Chapter 6
Life on Earth: What do Fossils Reveal?
Fossils

Fossils are the remains or traces of ancient life which have been preserved by natural causes in the Earth's crust.

Fossils include both the *remains* of organisms (such as *bones* or *shells*), and the *traces* of organisms (such as tracks, trails, and burrows - called *trace fossils*).
Baby mammoth preserved by freezing is weathering out of permafrost in Siberia.
Fossil Preservation

To become preserved as a fossil, an organism must:

• Have **preservable parts**. Bones, shells, teeth, wood are more readily preserved than soft parts.

• **Be buried by sediment** to protect the organism from scavengers and decay.

• **Escape physical, chemical, and biological destruction** after burial (bioturbation, dissolution, metamorphism, or erosion).
Upper torso of man preserved in peat bog. Lower half destroyed by harvesting machinery.
Fossil Preservation

Organisms do not all have an equal chance of being preserved.

The organism must live in a suitable environment.

Marine and transitional environments are more favorable for fossil preservation. Higher rate of sediment deposition.
Types of Fossil Preservation

1. Chemical Alteration of Hard Parts
2. Imprints of Hard Parts in Sediment
3. Preservation of Unaltered Soft Parts
4. Trace fossils
5. Preservation of Unaltered Hard Parts
Preservation of Unaltered Hard Parts

The shells of invertebrates and single-celled organisms, vertebrate bones and teeth:

a. Calcite (echinoderms and forams)
b. Aragonite (clams, snails, modern corals)
c. Phosphate (bones, teeth, conodonts, fish scales)
d. Silica (diatoms, radiolarians, some sponges)
e. Organic matter (insects, pollen, spores, wood, fur)
Chemical Alteration of Hard Parts

a. Permineralization - filling of tiny pores

b. Replacement - molecule-by-molecule substitution of one mineral for another (silica or pyrite replacing calcite)

c. Recrystallization - aragonite alters to calcite

d. Carbonization - soft tissues preserved as a thin carbon film (ferns in shale)
Fossil wasp, victim of a volcano and buried in lake sediment 30 mya, Florissant, Colorado
This shows an internal mold of a marine snail. An *internal mold* is formed when sediments or minerals fill the internal cavity of an organism, such as the inside of a bivalve or snail or the hollow of a skull.
This shows an **external mold** and **cast** of a trilobite that formed in a nodule of calcareous shale.
Preservation of Unaltered Soft Parts

- Freezing
- Desiccation
- Preservation in amber
- Preservation in tar
- Preservation in peat bogs
Amber is a form of **tree resin** -- exuded as a protective mechanism against disease and insect infestation -- that has hardened and been preserved in the earth's crust for millions of years. Often regarded as a gem, amber is actually an organic substance whose structure has changed very little over time, unlike that of other fossilized material, in which organic matter is replaced with minerals. Because amber oxidizes and degrades when exposed to oxygen, it is preserved only under special conditions. Thus it is almost always found in dense, wet sediments, such as clay and sand that formed at the bottom of an ancient lagoon or a river delta. Amber has preserved ancient life to such infinitesimal detail that it even captures fragments of DNA of the organisms entrapped in it. A wide variety of creatures has been found in Dominican amber. Scientists are able to reconstruct this ancient, 25 million year old ecosystem, with amazing intricacy.
Trace fossils

Markings in the sediment made by the activities of organisms

• Tracks
• Trails
• Burrows – in soft sediment
• Borings – in hard material
• Root marks
• Nests
• Eggs
• Coprolites
• Bite marks

Markings in the sediment made by the activities of organisms.
Crawling, resting, dwelling, grazing and feeding traces.
Trace fossils

Trace fossils provide information about ancient water depths, paleocurrents, availability of food, and sediment deposition rates.

Tracks can provide information on foot structure, number of legs, leg length, speed, herding behavior, and interactions.
Biological classification

A system of **binomial nomenclature** (i.e., two names) is used to name organisms.

The first of the two names is the **genus** and the second name is the **species**.

Genus and species names are underlined or italicized.

Genus is capitalized, but species is not.
The Species

A group of organisms that have structural, functional, and developmental similarities, and that are able to interbreed and produce fertile offspring.

