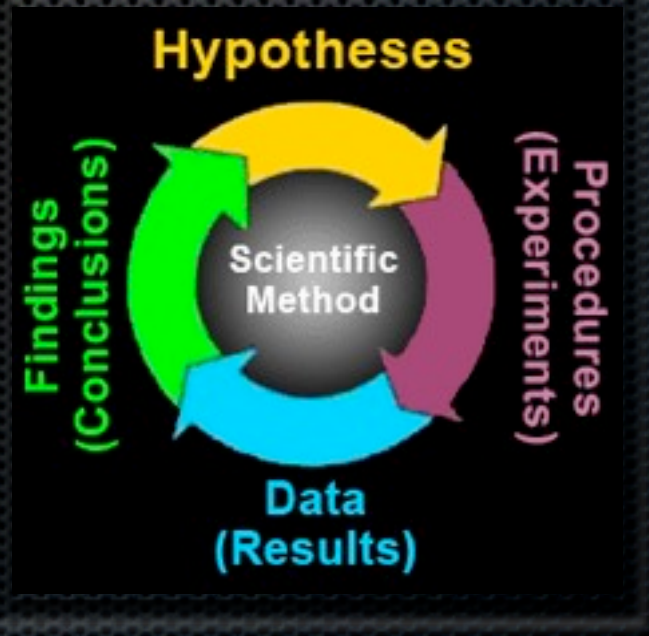
ESC101

Scientific Method

- The scientific method is an orderly and logical approach that relies on data to inform our understanding of a problem or process.
  - assumes that nature is consistent and predictable
    - tentative explanations, called a hypotheses, are produced to explain observed data
  - Multiple hypotheses are tested to see if what they predict actually occurs in nature



Stars and Galaxies

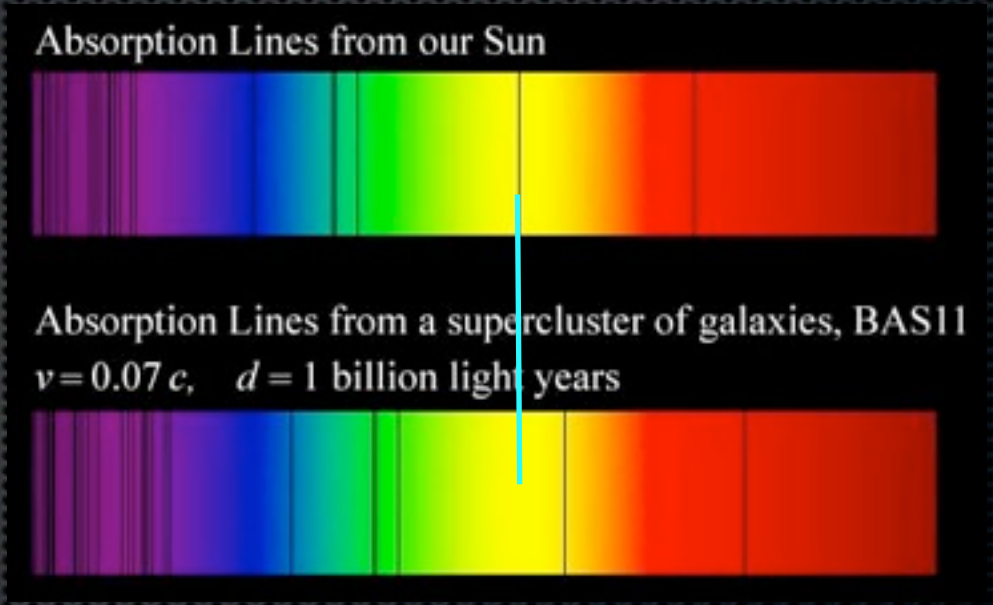
- Stars are immense balls of incandescent gas.
  - Light and heat derives from nuclear fusion reactions where atoms combine to make new elements
  - Gravity binds stars together into vast galaxies.
- The solar system is on an arm of the Milky Way galaxy.
  - Our sun is one of 300 billion

    stars in the Milky Way.

You are HERE!

The Beginning

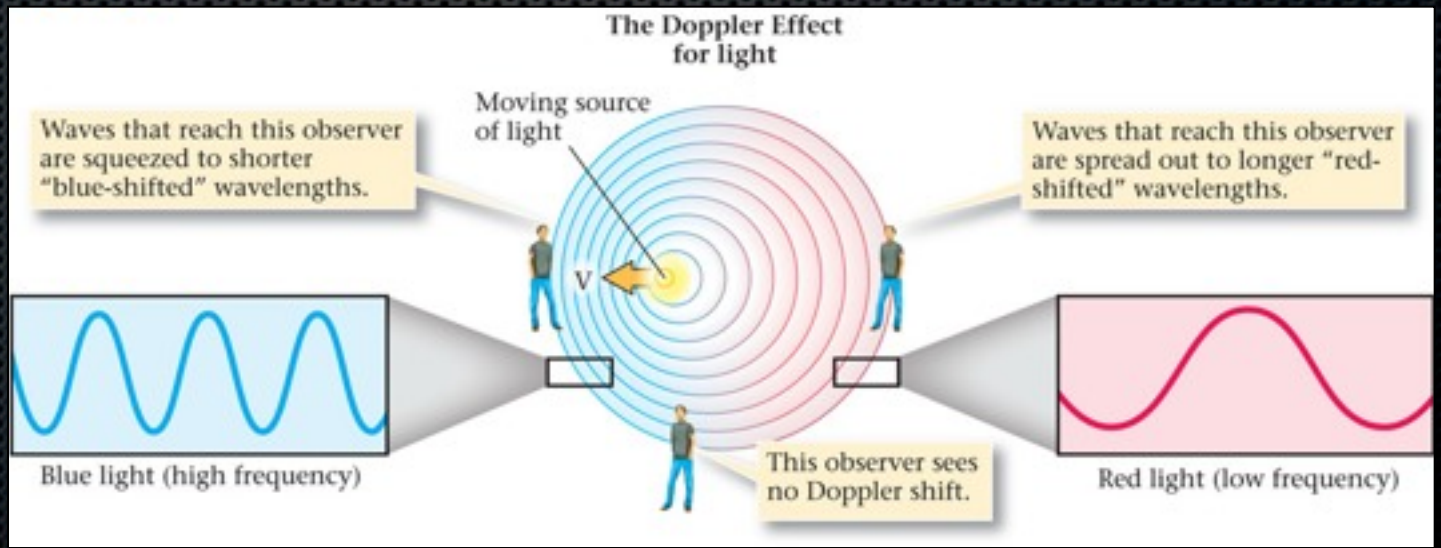
For years scientist observed an apparent red-shift in the light from distant galaxies



