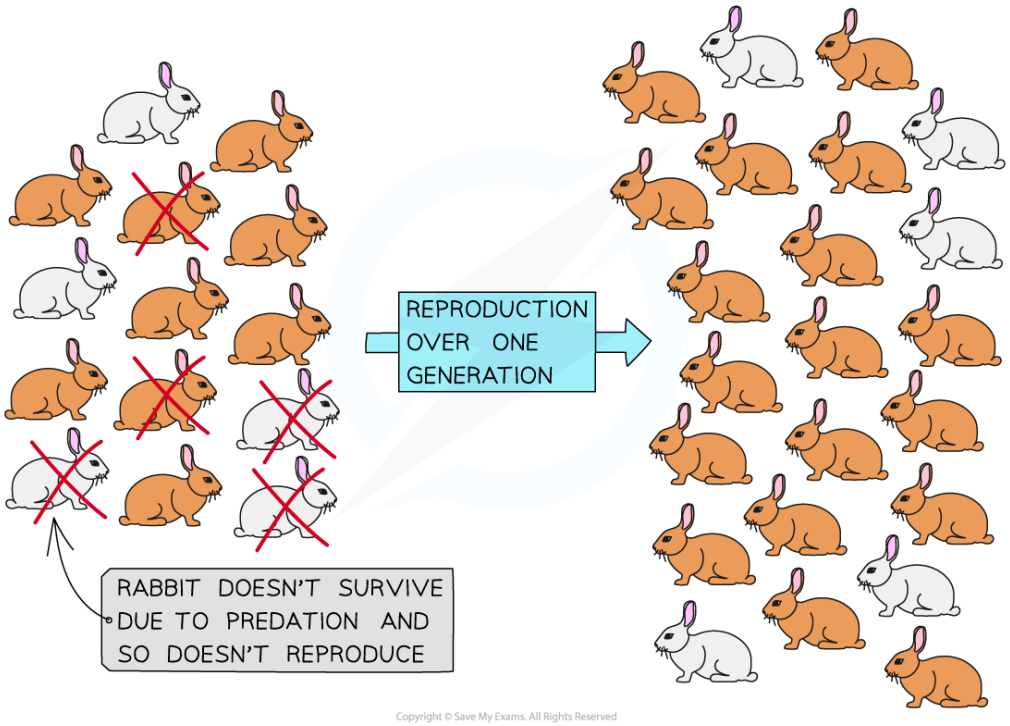
    - Environmental factors that influence survival chances are said to act as **selection pressures**
- In any population, due to the variation present, some individuals will have **characteristics** that make them **better adapted** for survival in the face of any selection pressures
    - This is sometimes described as '**survival of the fittest**'
- Individuals that are well adapted and **survive into adulthood** are **more likely to find a mate** and **reproduce**, producing **many offspring**
    - Individuals that are less well adapted **do not survive long** into adulthood are likely to **reproduce less often** than those that survive for longer, so producing **fewer offspring**
        - These individuals may not reach adulthood and so do **not get the chance to reproduce** at all
- This means that they are more likely to **pass on the alleles** that code for these **advantageous characteristics** to their offspring
    - Note that **non-heritable characteristics are not passed on to offspring**
        - Non-heritable characteristics are those **acquired during the lifetime** of an organism e.g. gaining weight after eating lots of nuts and berries in autumn, or being injured by a predator
- The number of individuals in a population with a particular favourable characteristic will increase over time; the characteristic is said to **increase in frequency**
- Eventually this favourable characteristic will become the **most common** of its kind in the population; the population can be said to have **adapted** to its environment by the process of **natural selection**
    - While favourable characteristics increase in frequency by natural selection, **unfavourable characteristics decrease in frequency** by the same process
    - Individuals with unfavourable characteristics are **less likely to survive**, **reproduce**, and **pass on the alleles** for their characteristics, so unfavourable characteristics are eventually **lost from the population**

An example of natural selection in rabbits

- **Variation** in fur colour exists within a rabbit population
    - One **allele** code for brown fur and another for white fur
- Rabbits have natural predators, such as foxes, which act as a **selection pressure**
- The brown rabbits are **more likely to survive** and **reproduce** due to having more effective camouflage
- When the brown rabbits reproduce, they **pass on their alleles** to their offspring
- The **frequency** of brown fur alleles in the population will increase

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

Your notes



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

Examiner Tips and Tricks

Remember that evolution occurs as a result of **natural selection,** a process that acts on **randomly occurring variation;** it does **not** occur as a direct, purposeful response to an environment. Avoid any statements that imply that evolution occurs 'so that' an organism can survive in its environment. Instead, it is correct to say that evolution occurs by **natural selection** as a result of **random variation** in populations.