The species is the fundamental unit of biological classification.
All organisms are composed of cells.

- **Eukaryotic cells** have a nucleus (or nuclei) and organelles.
  - Organisms with this type of cell are called eukaryotes (Domain Eukarya).

- **Prokaryotic cells** have no nucleus or organelles.
  - Organisms with this type of cell are called prokaryotes (Domain Archaea and Domain Bacteria).
Taxonomy

Organisms are grouped based on their similarities into **taxonomic groups** or **taxa**.

- Domain
- Kingdom
- Phylum (*plural = phyla*)
- Class
- Order
- Family
- Genus (*plural = genera*)
- Species (*singular and plural*)
Classification of the human

Domain Eukarya
Kingdom Animalia
Phylum Chordata
Class Mammalia
Order Primates
Family Hominidae
Genus Homo
Species sapiens
There are six kingdoms of organisms, grouped into three domains

1. Domain Eukarya
2. Domain Bacteria
3. Domain Archaea
Domain Eukarya

Organisms with **eukaryotic cells** (cells with a nucleus)

- Kingdom Animalia (animals)
- Kingdom Plantae (plants)
- Kingdom Fungi (mushrooms, fungus)
- Kingdom Protista (single-celled organisms)
Domain Bacteria

Organisms with prokaryotic cells (cells without a nucleus)

• Kindgom Eubacteria (bacteria and cyanobacteria or blue-green algae)
Domain Archaea

Organisms with prokaryotic cells, but which are very unusual and quite different from Bacteria. Archaea tend to live under extreme conditions of heat, salinity, acidity.

• Kingdom Archaebacteria
Evolution

Evolution = change

• *Organic evolution* refers to changes in populations

• In biology, evolution is the "great unifying theory" for understanding the history of life.
Evolution

Plants and animals living today are different from their ancestors because of evolution. They differ in appearance, genetic characteristics, body chemistry, and in the way they function.

These differences appear to be a response to changes in the environment and competition for food.
Fossils and Stratigraphy

The Geologic Time Scale is based on the appearance and disappearance of fossil species in the stratigraphic record.

Fossils can be used to recognize the approximate age of a unit and its place in the stratigraphic column.

Fossils can also be used to correlate strata from place to place.
Geologic range

**Geologic range** = The interval between the first and last occurrence of a fossil species in the geologic record.

The geologic range is determined by recording the occurrence of the fossils in numerous stratigraphic sequences from hundreds of locations.
Using Fossils to Correlate Rock Units
Cosmopolitan species have a widespread distribution.

Endemic species are restricted to a specific area or environment.

Cosmopolitan species are most useful in correlation
Pitfalls of Correlating with Fossils

Appearances and disappearances of fossils may indicate:

• Evolution
• Extinction
• Changing environmental conditions that cause organisms to **migrate** into or out of an area

Reworked fossils
Index Fossils

Index fossils (or guide fossils) are useful in identifying time-rock units and in correlation.

Characteristics of an index fossil:

1. Abundant
2. Widely distributed (cosmopolitan)
3. Short geologic range (rapid evolution)
Important guide fossil, *Archimedes*
Archimedes showing the lacy fronds around the central axis.
Conodonts are important guide fossils.
A living planktonic foraminifera
Fossil foraminifera from 14 million year old limestone
A coccolithophorid are single-celled algae. They are distinguished by special calcium carbonate plates of uncertain function called coccoliths, which are important microfossils. Due to their microscopic size and the broad distribution of many of their taxa, coccoliths have become very important as index fossils for solving various stratigraphic problems. Triassic to recent. Form most recent chalks.
Radiolarian protistans build coverings of silica.
Marine Ecosystem

The ocean may be divided into two realms:

- **Pelagic realm** = The water mass lying above the ocean floor.
- **Benthic realm** = The bottom of the sea
Marine Ecosystem

Pelagic realm

- **Neritic zone** = The water overlying the continental shelves.
- **Oceanic zone** = The water seaward of the continental shelves.
Marine Ecosystem