Edwin Hubble suggested the observed shift was due to the **doppler effect**

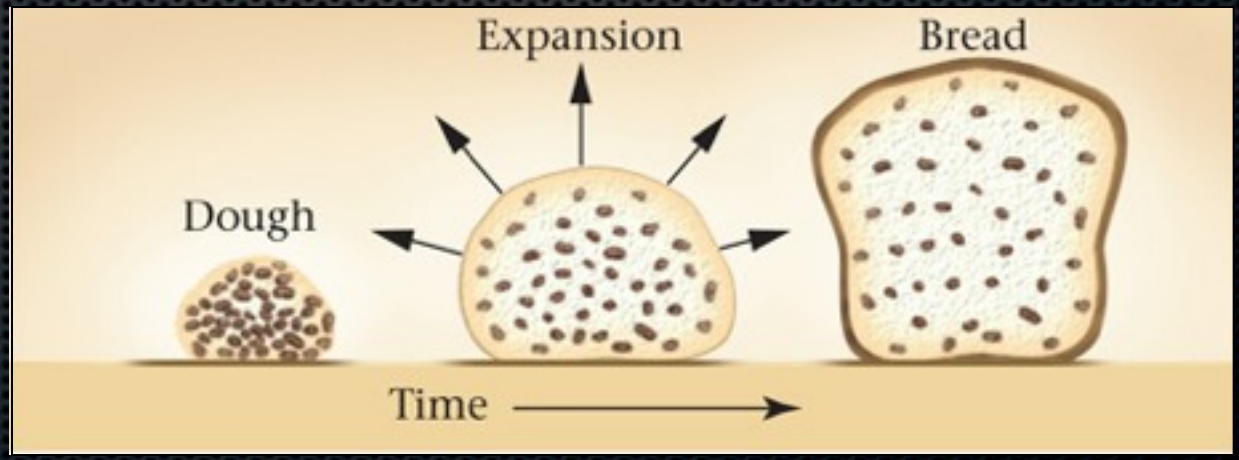
The Doppler Effect

- Visible light is electromagnetic radiation
  - Color is determined by the wave length of light
    - Blue = Higher frequency.
    - Red = Lower frequency.



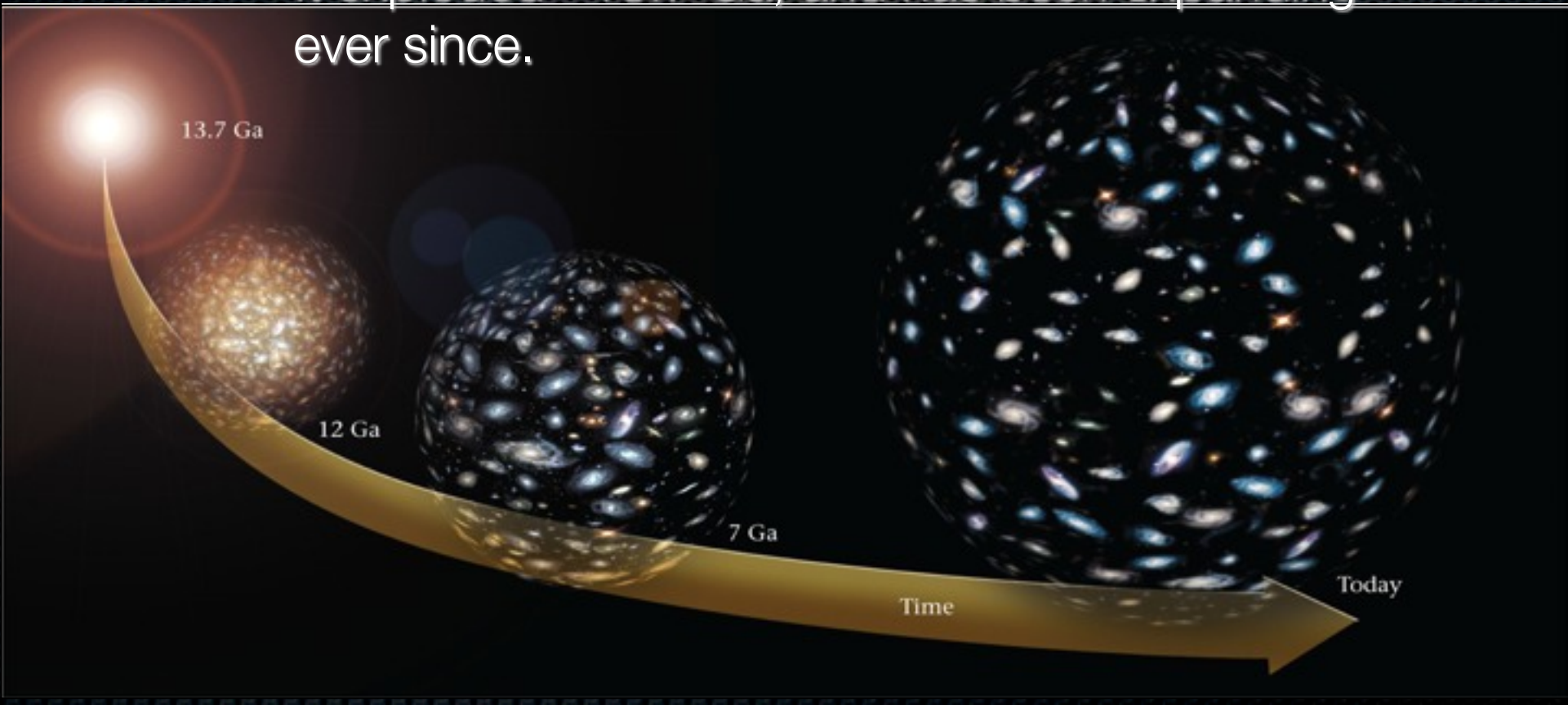
The Expanding Universe

- Light from galaxies was seen to be “red shifted.”
  - Curiously, no galaxies were found heading toward Earth.



Big Bang

- An expanding Universe? "When did it all begin?"
  - The Big Bang: All mass and energy in a single point.
  - It exploded ~13.7 Ga, and has been expanding ever since.



The Big Bang

- With expansion and cooling, atoms began to bond.
  - Hydrogen formed H_2 molecules - The fuel of stars.
  - Atoms and molecules coalesced into gaseous nebulae.
- Gravity caused formation of gaseous nebulae.
  - Resulted in increases in…
    - Temperature.
    - Density.
    - Rate of rotation.

After the Big Bang

- Condensed nebula formed flattened accretion discs.
- Heat and mass from collapse “ignited” nuclear fusion.
- These 1st generation stars consumed H_2 fuel rapidly.
- As the stars became H_2 starved, they initiated…
  - Collapse and heating.
  - Heavy element production.
  - Catastrophic explosion (supernova).

Nucleosynthesis

- Stars are truly "element factories."
- Big Bang Nucleosynthesis formed lighter elements.
  - Atomic #s 1, 2, 3, 4, and 5 (H, He, Li, Be, and B).
- Heavier elements are from Stellar Nucleosynthesis.
  - Atomic #s 6 – 26 (C to Fe).
- Elements with atomic #s > 26 form during supernovae.