You should be able to apply the process of natural selection to any scenario that you are presented with in an exam, as with the rabbit example above. Remember the following essential stages

1. **Variation** is present in a population
2. **Selection pressures** affect a population
3. Those with advantageous alleles are more likely to **survive** and **reproduce**
4. Advantageous alleles are **passed to offspring**
5. Advantageous alleles become **more frequent** in the population

Your notes

Isolation & Speciation

- 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**
- In order for speciation to occur two populations of the same species must be **isolated** from each other in some way
  - When this happens, there can no longer be an **exchange** of **genes** between the two populations
  - The exchange of genes is sometimes known as **gene flow**
- Isolation of populations may occur as a result of
  - **Geographical isolation**
    - This leads to a type of speciation known as **allopatric speciation**
  - **Random mutations** that **prevent them from interbreeding** with each other
    - This leads to a type of speciation known as **sympatric speciation**
- Populations that are isolated from each other may face different **selection pressures** in their environment e.g. different predators or sources of food
- The different environmental conditions for the two populations might mean that **different alleles are advantageous**, so different alleles are more likely to be passed on and become **more frequent** in each population; this is the process of **natural selection**
  - The allele frequencies in the two populations change over time
  - Note that a process known as genetic drift can also affect allele frequencies
- Over time the two populations may begin to differ **physiologically**, **behaviourally** and morphologically to such an extent that they can no longer interbreed to produce **fertile offspring**; speciation has occurred

Allopatric speciation

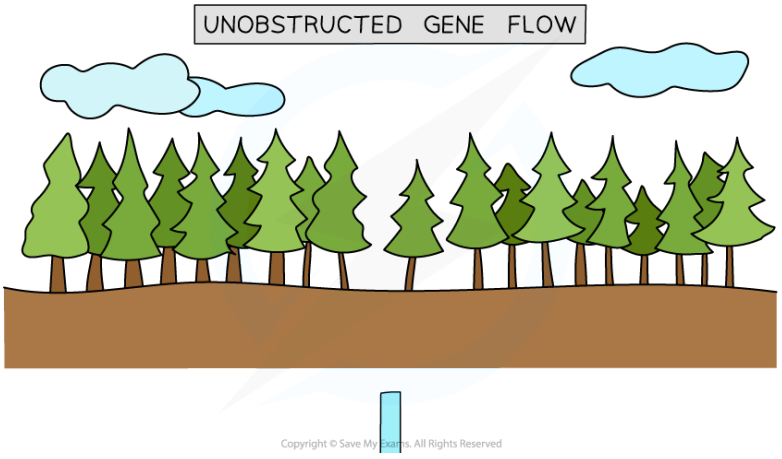
- Allopatric speciation occurs as a result of **geographical isolation**
  - It is the most common type of speciation
- Allopatric speciation occurs when populations of a species become **separated** from each other by **geographical barriers**
  - The barrier could be **natural** e.g. a body of water or a mountain range
  - It can also be **man-made** e.g. a motorway

