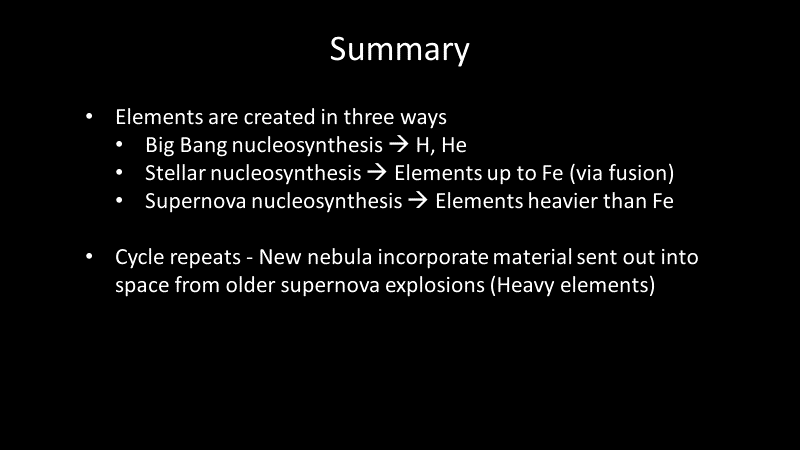
# Forming Elements

The universe began with the big bang at 13.8 Ga (Billions of years ago)

* At first there was only energy
* Within a few seconds: protons, neutrons, and electrons formed H(ydrogen)
* 3 minutes: Nuclear reactions fused H(ydrogen) to form He(lium) -> 98% of all matter
* Gravity brought these atoms together to make galaxies and stars that clung together in an expanding universe

Three types of nucleosynthesis

* Big Bang
  + The Big Bang nucleosynthesis formed H, He, Li, Be, B in the first 3 minutes of the universe’s existence.
  + Universe cooled, atoms formed molecules, they accumulated into patchy clouds called nebulae
  + In the very beginning of the universe, all Nebulae were 75% H and 25% He
  + Rest of elements came from stars….
    - Gravity pulls together material to make new stars and a surrounding accretionary disk
    - Center gets dense and hot -> fusion reactions begin
* Stellar
  + Nuclear fusion
  + Four 1H combine to form one 4He
    - 4H – 1He = 0.03 amu
    - E = mc2
  + Nuclear fusion creates a lot of energy
  + Power stars and makes moderately heavier elements (up to Fe [iron])
* Supernovae
  + Heavies natural elements made during supernova



# Global Population

Human use of Resources

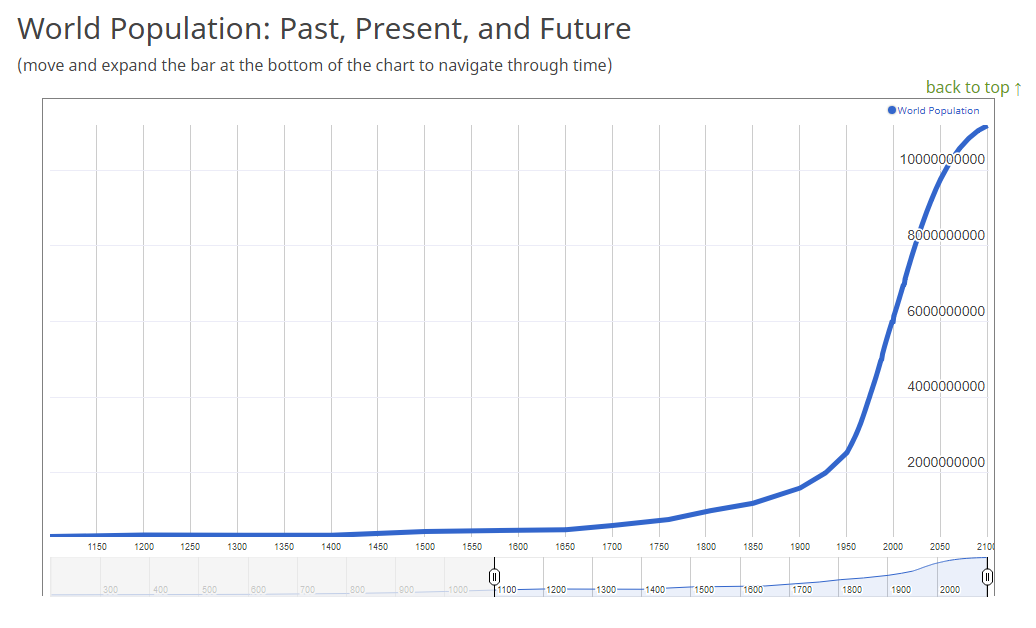
* Renewable - Replenished on human timetables
* Non-renewable - Formed over geologic (very long) timescales, effectively finite quantity available