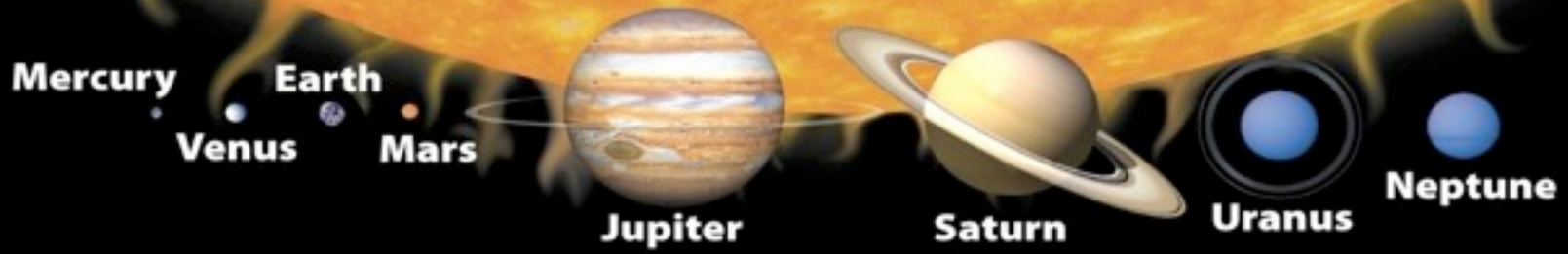
Nucleosynthesis

- The mass of a star governs its element production.
  - Smaller mass stars (like the Sun),
    - “Burn” slowly.
    - Live longer (10 Ga).
    - Create lighter elements up to carbon (C).
  - Larger mass stars (10–100x the mass of the Sun).
    - “Burn” rapidly.
    - Are shorter lived (10s of Ma).
    - Create heavier elements up to iron (Fe).

The Solar System

- Solar system: A sun, planets, moons and other objects.
- Earth shares the solar system with 7 planets. A planet…
  - Is a large solid body orbiting a star (the Sun).
  - Has a nearly spherical shape.
  - Has cleared it's neighborhood of other objects.
- Moon – A solid body locked in orbit around a planet.
- The solar system also includes asteroids and comets.

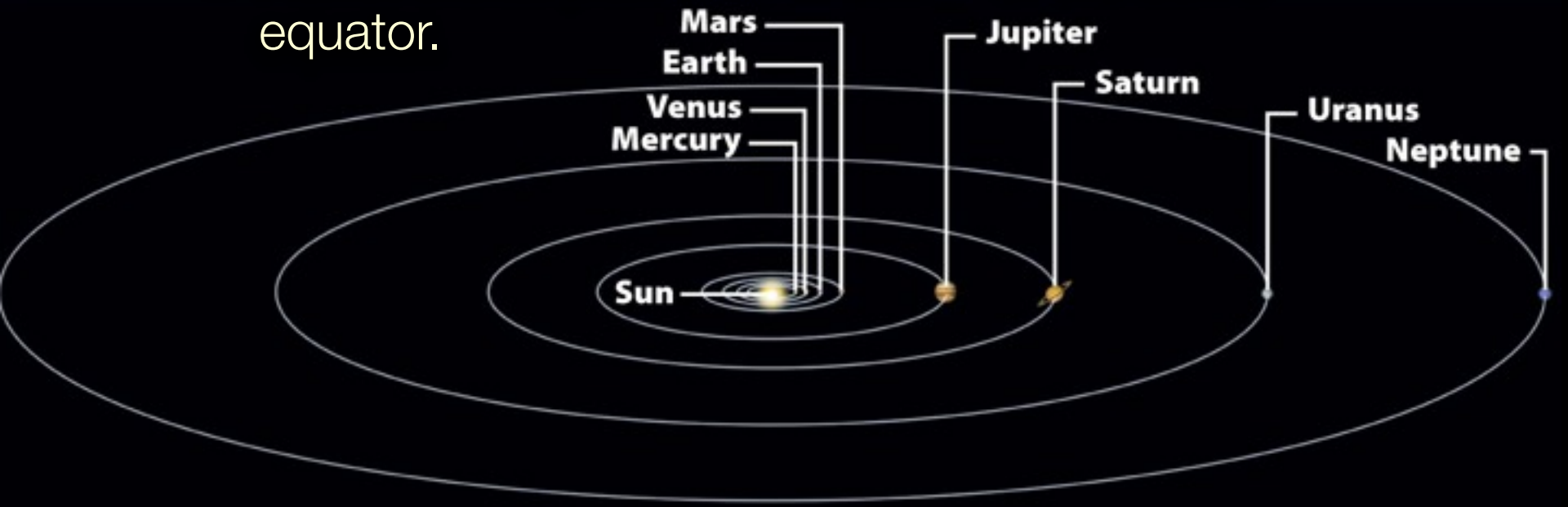
The Planets



- Two groups of planets occur in the solar system.
  - Terrestrial (Earthlike) – Small, dense, rocky planets.
    - Mercury, Venus, Earth, and Mars.
  - Jovian (Jupiter-like) – Large, low density, gas-giant planets.
    - Jupiter, Saturn, Uranus, and Neptune.
- Pluto is no longer considered to be a planet.

The Solar System

- The Terrestrial planets are the 4 most interior.
- The Jovian planets occupy the 4 outermost orbits.
- The asteroid belt lies between Mars and Jupiter.
- Planet orbital planes lie within 3^{o} of the Sun's equator.

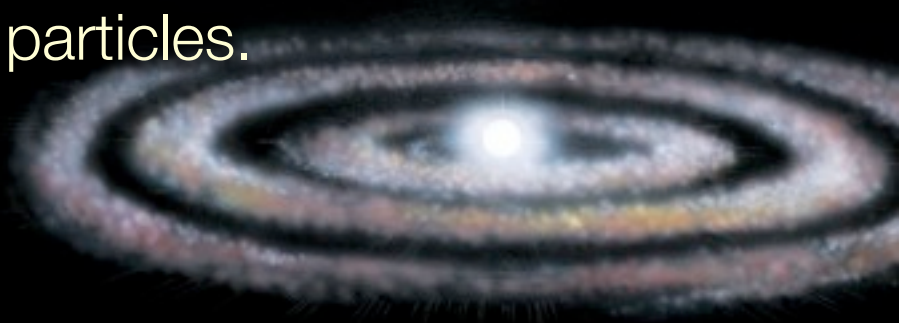


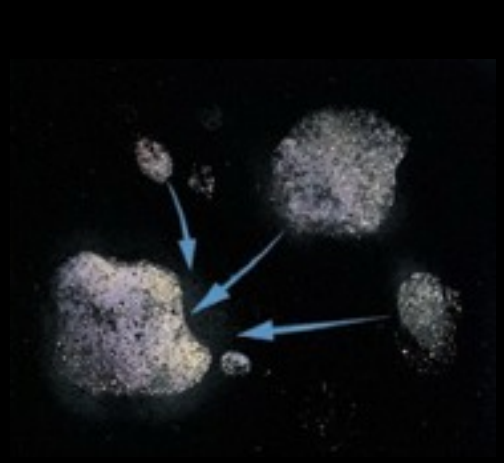
Solar System Formation

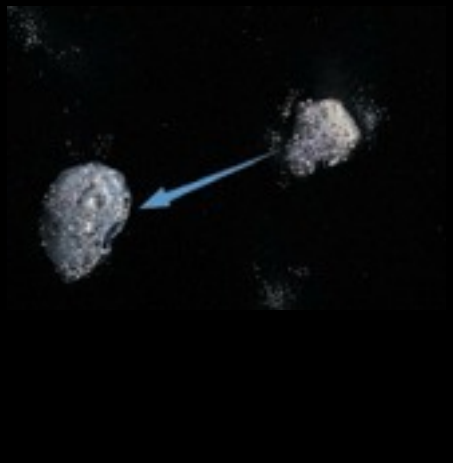
- The Nebular Theory.
- A 3rd, 4th or nth generation nebula forms ~4.56 Ga.
  - Hydrogen and Helium left over from the big bang.
  - Heavier elements produced by stellar nucleosynthesis.
- This material coalesces into an accretion disc with a protostar at the center.