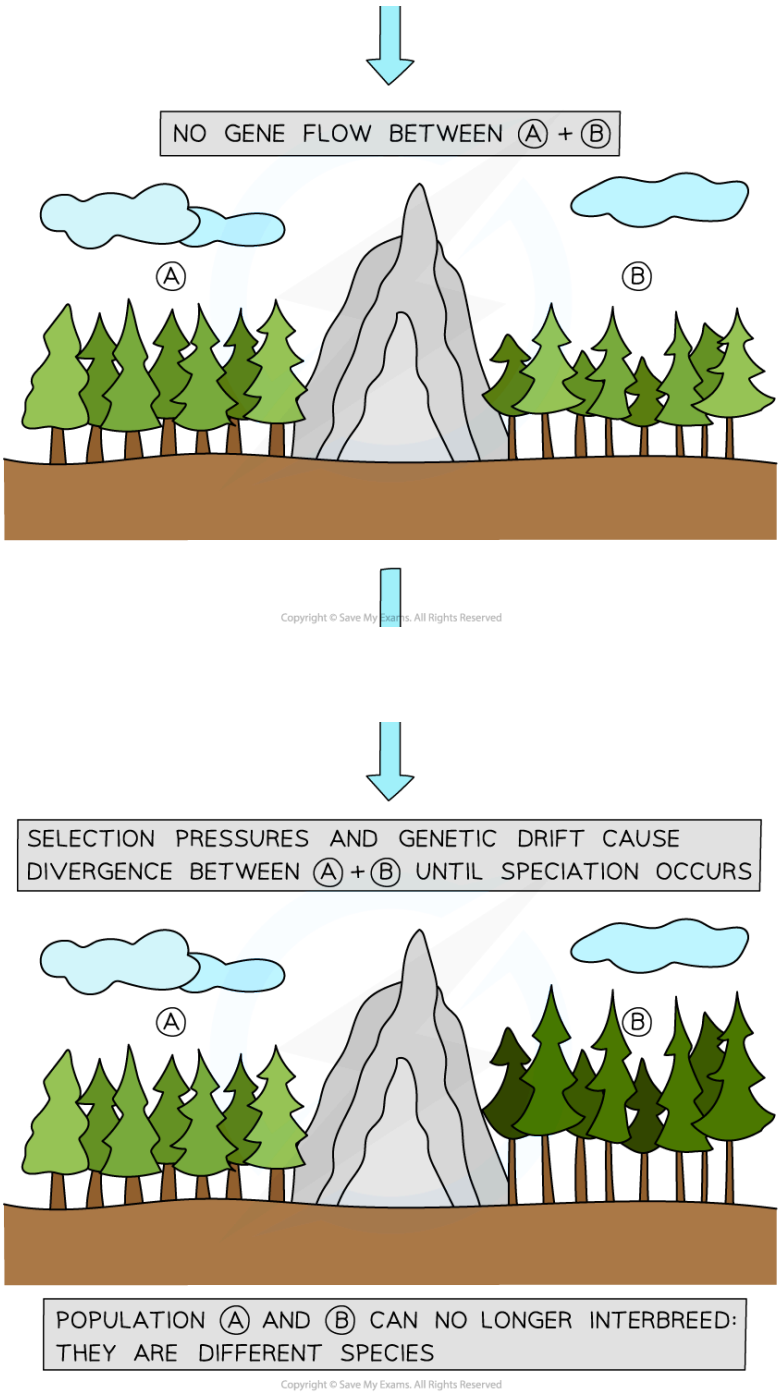
- This creates two populations of the same species between which no **gene flow** is taking place
- Allele frequencies in the gene pools of the two populations may change in different ways due to
  - Different **selection pressures** acting on them
  - The **accumulation of random changes** resulting from 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 no longer be able to **breed with each other** and **produce fertile offspring**, and can be said to be **separate species**

Your notes

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 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 different **alleles** become **advantageous**
- 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 can no longer interbreed to produce fertile offspring





