Unit 5: Formation of the Earth

Objectives:

E5.3B - Explain the process of radioactive decay and explain how radioactive elements are used to date the rocks that contain them.

E5.3C - Relate major events in the history of the Earth to the geologic time scale, including formation of the Earth, formation of an oxygen atmosphere, rise of life, Cretaceous-Tertiary (K-T) and Permian extinctions, and Pleistocene ice age.

Radioactive Isotopes

Rocks generally contain small amounts of radioactive material that can act as natural clocks. Atoms of the same element that have different numbers of neutrons are called isotopes. **Radioactive isotopes** have nuclei that emit particles and energy at a constant rate regardless of surrounding conditions.

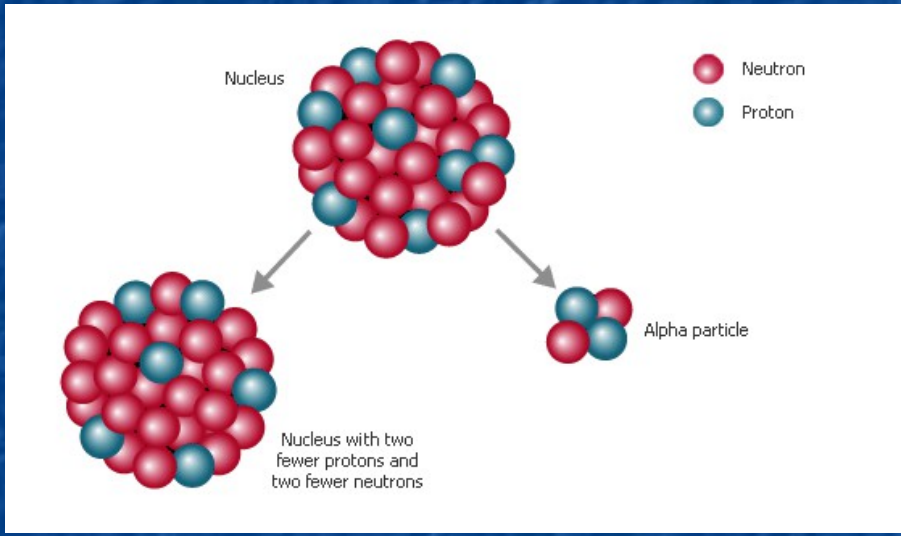
Uranium Ore

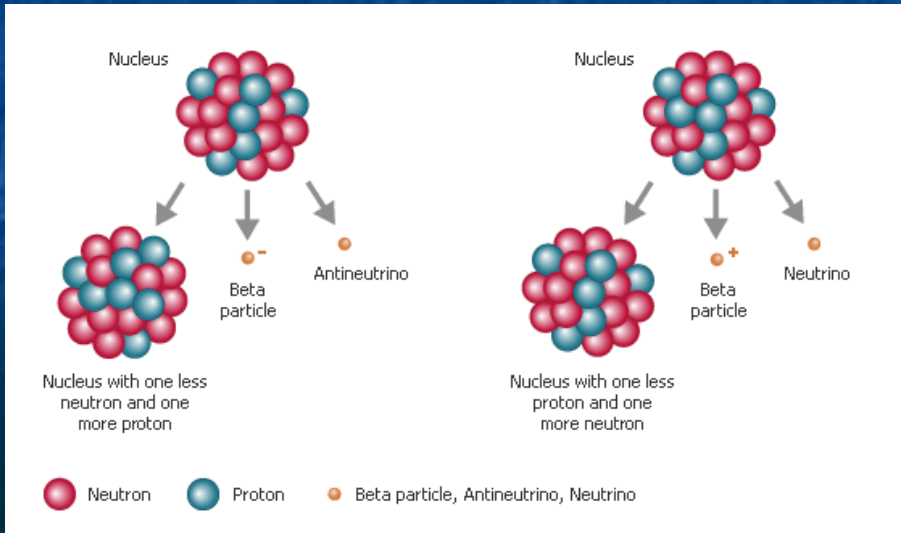
Radiometric Decay*

Alpha decay and beta decay are two forms of radioactive decay. In all forms of radioactive decay, an atom emits particles and energy.

Scientists use this natural breakdown of isotopes to accurately measure the **absolute age** of rocks.

