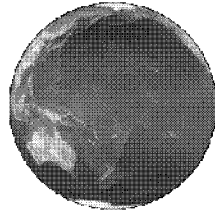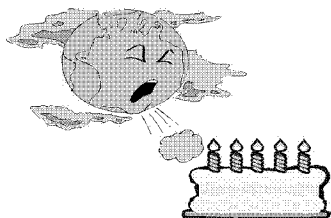Tuesday, September 28
The Geological Revolution:
How Old is the Earth?

The Geological Revolution
Key Concepts

1) Some cultures have believed the Earth to be young; others, to be infinitely old.
2) Geological evidence indicates the age of the Earth is large but finite.
3) **Radiometric dating** indicates the Earth is about 4.5 billion years old.

"How old is the Earth?"

In the Christian world, before the 18th century, **biblical chronology** was the accepted method of finding the Earth's age.

Ultimate precision:
in the 17th century, Archbishop
James Ussher wrote:

"The beginning of time…fell on the beginning
of the night which preceded the 23rd day of
October, in the year 4004 BC."

Hinduism:
Cycle of creation and destruction.
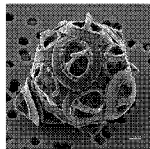"Day of Brahma" = 4.32 billion years.

Jainism:
"Know that the world is uncreated, as time
itself is, without beginning or end."

Buddhism:
"Many statements I have left unsaid. Why have I
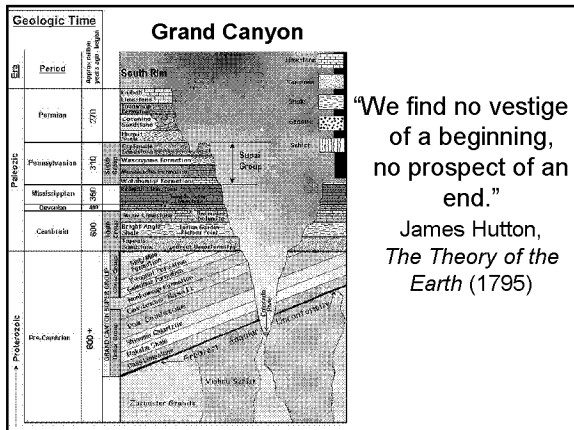left them unsaid? Because they are not helpful."

18th century: Geologists realized that the Earth
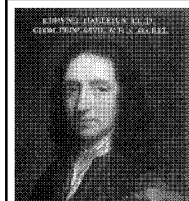is much more than 6000 years old.

The White Cliffs of Dover:
a layer of tiny shells,
100 meters thick.

There's a huge number & variety of fossils on
Earth (> 99.9% of all species are extinct).

Grand Canyon

Geologic Time		
Era	Period	Approx. radio- metric age (years)

Paleozoic	Permian	270
	Pennsylvanian	310
	Mississippian	350
	Devonian	400
	Cambrian	600
Proterozoic	Pre-Cambrian	600 +

South Rim

"We find no vestige of a beginning, no prospect of an end."
James Hutton,
The Theory of the Earth (1795)

Edmund Halley (1656-1742):
Oceans become saltier with time, as rivers wash salt into the sea.

The Earth is not very young
(oceans would be fresh water).

The Earth is not infinitely old
(oceans would be saturated with salt).

Best method for finding the age of rocks:
Radiometric dating

Energy

Radiation   (Flashforward to chapter 4)
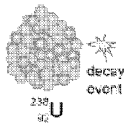
Radioactive Atom
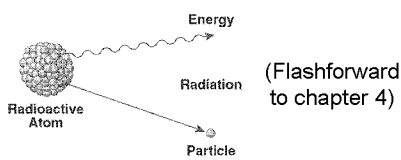
Particle

Some atomic nuclei are unstable.
They undergo radioactive decay, emitting particles to become a smaller, stable nucleus.

Example of an unstable nucleus:
Uranium-238
(92 protons + 146 neutrons = 238)
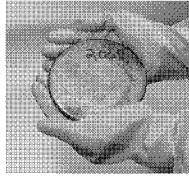
Uranium-238 decays to Lead-206
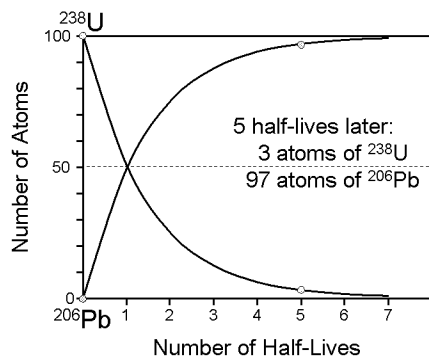(82 protons + 124 neutrons = 206)

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Decay of unstable nuclei is a **random** process.

$^{238}_{92}U$

You can't say when any particular nucleus is going to decay.

You can only give the **half-life**:
the time it takes **half** the nuclei in a lump of material to decay.

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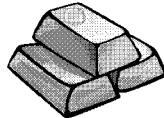Start with: 100 atoms of ^{238}U
0 atoms of ^{206}Pb

5 half-lives later:
3 atoms of ^{238}U
97 atoms of ^{206}Pb

The half-life of uranium-238 is
4.5 billion years.

Start with an ingot of solid uranium-238.

After 4.5 billion years (1 half-life),
½ the uranium will have turned to lead.

After 9 billion years (2 half-lives),
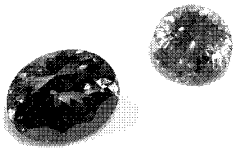¾ the uranium will have turned to lead.

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Radiometric dating (in principle):

Someone hands you an ingot of metal.
It's ¼ uranium-238, ¾ lead-206.

Age of ingot = 2 half-lives =
9 billion years, **IF** it started as pure
uranium-238.

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When it comes to radiometric dating, **zircons**
are a geologist's best friend.

Zircon =
zirconium silicate,
with various impurities

Newly formed zircon crystals are frequently
contaminated with uranium, never with lead.

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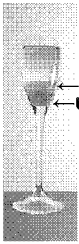
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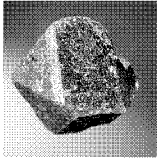
Zircon crystals are hard to destroy, easy to detect.

Grind up a zircon, do a chemical analysis, find the relative amounts of lead-206 and uranium-238.

Compute the number of half-lives that have elapsed.

Caveat: when zircon melts, very dense uranium sinks to bottom, separating from slightly-less-dense lead.

←lead
←uranium

The age of a rock found by radioactive dating is the time since the rock solidified.

Tomorrow's Lecture:

Cosmological Revolution:
How Big is the Universe?

This week's reading:

Chapters 2 & 3