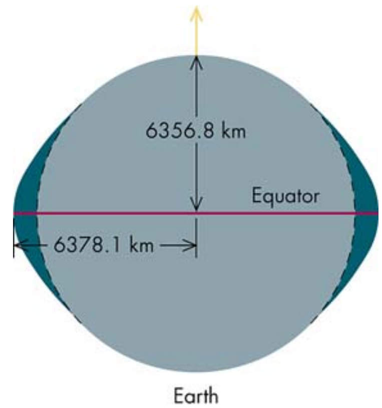
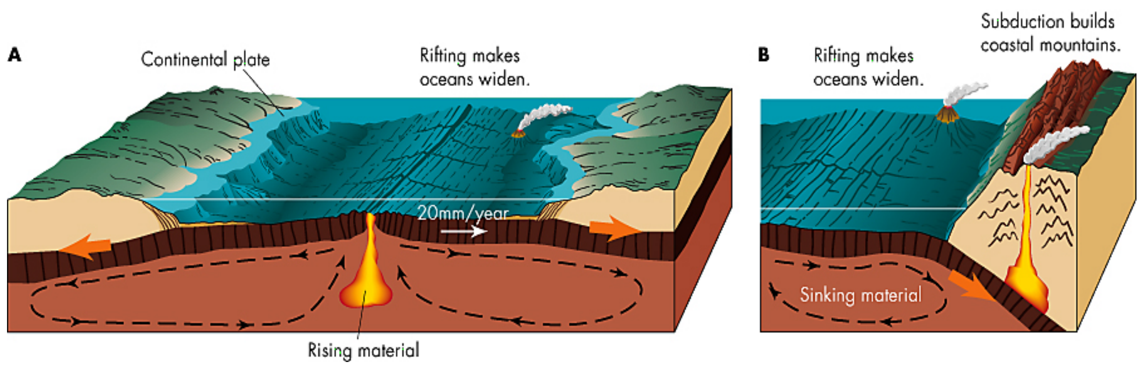
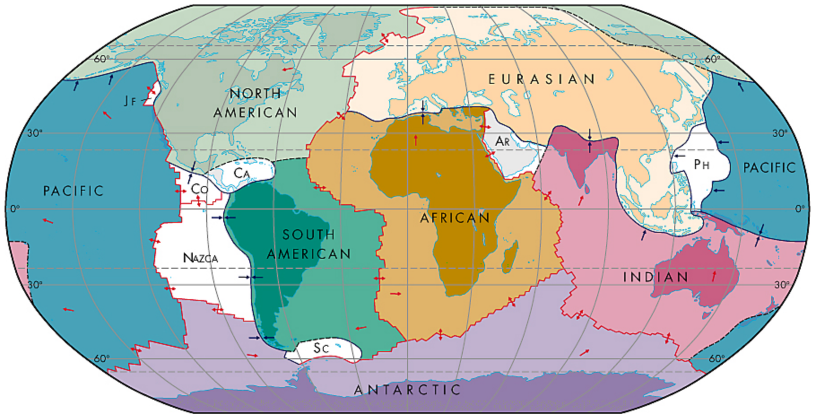
The Earth and the Moon

Earth



- About 4.5 billion years old – same age as the sun.
- About 8000 miles (12,800km) in diameter. An oblate spheroid in shape.
- About 25,000 miles in circumference
- Has a great deal of internal heat from two sources: radioactive decay (fission) and leftover heat from the planetesimal era (heat from collisions). Because rocks are moderately poor conductors of heat the *in situ* heat is released very slowly. Thus the interior of the earth is very hot because of both trapped heat leftover from the formation of the planet and small amounts of heat being released due to radioactive decay.
- Circulates rock from its lower levels to the surface (convection in the mantle). Has active geological processes including *erosion*, *plate tectonics*, *orogenisis*, and *volcanism*.

