Next:
Planetary Geology
Earth and the Other Terrestrial Worlds
Entering A New Phase of the Course

• First phase: Layout of the Solar system, why we see what we see
  - (hidden message: how science works)
• Second Phase: Why is the Solar system laid out this way?
• Third Phase: Evolution of the Planets
• Final Phase: What about other solar systems?
Today & Beyond:

- **Planetary Geology**
  - Inside the terrestrial worlds
  - How interiors work
- **Three Fundamental Properties**
  - a.k.a. Formation Properties
- **Four Geological Processes**
  - What they are
  - How they depend on a planet’s *fundamental properties*
Comparative Planetology

• **OK, so we made a solar system...**
  - Planets made of (mostly) the same stuff at the same time

• **Why do the planets look so different?**
  - Planets obey a few simple rules
    • Differences among the planets can be traced to fundamental properties such as size, location, etc.

• **Geology depends on what’s inside...**
Today: Let’s go inside the planets and see what makes them tick

• Interiors of the terrestrial planets
• Heating & Cooling processes
Terrestrial Worlds - Interiors & Surfaces

Mercury

Venus

Earth

Mars

Moon
Comparison of Planetary Surfaces

Main Features

• **Mercury & the Moon**
  - Heavily cratered *{heavy bombardment}*  
  - Some volcanic plains, a few cliffs & ridges
• **Venus**
  - Volcanoes and bizarre bulges
• **Mars**
  - Volcanoes and canyons  
  - Apparently dry riverbeds *{past running water?}*  
• **Earth**
  - Most of the above plus liquid water  
  - Not much cratering
Anatomy of a Planet

If defined by DENSITY

- **Core**
- **Metals** *(Iron, Nickel)*

- **Mantle**
- **Medium-density Rocks** *(Silicates: quartz, olivine)*

- **Crust**
- **Low-density rocks** *(Granite, Basalt)*
Anatomy of a Planet

If defined by **STRENGTH**

- Lithosphere
- Outer layer of cool, rigid rock
- Everything else
- The warmer, softer rock that lies beneath
<table>
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<tr>
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</tr>
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<tbody>
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The Moon has an overall density of 3.3 g/cm$^3$ - based on its density ONLY we would conclude it must be:

A. All rock
B. Mostly rock with some iron
C. Mostly rock with some water
D. Mixture of rock, water and iron
E. You can’t tell, it could be any of the above
### Clicker Question

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How do we know about the insides of planets?
Planetquakes can ‘ping’ the interior

- Vibrations that travel through Earth’s interior tell us about the densities and composition of material on the inside.
Magnetic fields are also clues to the inside

- 3 things are required for a magnetic field
  - Electrically conducting region
  - Convection
  - Rotation
How does a terrestrial world end up separated into a core, mantle, and crust?
Differentiation

- Gravity pulls heavy material to center
- Lighter material rises to surface
- Material ends up separated by density
Differentiation

- Requires that **ALL** material in the core/mantle was once molten
  - Metal and rock needed to melt to separate

Today, only part of the core and a very small layer of the mantle is liquid, the rest is solid

- Despite high temperatures, pressure keeps rocks solid
What part(s) of the Earth are liquid?

A. Everything under the crust
B. Part of the core and a very small part of the mantle
C. All of the core and part of the mantle
D. Just the core
E. Just the mantle
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Why is Earth’s core made of metals?

A. Materials with the highest melting point collect where it’s warmest
B. The core formed first in the solar nebula, then rocks collected around it
C. Earth’s magnetic field pulls metal to the center
D. Denser materials fell to the core, and lighter materials rose
E. Metals are less abundant, and collected in a smaller volume near the center
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Next: Planetary Interiors and Surface Effects

- Heating & Cooling processes
- Processes that shape a planet’s surface
Processes that HEAT planets

- Accretion
- Differentiation
- Radioactive Decay
Transporting HEAT away (i.e. COOLING)

1. Convection
Transportation of thermal energy as hot material rises and cold material falls (in the mantle)

2. Conduction
Transportation of thermal energy from hot material touching cold material (in the lithosphere)

3. Radiation
Transportation of thermal energy as light (at the surface)
How long does it take an object to cool off?

• **Heat content:**
  - Depends on volume

• **Heat loss:**
  - Depends on surface area (since surface is where heat is lost)

• **Time to cool:** Heat content/Heat loss
Think: What takes longer to cool off, a potato or a pea?
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• **Time to cool:** Heat content/Heat loss

\[
\text{time to cool } \propto \text{ volume to surface area ratio } = \frac{V}{A}
\]
As you increase the radius of a sphere, what goes up faster, the volume or the surface area?

A. Volume
B. Surface Area
C. It depends on the starting and ending radii
D. They both go up by the same amount
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\[
\text{time to cool} \propto \frac{V}{A} = \frac{\frac{4}{3} \pi r^3}{4 \pi r^2} = \frac{r}{3}
\]

*Larger objects take longer to cool*
Two planets have the same density, but one has a radius 3 times larger than the other. If the larger planet cools in 3 billion years, how long does it take for the smaller planet to cool?

A. Same time
B. 3 billion years
C. It depends on the starting and ending Temp
D. 1 billion years
E. 1 million years
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