Solar System Formation

- The ball at the center grows dense and hot.
- Fusion reactions begin; the Sun is born.
- Dust in the rings condenses into particles.







Solar System Formation

- **Planetesimals accumulate into a larger mass.**
- **An irregularly-shaped proto-Earth develops.**
  - **The interior heats up and becomes soft.**

  - **Gravity shapes the Earth into a sphere.**

  - **The interior differentiates into a-Fe core and stony mantle.**

Solar System Formation

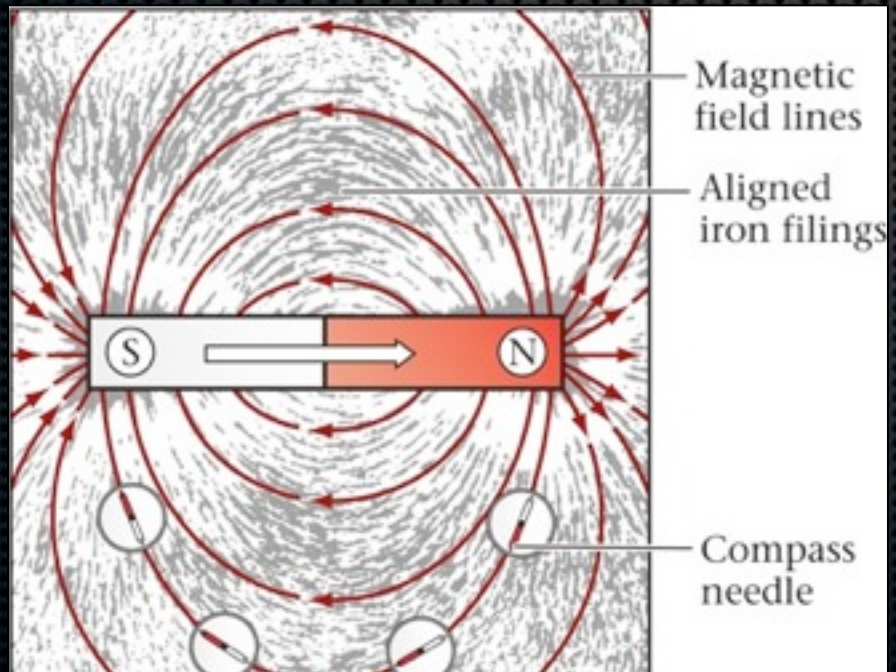
- **Soon, a small planetoid collides with Earth.**
- **Debris forms a ring around the Earth.**
- **The debris coalesces and forms the Moon.**

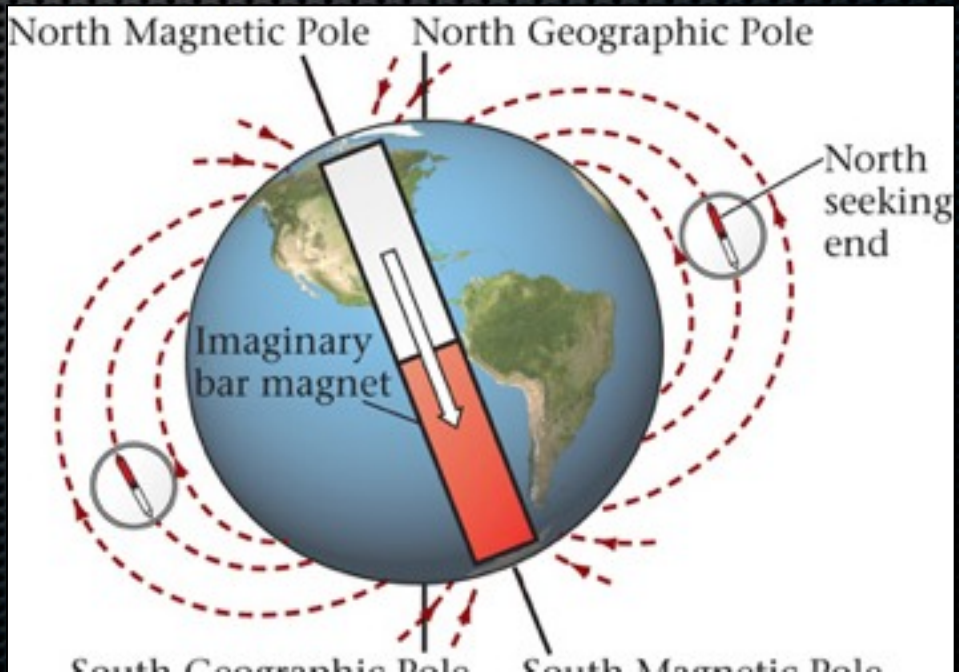
Solar System Formation

- The atmosphere develops from volcanic gases.
- When the Earth becomes cool enough.
  - Moisture condenses and accumulates.
  - The oceans are born.

Magnetic Field

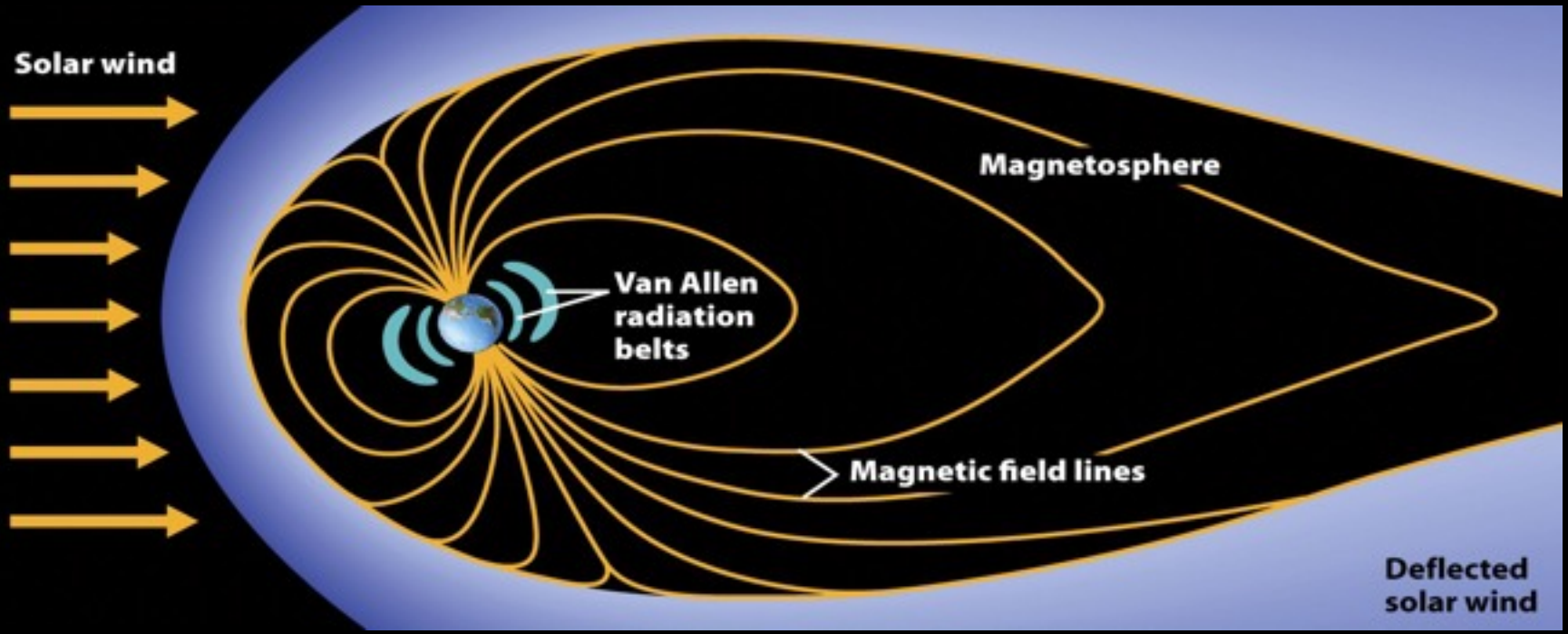
- Like a bar magnet, Earth has a dipolar magnetic field.
- Magnetic field lines flow from N to S and…
  - Extend into space and weaken with distance from Earth.
  - Create a shield around Earth (the magnetosphere).