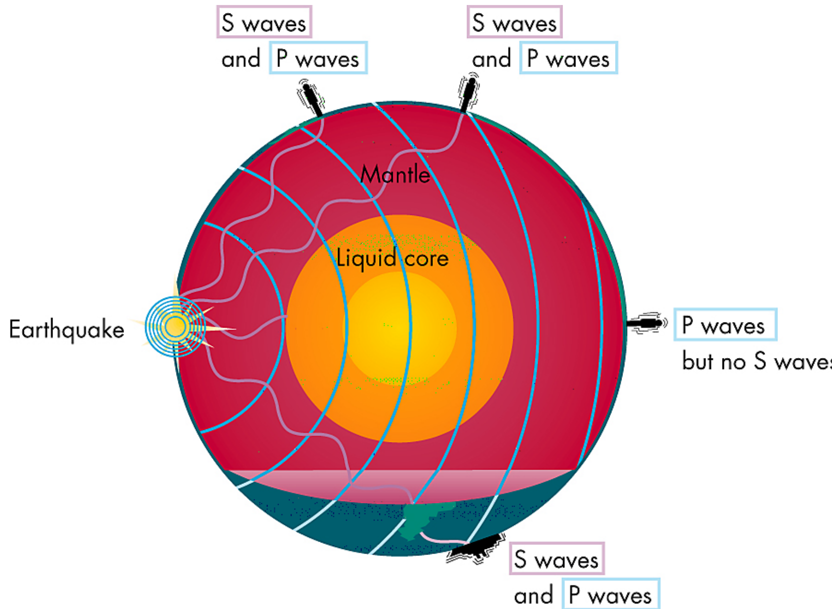


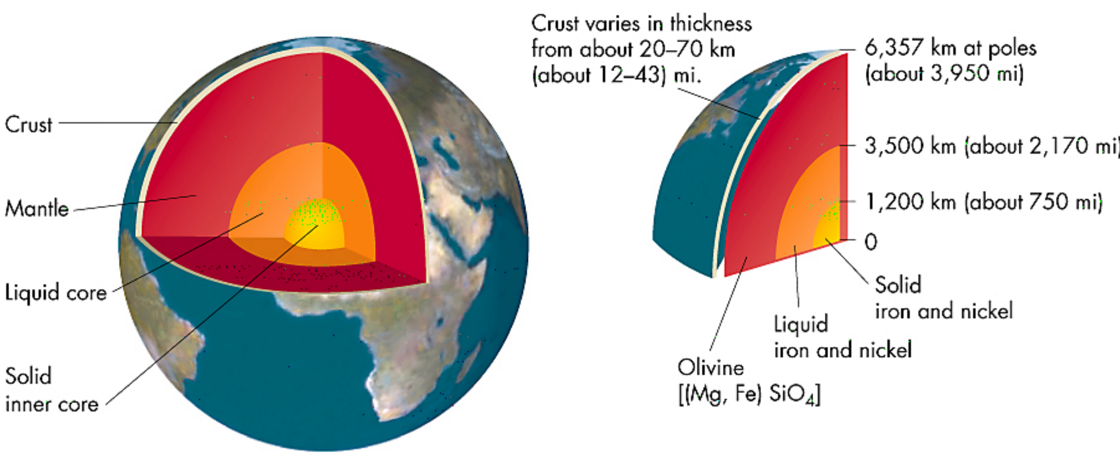


- Present composition of the earth: Oxygen (45.5%), Silicon (27.2%), Aluminum (8.3%), Iron (6.2%), Calcium (4.7%), Magnesium (2.8%), Sodium (2.3%), Potassium (1.8%), Titanium (0.6%), all others less than 1%
- Igneous, sedimentary, metamorphic rocks. Igneous rocks come from the cooling of molten rock. Sedimentary rocks are formed (lithified) from compressed sediments on the bottom of lakes or oceans. Metamorphic rocks are formed when igneous or sedimentary rocks are changed to to heat and/or pressure.
- Dating of the earth and it's rocks is accomplished by measuring what is left of small amounts of radioactivity "lock in" to the rocks as they condensed to solid form. Decay constants for radioactive elements are well known ($A = A_0 e^{-\alpha t}$) allowing us to date rocks with a fair degree of accuracy. A radioactive isotope of the element Potassium (K^{40}), for instance, decays to the stable element Argon (Ar^{40}) over time. It is known that the decay rate is such that half of the Potassium changes to Argon in 1.28 billion years. By measuring the ratio of Potassium 40 to Argon 40 in a rock it is possible to estimate it's age. A rock that contains a ratio of 50/50 ratio of K^{40} to Ar^{40}, for instance, is about 1.28 billion years old. A rock that contains a ratio of 25/75 ratio of K^{40} to Ar^{40} is about 2.56 billion years old. Radioactive dating indicates that the oldest rocks on Earth are about 4 billion years old.

