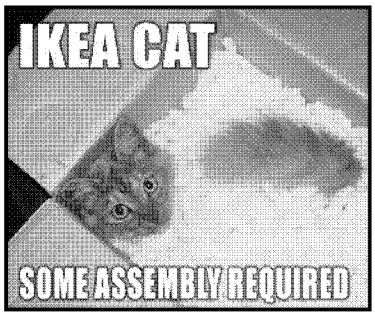
Tuesday, October 26
Assembling the Requirements of Life



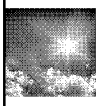
Requirements of Life
Key Concepts

1) Life requires a source of energy, complex chemistry, and (probably) a liquid solvent.

2) **Sunlight** is the main energy source in the Solar System, but other sources exist.

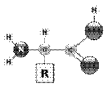
3) A planet's **equilibrium temperature** helps to determine whether it has seas & atmosphere.

Basic Requirements for Life



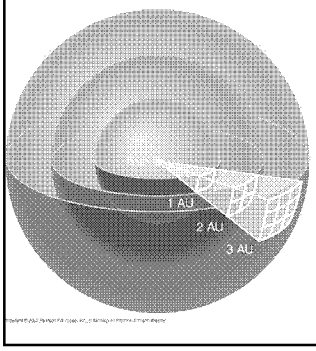
Source of Energy
Energy fuels chemical reactions.
Warmth permits liquid water (or other liquids?)

Complex Chemistry
Carbon (or other element?) permits the building of complex molecules.



Liquid Solvent
It provides a medium for chemical reactions.

The **Sun** is the main energy source in the Solar System.



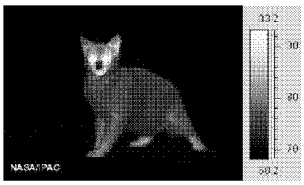
The flux of sunlight you receive depends on your distance from the Sun:

$$f = \frac{L}{4 \pi d^2}$$

f = flux of sunlight
L = Sun's luminosity
d = distance from Sun

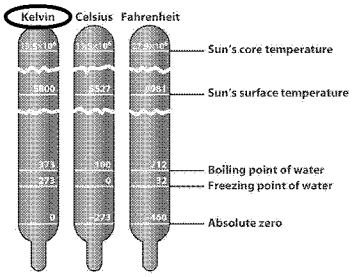
The surface of a **planet** absorbs solar energy and warms up.

As it warms up, it radiates infrared light.



A planet reaches **equilibrium temperature** when the rate at which it absorbs solar energy equals the rate at which it emits infrared energy.

What is **Temperature?** It's a measure of the typical speed of atoms' random motion.



Random motions stop at **absolute zero** temperature.

Kelvin = Celsius + 273

Water boils: 373 Kelvin (373 K)

Water freezes: 273 Kelvin

Absolute zero: 0 Kelvin

Room temperature: ~300 Kelvin

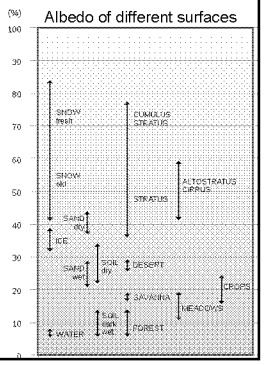
Surface of Sun: ~5800 Kelvin

The equilibrium temperature of a planet in the Solar System depends on:

1) The flux of sunlight it receives (& thus its distance from the Sun).

2) Its **albedo** (the fraction of light that it reflects).

Dark objects close to Sun are hot: shiny objects far from Sun are cold.



The **equilibrium temperature** of an object heated by the Sun (given without proof):

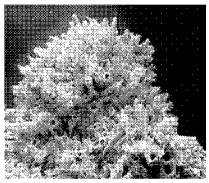
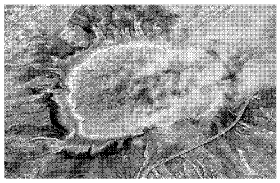
$$T_{eq} = 278K \frac{(1-A)^{1/4}}{\sqrt{d}}$$

d = distance from Sun (in AU)

A = albedo (1 = perfectly shiny, 0 = perfectly black)

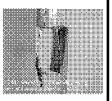
Wild card: **Extremophiles** on Earth remind us that the Sun isn't the only source of energy.

Life around deep-sea volcanic vents and in hot springs is powered by **geothermal** energy.

Wild card: Liquid **water** is a good solvent for life, but there might be other possibilities…

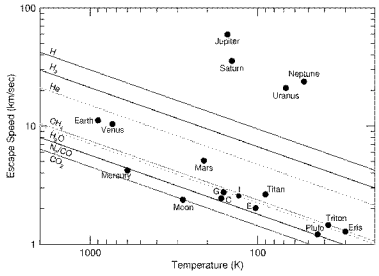

Water (H_2O): liquid from 0 to 100°C (100°C range)

Ammonia (NH_3): liquid from –78 to –33°C (45°C range)



Methane (CH_4): liquid from –182 to –164°C (18°C range)

Ethane (C_2H_6): liquid from –183 to –89°C (94°C range)


The ability of a planet to retain an atmosphere depends on its **mass** and **temperature**.

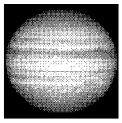


Massive planets have a high escape speed; cold planets have slow-moving atmospheric molecules.

An important factor in a planet's habitability is the amount of **atmosphere** it can retain.

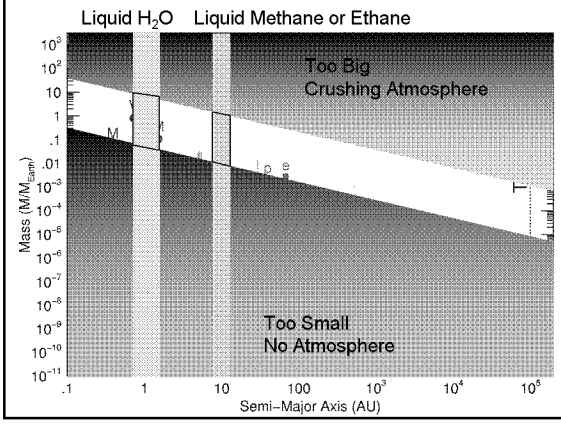
Small hot bodies have no atmosphere: bad for life.

Mercury

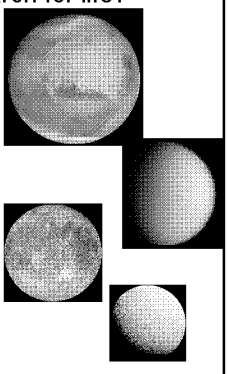


Jupiter

Large cool bodies have heavy hydrogen/helium atmospheres. Air pressure is very high: bad for life.



Where should we search for life?



Mars may have had liquid water & a thicker atmosphere in the past.

Titan (moon of Saturn) may have organic compounds in lakes of methane & ethane.

Wild cards:
Europa (moon of Jupiter) and **Enceladus** (moon of Saturn) may have liquid water under icy surfaces.