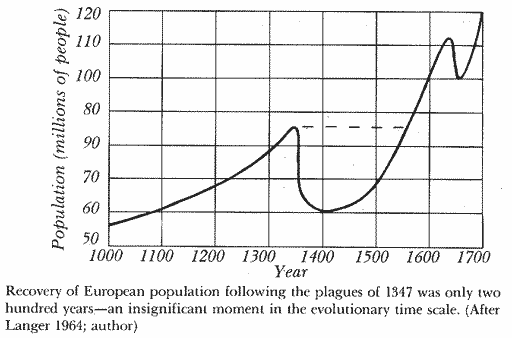
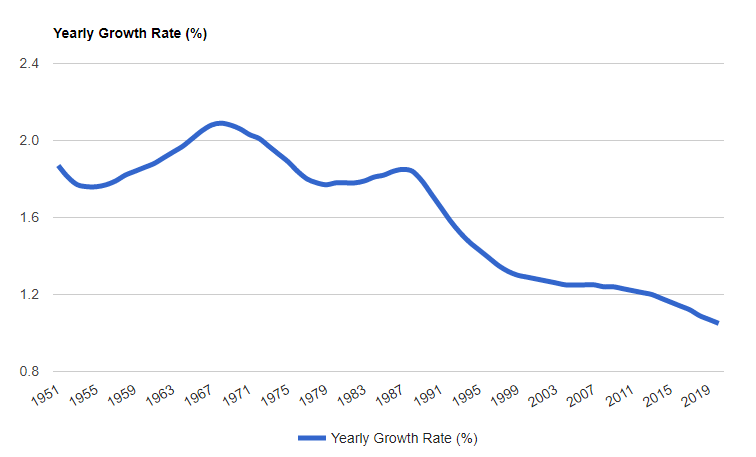
Why population is important:

* Malthus (1798) - Organism populations increase exponentially, whereas the “environment” is “fixed” (actually decreases)

World Population

* Unlike exponential growth, where the curve looks the same at every point, superexponential growth has one or more “knees” in the curve, places where growth suddenly switches from a slower to an even faster (or sometimes slower) exponential mode.
* called “Hockey Stick” or J-curve growth, as, like a capital J, there is a period of low growth, a knee of the curve, and then a period where growth goes almost vertical for a time.



* Pre-19th century growth rates were ~0.2%/yr
  + <1 billion
  + 1348 plague was beginning of the hook of the j-curve
* Recent
  + 1800 – 1 billion
  + 1930 – 2 billion
  + 1975 – 4 billion
  + 2018 – 7.6 billion
* Predicted:
  + 2030 – 8.6 billion
  + 2050 – 9.8 billion
  + 2100 – 11.2 billion

Factors affecting growth rate

* Growth = Birth Rate – Death Rate
* 1.1% = 1.9% - 0.8% (as of 2012)