The Van Allen Belts

- **The solar wind is deflected by the magnetosphere.**
- **Near Earth, the stronger magnetic field forms the Van Allen belts, which arrest deadly cosmic radiation.**

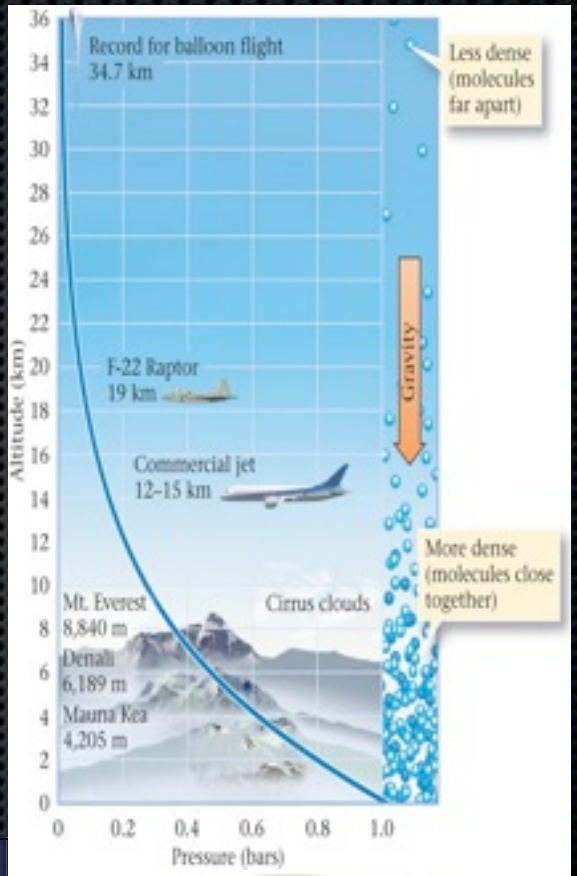


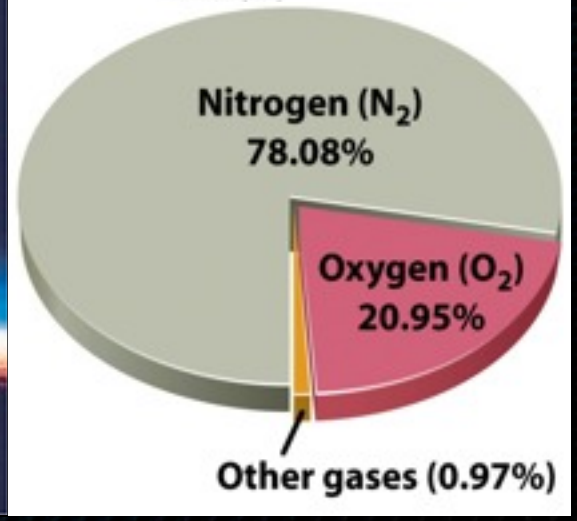
Aurorae

- Some ions escape Van Allen belts.
  - Pulled to the magnetic poles, the ions generate light.
- Spectacular aurora follow solar flares.
  - Aurora borealis – Northern lights.
  - Aurora australis – Southern lights.

The Atmosphere

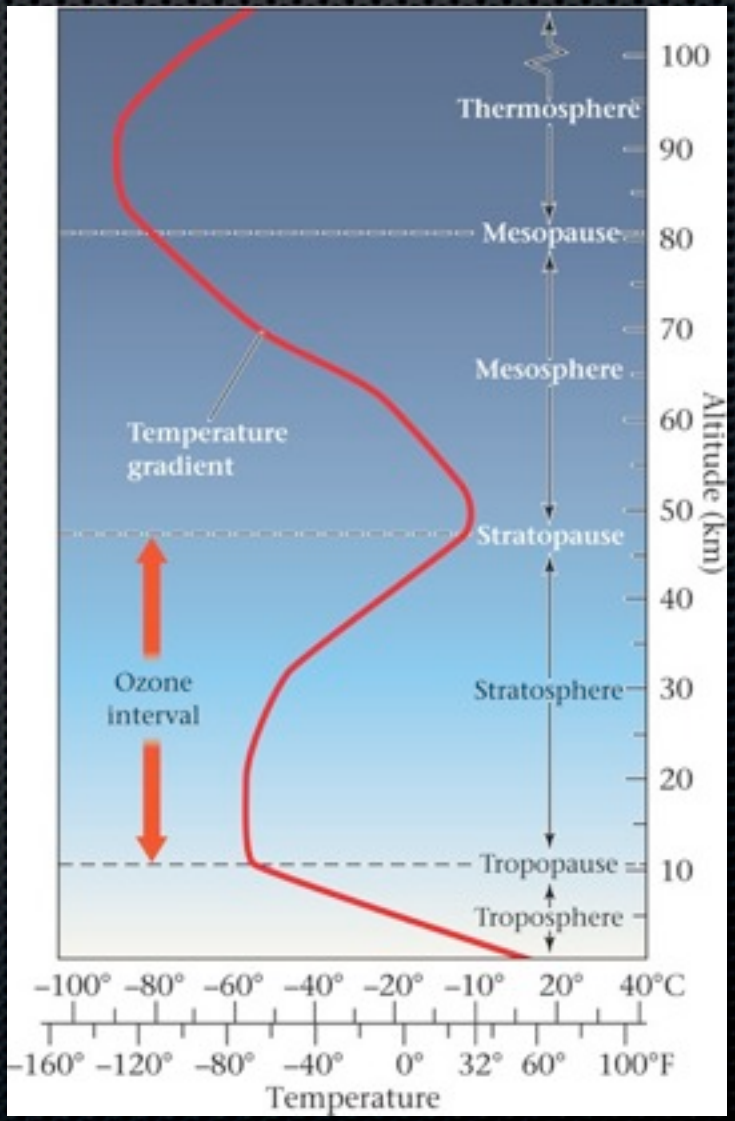
- Earth, with an atmosphere, is unique among the planets
- Densest at sea-level, the atmosphere thins upward.
- The atmosphere is mostly nitrogen (N_2).
- Oxygen was absent from the atmosphere before 2.5 Ga.





