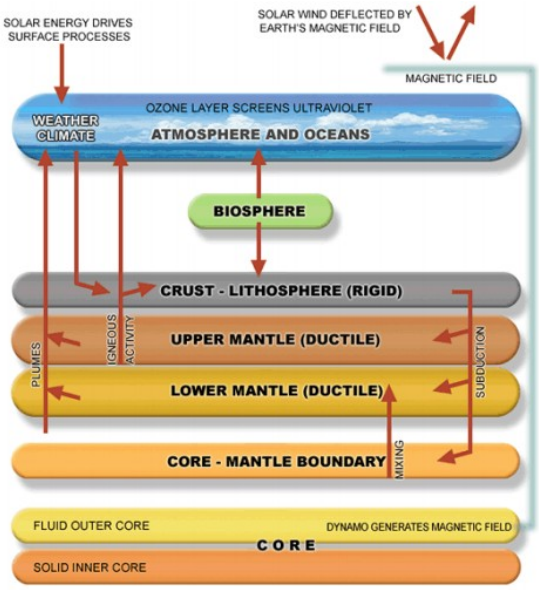
Module A

Lesson 1

1. Describe the concept of Earth System Science.
    a. Earth System Science views the Earth as a working system, each part having an impact and an effect on the other



    b.

2. Define the Scientific Method and explain how scientific tests are designed and conceptualized.
    a. Compile Observations, form hypothesis, test hypothesis, repeated testing (turns into a theory), if theory always happens it could be a law, continuous re-examination
3. Distinguish between a hypothesis, a theory and a law.
    a. Hypothesis comes from observations
        i. Theory comes from repeated hypothesis testing
            1. Law comes from theory being always observed to happen
4. Describe and label schematic diagrams of the Earth's interior and plate boundaries.
    a. Lithosphere- crust and uppermost mantle

b. Asthenosphere- upper mantle lubricating layer

c. Mantle- hot viscous, taffy like layer, continual motion

d. Outer core- liquid

e. Inner core- solid metallic composition

5. Plate tectonics

a. Grand unifying theory

i. The theory describes how the plates and the continents they contain are pushed and pulled around the surface of the Earth

ii.

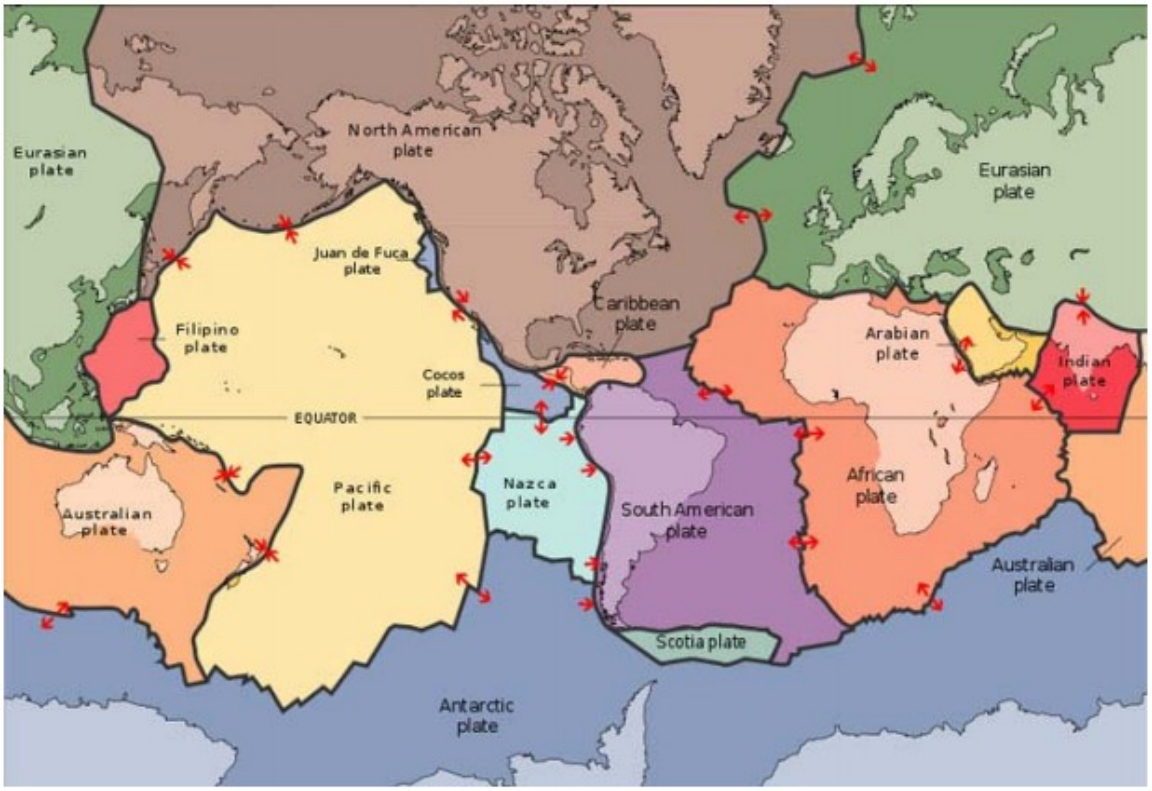


Plate boundaries

- Divergent (constructive)
  - Moving apart

- Mid Atlantic
  - Moves 2.5 cm per year
  - Notable b/c one of few observed on land

- Convergent (destructive)
  - Toward each other, collision
  - Continent- continent collision
    - HIMILAYA
  - Oceanic oceanic
    - Chain of volcanic islands develops
  - Ocean continent
    - Oceanic goes under it is more dense
    - Mountain ranges are produces
    - Such as the cascades
- Transform
  - Move past each other
  - Most famous
    - San Andreas Fault
    - North American Plate moves past the Pacific Plate
- Rock classification