The 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 isolation include

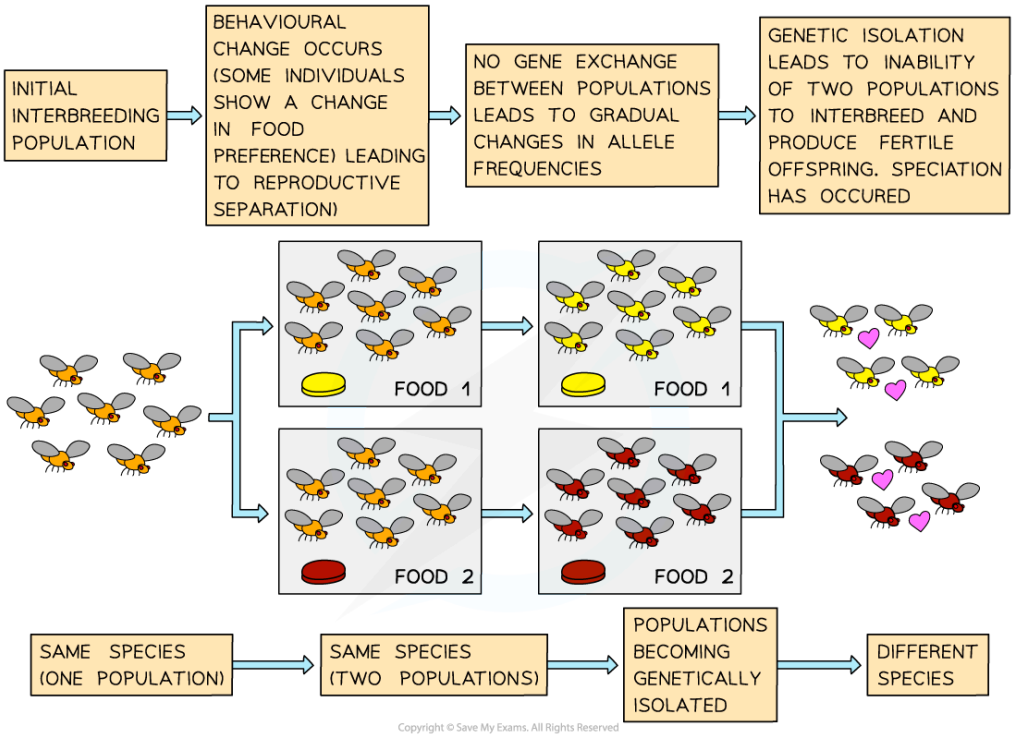

Your notes

- **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
- **Mechanical changes**
  - Some individuals in a population may develop changes in their **genitalia** that prevent them from **mating** successfully with individuals of the opposite sex i.e. their **reproductive body parts** no longer match up
- **Behavioural changes**
  - Some individuals in a population may develop changes in their **courtship behaviours** meaning they can no longer **attract** individuals of the opposite sex for **mating** i.e. their **methods of attracting a mate are no longer effective**

- The populations may still **live in the same habitat** but they are isolated from each other in the sense that 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
- If enough allele frequency differences arise between the two populations, then they will eventually no longer be able to **breed with each other** and **produce fertile offspring**, and can be said to be **separate species**

E.g. sympatric speciation in fruit flies

- A population of fruit flies exists in a laboratory
- A random allele change resulting from mutation **divides the species** into **two populations**
  - The allele changes leads to a change in phenotype e.g. food preference
- The difference in phenotype prevents the two populations from **interbreeding** so there is **no gene flow** between them
- Different alleles are therefore **passed on** in each population
  - This could be due to difference in selection pressure e.g. certain enzymes are advantageous for the digestion of different foods or due to genetic drift; the 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



Isolation mechanisms other than geographical isolation can also lead to speciation

Examiner Tips and Tricks

Note that you need to be able to apply the principles of **natural selection** to the process of speciation; the difference here is that natural selection will be acting differently on **two** isolated populations;

1. Variation is present
2. Selection pressures act on a population
    - These may be different between two isolated populations
3. Advantageous alleles provide some individuals with increase survival and reproduction chances
    - Advantageous alleles may be different between two isolated populations
4. Advantageous alleles are passed on
5. Allele frequencies change
    - Different advantageous alleles will accumulate in the two isolated populations until they become so different that they can no longer interbreed

Your notes

Your notes

Contentious Issues in Environmental Science

- It can be said that there is a **consensus**, i.e. everyone agrees, **among the scientific community** that
  - Increasing concentrations of greenhouse gases **cause** global warming
  - **Human activities are the direct cause** of increasing greenhouse gas concentrations
- Despite this there are some individuals, even among the scientific community, who **do not believe that the correlation** seen between humans burning fossil fuels and global warming is a **causal relationship**
  - These individuals claim that global warming is caused by **factors other than human activities**