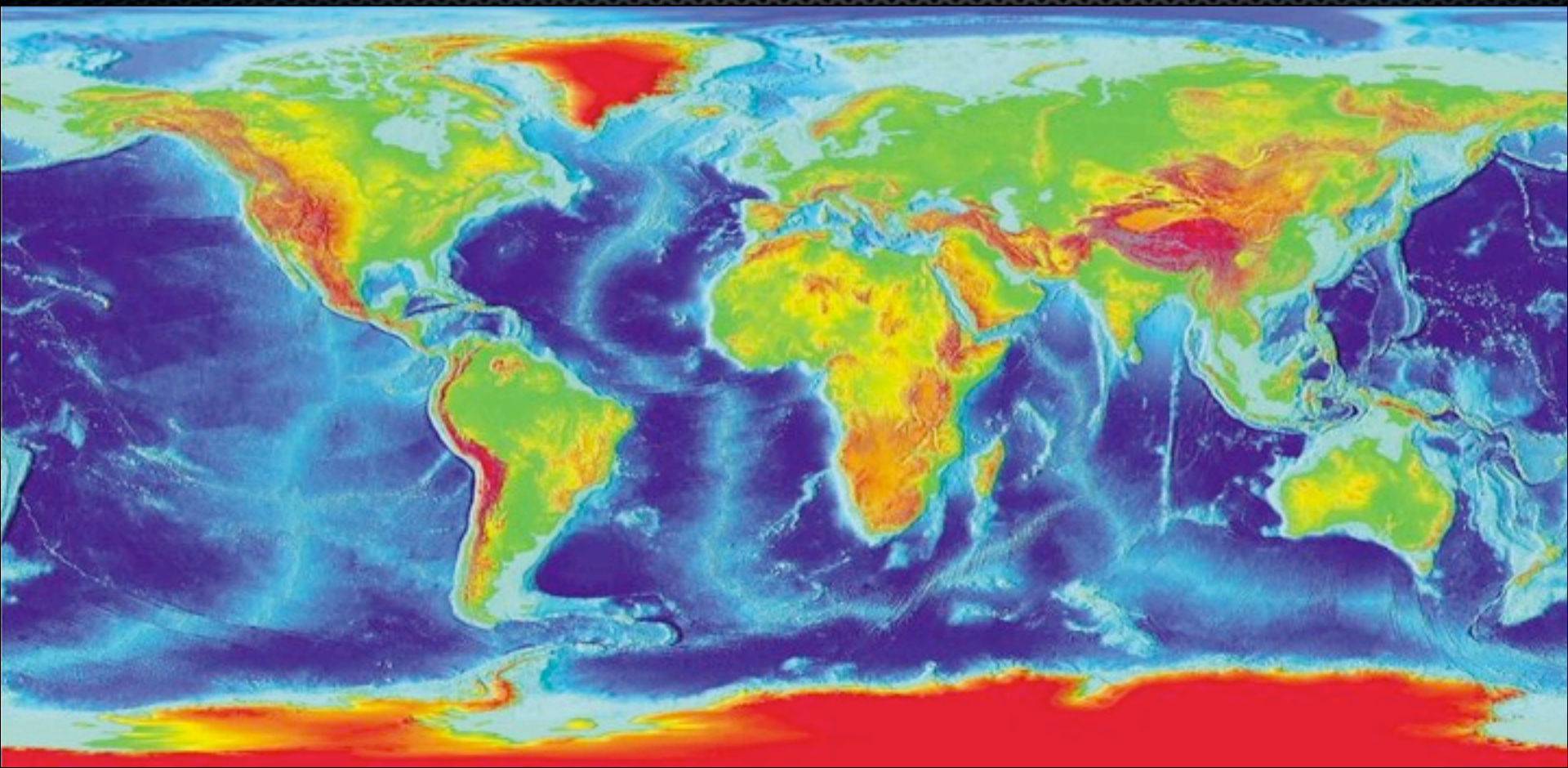
The Atmosphere

- Troposphere (0–11 km).
  - Mixing layer.
  - Weather is limited to this layer.
- Tropopause (11–12 km).
- Stratosphere (12–47 km).
- Mesosphere (47– 81 km).
- Thermosphere (> 81 km).
- Boundaries between layers are termed “pauses.”



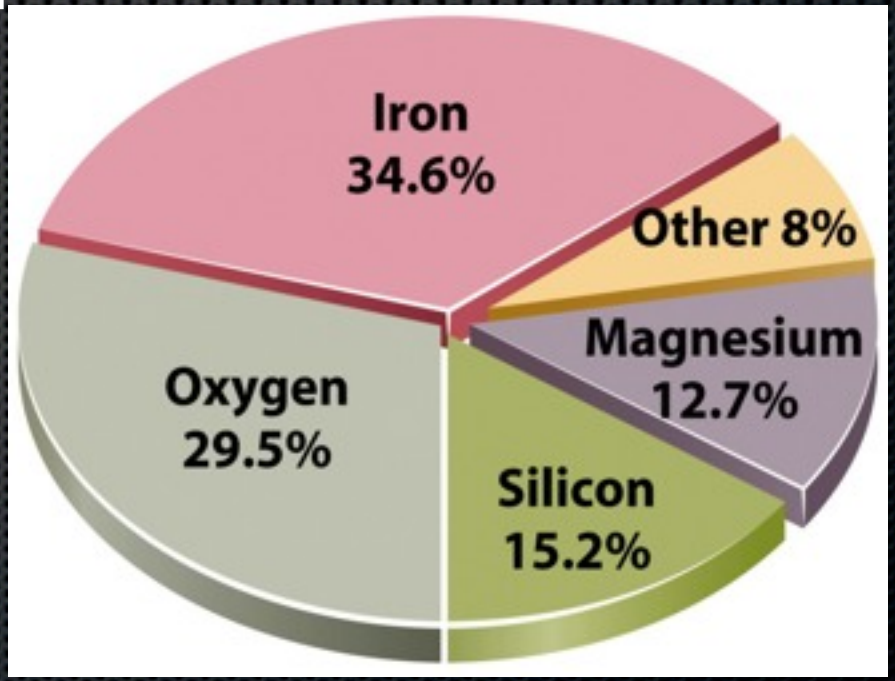
Surface Features

- Earth's surface: continents are high; oceans are low. Due to the differing buoyancy of each type of crust.



Elemental Composition

- 90% percent of Earth is comprised of 4 elements.
  - Iron (Fe) – 35%
  - Oxygen (O) – 30%
  - Silicon (Si) – 15%
  - Magnesium (Mg) – 10%
- The remaining elements?
  - Form 10% of Earth.

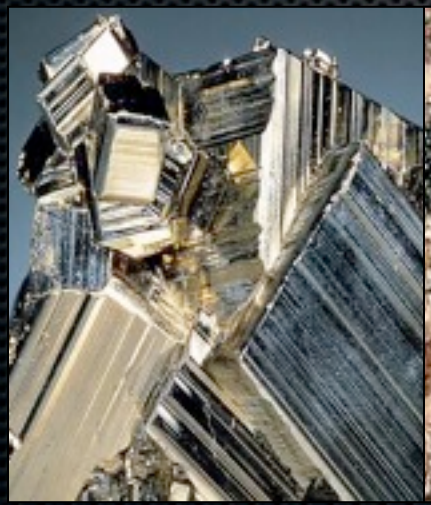


Earth Materials

- **Organic chemicals** – Carbon containing compounds.
  - Biological remains (wood, peat, lignite, coal, and oil).
  - Geologically rare (decompose in contact with oxygen).
- **Minerals** – Inorganic crystalline solids.
  - Comprise rocks and, hence, most of the earth.
  - Most minerals on Earth are silicates (based on Si and O).