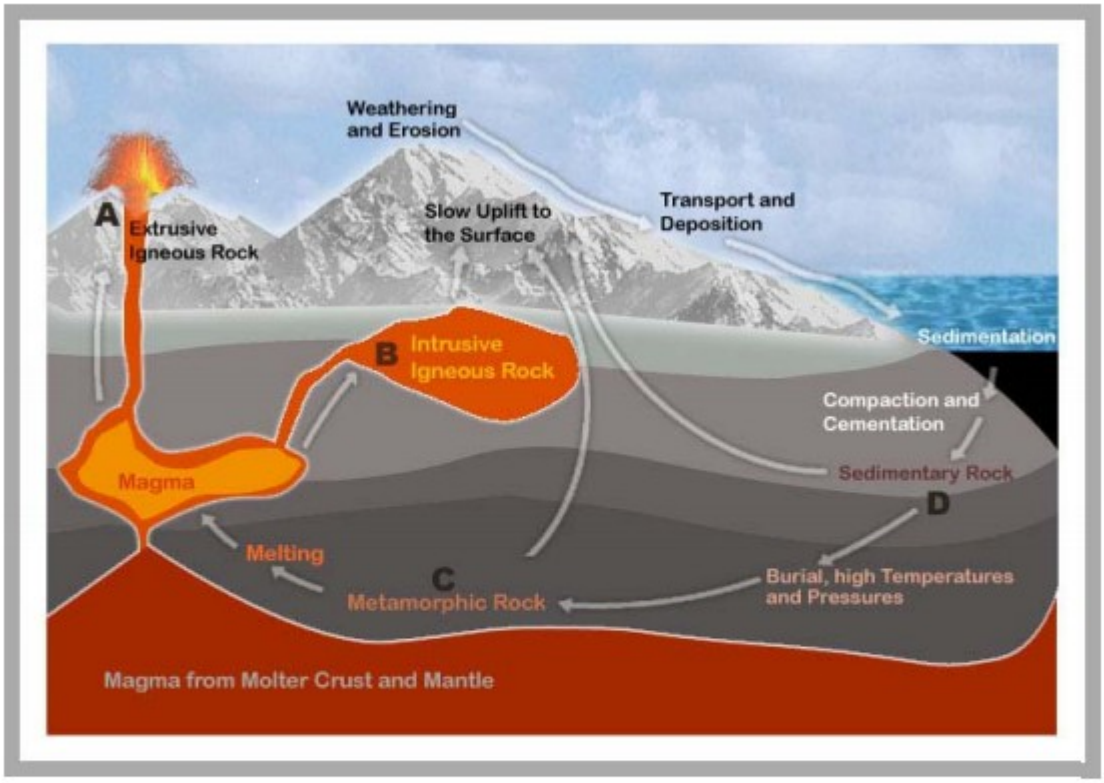


Figure A-8: Illustrating the Rock Cycle.

At **A**, extrusive igneous rocks form from magma that cools as it reaches the surface of the Earth. At **B**, Intrusive plutonic igneous rocks intrude from below the subsurface, cool, crystallize, and eventually are exposed by erosion at Earth's surface. At **C**, metamorphic rocks form as a result of the transformation of an existing rock. At **D**, sedimentary rock forms from sediments such as chalk, limestone, dolomite, sandstone, conglomerate, and shale, that are then compacted and converted to rock by the process of lithification.

- Igneous
    - Crystalize from molten material
    - If cools at surface earth it's called
        - Volcanic r extrusive
    - If cools inside the earth it is called

        - Plutonic or intrusive
            - Cool slow so have very large crystals
- Metamorphic
    - Formed by the alteration of pre-existing rocks using metamorphism
        - Process includes heat and/or pressure and often fluids
- Sedimentary
    - Formed from a number of processes
        - Physical erosion
        - Chemical precipitation to from an evaporate
        - Biological precipitation of minerals
            - Include production of coral reef , sediments composed of shells
    - Sediments are formed into rock through lithification or diagenesis
        - Similar to metamorphism but not to a degree that rocks and mineral are physically changed

Roc k cycle

Geological Time

- Humans have been around for almost none of earth's history
    - 1/20 of a second if earth's history was a calendar year

Lesson 2

People

- James Ussher
    - Used bible
    - Decided earth was 6000 years old
- George Louis De Buffon

- Said earth hardened from a molten state
- Said it was 75,000 years old

Stratigraphy

- Measures layers of rock
- Shows geologic history and relative ages of a region
- Shows how long it takes for a substance to accumulate
  - Muddy sediment 10 metres/ million years
- ERRORS
  - Not always constant rate
  - Might have erosion
  - Squishing can occur resulting in an underestimation

Relative dating

- Relies on basic laws of stratigraphy to estimate age of earth
- Original horizontality
  - Rocks that are currently folded or tilted were once flat horizontal layers
- Superposition
  - Layers of rock at the bottom are the oldest

Biostratigraphy and faunal succession

- William Smith
- Biostratigraphy
  - Based on principles of stratigraphy as it relates to time
- Faunal Succession
  - Different types of fossils can be found in regular order through sedimentary rocks
  - Sediments can be assigned a relative geological age based on fossils they contain
  - Fossil range