**Benthic realm**

- **Supratidal zone** = Above high tide line
- **Littoral zone** (or intertidal zone) = Between high and low tide lines
- **Sublittoral zone** (or subtidal zone) = Low tide line to edge of continental shelf (about 200 m deep)
- **Bathyal zone** - 200 - 4000 m deep
- **Abyssal zone** - 4000 - 6000 m deep
- **Hadal zone** - >6000 m deep; deep sea trenches.
Marine Ecosystem
Modes of Life of Marine Animals

**Plankton** - Small plants and animals that float, drift, or swim weakly.

- **Phytoplankton** - Plants and plant-like plankton, such as diatoms and coccolithophores
- **Zooplankton** - Animals and animal-like plankton, such as foraminifera and radiolaria
Modes of Life of Marine Animals

**Nekton** - Swimming animals that live within the water column

**Benthic organisms or benthos** - Bottom dwellers, which may be either:

- **Infaunal** - Living beneath the sediment surface; they burrow and churn and mix the sediment, a process called *bioturbation*
- **Epifaunal** - Living on top of the sediment surface
Marine Sediments

- **Terrigenous sediment** - from weathered rocks
- **Biogenous sediment** – of biological origin
  - *Calcareous oozes* - foraminifera, pteropods, and coccolithophores
  - *Siliceous oozes* - radiolarians and diatoms
  - *Phosphatic material* – fish bones, teeth and scales
- **Hydrogenous sediment** - precipitated from sea water - manganese nodules
A depth in the oceans (about 4000-5000 m), which affects where calcareous oozes can accumulate.

Above the CCD (shallower than 4000-5000 m), the water is warmer, and CaCO$_3$ is precipitated. Calcareous sediments (chalk or limestone) are deposited.
Below the CCD (below about 4000-5000 m), water is colder, and CaCO$_3$ dissolves. Clay or siliceous sediments are deposited.
Use of Fossils in Reconstructing Ancient Geography

Environmental limitations control the distribution of modern plants and animals.

- Note locations of fossil species of the same age on a map
- Interpret paleoenvironment for each region using rock types, sedimentary structures, and fossils.
- Plot the environments to produce a paleogeographic map for that time interval.
Land Bridges, Isolation and Migration

Migration and dispersal patterns of land animals can indicate the existence of:

- Former land bridge (Bering Strait)
- Mountain barriers
- Former ocean barriers between continents
Species Diversity and Geography

Species diversity is related to geographic location, particularly latitude.

As a general rule, species diversity increases toward the equator.
Use of Fossils in the Interpretation of Ancient Climatic Conditions

Fossils can be used to interpret paleoclimates (ancient climates):

1. **Fossil spore and pollen grains** can tell about the types of plants that lived, which is an indication of the paleoclimate.

2. **Plant fossils** showing aerial roots, lack of yearly rings, and large wood cell structure indicate tropical climates

3. Presence of **corals** indicates tropical climates
Use of Fossils in the Interpretation of Ancient Climatic Conditions

4. Marine molluscs with spines and thick shells inhabit warm seas

5. Planktonic foraminifera vary in size and coiling direction with temperature

6. Shells in warmer waters have higher Mg contents

Shell coiling direction in some foraminifera changes with water temperature.
Scientists can analyze the rock to determine how much oxygen-18 and oxygen-16 are present relative to one another, which tells them what the temperature was like when the calcite formed. A higher ratio of oxygen-18 to oxygen-16 indicates that the water was cooler when the calcite was formed.
Oxygen isotope ratio cycles are cyclical variations in the ratio of the abundance of oxygen with an atomic mass of 18 to the abundance of oxygen with an atomic mass of 16 present in some substances, such as polar ice or calcite in ocean core samples. The ratio is linked to water temperature of ancient oceans, which in turn reflects ancient climates. Cycles in the ratio mirror climate changes in geologic history. Higher ratios of oxygen 18 indicate decreases in ocean/atmosphere temperatures.

In the graph above, the dotted line shows average modern temperature as measured in 1950. The right axis indicates values of oxygen isotope O-18 as measured in deep sea carbonate/calcite sediment cores. Measures of temperature can be inferred from these values, and the left axis has estimated values for temperature at Vostok, Antarctica, near the geomagnetic South pole. This graph illustrates that temperature has not been constant at this location during the last 5.5 million years.