Key Concepts

(1) The **terrestrial** planets are made primarily of rock and metal.

(2) The **Jovian** planets are made primarily of hydrogen and helium.

(3) Moons (a.k.a. satellites) orbit the planets; some moons are large.

(4) Asteroids, meteoroids, comets, and Kuiper Belt objects orbit the Sun.

(5) Collision between objects in the Solar System cause **impact craters**.
Family portrait of the Solar System:

Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, (Eris, Ceres, Pluto):

My Very Excellent Mother Just Served Us Nine (Extra Cheese Pizzas).
## The Solar System: List of Ingredients

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percent of total mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>99.8%</td>
</tr>
<tr>
<td>Jupiter</td>
<td>0.1%</td>
</tr>
<tr>
<td>other planets</td>
<td>0.05%</td>
</tr>
<tr>
<td>everything else</td>
<td>0.05%</td>
</tr>
</tbody>
</table>
The Sun dominates the Solar System
Jupiter dominates the planets
<table>
<thead>
<tr>
<th>Object</th>
<th>Mass</th>
<th>Object</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Sun</td>
<td>330,000</td>
<td>10) Ganymede</td>
<td>0.025</td>
</tr>
<tr>
<td>2) Jupiter</td>
<td>320</td>
<td>11) Titan</td>
<td>0.023</td>
</tr>
<tr>
<td>3) Saturn</td>
<td>95</td>
<td>12) Callisto</td>
<td>0.018</td>
</tr>
<tr>
<td>4) Neptune</td>
<td>17</td>
<td>13) Io</td>
<td>0.015</td>
</tr>
<tr>
<td>5) Uranus</td>
<td>15</td>
<td>14) Moon</td>
<td>0.012</td>
</tr>
<tr>
<td>6) Earth</td>
<td>1.0</td>
<td>15) Europa</td>
<td>0.008</td>
</tr>
<tr>
<td>7) Venus</td>
<td>0.82</td>
<td>16) Triton</td>
<td>0.004</td>
</tr>
<tr>
<td>8) Mars</td>
<td>0.11</td>
<td>17) Pluto</td>
<td>0.002</td>
</tr>
<tr>
<td>9) Mercury</td>
<td>0.055</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A few words about the Sun.

The Sun is a large sphere of gas (mostly H, He – hydrogen and helium). The Sun shines because it is hot (T = 5,800 K). The Sun remains hot because it is powered by fusion of hydrogen to helium (H-bomb).
(1) The terrestrial planets are made primarily of rock and metal. Mercury, Venus, Earth, & Mars.

The terrestrial planets are:
- low in mass (< Earth mass)
- high in density (> 3900 kg/m$^3$).

Water = 1000 kg/m$^3$
Air = 1 kg/m$^3$
Rock = 3000 kg/m$^3$
The mass of a planet is determined by Newton’s version of Kepler’s Third Law, applied to a satellite (natural or artificial).

The average density is mass divided by volume (for a sphere, \( V = \frac{4\pi}{3} r^3 \)).

The density of terrestrial planets is greater than that of rock, reflecting the presence of extremely dense metal cores.
The Jovian planets are made primarily of hydrogen and helium. Jupiter, Saturn, Uranus, & Neptune:
The Jovian planets are:
high in mass (> 14 Earth masses)
low in density (< 1700 kg/m³).
Jovian planets are made mainly of light elements like hydrogen and helium.
Pluto is very low in mass and moderate in density (about 2000 kg/m$^3$). It is surmised that Pluto is made of mixture of ice and rock.
Spectra, again!

The spectrum of reflected light tells us what an object is made of (at least on the surface).

Example: The spectrum of Pluto is similar to that of methane ice (frozen CH\textsubscript{4}).
Moons (a.k.a. “satellites”) orbit the planets; some moons are large.

The current moon count:

Mercury = 0  Neptune = 13
Venus = 0  Ceres = 0
Earth = 1  Pluto = 3
Mars = 2  Eris = 1
Jupiter = 63  Jovian planets are moon-rich; others are not.
Saturn = 56
Uranus = 27
# The Giant Moons

(moons bigger than Pluto)

<table>
<thead>
<tr>
<th></th>
<th>Earth:</th>
<th>Jupiter:</th>
<th>Saturn:</th>
<th>Neptune:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The Moon</td>
<td>Io</td>
<td>Europa</td>
<td>Callisto</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ganymede</td>
<td></td>
<td>Titan</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Triton</td>
</tr>
</tbody>
</table>
Giant Moons and Dwarf Planets

The giant moons are low in density compared to the terrestrial planets.
Another Size Comparison
Asteroids, meteoroids, comets, and Kuiper Belt objects orbit the Sun.

**Asteroids:** made of rock and metal, less than 1000 km across. (Most asteroids are in orbit between Mars and Jupiter.)
Meteoroids: made of rock and metal, less than 300 meters across. (When a meteoroid enters Earth’s atmosphere, it produces a meteor.)
Comets: made of dirty ice, a few kilometers across. (Comets have tails of gas and dust when they come near the Sun.)
Kuiper Belt objects: made of ice, hundreds of kilometers across. (The “Kuiper Belt” lies beyond the orbit of Neptune.)
Collisions between objects in the Solar System cause impact craters. The orbits of the planets are well separated; planets do not collide with each other.

Smaller objects, though, frequently collide with planets and moons.
When a meteoroid, asteroid, or comet strikes a terrestrial planet (or moon), it blasts out an impact crater.

The Moon is heavily cratered; Earth has few craters, due to erosion and geological activity.
The few impact craters on the Earth have been smoothed out by erosion, glaciers, lava flows, etc.

A heavily cratered world is a geologically “dead” world.
The current state of the Solar System contains clues to its history.

Terrestrial planets are close to Sun

\[ a = 0.4 \text{ A.U.} \rightarrow 1.5 \text{ A. U.} \]

Jovian planets are far from Sun

\[ a = 5 \text{ A.U.} \rightarrow 30 \text{ A. U.} \]

Just coincidence, or an important clue?
All planets revolve in the same direction (counterclockwise, seen from above the North Pole).

Just coincidence, or an important clue?
Most (but not all) planets rotate in the same direction (counterclockwise, seen from above the North Pole).

Uranus and Pluto are “sideways”, Venus is “upside-down”.

Could this also be a clue?
Few closing questions:

1) How do we know the mass of Mars? Mass of Venus?
2) Which one is denser: Moon or Earth?
3) Which one is denser: Moon or Pluto?
4) Can density of a planet be lower than density of water?
5) What are the seasons on Uranus?