Required Reading

The Solar System:
Recall Kepler's Third Law (P^2 is proportional to a^3):

		a (average distance from the Sun, in AU)	**P** (orbital period, around the Sun)	
My	Mercury	0.3	88 days	
Very	Venus	0.7	243 days	
Educated	Earth	1 AU (by definition)	1 year (by definition)	
Mother	Mars	1.52	687 days	
Just	Jupiter	5.2	12 years	
Showed	Saturn	9.6	29 years	Discovered:
Us	Uranus	19	84 years	1781 William Herschel
Nine	Neptune	30	165 years	1846 Johann Galle
Planets	Pluto	40	248 years	1930 Clyde Tombaugh

Mercury-Saturn can all be seen with the unaided eye, and so were known to the ancients.

Nearly all the mass in the Solar System is in the Sun.
Jupiter has 3 times more mass than all the other planets put together.

The terrestrial planets are the Earth-like planets (Terra = "Earth," in Latin).
They're relatively small (with diameters less than 6400 km), and rocky.

The Jovian, or giant planets, include Jupiter, Saturn, Uranus (you-RAN-us), and Neptune.
They're all large and gaseous. All have rings, and extensive systems of satellites.
They're more like small stars than terrestrial planets: none have solid surfaces.

Small bodies, with diameters less than 1000 km, include:
Asteroids are from the inner Solar System, and are mostly rock.
Comets are from the outer Solar System, and are mostly ice.

Meteorites are asteroidal or cometary fragments that hit Earth.
Meteors burn up in Earth's atmosphere, because of ram pressure (not really "friction") from their high speed.

Between Mars and Jupiter is **the asteroid belt**, where hundreds of thousands of asteroids orbit the Sun. Not all asteroids are in the Main Belt: hundreds cross Earth's orbit. (!)
An impact of an asteroid or comet 10 km in diameter is thought to have caused the extinction of the dinosaurs, at the end of the Cretaceous Age, 66 million years ago.

Pluto is smaller than Earth's Moon. It was discovered in 1930. Since 1992, over 1,000 other, small, icy bodies have been found beyond the orbit of Neptune. These are called **Kuiper Belt Objects** (KBOs), or Trans-Neptunian Objects, or Ice Dwarfs.

Pluto is only slightly larger than another Kuiper-Belt object, Eris, which was discovered in 2003. Pluto was therefore demoted from being called a planet in 2006.

Beyond this is **the Oort Cloud**, a spherical shell of icy **comets**. The comets sometimes wander into the inner Solar System and dazzle us with their tails, which are their ice evaporating (actually sublimating) into space, in the light of the Sun.

Required Reading

The Solar System formed 4.57 $\pm$ 0.02 billion years ago, in the Solar Nebula.

The best evidence that this happened is:

(1) We can see it happening now around young stars, e.g. in the Orion Nebula.
(2) The scars of it, **impact craters**, are on Earth's Moon and other moons and planets.
(3) The age is known from radioactive dating of meteorites.

Earth's Moon is now thought to have formed in a giant impact, near the end of this process. A giant impact might also explain the retrograde (backwards) and slow rotation of Venus.

The four primary processes that shape the surfaces of planets and their satellites are:

(1) Impact cratering, which is rare on Earth because of wind and especially water erosion, and plate tectonics, which resurfaces Earth every 100 million years. Impact cratering is common elsewhere in the Solar System. It dominates the surface of Earth's Moon, most other satellites, Mercury, and the southern hemisphere of Mars.

(2) Tectonism: plate tectonics is the dominant process on Earth, forming folding mountains (such as the Sierras and the Rockies), continental drift and seafloor spreading, and earthquakes. It is rare elsewhere in the Solar System: it is found only on Ganymede, the icy largest moon of Jupiter (which is larger than Mercury).

(3) Volcanism: the largest mountains of any kind known in the Solar System are the volcanoes of Mars, which are three times higher than Mount Everest. Lava plains, or maria, on Earth's Moon, Mercury, Venus and Mars resemble the lava plains lining the ocean floors of Earth. Io (pronounced "EYE-oh"), a moon of Jupiter, is the most volcanically active body known: its heat comes from tides from Jupiter.

(4) Gradation: wind and especially water erosion are important on Earth. It's rare to find rocks on Earth over 600 million years old.

Mars shows signs of water erosion too, from over 3 billion years ago. This is the same time life was originating on Earth: the similarities between Earth and Mars during their early history are of great scientific interest.

Earth's Moon (which we usually call just "the Moon") and Mercury have no water or significant atmospheres. Their surfaces are covered with a layer of fine dust called regolith (not "soil"), due to slow erosion from micrometeorite impacts. Since the Moon has only $1/80^{th}$ the mass of Earth, any heat its interior ever had leaked out long ago, so the Moon has no plate tectonics. It's therefore rare to find Moon rocks less than 3 billion years old.

Venus has no water, but is quite flat because its surface is dominated by volcanic lava flows. This is because surface isn't brittle like rock, but is partially molten and therefore more like plastic. This is because of the high temperature of its horrible atmosphere, in which the Greenhouse Effect was discovered (by Carl Sagan), because it's mostly CO_2, except for the clouds of sulfuric acid and other poison gases. The atmosphere of Venus is 90 times denser than Earth's; the atmosphere of Mars is 90 times less dense than Earth's.

Required Reading

Europa is a large moon of Jupiter thought to have an ocean of liquid water beneath its icy crust, heated by Jupiter. Might it have life?

Enceladus (pronounced like “enchiladas”) is a small moon of Saturn also now known to have liquid water under its icy crust, heated by tides from Saturn and its other moons.

Titan is a large moon of Saturn, and it has an atmosphere and a surface covered in organic compounds and lakes of liquid methane, which rains out of its atmosphere.

“**Brown organic tarry gunk**” is found all over the Outer Solar System
(more formally, Polycyclic Aromatic Hydrocarbons, or PAHs).
(This is different from cosmic “dark matter,” which we’ll cover later in the course.)

“Organic”, in this course, specifically means containing carbon.

Living things are made of organic materials because carbon can bond to itself to make large, complex molecules can carry energy and information.

“Brown organic tarry gunk” is seen all over the Outer Solar System, where it’s cold, which preserves the material.

It’s not seen on Mercury or Venus, because the high temperatures break it down. It’s not on Mars, because the thin atmosphere of Mars has no ozone layer, so ultraviolet radiation from the Sun sterilizes the surface of Mars. It’s all over Earth, in the form of living things!

This “brown organic tarry gunk” is present seemingly everywhere in the Solar System it can exist. It has been found in:

- Carbonaceous asteroids (the most common type) and meteorites;

- Planetary atmospheres: Jupiter and Saturn have brown, yellow, and red clouds;

- The rings of Uranus and Neptune are made of dark, carbon-rich dust
(Jupiter’s rings are also dust, but less carbon-rich; Saturn’s rings are ice particles);

- Satellite atmospheres: Titan (the large satellite of Saturn)
Triton (the large satellite of Neptune);

- Comets are dirty snowballs: the nucleus of Halley’s Comet is black with organic material;

- When Comet Shoemaker-Levy 9 collided with Jupiter in 1994,
it made Earth-sized clouds of organic compounds in Jupiter’s atmosphere.