The method of using radioactive decay to measure absolute age is called **radiometric decay**.

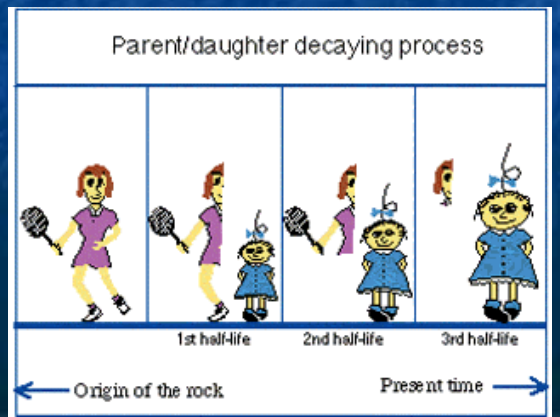




Parent / Daughter Isotopes

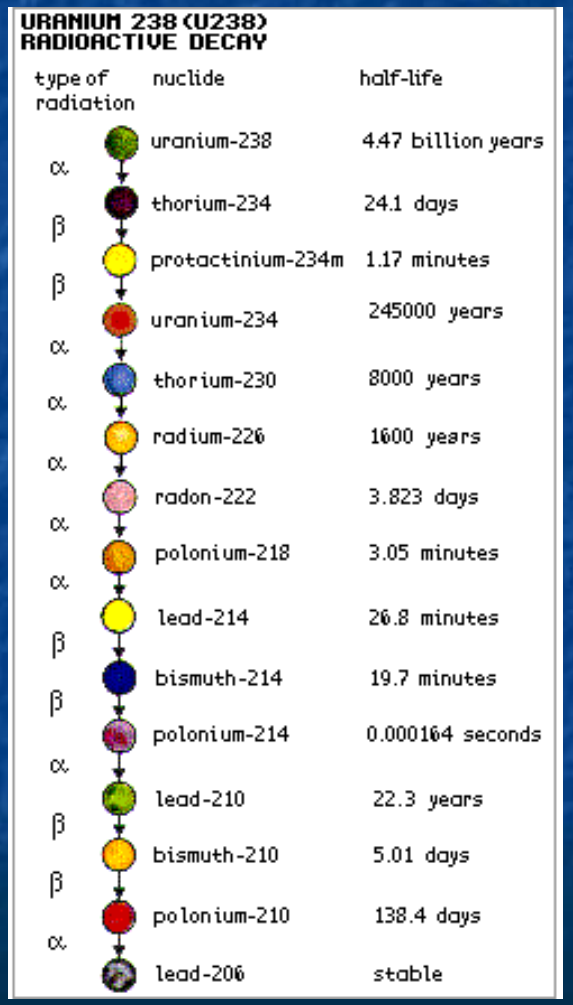
As an atom emits particles and energy, the atom changes into a different isotope of the same element or an isotope of a different element. Scientists measure the concentrations of the original radioactive isotope (known as the **parent isotope**), and of the new formed isotopes (known as the **daughter isotope**).

Using the known decay rate, the scientists compare the proportions of the parent and daughter isotopes to determine the absolute age of the rock.



Radioactive Isotopes

The amount of time that has passed since a rock formed determines which radioactive element will give a more accurate age measurement. If too little time has passed since radioactive decay began, there may not be enough of the daughter isotope for accurate dating. If too much time has passed, there may not be enough of the parent isotope left for accurate dating.



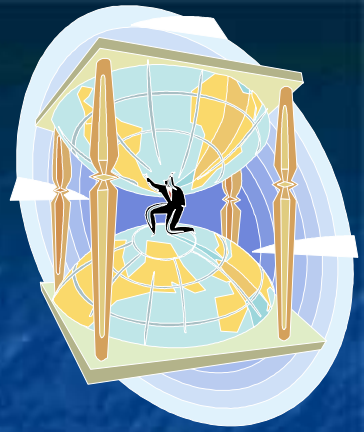
Radioactive Isotopes

Uranium-238 has an extremely long half-life of 4.5 billion years. It is most useful for dating geologic samples that are more than 10 million years old, as long as they contain uranium.

Other isotopes are also used to date rock samples. Potassium-40 has a half-life of 1.25 million years. Potassium-40 occurs in mica, clay, and feldspar and is used to date rocks that are between 50,000 and 4.6 billion year old.