    - Time between species evolution and extinction

Unconformities

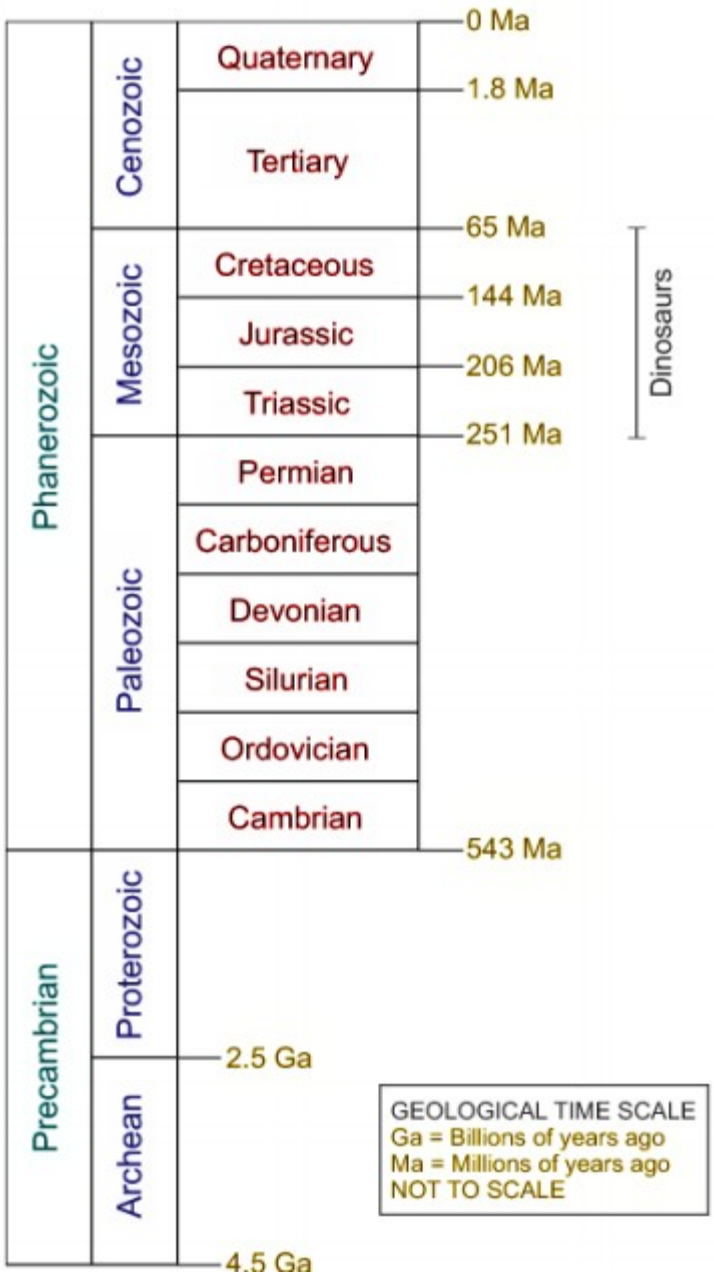
- Gaps in geological record of sedimentary rock
    - Often major geological events, mountain building, are responsible
- Angular unconformity
    - Sediments fold, erode and are covered by new sediments
    - Create time gap
    - Most famous is in grand canyon, 1.2 billion years
    -

Cross cutting relationships

- Brings all the rules together

Geological time scale

- Subdivides earth 4.5 billion years



- More subdivided in Phanerozoic because it is labelled by fossils
    - They are more abundant and diverse after Precambrian

Absolute Dating

- Uses radioactive decay to date rocks
- Also called radiometric or radioactive dating
- During decay parent atom reacts creating daughter atom and release of energy

    - Keeps happening until stable
- Only valid if it can be proved to happen in a closed system
    - No contamination or loss of parent or daughter material
    - Other limits
        - Weathering causes leakage of isotopic material
        - Metamorphism
            - Resets the time it can be dated from
        - Cannot be used on sedimentary rocks
- Must be used with relative dating

Mesozoic Era

- Cretaceous
    - 144-65 Ma
    - Jurassic 206-144 Ma
    - Triassic 251-206 Ma

Lesson 3

Important figures

- Leanardo da vinci
    - Was puzzled by fossil seashells he found on mountains
- Abraham Ortelius
    - Noticed jigsaw fit of east coast of south America and west coast of Africa
- Antonio Snider-Pellegrini
    - Constructed two maps showing all continents joined
    - Backed it up with plant fossils found in NA and Europe
    - Said continents were split by great flood

Geosynclinal Hypothesis

- First attempt at grand unfying theory
- Explain the location of earth's features
- Hypothesis
    - As earth cooled, it shrank and developed wrinkles like a rotting apple
    - Does not accept lateral movements discussed in plate tectonic theory
- Failed to explain
    - the jig-saw fit of many of the continents;
    - long linear coastal mountain ranges and the deep ocean trenches associated with them;
    - the distribution of chains of volcanoes and earthquakes, often around the edge of continents; and
    - the fossil and current distribution of life on our planet

Wegener and continental drift

- noticed the continents fits and drifted away
- continental drift theory born
- apparent fit of continents
    - all continents fit together very well
    - especially if continental edges 200 m below sea level are included

"Split Units"

- should be able to finding matching geological units on either side of a proposed split
    - ex. Appalachian mountain belt
        - newfoundland to Alabama
        - disappears into ocean at newfoundland reappears in UK and Scandinavia
        - in Pangaea form mountains form the 'central Pangaean mountains
    - shield areas

        - relatively old stable metamorphic rocks called gneiss
        - match from south America to Africa

Similarity of stratigraphic record

- stratigraphic record can be noticed between previously connected continents
- most famous across SA and Africa even matching lava flows

Climatic Evidence

- can't measure previous geological climates
- but it has effects on earth, use those effects as proxies to measure climate

Evidence from Ice

- glacial tilt
    - poorly sorted sediment deposited by glaciers
- glacial striations
    - leave scratches and grooves on the rock they move over
    - these are identifiable in areas that could never support glaciers
        - around equator

