Vocabulary:
- Paleontologist
- Fossil record extinct
- Relative dating
- Absolute dating
- Geologic time scale

Objectives:
- What are fossils?
- How are they made?
- How do scientists know how old things are?
- What is the difference between relative and absolute dating?
GEOLOGIC TIME & AGE OF THE EARTH

► Our planet is home to a huge variety of organisms!! (Scientists estimate 5 - 20 million species of organisms alive today)

► Even more amazing is evidence of organisms that once lived on earth, but are now EXTINCT.

► Several hundred million species have come and gone during the 4.6 billion years the Earth has existed.
Geologic Time- The History of the Earth

2 ways of determining age:

1) Relative Dating:

► order of events based on the position of rocks in a sequence

► older layers of rock are on the bottom; newer rock lays down on top of the older rock
2) Absolute Dating/ Radioactive Dating:

- some isotopes undergo radioactive decay where an alpha or beta particle of radiation leaves the nucleus thereby changing the original element into a new one

- each radioactive material has a specific and measurable rate of this decay (half-life)

- comparing the ratio of the original amount of radioactive material to how much is left can determine the age of the object
1. What is the fossil record?
2. What is extinction?
3. What is a paleontologist?
1. What is the **fossil record**?

   Information about past life showing change over time; evidence in form of fossils

2. What is **extinction**?

   Disappearance of a species from its geographical range

3. What is a **paleontologist**?

   Scientist who studies fossils (classifies fossils).
FOSSILS

cues to the past
A FOSSIL is the remains or evidence of a living thing

- bone of an organism or the print of a shell in a rock
- burrow or tunnel left by an ancient worm
- most common fossils: bones, shells, pollen grains, seeds.
**PETRIFICATION** is the process by which plant or animal remains are turned into stone over time. The remains are buried, partially dissolved, and filled in with stone or other mineral deposits.

A **MOLD** is an empty space that has the shape of the organism that was once there. A **CAST** can be thought of as a filled in mold. Mineral deposits can often form casts.

Thin objects, such as leaves and feathers, leave **IMPRINTS**, or impressions, in soft sediments such as mud. When the sediments harden into rock, the imprints are preserved as fossils.
PRESERVATION OF ENTIRE ORGANISMS:
It is quite rare for an entire organism to be preserved because the soft parts decay easily. However, there are a few special situations that allow organisms to be preserved whole.

FREEZING: This prevents substances from decaying. On rare occasions, extinct species have been found frozen in ice.

AMBER: When the resin (sap) from certain evergreen trees hardens, it forms a hard substance called amber. Flies and other insects are sometimes trapped in the sticky resin that flows from trees. When the resin hardens, the insects are preserved perfectly.
**TAR PITS:** These are large pools of tar. Animals could get trapped in the sticky tar when they went to drink the water that often covered the pits. Other animals came to feed on these animals and then also became trapped.

**TRACE FOSSILS:** These fossils reveal much about an animal’s appearance without showing any part of the animal. They are marks or evidence of animal activities, such as tracks, burrows, wormholes, etc.
Where would you expect to find older fossils and where are the younger fossils?

Why?
Fossil Formation

- Buried remains of organisms settle on the **bottom**
- **How is sedimentary rock formed?**
- New layers of sediment are constantly being deposited
  - The weight of overlying rock compresses the lower layers
  - Eventually the sediments
    - **ROCK**
The Fossil Record:

- Provides evidence about the **history of life on earth**
- It also shows how different groups have **changed over time**
REVIEW: What are the 2 ways paleontologists date fossils?

- Which gives an estimate age?
- Which gives an absolute age?
- What is an index fossil?
- Why are they important?
What are the 2 ways paleontologists date fossils?

● Which gives an estimate age?
  – Relative Dating

● Which gives an absolute age?
  – Radioactive Dating

● What is an index fossil?
  – fossil used to help determine the relative age of the fossils around it
  – must be easily recognized and must have existed for a short period BUT over wide geographical area.
Radioactive Dating =

Calculating the **ABSOLUTE age** of fossils based on the amount of remaining radioactive isotopes it contains.

**Isotope** = atom of an element that has a number of **neutrons** different from that of other atoms of the same element
Radioactive Dating

- Certain naturally occurring elements are radioactive, and they decay (break down) at predictable rates.
- An isotope (the “parent”) loses particles from its nucleus to form an isotope of the new element (the “daughter”).
- The rate of decay is expressed in a “half-life”.