Earth Materials

- **Glasses** – Noncrystalline mineral-like matter.
- **Rocks** – Aggregates of minerals. There are many types.
  - Igneous – Cooled from a liquid (melt)
  - Sedimentary – Debris cemented from preexisting rock.
  - Metamorphic – Rock altered by pressure and temperature.
- **Sediments** – Accumulations of loose mineral grains.



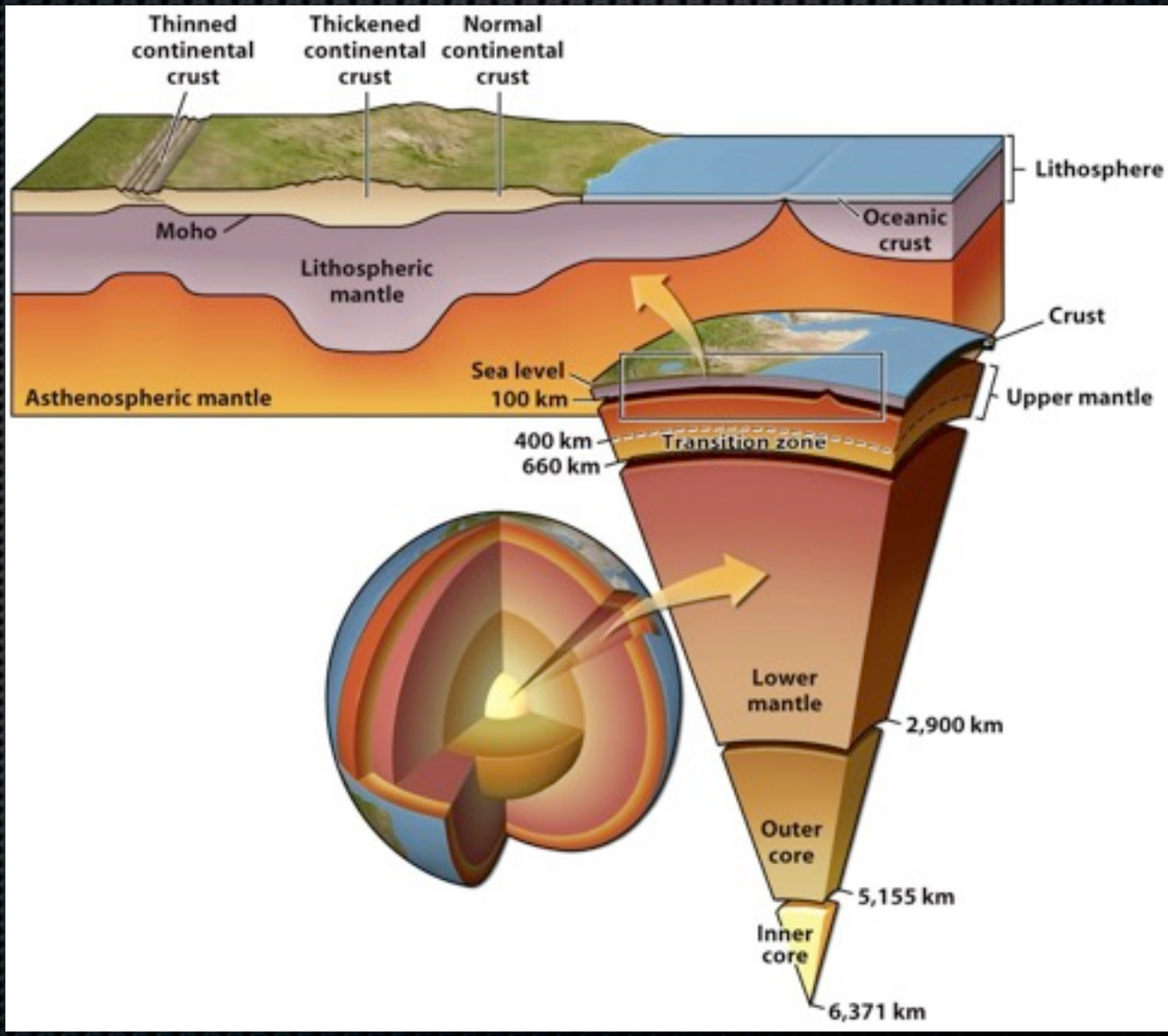

Earth Materials

- **Metals** – Solids made of metallic elements.
- **Melts** – Rocks that have been heated to a liquid.
  - Magma – Molten rock beneath the surface.
  - Lava – Molten rock at the surface.
- **Volatiles** – Materials that turn into gas at the surface.
  - H_2O, CO_2, CH_4, and SO_2,
  - Volatiles are released from volcanic eruption.



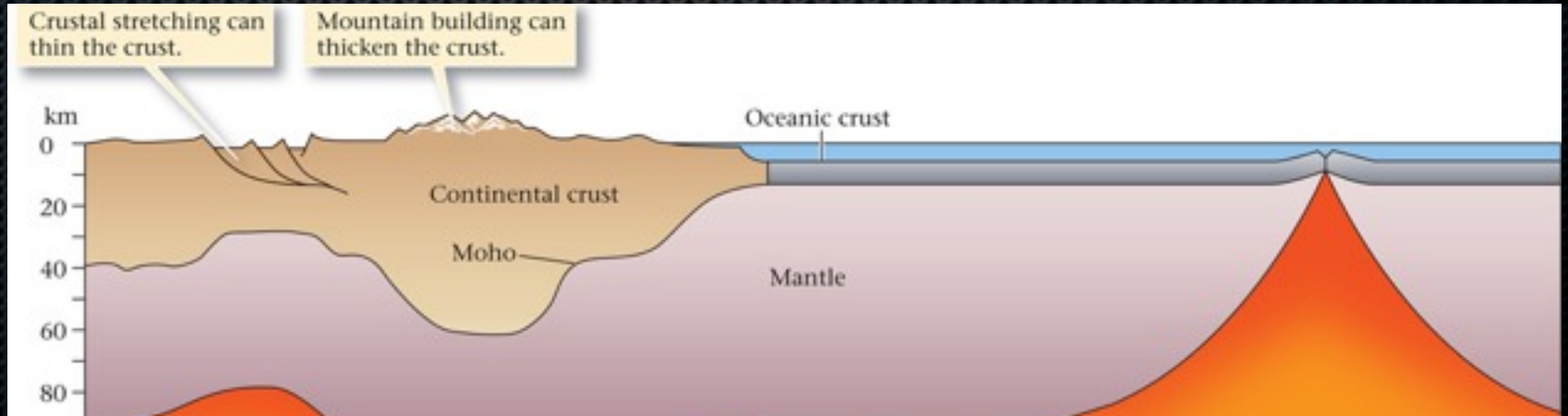
Earth's Interior Layers

- Crust
  - Continental
  - Oceanic
- Mantle
  - Upper
  - Lower
- Core
  - Outer - Liquid
  - Inner – Solid