Evidence from coal and coral

- evidence of coal used as climate proxy
- coal develops in hot humid areas
- a lot of coal mined in north America and Europe
    - must have drifted from tropical regions

Distribution of Life: Lystrosaurus, Mesosaurus, and the Glossopteris

- lystrosaurus
    - not strong swimmers
    - suggests continents where it can be found must have once been connected
        - Antarctica india and south Africa

- Mesosaurus
    - Freshwater creature
    - Found in Africa and south America
    - Couldn't swim across the ocean
- Glossopteris
    - A tropical fern
    - Not moved by wind salt water kills it
    - Found in SA, india Africa and Antarctica

Diamonds

- Diamonds get smaller the further down river they are
    - Diamonds in Africa get smaller and abruptly stop at the ocean
    - The diamond size is picked back up in SA and continues on

Wegeners Conclusions

- Said Pangaea existed 200 million years ago

Reception

- Very unfavourable
- Argued so many preconceptions
- Biggest problem was the mechanism
    - Said centrifugal force from spin of the earth and gravitational force generated by the moon dragged the continents around the surface
        - These were thought of as being too weak
        - They said land-bridges were the reason for these appearances
        - New techniques for imaging the ocean floor came up to support Wegener

Module B

Lesson 4

Early Origins

- Universe 12-14 billion years old
    - Big bang
- Water was pre-requisite for life on earth

Biosphere

- Thin veneer of life surrounding surface of our planet
- Dino's were part of an ancient biosphere
- Biosphere has modified conditions that support life
- Earth may have been very different without life

Origins of life on earth

- Hypothesis's
    - Panspermia: Life was Brought to Earth
    - Earth-based Origin: Ocean Margin Hypotheses
    - Earth-based Origin: Deep Ocean Hydrothermal Vent Hypothesis

Panspermia

- Meteorites and comets contain essential molecules for life
    - Very likely they were brought to earth by impacts
- It is suggested life itself was brought to earth by impacts
    - However, evidence of living microbes in extra-terrestrial is yet to be found

Ocean margin hypothesis

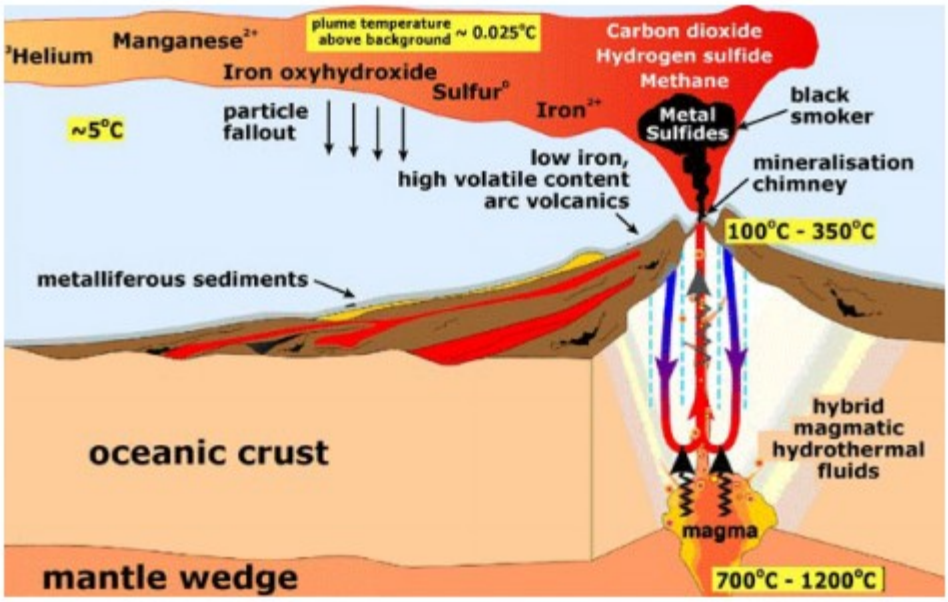
- Alexander Oparin, J.B.S Haldane
    - Proposed organic material formed from inorganic material through chemical reaction
    - Precursor for living cells
    - Millers experiment

        - Mimicked Archean climate and created amino acids, basic chain of protein

- Life must have
    - Metabolism
    - Growth
    - Ability to reproduce
    - Some sort of evolution with changing environment
- Sidney W Fox
    - Offered scenarios where protein could be polymerizedds
    - Used heated ocean water example
    - Clay could have played a role
        - Have specific electric charge that attracts amino acids