Rubidium-87 has a half-life of about 49 billion years. Rubidium-87 commonly occurs in minerals that contain potassium-40, so it can be used to verify the age of rocks previously dated by using potassium-40.

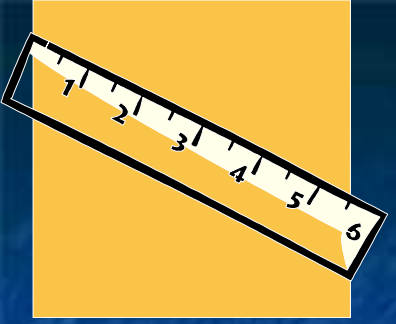
Geologic Time



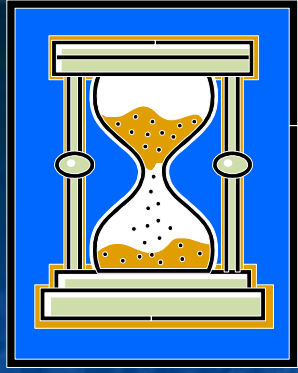
The geologic history of Earth is marked by major changes in Earth's surface, climate, and types of organisms. Geologists use these indicators to divide the geologic time scale into smaller units.

Rocks groups within each unit contain similar fossils. In fact, a unit of geologic time is generally characterized by fossils of a dominant life-form.

Because Earth's history is so long, Earth scientists commonly use abbreviations when they discuss geologic time. For example, Ma stands for *mega-annum*, which means "one million years."



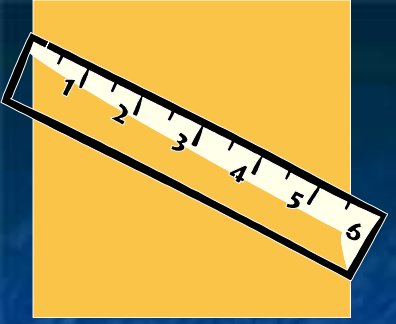
Eons and Eras



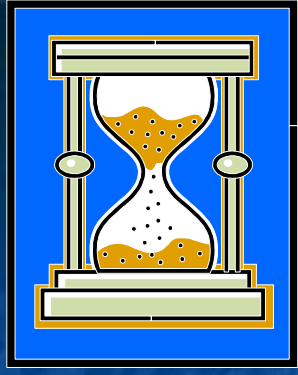
The largest unit of geologic time is an **eon**. Geologic time is divided into four eons – the Hadean eon, the Archean eon, the Proterozoic eon, and the Phanerozoic eon.

The first three eons of Earth's history are part of a time interval commonly known as **Precambrian time**. This four billion year interval contains most of Earth's history. Very few fossils exist in early Precambrian rocks.

Eons are divided into smaller units of geologic time called **eras**. The present era is the Cenozoic Era, which began about 65 million years ago. Fossils of mammals are common in Cenozoic rocks.

