FINALS NOTES PT 2

fossilization and information loss

strangely enough

- fossilization tends to be the exception for dead remains rather than the rule
- less than 5% (prob like 2.5%) of all remains of all living things can make it into fossil record
- fossilization is rare and for dead remains to survive to fossilize, it requires exceptional conditions

Information loss in the fossil record

- Scavenging
  - After an organism dies, its tissues are destroyed due to a variety of factors. At the macroscopic level: large scavengers (hyenas, vulture) take their share of soft tissues-> smaller scavengers (maggot) also eat
- Microbial Decay
  - microbes break down dead organic matter at the molecular level
  - Decay often proceed from the inside out (gut bacteria)
- Physical (mechanical) and chemical weathering
  - physical weathering mechanically breaks down mineralized tissues
  - mineralize tissues also dissolved (chemical weathering) and erode if exposed at surface

Hard Parts are Preferentially Preserved

- as a rule, hardparts (shells, bones, teeth, etc.) have greater chance of survival n the fossil record than do soft issue (skin, muscle)
- This is because hardparts are more robust, chemically stable, and resistant to destruction
- but they are rarely preserved intact because shot tissue decay removes incentive tissue that holds the hard parts together
- Gentle physical disturbance leads to disarticulation— disassociation of hard parts; and fragmentation— breakage and dissociation of fragments thus formed

Surviving hard parts can be subjected to

- Dissolution: breakdown of hard parts via dissolution of minerals in hard parts
  - make over prone to fragmentation and abrasion
- Abrasion: Erosion of hard tissues due to “sand blasting” effects of suspended sediment particles

Factors that work against preservation:

- predation,
- scavenging

- microbial decay
- fragmentation and dissolution of mineral components in hard parts

Factors that work to promote include

- absence of oxygen (slows down decomposition process, discourages scavenging)
- rapid entombment (discourages scavenging, prevents scattering of pieces)
- precipitation of stable minerals in/on remans after burial

Common Mineral Compositions of Hard Parts

- Calcium carbonate $CaCO3$
  - Aragonite- unstable
  - calciate- stable
- Silica $SiO2$ - stable
- Calcium phosphate- stable

modes of preservation

- petrifaction/permineralization (filling pores with additional minerals)
  - minerals usually comes from water
  - fossils are strengthened
- Replacement: Silicification (the hard parts are replaced entirely by another substance)
  - e.g. fossil sponge and brachiopod— originally made of calcite, but now entirely made of silica. $CaCO3$ dissolve (in acid) over time and silica replace it over time.
- Pyritization:
  - Occurs in environments where the conditions are acidic and bacteria is present
  - The $CaCO3$ in Brachiopods are replaced by pyrite
- Phosphatization:
  - shark skeleton is made of cartilage, so it will be difficult to preserve (bc soft). however if we have a lot of dissolved phosphate in water, the phosphate can replace the pieces of cartilage to preserve it
- d

Molds and Casts

- there is shell in sand that is buried beneath. The shell eventually dissolves away, there is now an open space within sand. The outside part of the shell is the external mold, the inside is the internal mold.
  - external- mold of outer surface//impression of shell on the outside
  - internal- mold of inside space of shell
- Cast: when the organism within cavity decays and internal mold is filled and fossilized

Soft tissue Preservation: Mineral Plating

- Soft bodied organisms are not likely be be preserved
- Clay molecules/molecules precipitate and plate on top of soft body organisms
- Thin film of mineral precipitates o original dead body, when the body is gone but the precipitate remans
- Still some of the original organic matter present
- e.. Aphaesia, Ophaesia

Soft Tissue Impressions

- Dickinsonia, sprigging, fern leaf
- like 2D olds of leaves
- had soft bodies and no skeleton

Soft Tissue Preservation: Carbonization

- Gently cooking an organism and most cooks away, leaving behind carbon
- Usually land-plants are kept this way bc cellulose is more resistant
- Residue of carbon
- Coal is basically this

Soft Tissue Preservation: Refrigeration

- Needs ice for this form of preservation
- Freezing organism
- Mammoth preserving original hair and soft tissue

Soft Tissue Preservation: Tar Impregnation

- Similar to pickling food— put in material that discourages decay
- Tar discourages decay
- "pickled" beetle

Soft Tissue Preservation: Phosphatization

- Phosphatized embryo of arthropod (baby crustacean in egg)

Soft tissue Preservation: amber Entombment

- Amber— tree resin
  - have natural antibacterial properties
- Preserves well because nothing can decay it/penetrate it well

Post-Burial Processes

- Effects of crystallization: over time, crystals of a given material tend to increase in size to achieve greater stability
  - increase size of crystals= loss of detail
- Effects of compaction:
  - fossil shape can be distorted
- Identification of Trace Fossils
  - record of the tissue of organism— record the activities of the organism
  - a single organism may produce multiple types of traces (e.g. trilobites produce resting, ploughing (feeding), and walking traces, all of which look very different)
    - can see of their different behaviour
  - Footprint Morphology
    - true track, under track,
    - having almost-dry mud, wont leave print on it=>softer mud will leave more detail=> if mud too wet, then footprints will be very blurry
    - footprints can determine behaviour
      - pace: each step- one foot to another foot
      - stride: same foot
      - To determine speed, the footprint can show the distribution of weight (running, see more toe and less heel// walking, uniform weight distribution)

Common Fossil Behaviours **prob don't have to know all of this**

- Escape burrow: going up and down to escape certain conditions (worms)
- Resting traces: example of organism in its resting position
- Grazing traces: can be complex and tight, however it will not touch

Behaviour patterns

- they can change and you can se the gradual change
- resting to furrowing to walking to striding.

Stromatolites

- trace fossil formation by sediment accreteon
- sediment trapping by bacterial slim mats
- Coprolites: fossil excellent (poop)

Primordial Soup in the Kitchen of Life: Origin of Life

Classify life

- Kingdom eubacteria, archaea, protista, plantae, fungi, animalia

3 domains:

- bacteria
- archaea
- eukarya: includes kingdom protista, plantae, fungi, animalia

Nanobacteria: about 1000x smaller than regular bacteria and way too small to contain genetic material to pass on

Viruses: are not classified as living things because they need a host to reproduce

Evolution of Earth's atmosphere

1. Initial atmosphere much like Jupiter

- rich in H and He derived from solar nebula
- burned off by solar wind/escaped weak gravitational field

2. Second atmosphere much like venus

- dominated by CO2 from earths interior— greenhouse effect, very warm
- "the big burp"

3. Third and present atmosphere

- rich in O2
- modified second atmosphere due to rise of anaerobic photosynthesizing orgnaisms (produces a lot of oxygen in earths atmosphere (modified the 2nd atoshpere)),

Some Basic Characteristics of Living Things

- Metabolism: living things harvest energy from environment, use energy to build, maintain their bodies
- Regulation: living things have a complex, integrated system that controls conditions within their bodies (homeostasis)
- Replication: Living things can produce offspring
- Response to external stimuli: living things respond to conditions of their external environments as individuals and larger populations

Basic Stages Envisaged In The Development of Life

- Raw Ingredients -> Monomers -> Polymers -> Cell Membrane -> Reproduction -> Living Cell
- Raw ingredients: assumed to have ben present in atmosphere adnd hydrosphere
  - water, co2, co, n-gases, s-gases, methane
- Monomers: demonstrated to be capable of forming abiotically in Miller experiment (and variants). Gas mixture including water, methane, ammonia, hydrogen. Energy.
  - Yields: amino acids, sugars, nucleic acid bases, lipids

  - concentrated in deep sea vents, hot springs
  - all molecules needed to produce life already in atmosphere
  - Miller-Urey Experiment (Spontaneous generation) (1953-59)
    - most important: amino acids are the building blocks of proteins (alanine, glycine)
    - ponnamperuma et al (1963)
      - used high energy electrons on a mixture of methane, water, and ammonia
      - adenine, ribose, and deoxyribose synthesized abiotically
    - Problem: ingredients used not concentrated in _____ emissions— therefore probably not in early atmosphere either
- Polymers: assumed to form through concentration, dehydration of monomers through:
  - Evaporation of solution near hot springs
  - freezing and concentration of solution in cold environments
  - absorption onto charged mineral surfaces
  - polymerization of simple organic molecules by _____ ________
    - molecules are attracted to surface
    - clay minerals and feldspar
  - Problem: forming genetic material
- Cell Membrane: covering/banding was required to form first isolated cell to contain necessary complex molecules
  - lipids can spontaneously form liposomes (hollow spheres of lipids)
  - also proteins will form microspheres wen dehydrated and agitated
  - important properties of these tiny spheres:
    1. maintain separate stable phases in water
    2. membrane maintains electric, PH, and redox gradients
  - coacervates: cell wall?
    - can be produced from ____ ____ (like oil in salad dressing)
- Reproduction: advent of reproduction very problematic in biogenic models
  - main problme: chicken and egg
    - synthesis and replication of RNA with help of enzymes (proteins)
    - proteins are synthesizing using coded RNA, infromation
    - RNA world (naked gene)
      - 1. info molecules that can replicate