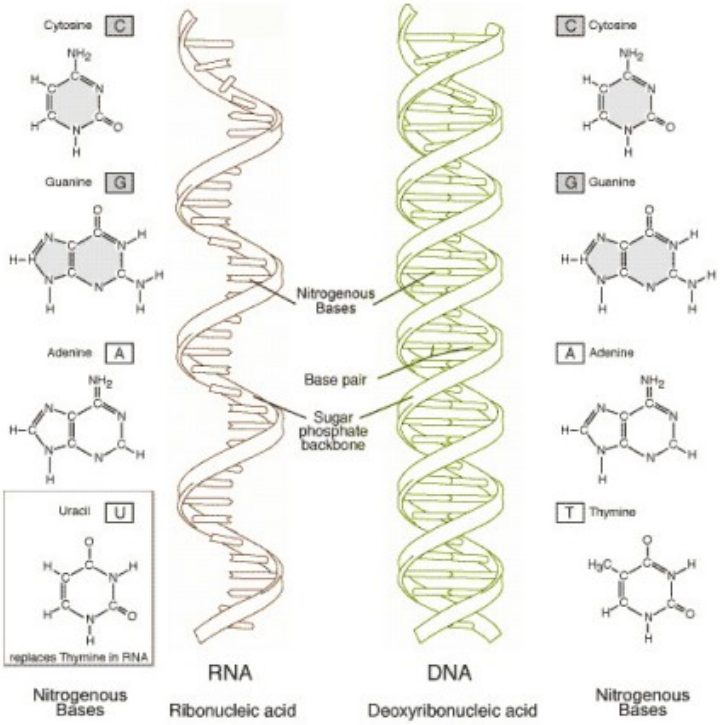
Deep Ocean Hydrothermal Vent Hypothesis

- Water falls into cracks in seafloor
- Heated up 350 Celsius and rises back up
- Dissolves minerals in ocean crust and transports them to surface where they are precipitated to form vents
- Some organic material and even amino acids have been found here LIFE!!
- Possible for life to have been created in more than one way



DNA or RNA

- If DNA is the blue print of life but can only reproduce itself with the aid of enzymes, which require DNA to be produced, in the first place, then how do we get the first DNA?
- RNA is self-replicating
    - Some people believe first human life was RNA based



Primitive Heterotrophs

- First fossils are advanced microbes
- Meaning
    - Life was brought to earth by panspermia
        - Unlikely due to earth adaptions
        - We are missing much of earth's history
- What early life was like
    - Life with no oxygen
    - Probably heterotrophic
        - Consumed their food not photosynthesized
        - Lots of ATP available in the ocean
    - Prokaryote

Next step: autotrophs

- ATP supply would eventually run out
- Forced evolution
- New strategies for nutrition would begin
    - Most likely fermentation

Earliest Fossils

- 3.5 billion years ago in Australia
- Hints of photosynthesis in Greenland before this
    - No fossils it is controversial

Stromalites

- Mats of cyanobacteria in shallow water marine conditions
- Oldest in Australia 3.5 billion years ago
- Got larger and more complex
- Now, are fed on by other life forms, keeping their growth in check

Increasing complexity

- Prokaryotes take up majority of life on earth history
- Eventually eukaryotes formed
    - Anything that isn't bacteria
- Differ from Prokaryotes
    - Larger more complex internal cell structure
    - Have dna in nucleus
- Sexual reproduction
    - Increases diversity
    - Before this binary fission was used, just creates exact replica's
    - Increased tempo of evolution
- Good biological evidence of eukaryotes

    - Endosymbiosis
- First fossils found 900 million years ago

‘Great oxygen crisis’ evidence

- Branded iron formations
    - Cannot possibly from under earth’s current condition
    - Existed in early oceans
    - Oxygen caused them to rust

Uraninite and Pyrite

- Commonly eroded into ocean sediments
- Once oxygen came they were oxidized
- Only in sediments 1.8 ga or older

Red beds

- Oxidized reduced iron turned red

Multicellular Creatures: The Rise of the Metazoans

- Advantages of multi cell
    - one can get larger and interact more effectively with the environment; and
    - one has the possibility of living longer by replacing dead cells.
- First discovered 550 million years ago Southern Australia
- Trace fossils have been found before this through larger organisms

Summary

Years Before Present	Event
3.8 billion	first **prokaryotes**
3.5 billion	**photosynthesis** developed
2.5-1.8 billion	the **Great Oxygen Crisis**
(?)1.4 billion	first **eukaryotes**
600 million	first **metazoans**

Lesson 5

Cambrian Explosion

- Came right after initial metazoan bodies
- First organisms with hard parts
- May have happened due to increase in oxygen
- Also break up of super continent Rodinia permitted circulation of
    - Phosphorus nitrogen and iron
    - Essential for animal 'hard parts"
- Thought hard parts may have come from increased metabolic process
    - Need ducts and tubes to collect/ rid of waste
- Hard shell gave these creatures advantage b/c
    - A hard shell would give greater protection from ultraviolet radiation. During the Cambrian, more UV radiation penetrated into shallow water because the ozone layer was thinner.
    - A hard shell would help prevent desiccation in organisms caught in an inter-tidal environment.
    - Hard parts can support soft tissues and act as supports for muscles and therefore aid locomotion.
    - Hard parts protect organisms from predators.

Timing of Cambrian Explosion

- Three phases
- Lowermost Cambrian fauna
    - Condontomorphs found simple teeth like structures
- Tommotian Fauna: small shelly fauna
    - Early Cambrian
    - More teeth
        - enigmatic fossils not assigned to any later phylum
        - sponge spicules
        - Monoplacophorans (ancestors of mollusks/brachiopods)
    - Evolution sped up with
        - Increasing defense
        - Predators adapting to the defense
    - Most fauna extinct after this
- Late early Cambrian
    - Rapid diversification
    - Anthropods (lobster)
    - Trilobites
    - First mullosks
    - Brachiopods

Evolutionary experiment

- Cambrian saw organisms that were ‘experiments’
    - Unlike other organisms
    - Didn’t really work
- Evolution could only proceed with strict body plans or “genetic rules”

The Burgess Shale: A Window into the Middle Cambrian Biosphere

- Some new forms of life
- Not as fast as early Cambrian
- Articulate brachiopods
- The condonts
- Found in yoho national park BC
    - Soft shelled organisms that usually wouldn't make fossilization
    - Shows BC was close to the equator
- Reef edge was unstable
- Earthquakes cost it to slide burying organisms
- Low oxygen so they didn't decay

Significant Specimen in Burgess Shale

- Pikaia: Early Chordate
- From Chordates, vertebrates and humans evolve
    - Unlikely to bet on them but it happened
- Opabinia
    - 5 eyes grasping trunk
    - No analogues today
- Hallucigenia
- Anomalocaris
    - Top predator in middle Cambrian oceans