![Diagram of radioactive decay]
HALF LIFE = the amount of time it takes for $\frac{1}{2}$ of a radioactive element to decay.

How to figure out the age of the object:
1. comparing the amount of the “parent” (original sample) to the amount of the “daughter” (remaining sample)
2. knowing the half-life, then do the math to calculate the age!
<table>
<thead>
<tr>
<th>Parent Isotope</th>
<th>Daughter</th>
<th>Half-Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium-238</td>
<td>Lead-206</td>
<td>4.5 billion years</td>
</tr>
<tr>
<td>Uranium-235</td>
<td>Lead-207</td>
<td>704 million years</td>
</tr>
<tr>
<td>Thorium-232</td>
<td>Lead-208</td>
<td>14.0 billion years</td>
</tr>
<tr>
<td>Rubidium-87</td>
<td>Strontium-87</td>
<td>48.8 billion years</td>
</tr>
<tr>
<td>Potassium-40</td>
<td>Argon-40</td>
<td>1.25 billion years</td>
</tr>
<tr>
<td>Samarium-147</td>
<td>Neodymium-143</td>
<td>106 billion years</td>
</tr>
</tbody>
</table>
$T = 0$ half lives
(rock crystallizes)

$T = 1$ half life
(1 billion years old)

$T = 2$ half lives
(2 billion years old)

$T = 3$ half lives
(3 billion years old)
Radioactive Dating

Example: Carbon-14

- Used to date material that was once alive
- C-14 is in all plants and animals
  - C-12 is too, but it does NOT decay!
- When an organism dies, the amount of C-14 decreases because it is being converted back to N-14 by radioactive decay
The Carbon Cycle

photosynthesis

C-14

C-12

breathing

eating
CARBON-14

- By measuring the amount of C-14 compared to N-14, the time of death can be calculated.
- C-14 has a half life of 5,730 years.
- Since the half life is considered short, it can only date organisms that have died within the past 50,000-60,000 years.
Cosmic radiation

Nitrogen 14 → Neutron capture → Carbon 14

All three isotopes of carbon (C-12, C-13, C-14) are absorbed by living organisms.

Following death & burial, wood & bones lose C-14 as it changes to N-14 by beta decay.

Carbon 14 → Beta decay → Nitrogen 14

Beta particle

Red: Proton  Blue: Neutron
Review: Radioactive dating vs. Relative dating

Radioactive dating: “actual” age using radioactive isotopes and half lives

Relative dating: age of the fossil compared to others in layers of sedimentary rock (uses index fossils)
Radioactive Decay of Potassium-40

Time (billions of years)
Amount of Potassium-40 (g)
1. What fraction of potassium-40 remains after two half-lives?

2. What fraction of potassium-40 will remain after five half-lives?

3. How many years does it take for one half-life to occur?
Radioactive Decay of Potassium-40

![Graph showing the radioactive decay of Potassium-40 over time. The x-axis represents time in billions of years, ranging from 0 to 11. The y-axis represents the amount of Potassium-40 in grams, ranging from 0 to 220. The graph shows a exponential decay curve starting from an initial amount of 200 grams and decreasing to nearly zero over the span of 11 billion years.]
Answers

1. What fraction of potassium-40 remains after two half-lives? \( \frac{1}{4} \)

2. What fraction of potassium-40 will remain after five half-lives? \( \frac{1}{32} \)

3. How many years does it take for one half-life to occur? 1.3 billion years
4) How many half-lives will it take for potassium-40 to decay to 50g?
5) How long will it take for 200 g of potassium-40 to decay to 50g?
4) How **many half-lives** will it take for 200 g of potassium-40 to decay to 50g?
**2 half - lives**

5) How **long** will it take for 200 g of potassium-40 to decay to 50g?
**2.6 billion yrs.**
MACROEVOLUTION

Definition: **Large scale evolutionary changes** that take place over *long periods of time*.