- 2. catalysts (like protein enzymes) as ribozymes
- Rationale of Naked Gene Hypothesis:
  1. earliest life for was an energy-harvesting RNA molecule that could caltalyze its own replication
  2. The Rna molecules most efficent at energy harvesting and protecting themselves from environmental change would win over less effective individuals
  3. Natural selection would build complex metabolic and regulation systems incorporating protein enzymes
  4. RNA that could replicate in double stranded form would proliferate since these forms would have two copies of each code, allowing better detection of errors in code
- Making genetic material is difficult
- Problems:

1. RNA, DNA are very complex moleucles
2. they need high concentrationof building blocks to concentrate and polymers
3. replication of RNA is a 2 step process
   - single strand of RNA present each of its links attract complimentary link (mirror image)
   - process would repeat using the new mirrored image to duplicate original side— requires enzymes

- Living Cell

Did replication start from proteins?

imagine:

1. sheltered lagoons filled with tiny proteinoid microspheres
2. proteinoid catalyze chemical reactions and form outer surfaces acting like cell membranes
3. nucleic acids (dna, rna) formed on proteinoid enzyme
4. dna or rna ____ to function as replicator molecules
5. ____ and fusion of microsphereser with exchange of material

Another Approach: The Clay Critter Revisited

Properties of mineral crystals

1. the rest of atoms naturally occur themselves
2. organization at micro and macro scale
3. charged minerals electrstatically charged, grow by adding layers to themselves
4. when broken, the fragments continue to grow on their own (abiotic reproduction)

Clay Critter Scenario

1. Growing clay crystals complete with each other for resources they to grow
2. crystals break apart, be transported in new area where they continue to grow and fragment again; in effct, the world is populated with competing “clay beings”
3. genetic code ineffect, charged clay crystals carbon based molecules apparatus (e.g. proteins)
4. synthesis of dna or rna to augment and ultimately replace clay-based genes

Panspermia Hypothesis

- earth life originated elsewhere
- fossils from ALH84001
- meteorites from mars but things on them could be produced by non living things
- dodges fundamental questions

Of Microbes and Martians: Earth’s Earliest Life

Origin of life: Recap

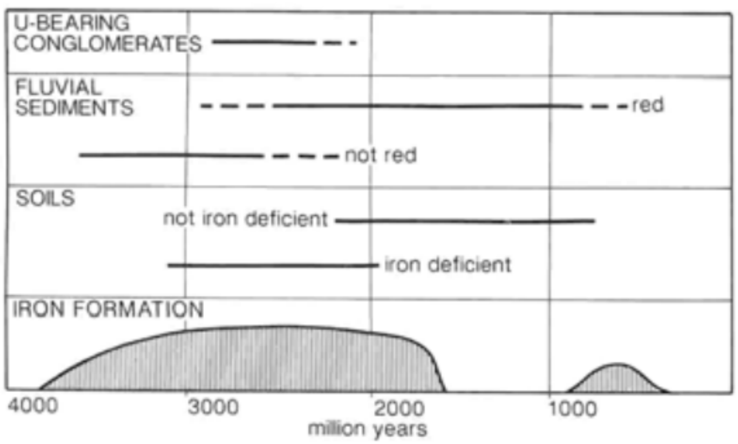
- The answer to the ultimate question of how (and where) the first living cell came into being remains elusive, but a few possibilities exist:
- 1. That the essential ingredients for life were assembled in an aquatic environment (in dissolved form) and these were later incorporated into a cell membrane
- 2. That the cell membrane itself (a permeable membrane) acted to bring the ingredients together, and that these were eventually incorporated within the membrane
- 3. That the complex ingredients (including genetic material) were assembled on charged mineral particles, and were later encapsulated in a cell membrane (perhaps the membrane originating as a film that covered the mineral surface)

Another approach: Panspermia Hypothesis

- Earth’s life Originated Elsewhere
- Fossils (perhaps nanobacteria?) from martian meteorite
  - nanobacteria, much smaller than normal bacteria
  - figured it was impossible for the nanobacteria to begin earth’s life, because cells are too small and cannot contain dna
- Whether life is evolved on earth or elsewhere, we still need to make living things out of non-living ingredients

Major Sedimentary Features of Early Earth

- uranium-bearing conglolmerate made with uranium, which dissolves easily in presence of O2
- Fluvial Sediment Going from green to red— reduced iron
- Soils:
- Iron formation: “banded iron formation”— special chemical sedimentary rock made of iron oxide and chert. It increases in abundance and then it drops off. It correspond to the soil getting iron and the river turning red



Microfossils

- Microscopic evidence of life — usually preserved in chert— contain organic matter— archaean eon
- cells of microbes are preserved — took many conditions for life to be abundant
- Flamentous prokaryote microfossils— prob cyanobacteria or bacteria that can photosynthesize

Macrofossils

- stromatolite (made by cyanobacteria), also archaean eon

2.5-2.9 Ga (proterozoic)

- time characterized by Banded Iron Formation (BIF) deposition
  - enough oxygen to form iron oxides in sea but not enough to rust on land
- in the bands, chert is precipitated as a chemical substance

- this represents a time that theres enough O2 to oxidize in ocean— barely any oxygen in ocean and very little in atmosphere
- iron oxide are found in o2
- a lot of silica in seawater at the time

2.0 billion years (proterozoic)— first definite appearance of redbed

- land-derived sediments that contain iron oxides indicating free oxygen in atmosphere to oxide iron in river water before it reaches the sea
- enoguh o2 from atmosphere
- Stromatolites in Gunflint Chert— 1.9 billion years
  - stromatolites aren't formed anymore
- Hypersaline Intertidal Conditions
  - few things live in these waters
  - not as much stromatolite because they are eaten by other organisms

Filaments

- growth of filaments: trapping of sediment
- Sediment trapping by bacterial mats
- cyanobacteria had a layer of mucus on it, which protected it— any sediment will get stuck on filaments and continuously grows

Microfossils

- prokartyote microfossils— proterozoic
- cyano bacterial filaments — 1.5 billiony ears (proterzoic)
- in bitter springs australia 1.5 billion years ago (proterozoic)
  - Spherical cyanobacteria
  - filamentous cyanobacteria
  - modern form of both have similar resembleances to their previous form

key points

- between 4.5 -2.5 billion years ago, there was almost no O2 present in either hydrosphere and atmosphere
- from 2.5-2.0 billion years ago, enough o2 was dissolved in seater to preicpiate iron oxides as sediment (forming magnetite and hematite in banded iron formation)
- beginning at about 2.0 billion years ago, there was enough oxygen in the atmosphere to oxidize (rust) iron on land— from here on, banded iron formations decrease in abundance because orion was no longer dissolved in high quantities
- Up to around 2 billions yearsago, life fluorished without o2

- evolution of simple, life (prokaryotes) was extremely slow (litlte change over the span of 3.5-1.5 bill y/a)
- simple eurkaryotes appeared at least 1.5 billion years ago
- euakryotes had a bit of a slow starts (1.5 billion and at least 575 billion yearsago) and explodes in diversity upon the rise of multicellular forms

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Evolution of Sex and Rise of Eukaryotes

2 main types of orgnaisms

- prokarotes: archaea and bacteria. distinguised by lack of true nucleus
- eukaryotes (eukarya only). possession of true nucleus

Prokaryotes

- very simple cell closed by cell wall containing inner part of amino acids, sugars, and outer part of lipids
- they have nucleoid, a single chromosome containing genes
- Reproduce though binary fission
  - cell makes identical copy of its genetic material, each of 2 copies ends up in each daughter cell
  - Daughter cells are clones of their parent
  - Advantages: reproduce very quickly, evolve much quicker because of how quickly newer generations are created
  - Disadvantage:

Eukaryotes

- complex cells with membrane-bound nucleus, and other structures like mitochondria and plastids
- cells of eukaryotes are much larger than prokaryotes
- Reproduction, genetic material is contained within chromosomes housed in nucleus (23 pairs in humans)
  - mitosis: replication of genetic material and splitting to form clones (2n)
  - meioisis: meiosis involves splitting of genetic material that can be recombined via sexual reproduction to restore full genetic code (n)

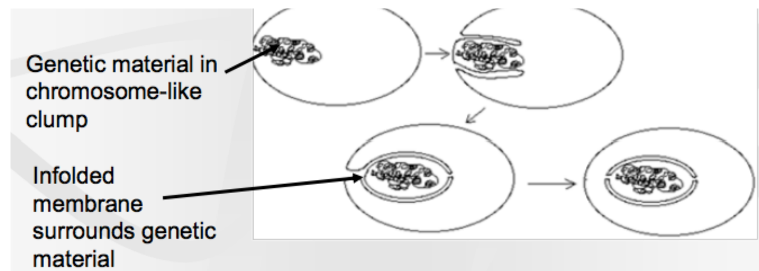
Function of Mitosis and meiosis in eukaryotes

- mitosis: main process involved in maintaining tissue growth, reproduction (splitting of amoebas or asexual budding)
- meiosis: fundamental process involved in reproduction among eukaryotes (meeting of sperm and egg from two parents to produce offspring)
- advantages:
- disadvantages:

Sources of Variation: Asexual vs. Sexual Reproduction

- asexual: reproduces quickly so evolution occurs more quickly due to mutation or errors in code transcription
  - if environment changes, then the entire population goes extinct because it will affect all of the bacteria
- mutations: mutation
- Errors in code transcription: errors in code transcription
  - crossing over: trading of genetic materials between chromosome pairs
  - Splitting and recombination of genetic material
  - genetically diverse
    - prevents inbreeding- certain flaws can be more announced
    - if environment changes, and many die, then there must be an individual has the ability to adapt to the environment
- Natural selection acts on these sources of variation to feed out the bad and retain the good. Sexual reproduction in eukaryotes ensures lots of variation and lots of change

Origin of Nucleus



- making a nucleus was probably not too difficult for first eukaryote. It has been speculated that the nucleus was produced by the infolding of the cell and engulfing of genetic material within cell.

