CLIMATE CHANGE

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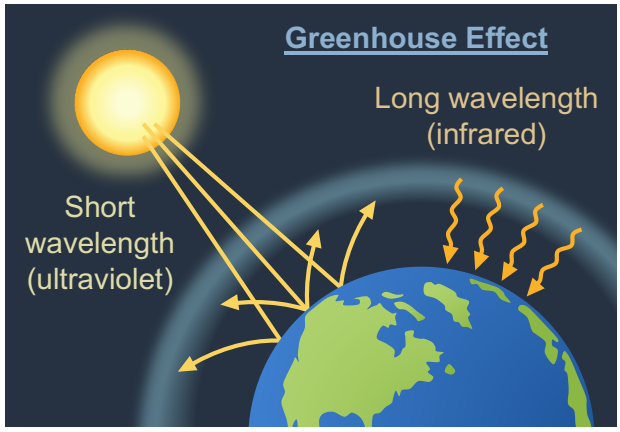
GREENHOUSE GASES

Greenhouse gases function within the atmosphere to trap and retain heat. This helps to ensure that the Earth maintains moderate temperatures needed by organisms to survive (no extreme fluctuations between day and night). The impact of a greenhouse gas is determined by its ability to absorb **long-wave radiation** as well as its concentration within the atmosphere. The greenhouse gases which have the largest warming effect are water vapour and carbon dioxide. Other greenhouse gases include methane and nitrogen oxides.

GREENHOUSE EFFECT

The greenhouse effect is a natural process whereby the atmosphere behaves like a greenhouse and acts to trap and retain heat. The incoming radiation from the sun is shorter wave radiation (**ultraviolet radiation** and visible spectrum). The surface of the Earth absorbs short wave radiation and emits it at a longer wavelength (**infra-red**). Greenhouse gases absorb and re-radiate this long wave radiation as heat – this keeps the temperatures within the atmosphere stable. Without the greenhouse effect, temperatures would drop significantly at night (no Sun).



HUMAN ACTIVITY

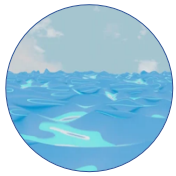
Human activity is increasing the concentration of certain greenhouse gases, which is creating an enhanced greenhouse effect and causing climate change. **Carbon dioxide** is the main anthropogenic greenhouse gas and is produced from the combustion of fossil fuels. Deforestation is reducing the photosynthetic uptake of carbon dioxide from the atmosphere, which is further contributing to the build-up of carbon dioxide in the atmosphere. Additionally, **methane** is a waste that is being emitted from landfills and is also being released via agricultural activities (it is produced by methanogens within the guts of ruminants – cows, sheep, etc). There is an established positive correlation between the atmospheric concentration of greenhouse gases and global temperatures over hundreds of thousands of years. This suggests that the current increases in greenhouse gas emissions might result in global warming (however correlation does not equal causation).

POSITIVE FEEDBACK CYCLES

Global warming has a positive feedback effect on greenhouse gas emissions – higher temperatures act to promote higher emissions of greenhouse gases. This creates a cycle whereby the ecosystem may become irreversibly destabilised. Many factors contribute to a positive feedback cycle for global warming, including:

Deep Oceans:

The ocean acts as a carbon sink and absorbs more than a quarter of all anthropogenic CO_2 emissions. However, the solubility of carbon dioxide is temperature dependent – the gas is less soluble when it is warmer. This means that global warming reduces the ocean's ability to act as a carbon sink, meaning higher temperatures will increase atmospheric CO_2 levels.



Loss of Reflective Ice:

The extent to which a surface reflects light is referred to as the albedo. Any surface that is light in colour (such as ice and snow) reflects more light and will have a higher albedo than exposed rock or soil. Global warming is causing polar ice caps to melt, meaning more solar energy (heat) is being absorbed by the earth – further increasing the global temperatures.

Permafrost:

Permafrost describes any ground that remains permanently frozen for over two years. As permafrost melts, it will expose previously undecomposed organic matter. Decomposition releases carbon dioxide into the atmosphere, so a higher rate of decomposition increases global temperatures (which causes more permafrost to melt in a positive feedback cycle).

Droughts and Fires:

Global warming increases the frequency of droughts, which dries out vegetation resulting in more wildfires. The burning of vegetation releases carbon dioxide into the atmosphere and reduces the available forest cover for photosynthesis. This means that carbon dioxide levels build up in the atmosphere, contributing further to an enhanced greenhouse effect.