Six patterns of macroevolution
1) Extinction / Mass extinction
2) Adaptive radiation (a.k.a. divergent evolution)
3) Convergent evolution (analogous structures)
4) Coevolution
5) Gradualism
6) Punctuated equilibrium
Extinction / Mass Extinction

- some species become extinct due to slow but steady process of natural selection (= “background extinction”)
- **MASS EXTINCTION** = an event during which many species become extinct over a relatively short period of time
  - entire ecosystems vanish
  - whole food webs collapse
Adaptive Radiation

Process of one species giving rise to many species that live in different ways (niches)

A.K.A.: DIVERGENT EVOLUTION

EX: Darwin’s finches!
Adaptive radiation in Galapagos finches

- medium tree finch (Camarhynchus pauper)
- small tree finch (Camarhynchus parvulus)
- vegetarian finch (Camarhynchus crassirostris)
- large cactus finch (Geospiza conirostris)
- cactus finch (Geospiza scandens)
- sharp-beaked ground finch (Geospiza difficilis)
- large ground finch (Geospiza magnirostris)
- medium ground finch (Geospiza fortis)
- large tree finch (Camarhynchus psittacula)
- mangrove finch (Camarhynchus heliobates)
- woodpecker finch (Camarhynchus pallidus)
- warbler finch (Certhidea olivacea)
- Cocos Island finch (Pinaroloxias inornata)
- small ground finch (Geospiza fuliginosa)

ancestral seed-eating ground finch

mainly seeds
mainly insects
buds and fruits
caucus seeds and parts
Organisms evolve a variety of characteristics that enable them to survive in different niches
CONVERGENT EVOLUTION:

- Different organisms (unrelated) look similar *because they live in similar environments*
- Different “raw material” for natural selection to work on, but…
  - Similar environmental demands
  - EX: moving through air, water, eating similar foods

![Diagram of convergent evolution examples: Falcon, Bat, Pterodactyl]
CONVERGENT EVOLUTION:

- Produces analogous structures like the dolphin’s fluke and a fish’s tail fin
  - Look and function similarly but do not share a common evolutionary history
CONVERGENT EVOLUTION:

THE PROCESS BY WHICH TWO LINES OF EVOLUTIONARY DEVELOPMENT BRING ABOUT SUPERFICIA LLY SIMILAR CREATURES. WHEN DIFFERENT GROUPS OF ORGANISMS ARE SUBJECTED TO THE SAME ENVIRONMENTAL SELECTION PRESSURES, THEY TEND TO EVOLVE SIMILAR DESIGN FEATURES.

INTERNAL STRUCTURE OF PECTORAL FIN: FIVE-FINGERED LIMB HAS EVOLVED INTO A FIN OF SAME SHAPE.

NOTE: EVEN THOUGH THESE TWO CREATURES LOOK SIMILAR, THEY ARE COMPLETELY DIFFERENT ANIMALS: ONE A MARINE REPTILE; THE OTHER, A MARINE MAMMAL FROM A COMPLETELY DIFFERENT TIME PERIOD.
COEVOLUTION:

- 2 species exert an evolutionary influence on one another (and so, coevolve)

Examples:
- a parasite and its host
- a flowering plant and its pollinator insect or bird
Rate of Evolution:

- evidence shows that evolution has often proceeded at different rates for different organisms at different times over the long history of life on Earth…

- Gradualism
- Punctuated Equilibrium
GRADUALISM: (Darwin’s idea of evolution):

- Darwin thought evolution only took place over a LONG time
  - Hutton and Lyell’s discussion of slow geologic change
- **GRADUALISM** = fossil record shows continuous, minor changes (**evolution is slow and steady**)!
Punctuated Equilibrium:

- Equilibrium—hardly any change
- Definition: A pattern of long stable periods interrupted by brief periods of rapid change
**Examples:**

When the equilibrium is upset, change can occur in a short period of time

- **EX:** A small group of organisms migrate to a new environment
  - Organisms evolve quickly to fill available niches (Galapagos Finches)

- **EX:** A small population is cut off from its original population
Example of Punctuated Equilibrium:

- Life is going on smoothly for a population of mice.
- Then **whoosh!**
- There is a flood which separates the population into two groups, one on one side of a river and one on the other side. (Geographic isolation $\rightarrow$ reproductive isolation!)

- What could happen as a result?
Gradualism vs. punctuated equilibrium:

- Biologists agree that either gradualism or punctuated equilibrium can result in speciation, depending on the circumstances.