Organelles

Mitochondria

- animal and plant cells have mitochondria, the “power plant of the cell”
- provide the energy a cell needs to move, divide, and produce secretory products
- food (sugar) s combined with oxygen o produce ATP (adenosine triphosphate)— primary energy source for cell
- similar to some bacteria in from and function (similar to bacterium Rickettsia— responsible for typhus

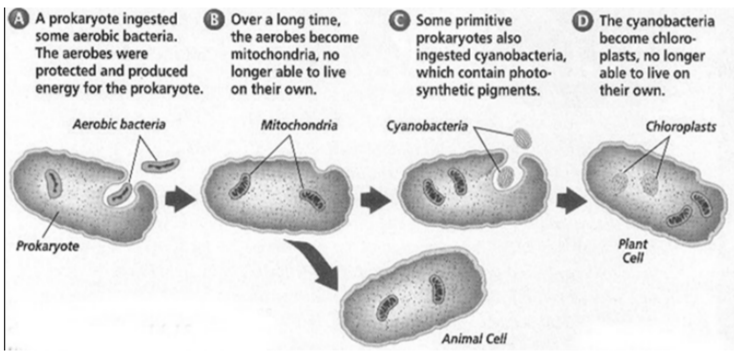
Plants have plastids

- the “food factories” of plant cels
- photosynthesis occurs ehere
- similar to cyanobacteria

Endosymbiotic

- suggested that mitochodria and plastids are bacteria that decided reside in large host prokaryotes— might have ben an accident
- Eukaryotes are large prokaryotes without mitochondria
- Giardia is an ancestral eukaryote are able to survive without a mitochondria— giardia is anaerobe— eats anaerobic bacteria— perhaps had a mitochondrion at one point but evolved without one.
- Perhaps something like this might have become a proto-eukaryotic cell upon formation of a nucleus and acquisition of symbiotic bacteria

Serial Endosymbiosis Hypothesis (Lynn Margullis)



- The basic thoughts on the origin of plant and animal cells— aerobic bacterium becomes mitochondrion, cyanobacterium become plastid (chloroplast)

Evidence for Origin of Mitochondria and Chloroplasts

- mitochondria and chloroplasts are similar size to bacteria
- complex double membrane system
- self contained
- divide by binary fission

Oldest fossil evidence of eukaryotes

- eukaryote fossil: grypania spiralis — carbonized aga strufcures 2mm wide 10cm long

- found in rocks
- oldest known acritarchs (algal cysts)

Formation and Breakup of Rodinia

- Supercontinent Rodinia forms at about 1100 million years ago
- It existed before pangaea existed (rodinia broke up 750million y/a and got put back together for pangaea)
- Conitnents clustered around equator
- believe to have triggered snowball earth— earth froze over
  - All continents have evidence of a widespread glaciation— glacial deposits
- Glacial Deposits overlain by carbonates
  - carbonate rocks, limestone, which usually form under tropical condition
- Glacial deposits have a lot of carbon dioxide
- Less co2 in tropical conditions-> carbonate minerals can precipitate out
- cold water held co2 and converted it to carbonic acid

The Snowball Earth

- during proterzoic
- snowball earth model: runawa icehouse effect
- all of earth froze over
- up to 4 major snowball events

Prologue: Beginning of Snowball Earth Time (750 ma)

- Breakup of single landmass (Rodinia) leaves small continents scattered near the equator
- CO2 is removed from atmosphere by intense
- —— of silica-rich continental rocks (under moist tropical conditions)
- Reduce CO2 in atmoshpere causes global temperatures to fall

Prologue: Before snowball (about 770ma)

- ice packs form in the polar ocenas, spread toward equator
- white ice reflects more solar energy than dark sea water, making temperature lower (colder)
- starts a runaway glaciation effect—

Into the ice house

- average global temperatures plummet to -50 degree celcits, No rainfall
- Oceans covered in ice over 1km thick, limited only by heat slowly released from earth’s interior by volcanoes

- Most microscopic marine organisms die; a few cling to life around volcanic hot springs
- With no rainfall, CO_2 emitted from volcanoes is not removed from atmosphere

Snowball to Slushball

- 10 million years of volcanic activitiy ultimately raises CO_2 concentration in atmosphere by 1000x
- Greenhouse warming effect causes ice at equator to melt
- Open water in the tropics absorb more solar energy than ice, accelerating the warming of the oceans
- Warming of oceans combined with increased co2 causes runaway greenhouse effect

From freeze to fry

- surface temperature soar to more than 50degrees celc. drinking an intense cycle of evaporation and rainfall
- Torrents of carbonic acid rain water and rode the rock debris left by retreating glaciers
- Swollen rivers wash bicarboniate and other ions, incl. Ca and Mg, leading to deposition of carbonate sediment

World's Oldest Known Complex Metazoans

- *charnia wardi* portugal cove, newfoundland
  - up to 2 meters long
- Preservation of Ediacaran Faua at Mistaken Point,
- Preservation of soft-bodied remains due to rapid deposition of volcanic ash
- An ideal situation: exceptional preservation plus can be dated

Evolution of complex life and snowball earth: cause-effect or coincidence

- species of churn fronds 575 ma now known
- snowball earth 750 to 620 ma
- modern pennatulacean

Possibliitys/Questions pose by timing of earliest complex metazoan and snowball earth

- 1. complex metazoans evolved from simple eukaryotes really fast 620-575 million years provides ~million years for complex metazoan to develop from very simple forms
- 2. compelx metazoans revolved before or during snowballl earth (how did it survive snowball earth?)
- 3. perhaps snowball earth wasn't as severe as oringally thought. perhaps a fair amount of open ocean at water
- Why did life get big at this time?

So the Ediacaran fauna record the rise of multicellular organisms. Also the basis of a new geological period

- Recognition of these Proterozoic fossils have resulted in the construction of a new period

- The Ediacaran Period was established in March, 2004.
- First period to be defined in 1891 (when geologist Henry Williams dived the carboniferous into two)
- Type section of boundary; enorama Creek, Flinders Range, Southern Australia

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Skeletons in the cloest: evolution of hard parts in metazoan and cambrian explosion

Additional comment on Ediacaran Fauna

- Remember earliest complex metazoan (ediacaran fauna) were all soft bodied (no skeleton)
- all preserved as impressions

Discovery of Ediacaran Fauna

- First found in australia
- recognized they were pre-cambrian, resembled living things
- not much detailed to ones found here
- Classification: lumped together as medusoid
- Eventually finds: Mawsonites, spriggina, dickinsonia

Differentiation of Tissues

- note that in order for differentiated tissues to have evolved (to allow development of organs for different purposes), hox genes must have developed
- How genes dictate the duties of particular cells for particular purposes

Adoph Seilacher— Concept of Vendozoa

- soft-bodied— quilted structure (fluid-filled bags)
- dependent on microbial mats
- mat stickers— fixed to seafloor, photosnythesizer,
- mat scratchers — grazed on microbial mats
- no carnivores

Latest Proterozoic (Ediacaran Period)

- also note that atmosphere and seas were well-oxygenated by this time, so metazoan had developed the means to cope with the high reactivity of oxygen
- so metazoan had developed means to cope with high reactivity of oxygens
- no predators yet

Why make skeletons?

- One might think that the development of hard parts came about due to the need for structural support or protection from predation

- but some ediacaran animals were already fairly large (remember the frond from newfoundland up to 2 meters long)
- no evidence of predation in ediacaran
- why would skeletons have developed?
  - origin of skeletons may have to do with chemical significance of minerals in organisms

Oldest widespread skeletons: all phosphatic

- tommotion fauna: first skeletonize organisms. Record rapid diversification of metazoan after extinction of many ediacaran forms. At base of cambrian.

Why Do So Many Metazoans Have Skeletons?