Factors affecting birth rate

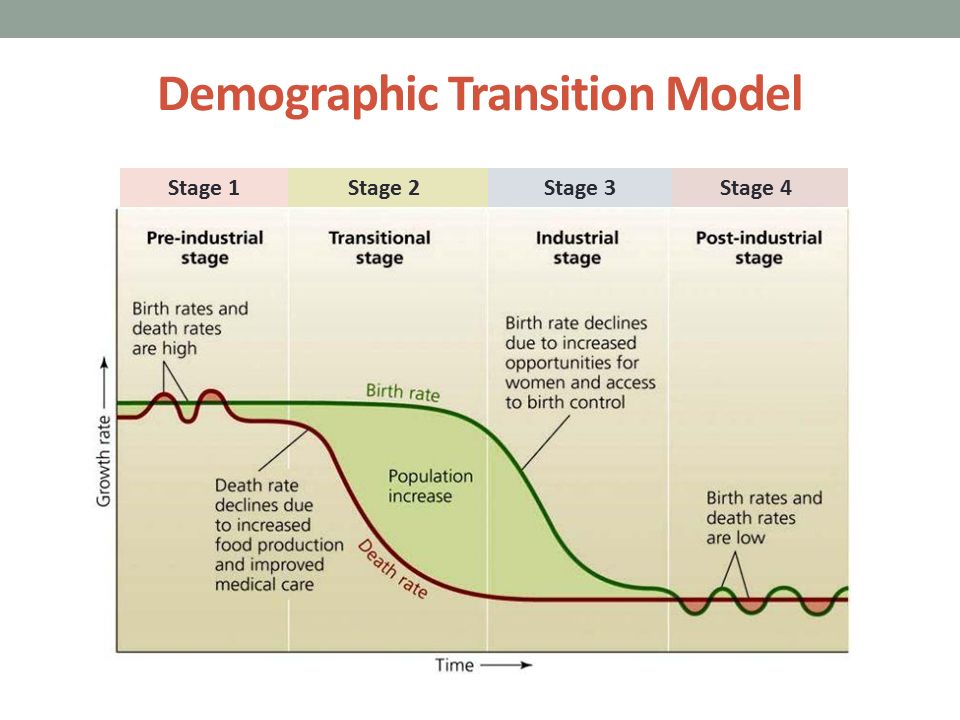
* Varies inversely with industrialization
* Global BR = 1.9% (higher in developing countries)
* To reduce birth rate:
  + Invest in family planning
  + Reduce poverty (and childhood mortality)
  + Elevate status of women

Factors affecting death rate

* Global DR = 0.8% (fairly equal globally)
* Low rates due to:
  + Medical treatments
  + Better food availability and nutrition
  + Improvements in sanitation
  + Access to clean water
* Lower DR main reason for global population increase

Carrying capacity

* Maximum number on individuals the environmental resources of a given region can support (K)
* Population growth and carrying capacity co-evolve
* Physical = “packing density” – spaces and resources
* Cultural = less, quality of life
* Accepted range for K is 10-20 billion

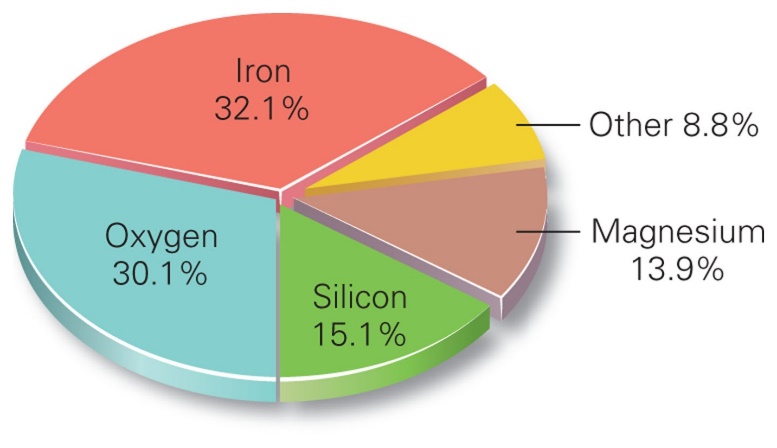
Demographic Transition

* Impact of economic development on growth rates
* Responsible for graduation reduction during 20th century

# Formation of the Earth and Earth’s Layers

Gravity pulls together material in nebula to make a new star with a surrounding accretionary disk

* Objects collide and gravity makes planets round
* One of these became Earth, other became rocky planets
* Lighter, lovality elements escaped, blown to edge of disk, and became gas giants