Internal Structure of the Earth

- Probed with seismic waves

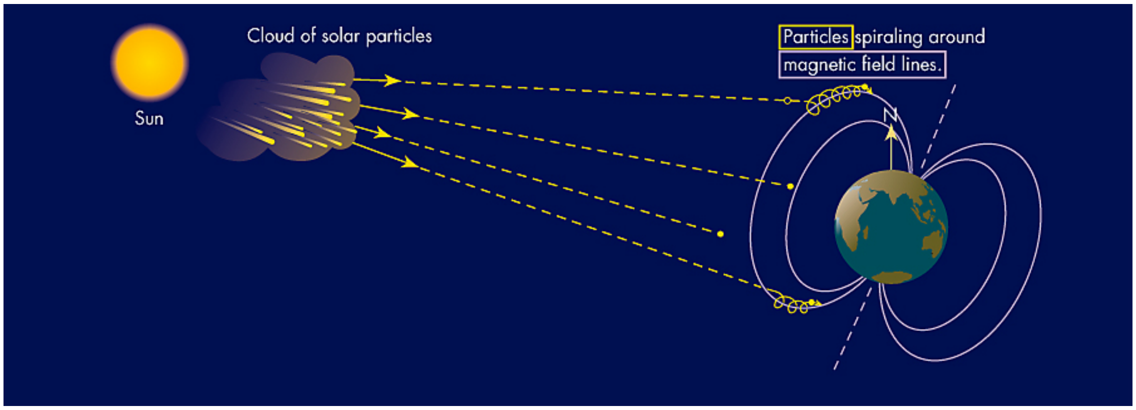




- Crust (silicates) solid, extends down to 20 – 70 km down
- Mantle (silicates - olivine rich) nearly molten solid, 3500 km down
- Liquid core (iron, nickel, sulfur?) molten, 4700 km down
- Solid core (iron, nickel) solid, 6400 km down
- Average density is about 5.5g/cm^3
- Inner core is solid even though it is hotter because of higher pressure and melting point. Temperature in the core is about 6500K (hotter than the surface of the sun!)
- The earth is *differentiated*: i.e., the materials from which it is composed are largely separated into layers by *density*.

Magnetic Field

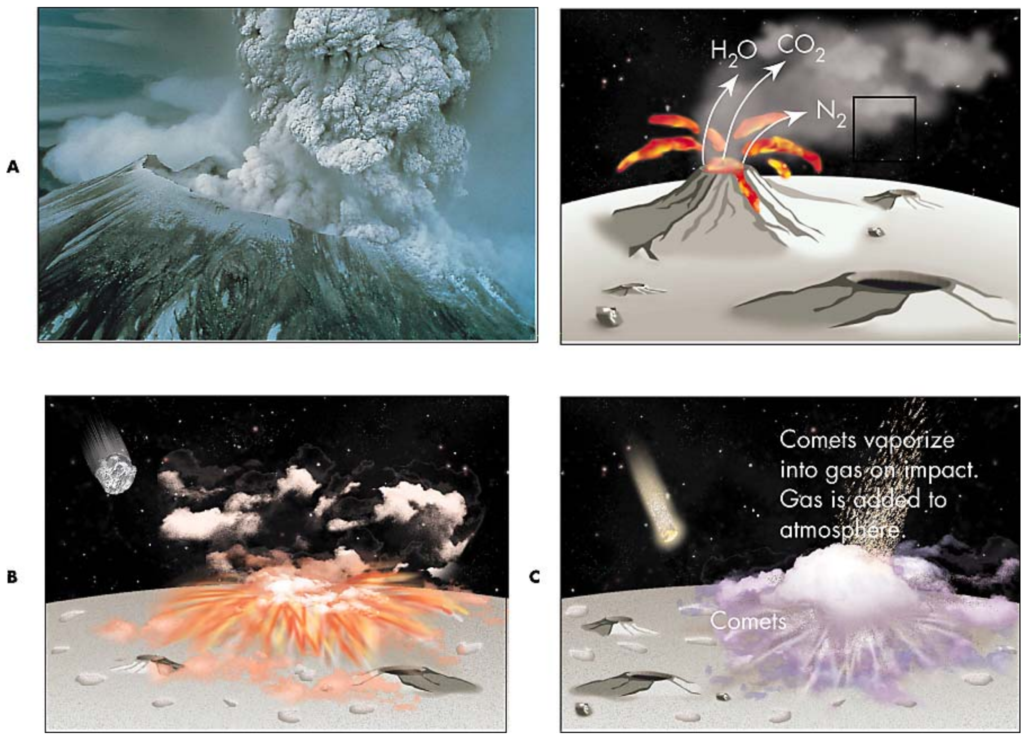
- Earth has a robust magnetic field due to the presence of charged particles moving within the mantle and cores. This magnetic field protects us from ionizing radiation in the solar wind.