1. support and muscles attachment areas for locomotory organs
2. protective (in vertebrates- rib cage) for soft internal organs
3. in shelled organisms, serves as a box to ensure protected environment for metabolic functions
4. Protection from predators
5. Receptacles for excess mineral matters
   - warm seawater commonly saturated with calcium carbonate
   - some organisms may have needed to get rid of excess calcium carbonate
   - first secreted it as a thin film
   - later produced a thicker shell as a form of protection
   - analogous to this, humans get rid of excess material (e.x.) kidney stones, gallstones in humans

6. Store houses for scarce minerals or means of slow release
   - bones and teeth, some shells composed of calcium phosphate
   - phosphate scarce in nature, but essential for metabolism also a key component of genetic material
   - calcium essential for heart, nerve, muscle functions, enzyme activation

Charles Walcott

- discovered middle cambrian burgess shale
- exception preserved soft-bodied organisms
- middle cambrian age (shortly after “

Burgess Shale, British Columbia

- Exceptionally reserved soft-bodied organisms
- Middle cambrian age (shortly after “cambrian explosion” of early cambrian)

- A snapshot of life assemblages (fossil record generally tends to preserve only hard parts of organisms, soothes is an important window)

Burgess Shale Fauna

- surprisingly diverse assemblage with very unusual forms
- e.g. cambrian critters from burgess shale, solenoids: a trilobite, a sponge, chordate
- Vauxia - sponge
- Vauxia “forest” with leanchoilia

Wiwaxia

- A worm, a mollusc, or something

Marella

- an early arthropod and might be related to trilobites

Anomalocaris: a case of mistaken identity

- anomalocaris: an unusual shrimp-like arthropod
- peytoia: a jellyfish??

Anomalocaris: a ____ of components previously believed to be _____ organism. a lobopod.

Opabinia: lobopod?

Hallucigenia: oddball of all oddballs

Hallucigenia: onychophoran worm or separate phylum

Pikaia: oldest known chordate

Phylum Arthropoda

- Subphylum Chelicerata
- includes: spiders, mites, ticks, scorpions, horseshoe crabs, all having feeding appendages called chelicerae

Sanctacaris

- has no _____, but is in all other respects similar to chelicerates

Catastrophic Burial

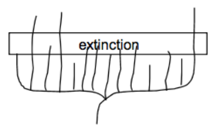
- Burgess Shale organisms living at the foot of a submarine escarpment (and possibly on top of escarpment) were smothered rapidly

Stephen Jay Gould — Radical Thinker

- Could some Burgess Shale organisms belong to extinct phyla? Is it possible that a phylum could be represented by a few or single species? If so, suggests that the Cambrian Explosion produced more phyla than are present today.

- Conventional View: gradual increase in number of phyla through time

- Gould's View: sudden appearance of phyla removal of many by mass extinction



Spineless Wonders: Survey of the Invertebrates

Discovery of classic Ediacaran Fauna- about 543 Million years ago

- Pound quartzite
- Ediacara Hills, north of Sydney, Australia Metazoan Fossils Found in 1946
- Classification: lumped together as medusoids

How do we classify life?

- Domains: Archaea, Bacteria, Eukarya
- Kingdoms: Eubacteria, Arcahea, Protista, Plantae, Fungi, Animalia

Conventional Classification of Major Phyla

- Protista: amoebas, foraminifera, radiolaria
  - presumed ancestors of metazoa
- Metazoa:
  - Porifera
  - Cnidaria
  - Several "worm" phyla
  - Brachiopoda
  - Bryozoa
  - Mollusca
  - Arthropoda
  - Echinodermata
  - Hemichordata

  - Chordata

Originally, there were many details overlooked in fossil

- many of their features are present in modern phyla

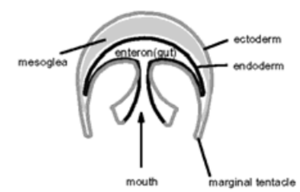
How do you make a metazoan? Protists

- Begin with a single celled protista— amoeba, foraminifera, radiolaria, etc.
- Phylum protista: the importance of choanoflagellates (protist with a flagellum and a collar)— use the collar around flagellum for food (flagella makes current and food gets into collar)
  - Some choanoflagellates form colonies, in these colonies, all individuals operate inmoving their flagellate, generating a current for food partifcles to be extracted

Phylum Prolifera (sponges) — most basic metazoan body plan

- Single layer of tissue (collared cells)
- Wter goes in through pores, and food gets strained out
- Sponges also have collared cells, but these form a larger, integrated structure supported by rigid spicules or organic tissues. The differentiation of cells required the evolution of Hox Genes (genes that dictate differing functions of cells)
- Similar to some of the ediacaran animals (frond-like creatures), sponges showa fractal organization
- Ascon grade sponge
- Sycon-gradesponge (multiple "ascon" elements)
- Leucon-grade sponge (multiple sycon-elements)

Phylum Cnidaria/Coelenterata (second major metazoan body plan)



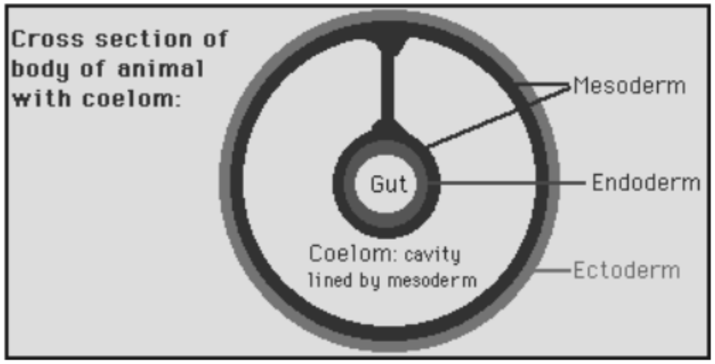
- 2 layers of tissue: ectoderm (outside), endoderm (inside)
- (probably resulted from invagination of ectoderm)
- like jellyfish, sea anemones
- all have stinging cells in tentacles
- Natural coral
- Computer-generated fractal
  - complex forms of these simple organisms fractal geometry is apparent

Worms or Bilaterans—3rd and most complex metazoan body plan

- triploblastic- 3 principal cell layers
- ectoderm, mesoderm, endoderm
- Basic bilateral symmetry: fractal geometery breaks down, but tissue differentiation is incredible!

The Coelom

- Ectoderm and endoderm can be viewed as essentially solid, continuous layers
- Mesoderm is a little more complicated in that it lines a fluid-filled body cavity called coelom. Within coelom that internal organs develop (respiratory organs)



Coelom and Orifice Development: Protostomes

•Protostomes (incl. molluscs, annelid worms, and artropods), the coelom develops directly from mesodermal tissue

•Another distinguishing characteristic to the protostomes is the development of the mouth before the anus in the young embryo

Coelom and Orifice Development: Deuterostomes

- In deuterostomes (incl. echinoderms and chordates), the coelom develops from out pockets of the gut (endoderm)
- Develop anus before mouth in young embryo (bastophore)

The evolution of the coelom

- intially evolved as a hydraulic device
- A bilateran with a coelom can squeeze its internal fluids with body muscles
- this squeezing bulges the body walk at the weakest point, and can be used as a power drill ofr burrowing

The evolution of the coelom

- this pumping could facilitate the transport of O2 through the body without relying on the bathing of tissues in oxygenated water by diffisuion though a thin ectoderm
- This means that animals could efficiently deliver oxygenn throughout their bodies without comparing the effectiveness of their ectoderm/size
- Meant that they could evolve exoskeletons

Important prOTOSTOMES

protosomes: phylum platyhelminthes

- Flatworms dont have a coelom, likely that something like a flatworm gave rise to more advanced coelomate bilaterans

Protosomes: Phylum mollusca

- each class derived from HAM 9hypothetical ancestral mollusc)
- key features: gut, mantle cavity (shell), radula (rasping organ) — used for feeding, gills, foot (well-developed)
- Gastropods (snail) / bivalves (clams and stuff) / cephalopods (squids, octopuses, cuttlefish (long fin), ammonoids)
- 2 valves stuck together like a ligament (acts as a spring)

Protosomes: Phylum Braciopoda (arm foot)

- key features: pedicle, gut, msucles, lophophore (breathing and collecting food)

Protostomes: Phylum Bryozoa (moss animals)

- key features: colonial habit, lophophore

Protostomes: Phylum Arthropoda

- jointed limbs. 3 fold divisions of body (Head, throrax, abdomen)
- abundant in Paleozoic

Deuterostomes

Phylum Echinodermata “spiny skin”

- key features: 5-fold symmetry, calcite plate (embryos are bilateral, suggesting a bilateral ancestor)
- sea urchins, brittle stars, starfish, sea cucumbers, crinoids

Phylum Hemichordata

- key features: 3 part division body pre oral lobe, collar, trunk), pharynx, gill slits, stomochord

Phylum Chordata

- key features: notochord, dorsal nerve cord, pharynx, gill slits, post-anal tail
- sea squirts and sales (urochordates)— start off like larvae (paedomorphosis), and amphioxus (cephalochordates)— seem more advanced because it makes fishes

Hallucigenia

- worm-like body with paired spikes, tentacles

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evolution of fish

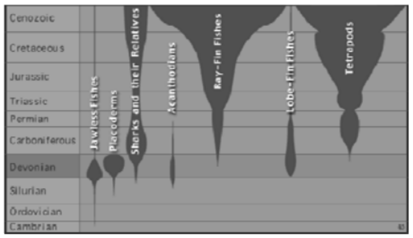
Origin

- origin of fish can be traced to first chordates (something like pike or modern branchiostoma) which lacked a backbone but possessed a flexible rod of tissue called notochord

- Like other chordates, they have the basic worm like body plan, muscle packs, and pharynx
- Primitive cephalochordates: fish-like forms without backbone (but with well-differentiated head and body)
  - amphioxus, conodonts

General picture

- started in cambrian
- length of spindles in diagram represents time ranges of major groups
- width of spindles denote diversity of species within each group
- Earliest fishes were jawless— which soon developed into jawed fishes
- Note: diversity of major fish groups peak in devonian period— “age of fishes”