Earth’s Layers

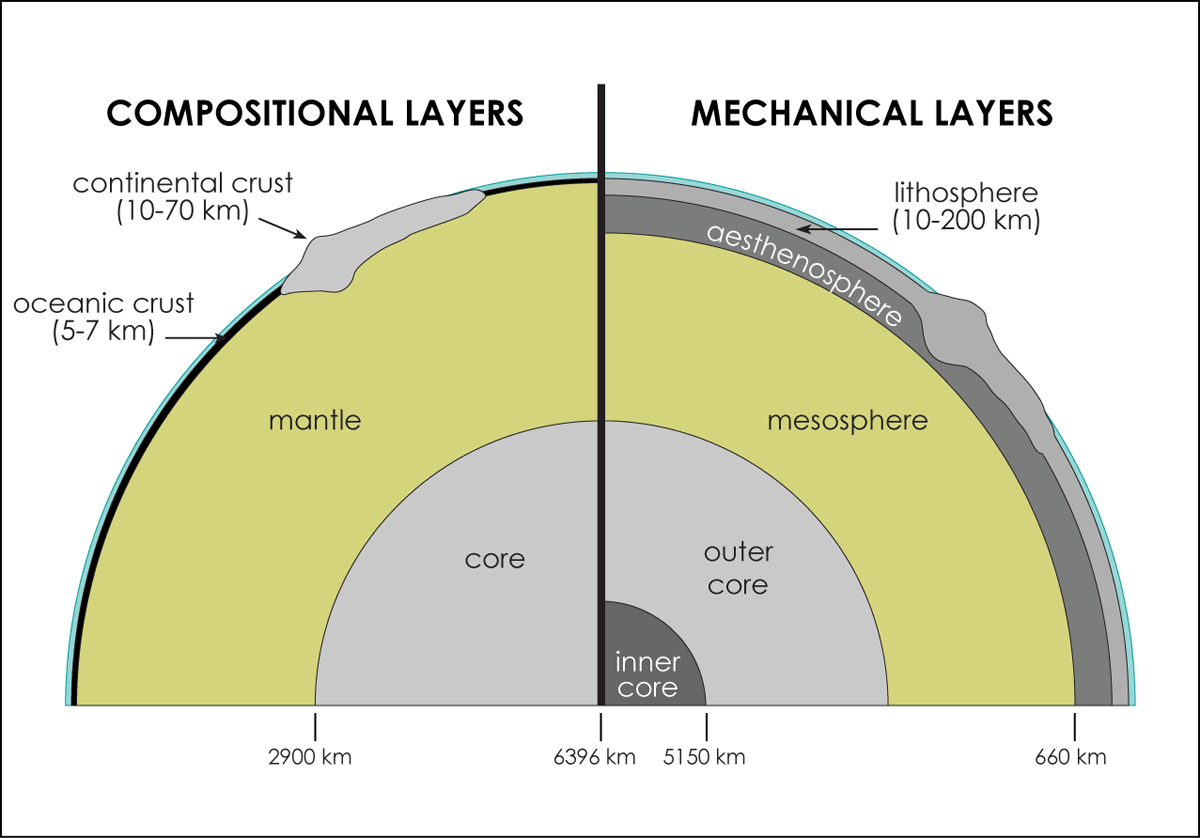
* Core: Fe (iron) + Ni (Nickel)
* Mantle and Crust: Sil icate (Silicon + Oxygen + Others)

Crust

* 8-45km
* Lowest density
* Si, O, Al

Mantle

* 45-2900km
* Silicate, Fe, Mg, Mn

Core

* 2900km – center
* Densest
* Fe & Ni

Physical Layers

* Lithosphere
  + Brittle
  + 0-100km
  + Cold
* Asthenosphere
  + Ductile
  + 100-700km
  + Warm, weak, slowly flows
* Lower mantle (menosphere)
  + Brittle
  + 700-2900km
* Outer core
  + Liquid
  + 2900-5100km
* Inner core
  + 5100-6370km
  + Brittle

# Plate Tectonics

Lithosphere consists of separate plates that move with respect to one another

* 12 major and minor plates
* Move relative to one another
* Minimal deformation in interior

Types of Crust

* Continental
  + Granitic
  + Si and Al
  + 2.7 g/cm3, 35~40km
* Oceanic
  + Balatic
  + Si-poor, Fe and Mg-rich
  + ~3.0 g/cm3, ~7-10km thick on avg

Types of plate boundaries

* Divergent
  + Sea-floor spreading pulls plates apart at mid-ocean ridges, magma wells fill up gaps
* Convergent
  + Plates move toward one another
  + Subduction
    - Ocean-ocean
    - Ocean-continent
    - Crust destroyed
    - Recycling of oceanic lithosphere
    - Volcanism
    - Trench
  + Collision
    - Continent-continent
    - No crust destroyed
* Transform
  + Form links between two other boundaries
  + Plates slide past
    - No creation or destruction
    - Continental
    - Oceanic
* Hot spots
  + Volcanoes independent of plates
    - Intra-plate volcanism
    - Leave distinct chain of volcanoes