Evaluating the data

- It is important to **evaluate any statement** that is made about the causes of climate change in the light of scientific evidence
  - **Consider how good the evidence is**
    - Does a statement address **all of the evidence**, or only part of it?
      - E.g. there may be some years when global temperatures go down, but there is strong evidence for an overall upward trend
    - Is the data reliable?
    - Does the data come from **several independent studies** i.e. is there plenty of evidence?
    - Does statistical analysis show that findings are **statistically significant**?
  - Find out whether the statement comes from a **trustworthy, unbiased source** e.g.
    - An individual working for an oil company or a particular government is likely to be **biased** because they have a **financial** or **political interest** in the outcome of a study
      - Several countries wrote to the United Nations in 2021 to ask that urgent recommendations against burning fossil fuels were toned down; all of these countries had economies that depended on the use of fossil fuels
    - An individual who campaigns passionately for conservation may be **biased** because they strongly believe that humans are causing climate change and they have an **emotional stake** in the outcome of a study
    - An individual who works for a renewable energy company may be **biased** because they are of the **opinion** that their technologies are better than fossil

fuel technologies as well as having a **financial interest** in the outcome of a study

Your notes

Evaluating Claims that Human Activities are not the Cause of Cimate Change Table

Claim	Evaluation
There have been changes in atmospheric carbon dioxide throughout Earth's history due to natural causes, and we are just experiencing another such change	Current carbon dioxide levels are higher than they have ever been at any point in Earth's history, suggesting that natural causes alone are not responsible
An oil company, when their scientists first predicted the climate impacts of continued combustion of fossil fuels, stated to the public that the evidence for a link between fossil fuels and climate change was 'inconclusive'	An oil company has a financial interest in people continuing to burn fossil fuels, so may not be telling the truth, or will at least be keen to play down the significance of research linking fossil fuels to climate change
Rates of warming have not been consistent; temperatures have cooled slightly at some points in the last 50 years, showing that global warming has stopped	Carbon dioxide levels are not the only factor that influences global temperatures; climate is highly complex and some factors may have a larger impact in some years than others

- When claims are made about the causes of climate change, it is important to evaluate these claims while bearing the following factors in mind
  - There is a **great deal of scientific evidence** that has been tested and checked by other scientists that **supports the hypothesis that humans burning fossil fuels causes climate change**; this increases the likelihood that further claims of this nature are correct
  - **Climate is highly complex**, so scientists need to be careful not to state that one factor alone has led to a specific event
    - Climate can be affected by any number of factors in any given year; it is important to look at **all of the data**
      - Climate and weather experts in the media are often asked about whether one particular extreme weather event is due to climate change; they always say that it is **wrong to draw conclusions from one event**, while also pointing to **that event's place in a trend** of increasingly extreme weather
    - Climate change is **not expected to be linear** in effect; scientists expect that there may be a **tipping point** beyond which changes happen faster
      - This makes it very **difficult to make predictions** about exact future climate conditions
  - People may have a **personal interest**; some are especially passionate about the environment, while others depend financially on fossil fuels
    - It is important that we are aware of the personal **biases** of those making claims about the causes of climate change

- If predictions about global warming are correct, then the potential impacts on the future of Earth are huge
- As scientists, it is our responsibility to be aware of the important factors surrounding this debate so that we can help other to assess evidence thoroughly

Your notes

Your notes

Examples of Sustainable Conservation

- **Sustainability** is about **making use of the world's resources** in ways that **do not damage the environment** and that **can be maintaine**d for future generations.
- The use of **extrapolation to model climate change** shows that the consequences of global warming could be **extremely serious** for humans and global biodiversity **if we continue** with current human activities
- If we want to be sustainable and limit the consequences of global warming it is essential that we act quickly to **reduce carbon emissions** and **increase the rate at which carbon is removed from the atmosphere**
- Our knowledge of the carbon cycle tells us that we can do these things in several ways