First true fishes: jawless fishes (Agnatha); anceint, armoured forms (ostracoderms

- Range: Cambrian-carboniferous
- had heavy external, armour, but soft, cartilaginous internal skeleton
- after jawless fish, jawed fish followed

Modern agnatha: hagfish— jawless fish have survived but none have armour (hag fish produces a lot of slime— many modern agnatha have many gill openings

Evolution of jaws

- evoution of jaw is an example of evolutionary modification of existing structures to perform new functions. jaws are modified gill arches. Start with no jaws and many gill slits (‘skeletal rods”)
- lose fist cuple of gill arches and modify third in line into solid jaws (upper _ _ is up part of arch becomes attached to skll, lower mandible remain free)
- modify next gill arch in line into secondary components

First Jawed fishes

Acanthodians

- distinguisehd by spines that supported primitive fns and hardened internal skeleton
- range: silurian-permian

- ancestors of jawless fishes

Placoderms

- distiinguished by jaws and thick plates of bony armour
- range: silurian- carboniferous
- antiarchs and arthrodires

Cartilaginous fishes: chondrichthyes (sharks, rays, skates)

- skin with denticle
- distinguisehd by cartilaginous skeleton, exposed gill slits, and skin with imbedded denticles
- range: silurian-recent

bony fish: ray fins, lobe fins

- fins suproted by thin bones that portrude out from body. fins attached to body by fleshy lobe with complex internal be structure
- fish much more defined and muscular than ray fined fish
- range: devonian- recent

ray finned fishes: forms one usually thinks f as “fishes. more diverse group of present day fishes

lobe fined fishes:

- once fairly diverse esp in late paleozoic
- 3 major groups: coelocanths, lungfishes, rhipidistians
- only 2 major groups have survived to the present day : coelocanths, lungfishes
- thought to have gone extinct by the cretaceous— use fins for propulsion because of the bones in their lobe
- first living coelacanth caught off the coast of south america in 1938
- there are lung fishes that have gills but can also breathe through lungs
  - various species live today in south america, arfiaca and australia
  - during dry season, some can burrow into mud and make a cocoon out of skin and breathe air through openings to surface
- lobe finned fishes : towards tetrapods
  - Lived in shallow ponds, probably had lungs— may have been a sister group to lungfishes

- similar skeletal structure to amphibians
- the only group of fish that had developed an opening to the nostrils inside the mouth - a feature which is found in all the land vertebrates
- labyrinthodont teeth (wth folded enamel) provides close link with early amphibians
- these leads us to the next stage of vertebrate evolution— leaving the water

Why leave water?

- new, and as yet unexploited, food resources in terrestrial
- escape from predators
- drying up ponds (need to cross land to reach other water bodies)

Challenges

- support of the body in water is made possible by water, by very difficult to support on land (i.e. in air)
- need to strengthen shoulder and hip girdles that supported limbs
- modify oesophagus into lungs to breathe out of water
- modify ears to pick up soundwaves in ear

Lungs for Land: Evolution of Amphibians

Middle to late devonian: rhipidistians

- lungs were developed in two groups of lobe-finned fishes — rhipidistians and lungfishes
- the rhipidistians are considered to be the ultimate ancestors of the —vertebrate animals with four limbs adapted for life on land)
- Rhipidistians such as eusthenopteron had evolved land animal-like features approaching those primitive tetrapods
- note: rhinodistians is used here to avoid having to use even more horrible terms

An important link: tooth structure

- labyrinthodont tooth structure with complexly unfolded enamel is shared between rhipidistian fishes and the earliest amphibians. strongly support relationship between two groups

Skeletal modifications

- skeletal structure of rhipidistians was already similar to **labyrinthodont (**unsure of this answer) (esp in the fins)

Moving toward a more amphibian-like form

- by at least the late devonian, some lobe-finned fishes, such as tikaalik had developed features that were even more amphibian-like
- tikaalik (inukitut word for a big freshwater fish
  - discover in 2004 ellesmere island, nuns by team led by neil shubin

Notable Characteristics found in Tiktaalk include:

- fish characteristics:
  - gills
  - scales
  - fins (no true digits)
- Amphibian characteristics
  - robust rib bones
  - triangular skull shape
  - neck with separate pectoral girdle (i.e. shoulder supports)
  - functional wrist joint
  - lunges (probably)
- shubin referred to the tikaalik as sort of a fishapod — a transitional form combining fish and tetrapod characteristics
- the scientific term for this group (subclass) of half fish / half tetrapod forms is tetrapodamorpha but we'll go with fishapod

Late devonian: ichthystega and acanthostega

- ichthyostega was an early true tetrapod
- robust ribcage would have allowed greater lung breathing efficiency
- stronger pectoral and pelvic girdles allowed the primitive amphibian to cope with the minimal support provided by support on land
- like some modern amphibians, primitive tetrapods such as ichthyostega and acanthostega probably had some special kind of skin helped them retain bodily fluid and deter desiccation, allowed gas exchange

Change in function of limbs

- whereas their fish ancestors used their for propulsion and their fins for maneuverability

- fishapods and tetrapods such as ichihyostega and acanthostega had begun to use their limbs for propulsion and their tails for balance

Carboniferous to permian

- amphibian nostrils became increasingly functional for breathing air
- amphibians evolved hands and feet with five digits
- amphibian tails become reduced in size
- amphibian backbones grew stronger — this nabled amphibian bodies to grow bigger
- amphibian obtained eardrums

Evolution of neck and ear

- fishes need limbs to support bodies and ears to hear sounds in the air
- fins changed to legs
- several bones of the hyoma changed to the shoulder bones
- tongue cartilage (part of the jaw in fish) became an ear bone

Amphibian diversification

- by the permian period, amphibians had become quite diverse (nad some where very large
- advantages for amphibians living on land:
  - less competition for food
  - avoidance of large predatory
- Disadvantages for amphibians living on land
  - amphibians have gas-permeable skin to aid their inefficient lungs. this skin must be kept moist
  - they must have water to reproduce— waters needed for external fertilization that is the characteristic of amphibians.
  - amphibian jelly-like eggs cannot survive out of water

Modern amphibian:

1. anura (frogs and toads)
2. caudata (salamanders and newts)
3. apoda (caecilians)

from slime to scale: evolution of reptiles

Review: disadvantages of being an amphibian

- __________ eggs of amphibians cannot survive out of water, so amphibians are limited in terms of the environments in which they can ____ their eggs.
- Water is needed for the __________ fertilization that is characteristic of amphibians so again amphibians must characteristic of amphibians so, again, amphibians must return to some sort of ____ body to reproduce.
- Amphibians have ___-permeable skin to aid their inefficient lungs in breathing. This skin must be kept moist, so restricted to ______ environments !

Major innovation in reptiles

- development of amniote egg (egg shell)
- change in body covering (scales, shell, etc.)
- change in skull structure
- change in post-cranial skeletal structure (sprawling to upright)

Amniote Egg

- The appearance of the amniote egg was a great leap forward for tetrapods (4 legged, land-dwelling vertebrates)
- The amniote egg is certainly not immune to various dangers posed by terrestrial conditions
- provided a greater change in lifestyle — dont need to be suspended in water
- however the amniote egg provided a greater range of ____ that did the eggs of ___ and _____

Outer Hull/ Egg Shell

- egg shell, made of leathery or hard material, (not needed for amphibious eggs which are suspended and supported by water)
- shell protects contents of egg from outside conditions but is permeable to gases
- egg can get laid away from water because everything is self-contained

Crew Quarters/ Amnion

- amnion is a fluid-filled sac in which the embryo floats
- amniotic fluid mimics the conditions that the embryo would require if the egg lacked a tough shell

Outer Hull / Shell

- the allantois serves 2 important functions

1. to deliver oxygen to embryo and to take carbon dioxide away
2. to store excretory products (waste)

Food Supply/ Yolk

- amniote egg: the yolk serves as embryos food supply

Water supply/ albumen

- albumen (whites) is embryos water supply— also acts like a shock absorber

Advantages of amniote egg

1. because amniote eggs are self-contained units, they could be laid on dry land away from water
2. embryos in amniote eggs were less prone to being adversely affected by changing enviromntela conditions (drying of ponds, changing temprature, agitation, etc.
3. greater strength of shells allow animal to lay larger eggs

- this allowed a longer development period for the baby animal
- longer development time within the egg meant that babies were better equipped fr survival after hatching (better survival)

Changes in Skin Texture

- another major medication mad ein the evolution of reptiles from amphibians was the development of a touch, dry, covering of keratin (same protein is in our hair and nails) on the surface of skin
- scales and similar hardened structures on reptilian skin are made of scales
- meant reptiles skin is not inconstant danger of drying out, unlike amphibians

Captorhinomorphs: stem reptiles

- oldest known reptiles called captorhinomorphs appeared in the carboniferous period. this group of reptiles is presumed to have been the stem group for all later reptiles, and are therefore called "_____ reptiles"
- Hylonomus, one of the oldest known captorhinomorphs, has been found in carboniferous rocks dating about 315 million years, exposed joggins, novascotia. interesting, these specimens have been found in sandstone-filled tree trunk casts.

