TOPIC: FOSSILS

Key Knowledge:

- Changes in species over geological time as evidenced from the fossil record: fossil succession, index and transitional fossils, relative and absolute dating of fossils

PALAEONTOLOGY

Palaeontology is the study of fossils, which are the preserved remains or traces of any organism from the remote past. The totality of fossils (both discovered and undiscovered) and their placement in sedimentary layers (strata) and rock formations is known as the **fossil record**. By comparing the anatomies of fossils against modern species, palaeontologists infer the evolutionary pathways taken by particular species. Different kinds of organisms are found in a consistent order within strata (e.g. prokaryotes before eukaryotes), which indicates a sequence of development known as the **law of fossil succession**. Within the fossil record are intermediary forms that establish links between species by exhibiting traits that are common to both an ancestor and its descendants (**transitional fossils**).

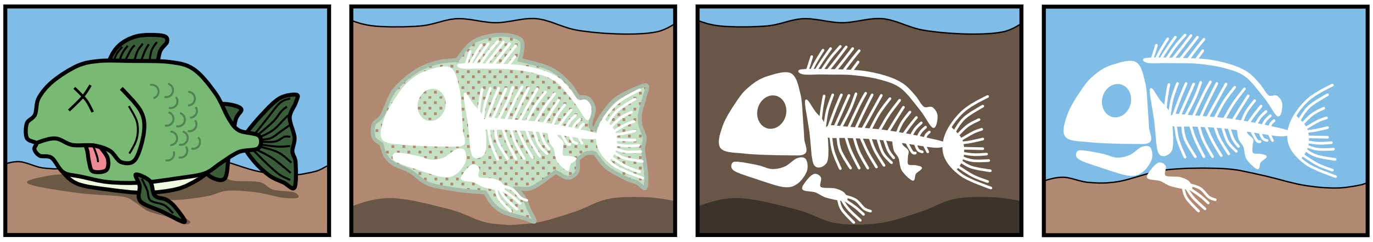
Fossil: Archaeopteryx

FOSSILISATION

Fossilisation is a very rare occurrence that requires an unusual set of circumstances in order to occur. It is extremely uncommon for an organism to be preserved upon death (e.g. frozen or encased in amber). Most fossils are formed via a process of **permineralization**, which requires certain key conditions:

- Hard body parts (e.g. shells, bones, etc.) – soft parts will not fossilise but may leave behind imprints
- Preservation of remains – scavengers must be prevented from eating and scattering the organism
- Anoxic conditions – a low oxygen environment is necessary to prevent decomposition by saprotrophs
- High pressure – promotes permineralization of remains (converts hard body parts into fossilised rock)

The conditions for fossilisation can be achieved via **rapid burial**, however subsequent erosion and exposure is then required in order to displace the fossil and return it to the surface for discovery by palaeontologists.



Death and decay | **Rapid Burial** | **Permineralization** | **Erosion / Exposure**

TYPES OF FOSSILS

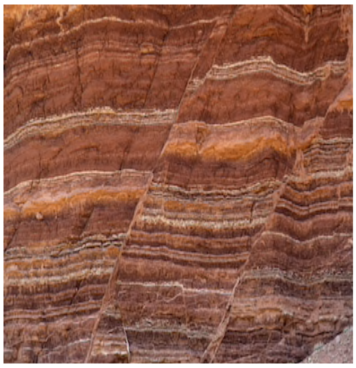
Fossils can be categorised according to three main groups. **Physical fossils** represent the actual remains of past ancestral life and can include body fossils (preserved remains) and petrified fossils (mineralised hard parts). **Trace fossils** represent the indirect remnants of past life and include moulds (hollow outlines), casts (filled cavities), tracks, burrows and faeces (coprolites). **Biosignatures** represent the chemical evidence of ancestral life, including the discovery of cell biosynthesis products (such as amino acids or nucleic acids).

DATING METHODS

Scientists have developed multiple methods of determining the ages of prehistoric life forms. This allows the evolutionary history of a species to be mapped according to past geological and biological events. **Relative dating** uses geological evidence to assign comparative ages of fossils, whereas **absolute dating** uses radiometric data analysis to determine more exact ages.

RELATIVE DATING

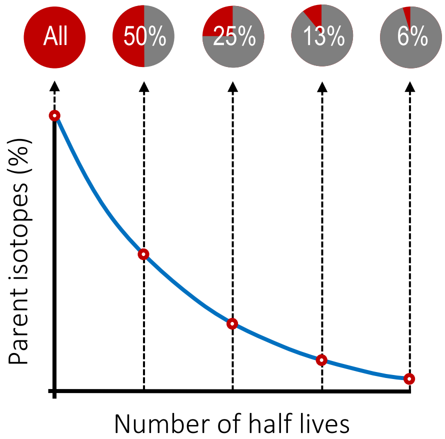
The Earth is arranged into sedimentary layers called strata, with younger strata positioned on top of older strata (as per the **law of superposition**). The age range of a fossil can be determined according to the age of the stratum in which the fossil is found. The interpretation of geological time periods based on rock layers is known as **stratigraphy**. Occasionally, a stratum representing a particular time period may be missing or displaced due to environmental actions (such as flooding, earthquakes or erosion). The rock layers in two different regions can be synchronised based on the presence of **index fossils**. Index fossils represent species that were short-lived but widely distributed, and hence represent a specific time period.



Strata *(broken by fault lines)*

ABSOLUTE DATING

Absolute dating involves determining the specific age of a fossil via radiometric analysis. Radioisotopes are alternate forms of common elements that are unstable and undergo radioactive decay to form more stable daughter isotopes. The rate of radioactive decay is both constant and specific to a given radioisotope. The time taken for the level of radioactivity to fall to half of its original level is known as the **half-life** (i.e. the time taken for a radioisotope to decay by half). By comparing levels of radioisotopes within a fossil to the levels found in the atmosphere (which represent the original levels in the fossil), scientists can determine precisely when the past life form existed.



1. SHORT-RANGE TECHNIQUES

- All living things contain carbon which exists as a mix of two isotopes – ^{12}C (stable) and ^{14}C (radioactive)
- While alive, the proportion of the two isotopes in the organism will mirror the environmental levels
- When an organism dies, the ratio no longer remains fixed, but changes as radiocarbon decays (to ^{14}N)
- Scientists can measure the amount of radiocarbon remaining to determine how long ago a fossil died
- Radiocarbon has a half-life of 5,730 years and so can only date samples **less than 60,000 years** old

2. LONG-RANGE TECHNIQUES

- Longer range dating can be accomplished by using radioisotopes with significantly longer half-lives
- Uranium-238 has a significantly longer half-life of 704 million years (^{238}U will decay to form ^{207}Pb)
- Potassium-40 is released from active volcanos and decays into an inert gas (^{40}Ar) over 1.3 billion years
- These long-range radioisotopes are **not** found in fossilised remains or sedimentary strata and so can only be used to date the surrounding **igneous rocks** (uses relative dating to determine an age range)