- Earth's magnetic field peridocially reverses
- The interior of the earth acts like an electromagnet
- Magnetic field lines in space are referred to as the Van Allen radiation belts

Atmosphere/Oceans of the Earth

- The primordial atmosphere was rich in nitrogen, carbon dioxide, hydrogen rich compounds such as methane and ammonia and water vapor
- The primodial atmosphere formed when these gasses were liberated from the earth's interior due to collisions and volcanic activity. Comets may have also contributed water to the primordial atmosphere. Methane and ammonia were broken down into hydrogen, carbon and nitrogen by sunlight. Most of the nitrogen and carbon remains while the hydrogen long ago escaped into space.

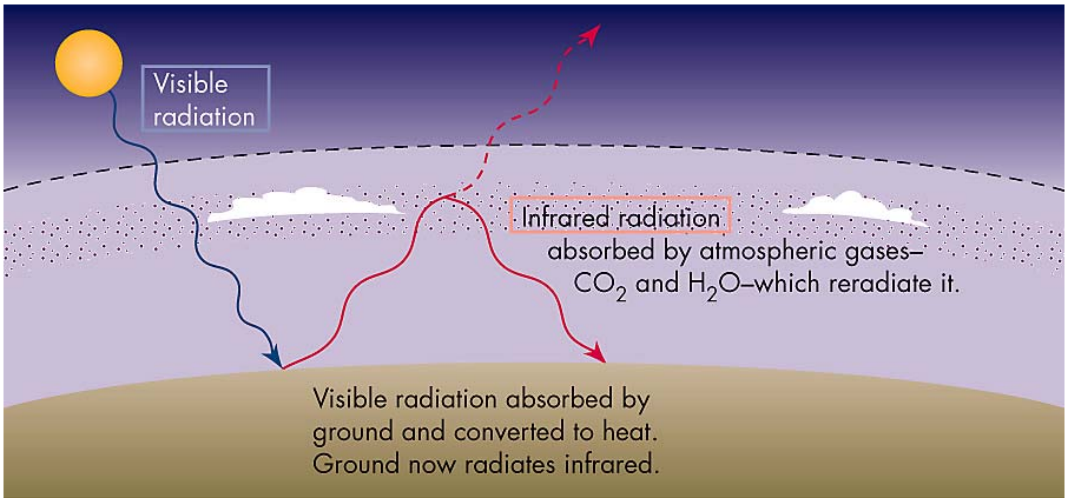


- The modern atmosphere is relatively oxygen rich (about 78% nitrogen and 21% oxygen). Oxygen came from the rise of organisms (plants).
- Earth's atmosphere has several layers: the one in which all weather (and life) exists is the *troposphere*. The troposphere extents from the surface to about 10 kilometers above the ground. The *stratosphere* lies above the troposphere and is important to life because stratospheric ozone (O_3) is largely responsible for absorbing ultraviolet radiation from the sun. The stratosphere extends to about 50 kilometers above the earth's surface. The *mesosphere* extends to about 85 kilometers above the earth's surface and the *thermosphere* extends to the edge of space 120 kilometers up.
- Temperature decreases with height in the earth's atmosphere in the troposphere and mesosphere but *increases* with height in most of the stratosphere and all of the thermosphere.

- The earth has oceans. Primordial oceans formed when water vapor in the atmosphere cooled as the planet cooled and condensed into liquid water.