Skull Structure

- now that we have looked at the earliest group of reptiles, we can consider how amniotes (reptiles in a loose sense) are classified.

- the basis of amniote classification is the number and arrangement of holes (______ fenestrae) behind eye socket in skull
- with respect to these fenestrae, most important bones are the <u>post-orbital</u> and <u>squamosal</u> bones.

<u>Anapsids</u>

- the synapsid condition is characterized by the absence of temporal fenestrae
- most primitive skull type among amniotes
- anapsid groups includes earliest stem reptiles (captorinomorphs) and perhaps the turtles and tortoises but this is debated

<u>Synapsids</u>

- synapsid condition characterized by a single opening bellow junction of post orbital and squamosal bones
- includes pelycosaurs (sail-backed reptiles)
    - therapsids (mammal-like)
    - true mammals

<u>Diapsids</u>

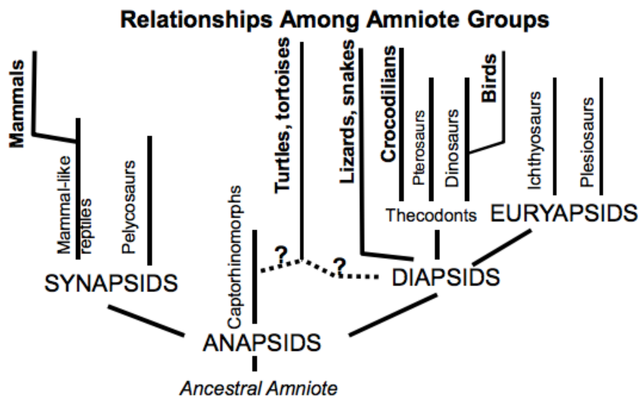
- diapsid condition is characterized by 2 openings — one above and hellow junction of post orbital and squamosal bones
- represented by archosaurs (ruling reptiles) including : snakes and lizards
- thecodonts (ancestral group of higher diapsids)
- crocodiles (e.g. crocodiles and alligators)
- pterosaurs (flying reptiles)
- birds
- important that legs are underneahtlh bodies and are more upright in posture

<u>Euryapsids</u>

- the euryapsids condition is characterized by a single opening above the junction of post orbital and squamosal bones
- represented by extinct "munre reptiles"
- ichthyosaurs
- plesiosaurs

To Summarize

- **Anapsids: ___ ________- fenestrae**
  - turtles, tortoises, captorhinomorphs
- **Diapsids: ___ _________ fenestrae**
  - lizards and snakes, crocodilians, pterosoaurs, dinosaurs, birds
- **Synapsids: ____ _____ _______ low in skull**
  - pelycosaurs, mammal-like reptiles, mammals
- **Euryapsids: ____ ______ _______ high in skull**
  - ichthyosaurs, plesiosaurs



This is a ***very*** generalized schematic diagram indicating the relationships among the four major amniote groups (and various important subgroups). Note that a few of these relationships are still being debated.

Limitations of post-cranial skeletons in primitive amniotes

- one setback remaining for primitive reptiles (and a characteristics still retained by present-day lizards) was the sprawling stance imposed by position of the legs relative to the body
- sprawling stance is okay for reptiles that are active only sporadically (e.g. lizards that ambush prey or escape quickly, but briefly)

- but side-to-side motion of the body that accompanies walking deforms rib cage and with each bend and prevents lungs from expanding to their flu capacity
- animal cannot sustain speed for long periods of time and the waddle wastes a lot of energy
- lots of stress is imposed on shoulder and hips because most of the animals weight is supported at the junction between limbs and body
  - difficulty breathing and cant sustain speed
  - Problem of weight support would be solved by members of both diapsids and synapsids

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Dig the Dragons: Evolution and Diversification of dinosaurs

Dinosaur Hip Structure

Thecadonts ancestors of dinosaurs— they stood upright

- Saurischian (allosaurus)
  - oldest known dinosaur
  - lizard-hipped, plant and meat eaters, public bone sticks out, birds arise from this, but it has a similar structure to the ornithischian (came to this structure in a different way)
  - Main group: Theropods (meat eaters) and Sauropods (plant eaters)— sprawled, 4 legged posture
  - Theropods had a more bipedal, upright posture giving them an advantage in many different things — mating, hunting
    - tyrannosaurus rex— very large head with a really large tail to balance out the weight. Large head compensates for the small arms. Bounce when they walk. Probably warm-blooded
  - Sauropods: Giants of the dinosaur world— quadrupedal. Large stomach that probably hung down. Very long neck, and very long tail, but a very small head with simple teeth structure. Most processing went in the stomach. Probably cold-bloodedness because heat from digestion of food sustained it.
- Ornithischian (Stegosaurus)
  - pubic bone rotates backwards
  - herbivores— has a larger stomach, so it makes sense for the pubic bone to be backward to make space for a larger stomach
  - Ornithopods (hadrosaurs: duck-billed dinosaur): back legs longer than front (bipedal). Had a hollow dome on head that was used for display, fighting, but primarily it has tubing for sound amplification and communication.

- Stegosaurs (plated dinosaurs): quadrupedal. Small skull with a walnut-sized brain. Tail has spikes. Back-end probably has many nerves to control tail (main defence weapon). Plates on top of back are light and riddled with blood vessels (possibly to regulate body temperature)— so not used for armour.
- Ceratopsians (horned dinosaurs): nose horn on snout, 2 other horns near house. Frill at back of head (can be a shield, or for mating). Not all have horns
- Ankylosaurs: A club at the end of their tail, solid bone (not porous). Armour all over body, incl. eyelids. Wide-stance to support the heavy armour.
- Pachycephalosaurs (bone-headed dinosaur): relatively small. On the cranium, there is a very thick layer of bone. Used for fighting for mates
- Maiasaura ("good mother lizard"): Dinosaurs had similar habits of modern day birds— they were surprisingly good parents. Dug a hole into ground with raised rim and deposit the eggs (like a nest) and covered it with garbage to disguise/hide the eggs from predators. Composting (garbage) was a way to keep their eggs warm because during the process of composting, it release heat.
  - Hatchling— just hatched // Nestling— lived in the nest (for a long period of time)
  - because nestlings can grow to be very large and remained in the nest, the dinosaurs had to go fetch food and regurgitate to feed them.
- Oviraptor ("egg stealer"): Eggs originally thought to belong to Protoceratops was later discovered to contain Oviraptor embryos— so this revealed the oviraptor as a caring mother protecting the nest.

- Bird-Like Dinosaurs: Liaoning Province, China
  - Sinosauropteryx: "Eastern lizard wing". Covered in wispy "dino-fuzz" along its back and all over body — assuming they needed insulation and were warm-blooded.
  - Caudipteryx: Relatively short arms with plumage, similar to modern birds. Probably used for sexual display.

Serpents and Spitfires: Marine Reptiles and Flying Reptiles

- The great diversification of reptiles, beginning in the Triassic Period, and coming to ahead in the Cretaceous Period, included the appearance and great success of marine and flying reptiles.
- Among the marine reptiles were the ichthyosaurs (euryapsids), plesiosaurs (also euryapsids), marine turtles (anapsids or possibly diapsids and mosasaurs (diapsids)(— closely related to lizards)
- At least in the early part of the mesozoic era, pterosaurs ruled the skies

Ichthyosaurs

- Evolved from land-dwelling reptile

- Note modification of body for life in sea. (fins on back and tail, modification of limbs to form flippers) (resembles dolphins and swordfish)
- Body was streamline, developed a dorsal fin (like sharks), have internal fertilization and bore live young instead of laying eggs.

Plesiosaurs

- Long-necked forms: Elasmosaurs
- Short-necked forms: Pliosaurs
- Tails were shortened and necks were lengthened — ambush predators (lurking in kelp forests and lurch out to catch prey). Small head (prey doesnt see them as quickly)
- As with ichthyosaurs, evolved from a land-dwelling reptile. Modification of limbs to form flippers and lengthening of neck for darting movement to catch prey
- Ate anything
- Cretaceous pliosaur from Manitoba: Western mountains were thrusted up by a forming trough flooded by the sea

many reptiles came back to sea because of the abundance of food

Turtles

- During mesonoic, marine turtles also got very large

Mosasaurs

- Giant marine lizards (the komodo dragon is closest living relative to these)
- on roof of mouth (palate) there is an extra set of teeth (for more grabbing power)
  - teeth of all different sizes, going in many different directionsrin
- Evolved from land lizard, retaining lizard-like body but limbs and tail were modified for swimming
- Common prey for mosasaurs:
  - other marine reptiles
  - birds
  - large ammonites (squid-like molluscs) (cephalopods)
    - move in a rocking motion— like submarine

Modifcations for Flight

- Extreme lightweight skeletons (hollow bones)

- long tail for balance in early form but smaller tail in alter forms
- wing produced by modification of last finger and development of membrane connecting the wing to the body
- prominent sternum (breastbone) for attachment of strong flight muscles
- Similar to modern-day bird and eventually lead to modern structure. Wing is stretched from pinky finger

Pterosaurs and Pterodactyls

- tail was used for steering
- Rhamphorhynchus: showing wing membrane
- pterodactylus: size of crow, smalll teeth for catching fish