TIPPING POINTS

A carbon sink is a component of an ecosystem that absorbs more carbon dioxide from the atmosphere than it releases. Boreal forests (taiga) normally act as carbon sinks and store carbon as organic matter (biomass). Because the climate is cold in boreal forests, the rate of decomposition is decreased (saprotrophic bacteria are inactive at low temperatures). Provided decomposition rate is less than the rate of photosynthesis, the forest will function as a net carbon accumulator. However, if global warming increases the temperatures in the boreal forest, then the forest change from a sink to a source (net carbon releaser). The warmer climate will lead to reduced water availability, lowering the primary productivity of the taiga (less photosynthesis). Prolonged drought conditions will cause trees to wilt prematurely and lose their leaves ('**forest browning**'). The drier conditions will also increase the frequency and intensity of forest fires, releasing carbon stored in the vegetation back into the atmosphere (**legacy carbon combustion**). The entire ecosystem could collapse.

Cold Climate:
Taiga acts as a carbon *sink* (accumulator)

Tipping Point

Hot Climate:
Taiga acts as a carbon *source* (net releaser)

CLIMATE IMPACTS

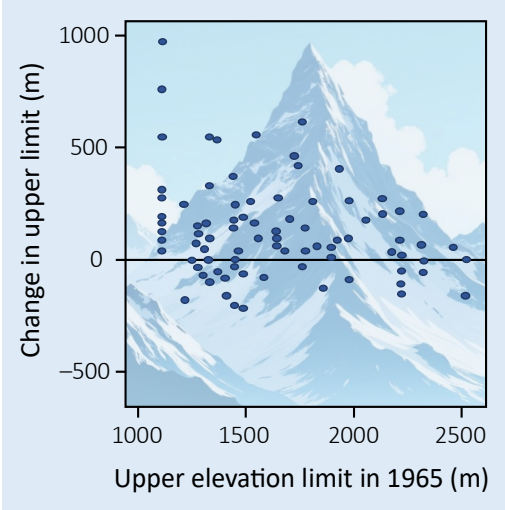
There are many predicted environmental consequences associated with anthropogenic climate change. Global warming is expected to alter both terrestrial and aquatic ecosystems. Potential impacts may include melting of polar ice, range shift of temperate species, changes in ocean currents and threats to coral reefs.

Melting of Polar Ice:

Polar habitats are very cold and contain both sea ice (when ocean freezes) and landfast ice (ice attached to land). Polar habitats are occupied by Emperor penguins in the south (Antarctica) and walruses in the north (Arctic). Emperor penguins breed on the sea ice, where they lay their eggs and raise their young. Melting of the sea ice is forcing changes to breeding habits, which is adversely affecting penguin population numbers. Walruses also use the sea ice to nurture their young. A loss of sea ice requires walruses to nurture the pups further from the ocean, which leaves them unprotected for longer periods while the mothers hunt for food.

Range Shift of Temperate Species:

A species can only exist within specific environmental tolerance limits (i.e. their fundamental niche). Climate change is altering environmental conditions such that many species must migrate to new locations (a range shift). **Poleward shifts** are relocations towards the poles. Due to global warming, the North American boreal forests are experiencing range contraction and northern spread. **Upslope shifts** describe relocations to points of higher elevation (such as moving to a higher altitude on a mountain). Montane birds in Papua New Guinea have displayed an evident upslope migration trend over the last 50 years. This may reflect temperature changes (higher altitudes are warmer than before).

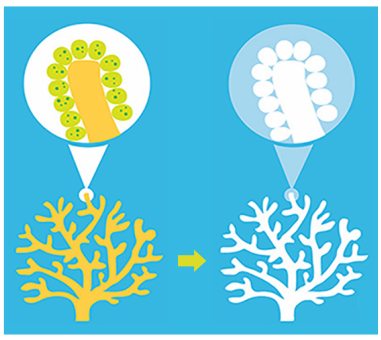


Changes in Ocean Currents:

Ocean currents play an important role in transferring heat and nutrients and changes in ocean currents can alter the timing and extent of these redistributions. **Upwelling** occurs when colder, nutrient-rich water rises to the surface as a consequence of wind and wave movement displacing the warmer surface water. Climate change is increasing ocean temperatures, preventing nutrient upwelling and lowering primary production.

Threats to Coral Reefs:

The coral polyps that comprise the reef exist in a mutualistic relationship with zooxanthellae (algae). The algae provide the polyps with food, while the polyps provide resources and protection. Higher ocean temperatures cause the polyps to expel their algae, leading to coral bleaching. Carbon dioxide emissions also cause ocean acidification. Free carbonate ions in the water will buffer the pH change, but this reduces the availability of carbonate ions to be used in the development of the coral exoskeletons.



CARBON SEQUESTRATION

Carbon sequestration describes the process of capturing and storing carbon dioxide from the atmosphere. It is accomplished naturally by forests and peat-forming wetlands (carbon sinks). The role a forest plays in sequestration can be enhanced by regeneration (plant trees in deforested areas) or afforestation (plant new forests). The restoration of peat-forming wetlands will similarly increase their capacity to sequester carbon.