Greenhouse Effect

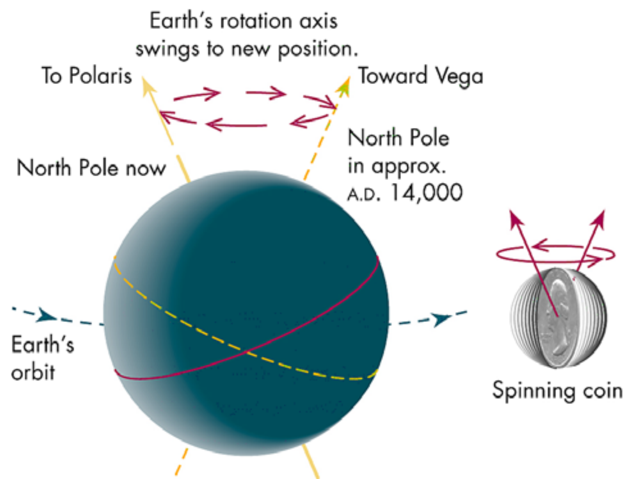
- Earth, Venus, Mars all have greenhouse gasses in their respective atmospheres
- A greenhouse effect due to the partial opacity of the atmosphere to infrared light helps moderate temperature on earth.

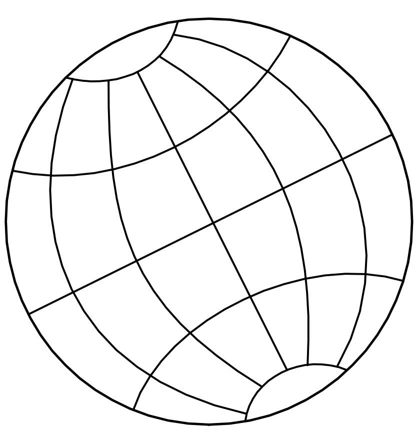


- Although Earth has always had a "greenhouse effect", human activities are increasing both the amount of greenhouse gasses in Earth's atmosphere and the infrared signature of Earth's surface.
- Global warming is an established scientific fact

Motions of the Earth

- Earth spins on it's own axis. This gives rise to a *diurnal* cycle. The period is a day. A *solar* day varies slightly from a *sidereal* day. The spin of the earth gives rise to the *Coriolis Force*.
- Earth orbits the sun in along an elliptical path. The period is 1 year. The elliptical nature of the earth's orbit has very little to do with the change of seasons. The earth is closest to the sun at *perihelion* and farthest from the sun at *aphelion*. The earth's speed changes along it's orbital path in accordance with Kepler's laws.
- Earth precesses, i.e., it's rotational axis "wobbles" like that of a top. The period is about 26,000 years.
- Change of seasons: The earth is at perihelion in early January each year. This is when its orbital speed is greatest. It gradually slows down until reaching aphelion in July when its orbital speed is at its minimum. *The earth is actually closer to the sun when temperatures are coldest in the northern hemisphere*. This is possible because even though the sun is much closer to the earth during our winter months, the sun's rays travel a greater distance through the atmosphere and strike the earth at a more oblique angle in the northern hemisphere due to the $23\frac{1}{2}^0$ tilt of the earth about its rotational axis.





Energy from the sun that strikes the earth from directly overhead is more intense than energy that strikes the earth at an angle because the light at an angle is spread out over a greater area. You can verify this for yourself with a flashlight. Hold the flashlight about a foot above any flat surface and shine the beam directly onto the surface then from the same height shine the beam onto the surface at an angle of about 45^0. It is easy to see that the same amount of light is spread out over a larger area in the latter case. This lowers the intensity.

Even though the difference between the earth's perihelion and aphelion distances is less than 3%. The amount of solar energy striking the earth is 7% greater at perihelion (in January) than at aphelion (in July). This would lead one to conclude that summer in the southern hemisphere, which occurs at perihelion, is warmer than summer in the northern hemisphere. This, however, is not the case. Most of the land mass of the earth is concentrated in the northern hemisphere. The southern hemisphere, by contrast, is 80% covered by water. Water has the ability to absorb large amounts of heat without changing temperature very much. The additional solar energy supplied by the sun at perihelion is absorbed by the large bodies of water in the southern hemisphere. The result is that temperatures are actually more moderate during summers in the southern hemisphere. On Mars, which does not have any oceans to absorb heat, the temperature fluctuations are much greater due to perihelion and aphelion.

Spring and summer are shorter in the southern hemisphere than in the northern. This is because of the earth's varying orbital speed. The number of days from the *vernal equinox* (March 20) to the *autumnal equinox* (September 22) is about a week longer than from autumnal to vernal.