Climate change, temperature and sustainability

Evidence for climate change and its causes, the greenhouse effect and the carbon cycle, models and their limits, effects on organisms, enzymes and temperature (Q10), and balancing human needs with conservation.

Evidence for climate change

Evidence comes from **records** and **proxies**:

- **Carbon dioxide records**: direct measurements (Mauna Loa, since 1958) and **ice cores**, which trap bubbles of ancient air and show past CO_2 and temperature (over hundreds of thousands of years).
- **Temperature records** from thermometers and satellites, showing a rise in the mean global temperature.
- **Pollen in peat bogs**: layers of preserved pollen show which plants grew at each time, which indicates the climate.
- **Dendrochronology** (tree rings): wide rings show good growing conditions (warm and wet) and narrow rings show poor conditions.
- Other: retreat of glaciers and sea ice, sea level rise, changes in distribution of species.

> **Distinguish correlation from causation. A correlation between CO_2 and temperature suggests a link; the mechanism (the greenhouse effect) and the correlation over long periods together support the causal explanation.**

The causes of anthropogenic climate change

Anthropogenic means caused by human activity. The **greenhouse effect** is natural. The Earth's surface absorbs short-wave radiation and re-emits it as **longer-wave infrared** radiation. **Greenhouse gases** (carbon dioxide, methane, water vapour, nitrous oxide, CFCs) absorb some infrared radiation and **re-radiate** it, which **warms** the atmosphere.

Human activity has increased greenhouse gases:

- **Carbon dioxide** from burning **fossil fuels** and from **deforestation**.
- **Methane** from cattle, rice paddies, landfill and fossil fuel extraction. It is a stronger greenhouse gas than CO_2 per molecule.
- **Nitrous oxide** from fertilisers.

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The carbon cycle

Carbon moves between the atmosphere, plants, animals, soil, oceans and rocks.

- **Photosynthesis** removes CO_2 from the atmosphere.
- **Respiration** (plants, animals and decomposers) and **combustion** return it.
- **Fossil fuels** are stores of carbon that took millions of years to form.
- The **oceans** absorb CO_2.

Methods to reduce atmospheric carbon dioxide

- **Reduce fossil fuel use**: renewable energy, efficiency, and carbon capture.
- **Reforestation** and **afforestation**: trees take up CO_2 as they grow.
- Protect **peat bogs** and forests (**carbon sinks**).
- **Biofuels** (e.g. bioethanol and biodiesel) can be **carbon neutral** because the CO_2 released was taken up by the plants as they grew.

Models and predictions

- **Data** (past trends) can be **extrapolated** to predict the future, and **computer models** of the climate use data on CO_2, temperature and other factors to predict future change.
- Limitations: **many variables** interact; **feedback** effects (e.g. melting ice reduces reflectance and so increases warming) are difficult to include; assumptions about future emissions are uncertain; data are incomplete; and predictions get **less reliable the further** they extrapolate. Models give a range of possible outcomes, rather than a single certain answer.

Effects of climate change on organisms

- **Distribution** of species shifts toward the poles or to higher altitudes, as the range of suitable temperature moves.
- **Changing rainfall patterns** can lead to drought or flooding and affect plant growth.
- **Seasonal cycles** change: earlier flowering, earlier egg-laying and migration, which can cause **mismatches** between predator and prey or plants and pollinators.
- **Life cycles** and development rates change (many organisms develop faster in warmer conditions).
- Some species may become **extinct** if they cannot adapt or move.

Temperature and enzyme activity

A rise in temperature increases the rate of enzyme-controlled reactions, up to the optimum, and so affects **plants, animals and microorganisms**. Above the optimum, enzymes are **denatured**.

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The **temperature coefficient** Q_{10} describes the effect of a 10 °C rise:

$$Q_{10} = \frac{\text{rate at } (T+10)\,°C}{\text{rate at } T\,°C}$$

For many biological reactions $Q_{10} \approx 2$. A value of **1** shows no effect of temperature.

> **TRY IT**
>
> The rate of respiration of a beetle is 4 units at 15 °C and 9 units at 25 °C. Calculate Q_{10}.

$Q_{10} = 9/4 = 2.25.$

Core Practical 12: temperature and development

Investigate the effect of temperature on the **development** of organisms, such as the **growth rate of seedlings** or the **hatching rate of brine shrimp** eggs, at a range of temperatures (water baths). Control the other factors (light, volume, salinity), measure the rate (shoot length or percentage hatching), and take into account the **ethical use** of organisms: keep numbers low, treat humanely and return or dispose of them correctly.

Conflict between human needs and conservation

Controversial issues, such as actions to reduce climate change, are judged by different groups. Conclusions can depend on **who is reaching** them: scientists, governments, the fossil fuel industry, campaigners and developing countries have different interests, and may select evidence to support their views. Look at the **source**, whether the data are **peer-reviewed**, and whether there is **bias** or a conflict of interest.

Managing the conflict between **human needs** and conservation:

- **Reforestation** (replanting trees) restores habitats and takes up CO_2, although a **monoculture** plantation supports fewer species.
- **Sustainable resources** are used no faster than they can be replaced, including **biofuels**. But growing biofuel crops competes with **food crops** for land and can lead to deforestation.
- Other methods: **selective logging**, **fishing quotas**, **protected areas**, and **community involvement** in conservation.

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