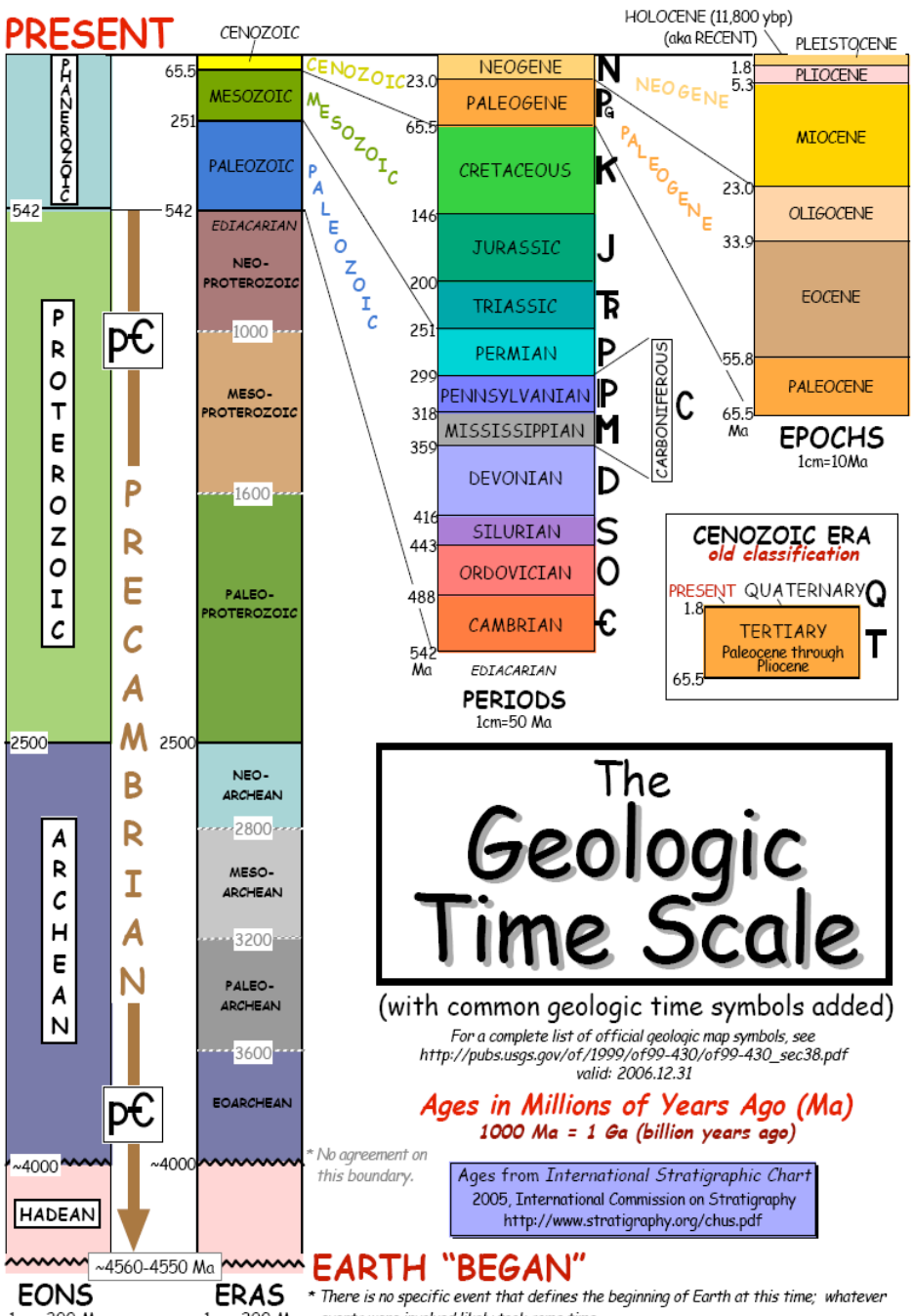


Periods and Epochs



Eras are divided into shorter time units called **periods**. Each period is characterized by specific fossils and is usually named for the location in which the fossils were first discovered.

Where the rock record is most complete and least deformed, a detailed fossil record may allow scientists to divide periods into shorter time units called **epochs**. Epochs may be divided into smaller units of time called **ages**. Ages are defined by the occurrence of distinct fossils in the fossil record.