# Minerals

Minerals are the building blocks of rocks

Provide clues about rock’s history

Sometimes contain valuable elements

Definition:

1. Naturally occurring
2. Inorganic
3. Solid
4. Specific chemical composition
5. Crystalline structure

Chemical compositions:

* Each mineral has a chemical formula
* Eg, Quartz (Sio2), Pyrite (FeS2), Potassium Feldspar (KAlSi3O8), Diamond (C)

Crystalline structure:

* Atoms have ordered microscopic structure, order repeated in all directions
* Solids without one = amorphous
  + Glassy
* Crystal is a single continuous piece of a mineral

Formation

1. Solidification of a melt
2. Precipitation from solution
3. Solid state diffusion (metamorphism)
4. Biomineralization
5. Precipitate from gas

Classification

* Atoms
  + Protons – Positively
  + Neutrals: Neutral
  + Electrons: Negative
* Ions
  + Gains electrons to become negative charged anions
  + Lose electrons to become positively charged cations
* Minerals classified based on dominant anion

|  |  |  |
| --- | --- | --- |
| Silicates | SiO44- | Rock-forming minerals |
| Sulfides | S- | Pyrite, Galena |
| Carbonates | CO32- | Calcite, Dolomite |
| Native elements | (no anions) | Copper, Gold, Graphite |
| Oxides / hydroxides | O2− | Hematite, magnetite |
| Sulfates | SO42- | Barite, Gypsum |
| Halides | a halogen (eg. F-, Cl-) | Halite, fluorite |
| Phosphates | PO43- | Apatite, monazite |

Silicate minerals

* Rock-forming minerals
* Make up >95% of continental crust

# Rocks

Coherent, naturally occurring solids consisting of an aggregate of minerals a mass of glass

Weathering

* Breakdown of rocks by chemical and mechanical processes

Erosion

* Transport of material by mobile agents such as water, wind, ice, or gravity

Sediments can be transported and deposited

* Can be buried and lithified
  + Process of turning unconsolidated sediment into a solid sedimentary rock

# Ore

Cobalt:

* Mined from metallic minerals, found with other metals like copper
* Used in many other applications like stainless steel
* Mostly mined from Africa

Lithium:

* Mined from a mineral found in trusive igneous rock
* Mined from brine (very salty water)
  + One spot of the andes mountains

Cut-off grade:

* If the concentration of ore is higher than cut-off grade, then mining can be profitable

Acid mine damage:

* Increases acidity in waters draining mines (where sulfide minerals are present)

# Sedimentary Deposits

Laterite

* the elements aluminum (from bauxite), nickel, iron
* develop by intensive and long lasting chemical weathering of the underlying parent rock (some minerals are soluble, some not whose residuals remain)
* hot, wet dropical areas

Evaporite

* Na and K-salts, gypsum, borates
* ion saturated water evaporates, condensing into evaporite deposits that builds into sedimentary rocks
* shallow basins, on land, or in the sea

Placer

* the elements gold, Silver, Titanium (from rutile, titanite), Diamonds
* heavier minerals snowball into large sedminetary deposits
* streams and shores of areas with heavy wind and rain

Banded Iron Formation

* iron
* dissolved iron oxygenized in pulses, results in some layers precipation of hematite and chert in
* ocean depths near continental shelves and volcano settings, conditions no longer exist

# Igneous and Metamorphic Deposits

Porphyry

* Elements copper, molybdenum, gold and tin
* magma from volatile enhanced melting cools, as it moves up it shatters rocks around it and fills cracks
* convergent zones, volatile-enhanced melting

Layered igneous intrusion

* the elements iron, chromium, titanium, nickel, platinum-group elements (PGE)
* magma cools and becomes a solid before it reaches surface
* hot spots

Volcanogenic Massive Sulfide

* The elements nickel and cobalt. Also, the elements iron, copper, silver, mercury, gold, and manganese.
* hydrothermal fluid erupts into sea and quickly cools (black smokers)
* mid ocean ridge

Kimberlite

* diamonds (minerals)
* cooling after sub surface magma explosions
* extremelys hot temperatures deep within mantle, before 40 million years ago

Pegmatite

* aluminum (from the mineral nepheline), tin and tantalum (elements), beryllium (element from the mineral beryl), muscovite (mineral), potassium feldspar (mineral)
* end stage of magma crystallization, magma cools below surface
* edges of batholits and in fractures