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Barney to Big Bird: The Origin of Birds

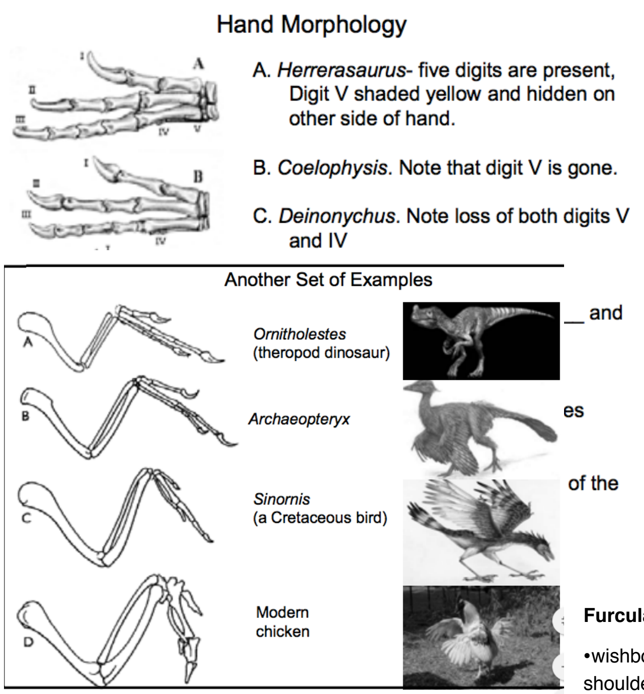
Fuzzy Dinosaurs

- Caudipteryx
- Th discovery of feathered dinosaurs in Liaoning, China, has excited many palaeontologists who suspected a direct link between dinosaurs and birds.
- But the idea of a close link between dinosaurs (or at least reptiles) date back to the discovery of the remains of Archaeopteryx in hte upper jurassic solnhofen limestone of bavaria
- Background on Solnhofen Limestone
  - late jurassic, much of what is now Germany was covered by warm shallow sea fringed with reefs made by songs and corals
  - Between these reefs and the land were isolated lagoons that were cut off from the rest of the sea. These lagoons had too much salt and too little oxygen for anything more complex than bacteria or protists
  - An organisms that fell into, or were washed into lagoons were buried in the soft carbonate mud with a lack of oxygen
  - Storms probably were responsible for the rapid rates of urial required for exceptional preservation of remains in the lagoons
  - So the remains were protected from scavengers and currents, and were preserved in tact what would become fine-grained limestone
- Archaeopteryx- first significant specimen
  - the first fossil of arhaotpterix was a single feather, fund in 1860

  - This feather was exceptionally preserved and showed the asylumetric form that is a characteristic of flight feathers.
- Archaeopteryx- The London Specimen
  - Found in 1861 and was significant because it established the type of bird from which the single feather found the previous year was derived.
  - There were so few specimens that the Archaeaopteryx are named after the museums or cities they reside in)
- Arcaheaopteryx- Berlin Specimen
  - by far the most famous and best-preserved specimen of archaeopteryx is the berlin specimen discovered in 1877
  - Specimen shows the most significant features that are considered evidence of dinosaur-bird connection.
  - Long tail, have hands, reptile-like head
- Birds share many characterstics with theropod dinosaurs, suggesting a close (and perhaps direct) like between the two groups.
- The solnhofen specimen found in 1960s was initially identified as the theropod dinosaur *Compsognathus*
- In 1980s, it was noted that the dimensions of the forelimbs in the specimens were too long for *Compsognathus.* Furhther preparation revealed faint feather impressions allowing this specimen to be identified as Archaeaotperyx.

Archaeatoerpyx Specimens

- Note that the solnhofen limestone is quarried in many locations in Bavaria and at slightly different stratigraphyc levels within this unit
- it is possible that there are more than one sees is represented in the total number of specimens known (8 major specimens)
- Similarities between archaeopteryx and modern birds
  - bird wing tips are modified hands: Hoatzin chicks retain the three fingers in a “hand” prior to the forehand developing into an adult wing.
  - long tail
  - S-shaped neck, and locomotion (walked) on toes
  - Foot morphology: Deinonychus have similar feet to vultures. These feet are used like a hook rather than a slashing-weapon. Hunted in packs for prey, aimed for jugular when hunted.



Hand Morphology

•D. Note very close correspondence in proportion and relative lengths of bones to deinonychus

__ and

es

of the

Furcula (Wishbone)

•wishbones are attached to shoulder bone

•wishbones are found in birds as well as some dinosaurs

- the wishbone basically acts like a spring
  - in birds, it has to do with frequent use of arms for flight
    - as the bird flaps its wings, its chest collapses a bit and to bring it back out, the wishbone helps

Upstroke

- the upstroke in flight is made possible by pulley system involving muscles and tendons

- The supracoracoideus muscle (the tender of a chicken breast0 is attached to the sternum
- Contraction of the supracoracoideus pulls on a tendon that loops through the top of the shoulder and is attached to the upper surface of the humerus (upper arm)
- The arm is raised as the tendon pulls tight.
- Flexes muscle that pulls tendon

Downstroke

- The downstroke i flight is accomplished by outer chest muscles
- The pectorals muse (big part of chicken breast) is attached to he understide of humerus and the keep of the sternum
- Contraction of pectorals muscle pulls the arm downward
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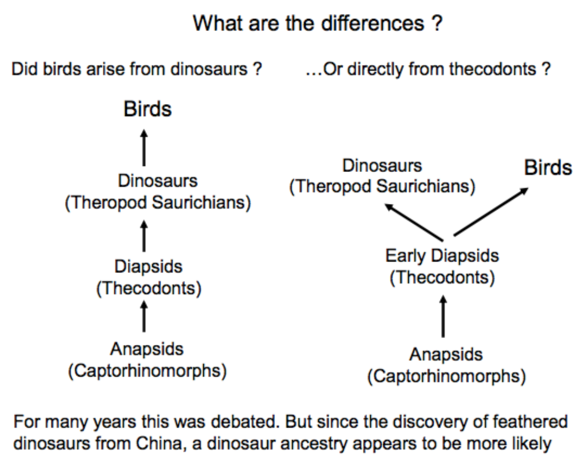
- Nomingia (oviraptorosaur) and vultures both have this
- tail started to shrink in theropods because they're getting lighter

Hollow Bones

- bones of a bird are incredible light due to the large amount of empty space inside, but there also very strong for flight
- the strength is provided by the interior struts — similar to grillwork in high-rise building

Lightweight construction: "sue"

- overal skeleton structure of theropod dinosaurs is optimized for light weight— even soul is supported by vertical struts



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Serpents and Spitfires: Marine Reptiles and Flying Reptiles

- The great diversification of reptiles, beginning in the Triassic Period, and coming to ahead in the Cretaceous Period, included the appearance and great success of marine and flying reptiles.
- Among the marine reptiles were the ichthyosaurs (euryapsids), plesiosaurs (also euryapsids), marine turtles (anapsids or possibly diapsids and mosasaurs (diapsids)(— closely related to lizards)
- At least in the early part of the mesozoic era, pterosaurs ruled the skies

Ichthyosaurs

- Evolved from land-dwelling reptile
- Note modification of body for life in sea. (fins on back and tail, modification of limbs to form flippers) (resembles dolphins and swordfish)
- Body was streamline, developed a dorsal fin (like sharks), have internal fertilization and bore live young instead of laying eggs.

Plesiosaurs

- Long-necked forms: Elasmosaurs
- Short-necked forms: Pliosaurs
- Tails were shortened and necks were lengthened — ambush predators (lurking in kelp forests and lurch out to catch prey). Small head (prey doesnt see them as quickly)
- As with ichthyosaurs, evolved from a land-dwelling reptile. Modification of limbs to form flippers and lengthening of neck for darting movement to catch prey
- Ate anything
- Cretaceous pliosaur from Manitoba: Western mountains were thrusted up by a forming trough flooded by the sea

many reptiles came back to sea because of the abundance of food

Turtles

- During mesonoic, marine turtles also got very large

Mosasaurs

- Giant marine lizards (the komodo dragon is closest living relative to these)

- on roof of mouth (palate) there is an extra set of teeth (for more grabbing power)
  - teeth of all different sizes, going in many different directionsrin
- Evolved from land lizard, retaining lizard-like body but limbs and tail were modified for swimming
- Common prey for mosasaurs:
  - other marine reptiles
  - birds
  - large ammonites (squid-like molluscs) (cephalopods)
    - move in a rocking motion— like submarine

Modifcations for Flight

- Extreme lightweight skeletons (hollow bones)
- long tail for balance in early form but smaller tail in alter forms
- wing produced by modification of last finger and development of membrane connecting the wing to the body
- prominent sternum (breastbone) for attachment of strong flight muscles
- Similar to modern-day bird and eventually lead to modern structure. Wing is stretched from pinky finger

Pterosaurs and Pterodactyls

- tail was used for steering
- Rhamphorhynchus: showing wing membrane
- pterodactylus: size of crow, smalll teeth for catching fish

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Barney to Big Bird: The Origin of Birds

