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Paleoclimate
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1. Definition: climate is defined by mean and variance of atmospheric condition over "long" periods
2. Typical climate parameters: annual and monthly mean temperatures, diurnal temperature range, precipitation, humidity, winds, cloud cover, ice cover, vegetation cover, CO2...
3. Climate data: direct measurements (present-day); proxy data or climate indicators (past)
4. Climate proxies: geological (landforms, stratigraphy), biological (distribution of species), chemical (isotopes)
5. Element: neutron, proton, electrons. Atomic mass = number of neutrons + protons. Isotopes: elements with same number of protons and electrons, but different number of neutrons. E.g. {Hydrogen, deuterium, tritium}; {\(^{12}\text{C}, {^{13}\text{C}, \text{^{14}\text{C}}}\}; {^{18}\text{O}, {^{17}\text{O}, {^{16}\text{O}}}}}. Similar chemical properties. Stable versus radioactive isotopes.
6. Fractionation: separation of isotopes because mass differences. Lighter isotope diffuses faster than heavier isotope. Degree of fractionation is temperature dependent. Hence D/H, \(^{18}\text{O}/^{16}\text{O}\) are useful climate proxies.
7. Biological uptake $\rightarrow$ lighter C into plant. \(^{13}\text{C}/^{12}\text{C}\) is a useful biological indicator.
8. Sources of paleoclimate data: sediments, ice core, corals, tree rings, ...
9. Paleoclimate: Variable. Warmer than present in the Mesozoic. Long-term cooling in the Cenozoic. Clear signatures of glacial-interglacial cycles. Climate has been stable and warm in the past 10 KYBP.

![Graph showing oxygen-isotope variations during the last 2 million years based on analyses of deep-sea sediment cores. The curve illustrates changing global ice volume during successive glacial-interglacial cycles of the Quaternary Period.](image)
Figure 11.3 Changes in the temperature of Earth over time. (a) The temperature record of Earth during the past 100 million years; (b) an expanded representation of the last one million years; and (c) an expanded view of the last 100,000 years. (After UCC/BONES, 1999a.)

Figure 11.6 The Milankovitch theory of climatic change during the Pleistocene. The area of ice cap formation is much greater in winter than in summer. The Milankovitch theory is based on the assumption that changes in the Earth's orbit and tilt are the primary factors controlling the climate. The elliptical shape of the Earth's orbit and the tilt of the Earth's axis affect the amount of sunlight received at different latitudes. This, in turn, affects the climate and the distribution of ice and water. (After Corrigan, 1984.)