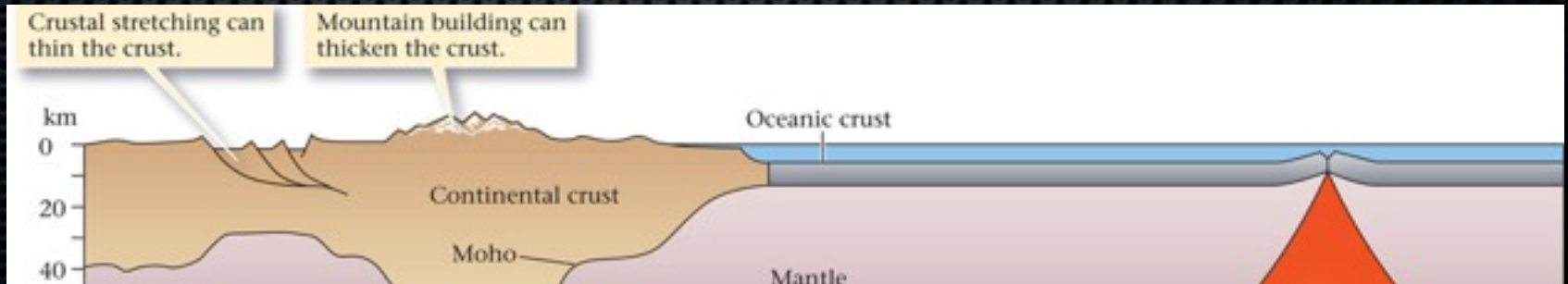
The Crust

- The outermost “skin” of Earth with variable thickness.
  - Thickest under mountain ranges (70 km - 40 miles).
  - Thinnest under mid-ocean ridges (3 km – 2 miles).
- The Mohorovicic discontinuity is the base of the crust.



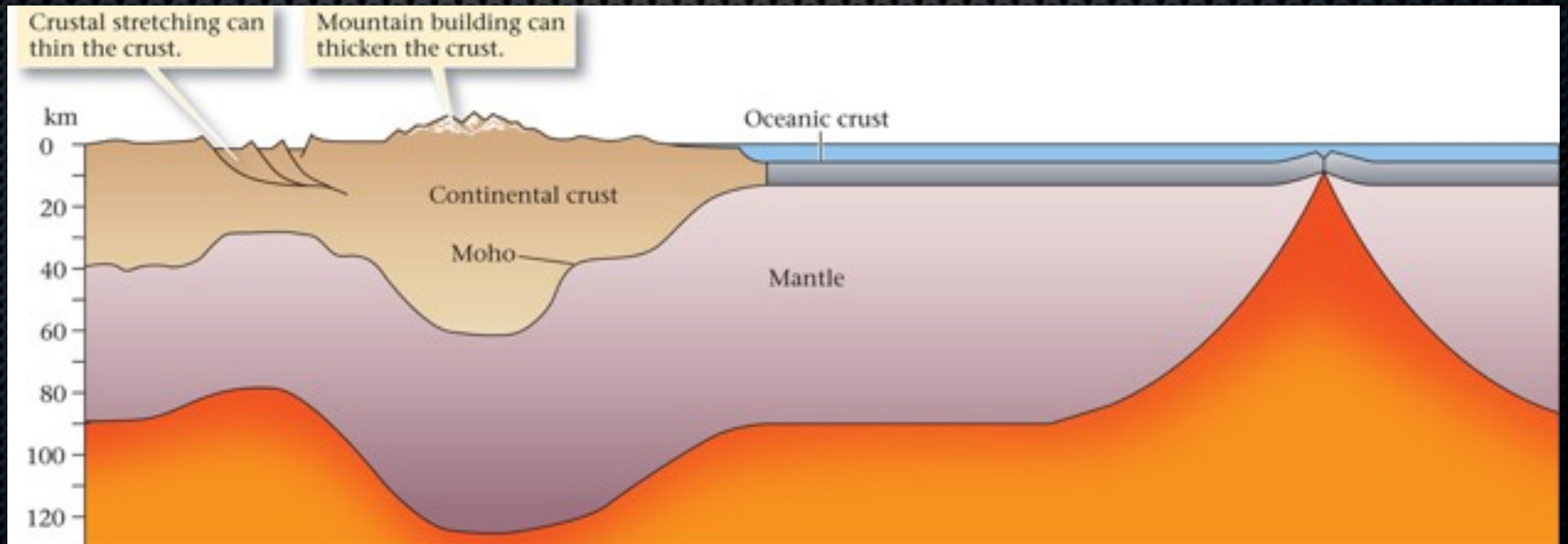
Two Types of Crust

- **Continental crust** – Granitic, underlies the continents.
  - Average rock density about 2.7 g/cm^3.
  - Average thickness 35–40 km.
- **Oceanic crust** – Basaltic, underlies the ocean basins.
  - Density about 3.0 g/cm^3.
  - Avgerage thickness 7–10 km.



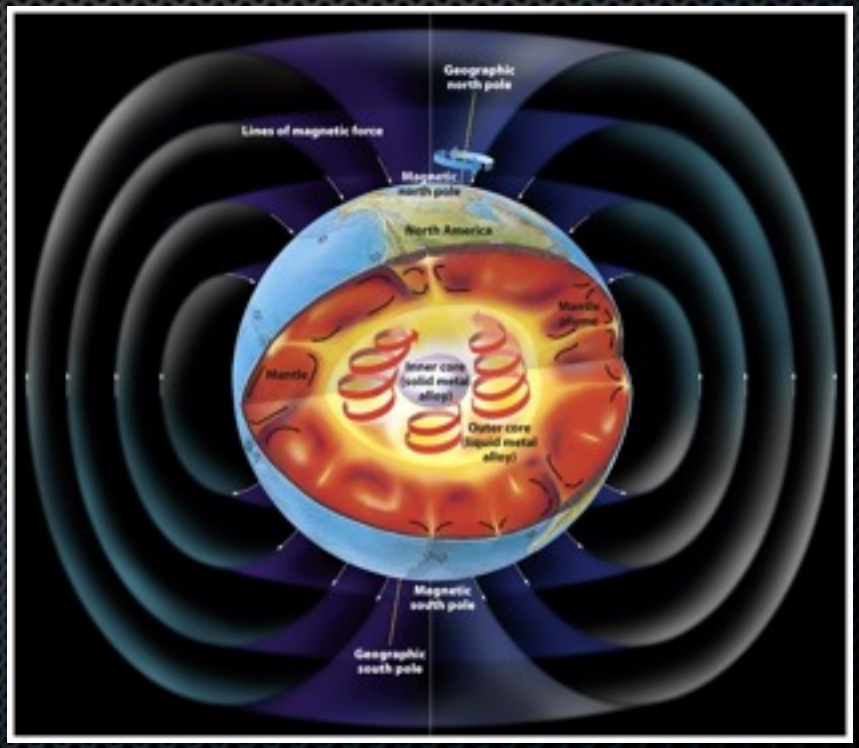
Earth's Mantle

- Solid rock layer between the crust and the core.
- Mantle composition is the ultramafic rock peridotite.
- Below ~100–150 km, the rock is hot enough to flow.



The Core

- **An iron-rich sphere with a radius of 3,471 km.**
- **2 components with differing seismic wave behavior.**
  - Outer core
    - Liquid iron-nickel-sulfur
    - 2255 km thick.
    - Density – 10-12 g/cm^3
  - Inner core
    - Solid iron-nickel alloy.
    - Radius of 1220 km.
    - Density – 13 g/cm^3.
- **Flow in the outer core generates the magnetic field.**



Lithosphere–Asthenosphere

- Lithosphere – The outermost 100–150 km of Earth.
  - Made of 2 components: Crust and upper mantle.
- Asthenosphere – Upper mantle <u>below</u> lithosphere.
  - Shallow under oceans; deep under continents.