Anthropods in burgess shale

- Over 40% of burgess shale fauna ere anthropods
- Canadaspis

    - Crustaceans ancestor
    - Among first hard shelled life
- Aysheaia
    - Ancestor of insects
    - Velvet worm
- Sanctacaris
    - Ancestor of scorpion and spiders
- Most burgess shale were extinct at and of Cambrian

Lesson 6

Earth's changing Biosphere

- Biosphere is always evolving and changing
    - Like an ongoing play

The Development of the Concept of Extinction

- Late 1700's started to think earth is old and extinction exists
- George cuvier mammoths
- Phanerozoic based on creatures with hard parts
- Base of Mesozoic and Cenozoic is new species after mass extinction
- Base of all periods is life through radiation

Mass extinction definition and number

- Definition
    - at least 30% of Earth's species must be lost;
    - loss of species must be across a broad range of ecologies, not restricted to any one niche; and
    - event must have a short/sudden duration (around 1 million years maximum).
- 5 major extinctions
    - 1. Cretaceous / Tertiary (KT), 65 Ma

- 2. Late Triassic, 205 Ma
- 3. Permo / Triassic, 251 Ma
- 4. Late Devonian, 360-375 Ma
- 5. Late Ordovician, 440-450 Ma

Causes of mass extinction

- Biological
  - a. competition between creatures occupying the same ecological niche
  - b. (excessive) predation
  - c. pathogens: disease being introduced to an area by incoming plants or animals
- earth based
  - continent drift
    - changes climate and other features
    - larger landmass less diversity
      - more competition
  - changes in atmosphere
    - volcanic activity
    - gases CO2 greenhouse warming
- Extra-terrestrial impacts
- Combination
  - Usually it is a combo

Periodicity of mass extinctions

- Raup and Sepkoski
  - Extinction mass every 25 mill years
  - Thought Oort cloud shift dropping comets
  - Could have causes

    - We move through the galaxy up and down
    - Every 25-25 mill years we go through most dense part
        - More gravity
- We passed through densest part 1 million years ago
    - Takes million years for comets to reach earth
    - We are due

The Permo-Triassic Extinction: The Worst "Day" For Biosphere 251 Ma

- 95-98% of life lost
- Less than mill years
- End of Paleozoic
- Carbon levels show shortage of photosynthesis as plants are extinct

Causes

- Pangaea meant more competition less diversity
- Sea level fall
    - Killed those animals living in shallow water environment
- Ocean stagnation
    - Less oxygen flow CO_2 influx killed deep marine animals
- Climate change
    - Drier climate subject to drought
- Massive volcanic activity in Russia
    - Produce acid rain
    - Secondary effect was melting of gas hydrates
        - Ice that contains greenhouse gas methane
- Possible impacts

- Controversial idea

Module C

Lesson 7

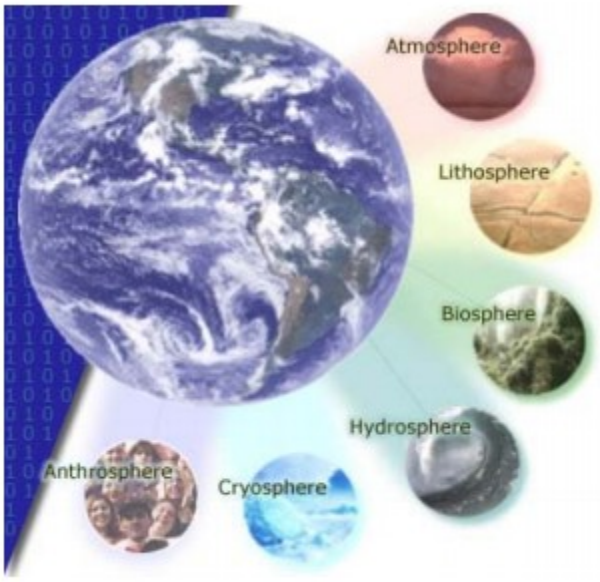
Systems theory

- A system is defined as any portion of the Universe that can be isolated from the rest of the Universe for the purposes of observing and measuring
- Isolated system no interaction
  - SPACE STATION
- Closed – light and energy but no matter
  - Earth
- Open energy light and matter
  - Ocean

Hierarchy

- Biological
  - Human
    - Cell organ whole human
- Chemical
  - Dna
    - Proton, nucleus, atom, molecule, dna
- Social
  - People
    - Self family, bc, Canadian, NA, world
- Hierarchy provides stability

Earth systems



- Geosphere
  - Crust and below it
- Hydrosphere
  - All water except atmosphere water
- Cryosphere
  - All earths surface where water is solid
- Atmosphere
  - Gasses that surround earth 100 km
  - Nitrogen oxygen argon CO2 water vapour
- Biosphere
  - Organisms and organic matter
- Anthrosphere
  - Part of biosphere
  - Part that has human beings

Feedback

- Negative feedback loop
  - Leads to homeostasis
  - Used on earth cyclic cycles
- Positive
  - Unstable more input means more output
  - Global warming
- Energy cycle
  - Sun to earth
    - Reflected energy
    - Earth emitted energy
  - First law of thermodynamics
    - Energy and matter is not created or destroyed
  - Second law
    - Energy spreads out if not stopped
  - Solar radiation
    - Most of earth energy
  - Geothermal energy
    - Temp goes up as you go into earths core
    - Crust acts as blanket
  - Tidal energy
    - Least significant energy source
  - Reflected energy
    - If energy not displaced earth would be too hot
    - Albedo shows how much is reflected
    - Venus has high albedo