Reducing carbon emissions

- Carbon emissions can be reduced by **limiting the rate at which fossil fuels are burned**
  - This is challenging as so many of our **daily activities depend on the burning of fossil fuels** to release energy
    - Transport of people and goods
    - Electricity generation
    - Food production
- Two current ways of reducing carbon emissions are
  - Burning biofuels instead of fossil fuels
  - The use of other renewable energy resources

Biofuels

- These fuels are made from **recently living plant biomass** such as sugar cane
- Biofuels can be burned in the same way as fossil fuels, **releasing carbon dioxide** as they burn
- Arguments in support of biofuel use include
  - Biofuels are often cheaper than oil
  - It is argued that biofuels are **'carbon neutral'** meaning that they only release carbon that was recently removed from the atmosphere when the plants were alive
    - They do not release carbon that has been stored away for millions of years as with fossil fuels
  - Biofuels are a **renewable** source of energy, i.e. they can be regrown quickly
- There are several arguments against the use of biofuels

- They do still release carbon dioxide into the atmosphere
- The vast amounts of land required to grow biofuels **could otherwise have been used for food production**
- Creating land for biofuel growth often involves the loss of other types of habitats e.g. rainforest; this is **bad for biodiversity**
- Cutting down mature trees to create land for biofuel growth **reduces the removal of carbon from the atmosphere by photosynthesis**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Other renewable sources

- For example wind, solar, geothermal, and tidal energy
- Arguments in favour of such renewable resources include
  - These kinds of technologies are **advancing quickly** and are becoming **cheaper and more efficient** to use
  - **No carbon dioxide is released** when these technologies are used to generate electricity
- The current disadvantage of such renewable resources is that **no single source is perfect** e.g.
  - Geothermal energy can only be used when there is volcanic activity close to the earth's surface
  - Solar energy depends on sunshine hours
  - Wind energy depends on wind speeds and some conservationists are concerned about the impact of wind turbines on birds and bats
    - Some are also concerned about the visual impact of wind turbines on the landscape
  - Tidal energy can only be generated near the coast

Comparing Energy Resources Table

Your notes

Energy Resource	Renewable?	Advantages	Disadvantages
Fossil fuels	No	Reliable. Can produce large amounts of energy at fairly short notice.	Produces significant greenhouse gases and pollution
Nuclear	No	Reliable. Produces no greenhouse gases or pollution. A large amount of energy is produced from a small amount of fuel.	Produces dangerous radioactive waste that can take thousands of years to decay
Bio-fuels	Yes	The CO_2 produced while burning the fuel is balanced by the CO_2 absorbed whilst producing it.	Can take up a lot of land and consume resources that are needed for food production
Wind	Yes	Produces no greenhouse gases or pollution. Land can still be used for farming.	Not reliable. Turbines can be noisy and ugly. Not everywhere is suitable
Hydroelectric	Yes	Reliable and can produce large amount of energy at short notice. Produces no pollution of greenhouse gases.	Can involve flooding large area, destroying important wildlife habitats
Tidal	Yes	The tides are very predictable, and a large amount of energy can be produced at regular intervals.	Very few suitable locations. Can cause environmental harm to estuaries and disrupt shipping
Geothermal	Yes	Reliable. Geothermal stations are usually small.	Can result in the release of harmful gases from underground. Not many places are suitable
Solar	Yes	Produces no greenhouse gases or pollution. Good for producing energy in remote places.	Not reliable (only works when sunny). Solar farms can use up lots of farmland.

Increasing carbon removal

- There is much excitement over the future potential of new carbon capture technologies, but the reality is that the technology to remove vast quantities of carbon from the atmosphere and store it away **does not yet exist**
- We need to rely on **existing methods of carbon removal**, and the main existing mechanism is **photosynthesis**
- Humans can increase the global rates of photosynthesis by
  - **Stopping** the destruction of forests by **deforestation**

- Planting trees, also known as **reforestation**
  - If trees are allowed to grow to maturity, they can **store huge amounts of carbon in their** biomass
  - Some countries around the world have shown that it is possible to restore lost areas of forest by carrying out reforestation, e.g. Costa Rica now plants seven times more trees than it cuts down
    - This kind of achievement requires huge government inputs in the form of benefits to landowners

Your notes