PRESENT
CENOZOIC
HOLOCENE (11,800 ybp)
(aka RECENT)
PLEISTOCENE
PHANEROZOIC
PROTEROZOIC
ARCHEAN
HADEAN
pC
PRECAMBRIAN
65.5
251
542
1000
1600
2500
2800
3200
3600
~4000
~4560-4550 Ma
MESOZOIC
PALEOZOIC
EDIACARIAN
NEO-PROTEROZOIC
MESO-PROTEROZOIC
PALEO-PROTEROZOIC
NEO-ARCHEAN
MESO-ARCHEAN
PALEO-ARCHEAN
EOARCHEAN
EONS
1cm=200 Ma
ERAS
1cm=200 Ma
CENOZOIC
MESOZOIC
PALEOZOIC
NEOGENE
PALEOGENE
CRETACEOUS
JURASSIC
TRIASSIC
PERMIAN
PENNSYLVANIAN
MISSISSIPPIAN
CARBONIFEROUS
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
23.0
146
200
251
299
318
359
416
443
488
542 Ma
EDIACARIAN
N
Pg
K
J
TR
P
PM
M
C
D
S
O
€
PERIODS
1cm=50 Ma
1.8
5.3
23.0
33.9
55.8
65.5 Ma
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
PALEOCENE
EPOCHS
1cm=10Ma
CENOZOIC ERA
old classification
PRESENT
QUATERNARY
Q
1.8
TERTIARY
Paleocene through Pliocene
T
65.5
The
Geologic
Time Scale
(with common geologic time symbols added)
For a complete list of official geologic map symbols, see
http://pubs.usgs.gov/of/1999/of99-430/of99-430_sec38.pdf
valid: 2006.12.31
Ages in Millions of Years Ago (Ma)
1000 Ma = 1 Ga (billion years ago)
* No agreement on this boundary.
Ages from International Stratigraphic Chart
2005, International Commission on Stratigraphy
http://www.stratigraphy.org/chus.pdf
EARTH "BEGAN"
* There is no specific event that defines the beginning of Earth at this time; whatever events were involved likely took some time.
* Candie (2005) gives the following dates: the solar nebula formed 4570 Ma, early asteroids melted 4566 Ma, and Earth accreted/Moon formed by 4530-4520 Ma.
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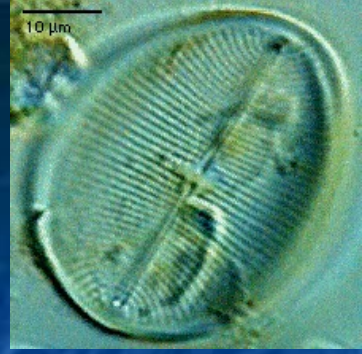
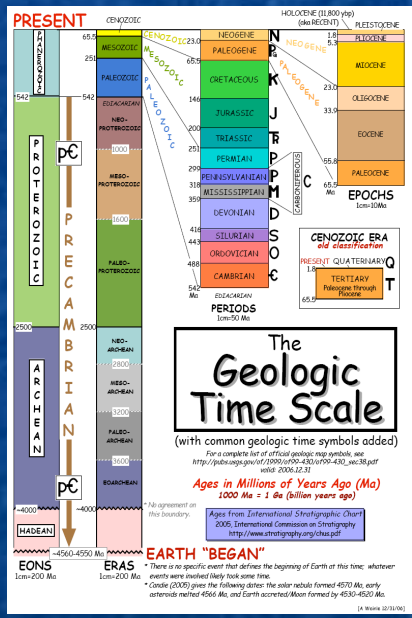
Precambrian Time*



Precambrian time starts about 4,600 Ma (million years ago) and continues up to 542 Ma. Important events during this time include:

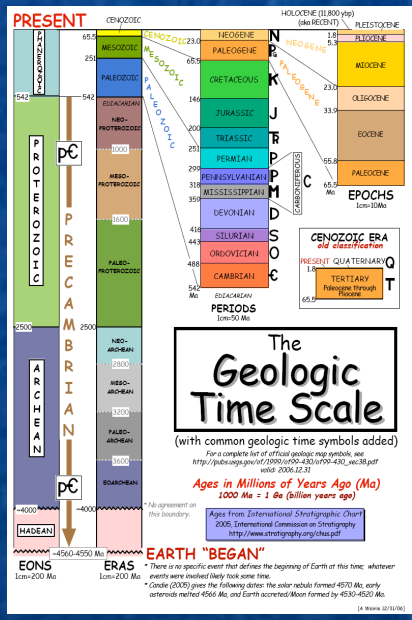
- 4,600 Ma – The formation of the planet Earth.
- First crustal rocks form
- Earth's surface is cool enough for liquid water
- 4,000 – 3,800 Ma – First known unicellular life appears
- 2,400 – 2,300 Ma – Earth's atmosphere starts to become oxygen rich
- First known multicelluar life appears
- First fungi appear
- First shelled organisms, such as arthropods and mollusks, appear



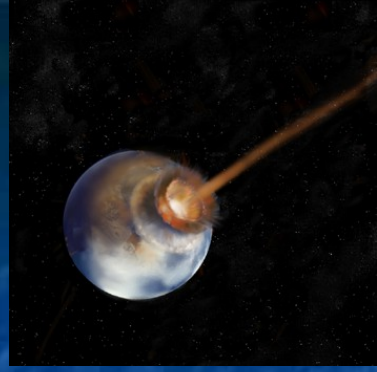
Paleozoic Era*

The **Paleozoic Era** starts about 542 Ma and continues up to 251 Ma. Important events during this time include:

- First possible vertebrates appear (Cambrian Period)
- Modern, oxygen-rich atmosphere has formed (Ordovician Period)
- First land plants appear (Silurian Period)
- First arthropods appear on land (Silurian Period)
- First amphibians appear (Devonian Period)
- First reptiles appear (Pennsylvanian Period or Carboniferous Period)
- Formation of Pangaea is complete (Permian Period)
- 251 Ma – Permian mass extinction results from major environmental changes such as tectonic activity and the disappearance of shallow inland seas (Permian Period)

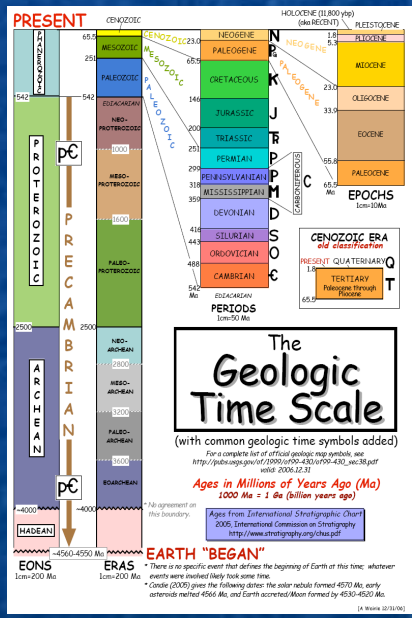


Mesozoic Era*



The **Mesozoic Era** starts about 251 Ma and continues up to 65.5 Ma. Important events during this time include:

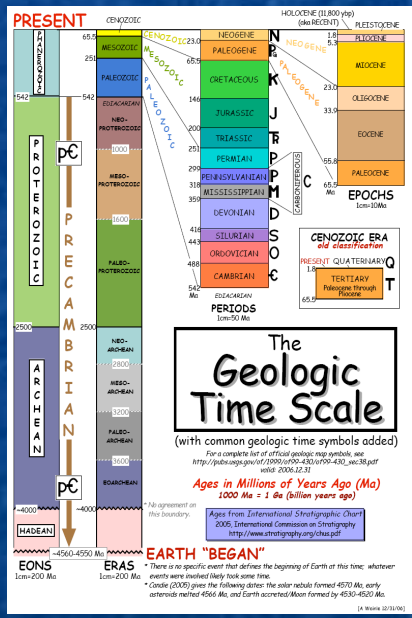
- Pangaea begins to break apart (Triassic Period)
- First mammals appear (Triassic Period)
- First primitive birds appear (Jurassic Period)
- First flowering plants (angiosperms) appear (Cretaceous Period)
- First modern birds appear (Cretaceous Period)
- 65.5 Ma – The last dinosaur becomes extinct. Catastrophic meteorite impact occurs. (Cretaceous Period) The Cretaceous-Tertiary boundary contains a layer of iridium-laden rock. Iridium is a substance that is uncommon in rocks on Earth, but is common in meteorites.



Cenozoic Era*

The **Cenozoic Era** began about 65.5 Ma and is the current, ongoing era. Important events during this time include:

- Most modern mammal families, including whales, carnivores, hoofed animals, and primates have appeared (Eocene Epoch)
- First grasses appear (Eocene Epoch)
- India collides with Asia, and Antarctica drifts over the South Pole (Oligocene Epoch)
- First hominids (early human ancestors) appear (Miocene Epoch)
- Modern Ice Age begins (Pliocene Epoch)
- 1.8 Ma – Pleistocene Ice Age begins (Pleistocene Epoch)
- Modern Humans appear (Pleistocene Epoch)



Holocene Epoch*

The current epoch, the **Holocene Epoch**, began about 11,500 years ago. Important events during the current time of our geologic time scale include:

- 11,500 years ago – The end of the last glacial period
- The Great Lakes formed
- Modern humans developed agriculture and began to make use of tools.

Human history is extremely brief. If you think of the entire history of Earth as one year, the first multicellular organisms would have appeared in September. The dinosaurs would have disappeared at 8 P.M. on December 26. Modern humans would have not appeared until 11:48 P.M. on December 31.