    - Radiated energy
        - Second law
        - Short wave turns to long
        - Sent as heat back into space
- Water cycle
    - Goes from surface to atmosphere and back to surface
- Biochemical
    - Chemical compounds go through subsystems
- Rock cycle

Lesson 8

Gaia Hypothesis

- Earth is a sustainable self regulating system
- Lovelock

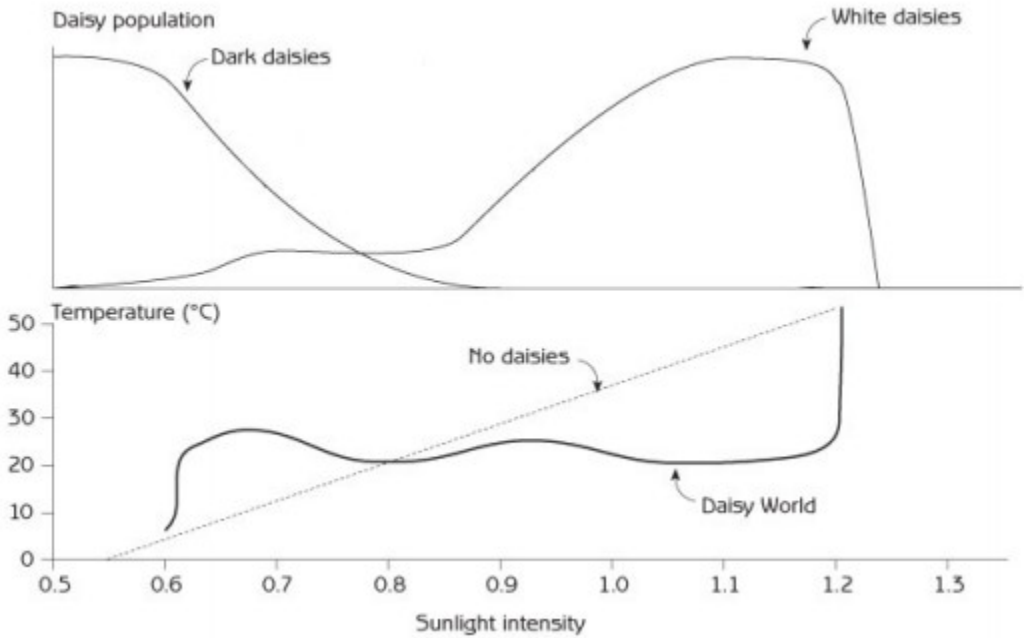
Geophysiology

- Earth saltiness
    - Perfect salinity for life
    - Clearly regulation
    - Evaporates and sabkha
- Carbon cycles
    - Short
        - Plants and animals
    - Medium
        - Plants and animals
        - Goes into geosphere

        - Humans have sped this up with mining burning fossil fuels
    - Long
        - Limestone metamorphic rocks in geosphere

Daisy World Model

- Shows how earth can regulate temp with no intelligence
- White and black daisy with high and low albedo



-

Lesson 9

Hydrosphere

- All earth's water
    - Cryosphere ice and snow is a subset

Hydrosphere interactions

- With geosphere
    - Erosion and deposition of rocks
    - Subsurface geosphere
        - Interacted through continent drift

        - Hydrothermal alteration
- With biosphere and atmosphere
    - Rain, snow, sleet, hail, clouds
    - Gives environment for many animals in biosphere
    - Water essential to all life
    - In most reactions
- Anthrosphere
    - Controls distribution of population centres

Water distribution

- 97.5 in oceans
- 2.5 is freshwater
    - 69.5 in ice
    - 30.1 in groundwater
    - 0.4% of the 2.5 is present on earths surface and atmosphere

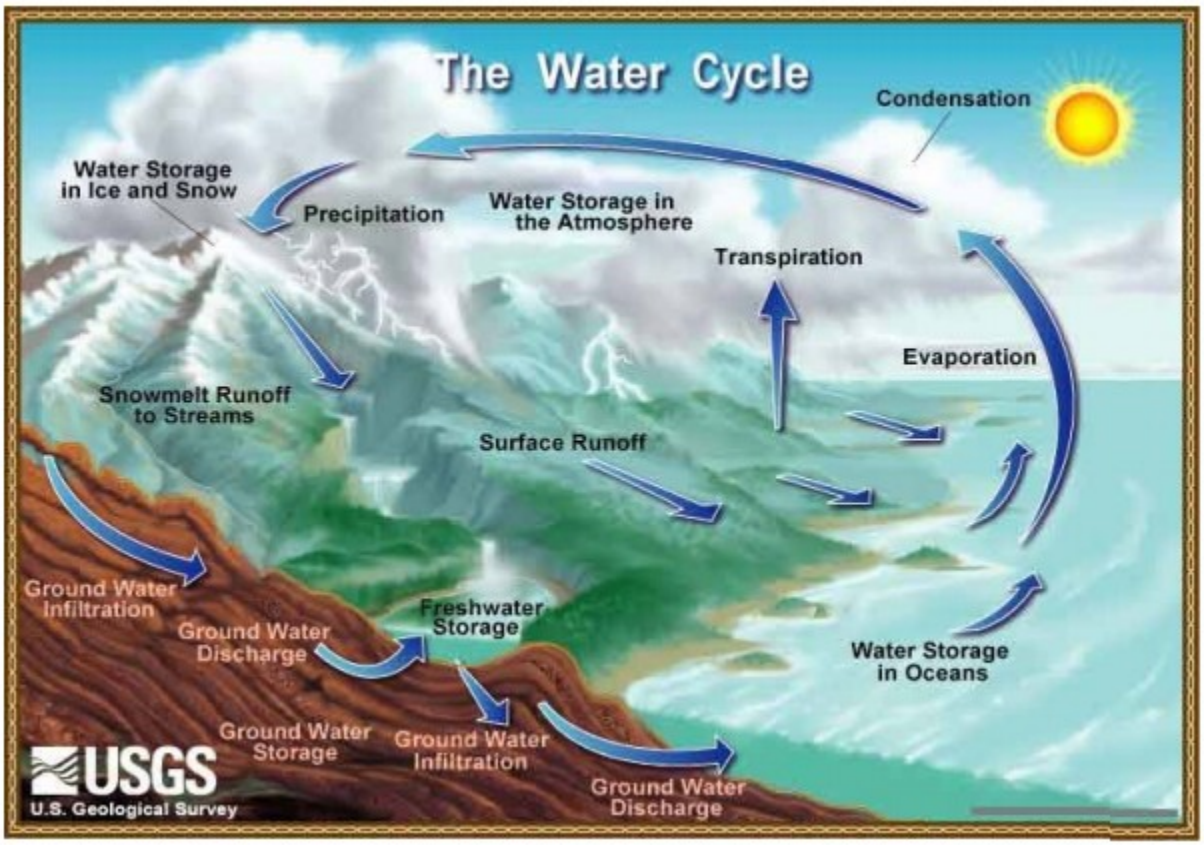
Three phases of water

- Liquid
    - Dipolar
    - Universal solvent
- Solid/ ice
    - Less dense when solid
    - If not ice would have pushed cold water up and frozen
    - All water would be frozen, no life!!
    - Ice increases albedo meaning colder and more ice
    - Ice age!!
- gas / vapour

- important for heat transfer from sun to ocean and ocean to atmosphere
-

- We have all three
- Live in goldilocks era
  - Just right!

Water Cycle



Residence time

- The average estimated time water spends in each part of the hydrological cycle
  - Ground water

        - 1-2 months
    - Rivers
        - 2-6 months
    - Lakes
        - 50-100 years
    - Glaciers
        - 20 – 100 years
        - Up to 800,000 years
    - Ocean
        - 1,500-200 years

Lesson 10

Age of oceans

- water
    - Sedimentary rocks show 3.8 billions years ago
        - Although most likely much before this
- Ocean basins
    - Oldest crust on our planet
        - Sea of japan
        - 170 million years

Depth

- Rough floors
- Deepest is mariana trench
    - 10,942 metres

- 2 km deeper than Everest

Salinity

- 2.5 billion tons of salt brought to oceans each year
  - Streams rivers volcanic activity
  - 3.5 percent salt
  - 96.5 water
  - Na and CL have long residence times

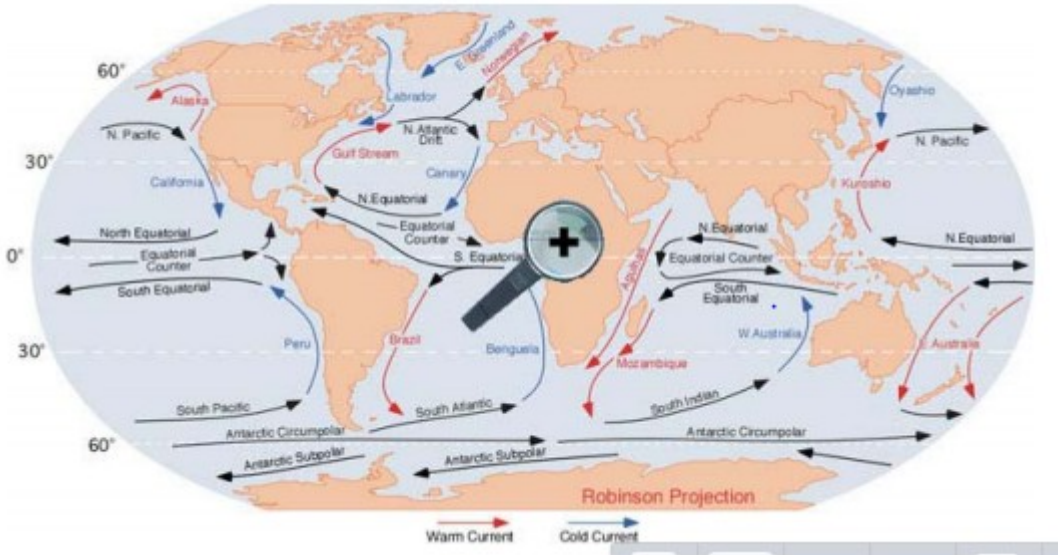
Temperature

- Ocean is heat sink
- Absorbs much of the suns radiation heat

Vertical stratification

- Earth's layers
  - Surface zone
  - Pycnocline
    - Rapid density change
    - Due to salinity and temp
  - Deep ocean
    - 80 percent of seawater
    - Up to 500 metres deep

Oceanic circulation



- As the wind moves over the surface of the water, frictional drag with the surface of the water causes it to move to the right of the wind direction in the northern hemisphere and to the left of the wind direction in the southern hemisphere. This response is due to the Coriolis effect.

Lesson 11

- Late Triassic
- NA and Africa began to split
- Tethy and pacific ocean moved in
- Antarctica and Australia drifted away from SA and Africa
- During Jurassic
    - Africa and SA rifted bringing in south atlantic ocean
- By end of cretaceous
    - Antarctica and aus split
    - India moved to equator
    - Africa and SA fully split
- Tethy today

- Mediterranean and black sea

- Sea level changes
  - Ocean ridges
  - Collision of continents
    - See levels fall
  - Volcanic activity
  - Ice
  - Thermal expansion of seawater
- Constant during Triassic
- Very somewhat in Jurassic
- Steady growth through cretaceous
  - World 40 percent more flooded than today
-