Fuzzy Dinosaurs

- Caudipteryx
- Th discovery of feathered dinosaurs in Liaoning, China, has excited many palaeontologists who suspected a direct link between dinosaurs and birds.
- But the idea of a close link between dinosaurs (or at least reptiles) date back to the discovery of the remains of Archaeopteryx in hte upper jurassic solnhofen limestone of bavaria
- Background on Solnhofen Limestone

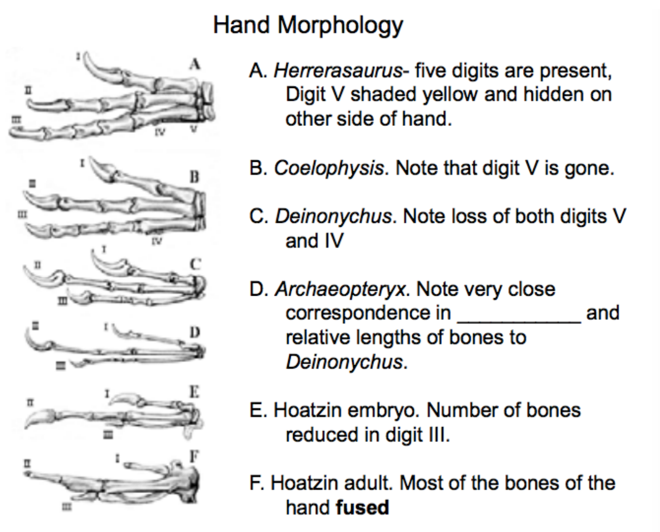
  - late jurassic, much of what is now Germany was covered by warm shallow sea fringed with reefs made by songs and corals
  - Between these reefs and the land were isolated lagoons that were cut off from the rest of the sea. These lagoons had too much salt and too little oxygen for anything more complex than bacteria or protists
  - An organisms that fell into, or were washed into lagoons were buried in the soft carbonate mud with a lack of oxygen
  - Storms probably were responsible for the rapid rates of urial required for exceptional preservation of remains in the lagoons
  - So the remains were protected from scavengers and currents, and were preserved in tact what would become fine-grained limestone
- Archaeopteryx- first significant specimen
  - the first fossil of arhaotpterix was a single feather, fund in 1860
  - This feather was exceptionally preserved and showed the asylumetric form that is a characteristic of flight feathers.
- Archaeopteryx- The London Specimen
  - Found in 1861 and was significant because it established the type of bird from which the single feather found the previous year was derived.
  - There were so few specimens that the Archaeaopteryx are named after the museums or cities they reside in)
- Arcaheaopteryx- Berlin Specimen
  - by far the most famous and best-preserved specimen of archaeopteryx is the berlin specimen discovered in 1877
  - Specimen shows the most significant features that are considered evidence of dinosaur-bird connection.
  - Long tail, have hands, reptile-like head
- Birds share many characterstics with theropod dinosaurs, suggesting a close (and perhaps direct) like between the two groups.
- The solnhofen specimen found in 1960s was initially identified as the theropod dinosaur *Compsognathus*

- In 1980s, it was noted that the dimensions of the forelimbs in the specimens were too long for *Compsognathus*. Furhther preparation revealed faint feather impressions allowing this specimen to be identified as Archaeaotperyx.

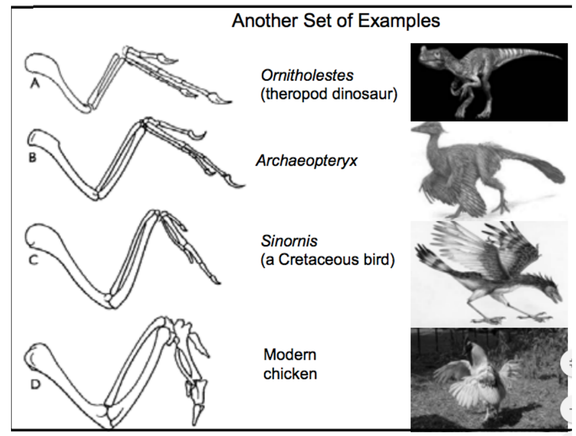
Archaeatoerpyx Specimens

- Note that the solnhofen limestone is quarried in many locations in Bavaria and at slightly different stratigraphyc levels within this unit
- it is possible that there are more than one sees is represented in the total number of specimens known (8 major specimens)
- Similarities between archaeopteryx and modern birds
  - bird wing tips are modified hands: Hoatzin chicks retain the three fingers in a “hand” prior to the forehand developing into an adult wing.
  - long tail
  - S-shaped neck, and locomotion (walked) on toes
  - Foot morphology: Deinonychus have similar feet to vultures. These feet are used like a hook rather than a slashing-weapon. Hunted in packs for prey, aimed for jugular when hunted.

Hand Morphology



•D. Note very close correspondence in proportion and relative lengths of bones to deinonychus



Furcula (Wishbone)

•wishbones are attached to shoulder bone

•wishbones are found in birds as well as some dinosaurs

•the wishbone basically acts like a spring

•in birds, it has to do with frequent use of arms for flight

•as the bird flaps its wings, its chest collapses a bit and to bring it back out, the wishbone helps

Upstroke

- the upstroke in flight is made possible by pulley system involving muscles and tendons
- The supracoracoideus muscle (the tender of a chicken breast0 is attached to the sternum
- Contraction of the supracoracoideus pulls on a tendon that loops through the top of the shoulder and is attached to the upper surface of the humerus (upper arm)
- The arm is raised as the tendon pulls tight.
- Flexes muscle that pulls tendon

Downstroke

- The downstroke i flight is accomplished by outer chest muscles
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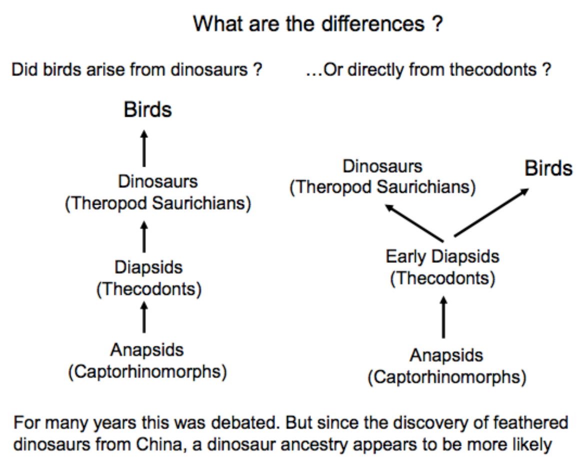

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Cretaceous Calamity: Cretaceous-Tertiary Mass Extinction and other mass extinctions

Mass extinctions of the Phanerozoic Eon: The big five

- Total number of families
- Extinction at the end of Ordivician period, late devonian period, end of permian, end of triassic, end of cretaceous,
- increasing amount of families going extinct occurred at the ends of these eras

K-T Mass Extinction (sea level fall)

- end cretaceous mass extinction

Late mesozoic:

- sea levels high
- land areas separated (despite fairly close proximity of continents to one another)
- lots of shelf area for shallow marine organisms

Early cenozoic:

- climate changed dramatically
- sea level lower
- continents further apart (less shelf area for shallow marine organisms)

Drainage of Interior Seas

Lowering of sea level resulted in:

- loss of shelf area (largely through loss of interior seas such as western interior seaway of north america)
- aridification (process of region becoming increasingly dry) of land areas (less habitat diversity)
- more connection between continents via land bridges

Flood Basalt Volcanism

- Result of great volcanic activity associated with rising heat plumes from mantle
- Deccan Traps (India) record eruption of more than 500,000 million cubic km of basaltic lava over perhaps about 5 million years but began before end of Cretaceous Period
- There appears to be correspondence between some mass extinctions and flood basalt events

Initial Evidence of Bolide Impact: Iridium

- iridium-rich boundary clay layer
- iridium “spike”: high iridium concentrations from asteroids/comet or volcanism

Computer model of effects of K-T Impact Winter

- No sunlight = no photosynthesis = cascade of death through food chains
- Earth in darkness for at least 6 months after asteroid impact

Shocked Quartz in K-T Boundary Clay

- Shock metamorphism has only been observed at meteorite impact sites and nuclear test sites

Tektites, glass beads found in boundary sediments

- due to melting of rock by energy of bolide (asteroid or comet) impact
- glass found in boundary sediments of gulf of mexico

Soot particles found in boundary clay. similar to fly ash from coal-burning plants

- Suggest global wilderness association with ignition of large amounts of dead plant matter on earths surface

Fern Spike/ Pollen Trough

- Pollen/spore ratio takes a ratio at about same level as iridium spike
- Records early recolonization of land after impact winter

Impact Site: Chicxulub

- greater discovered in 1978 by a geophysicist working for Petroleos mexicanos
- Pemex did not release the data for fear of revealing valuable information to competitors
- 180-300km in diameter

K-T Asteroid Impact Winter

- asteroid and shock wave blast one trench
- rings of copal creates form, by rebound
- Impact winter:
  - debris injected into atmosphere
  - lots of dead, rotting organic matter
  - global wildfires
  - blocking of sunlight
  - consumption of ozone

Bedrock Lithology in vicinity of Crater

- Yellow= anhydrite (gypsum + water— burned = sulphur)
- Green= carbonates (co2 + water)
- Effects of vaporization during impacts? Severe acid rain?

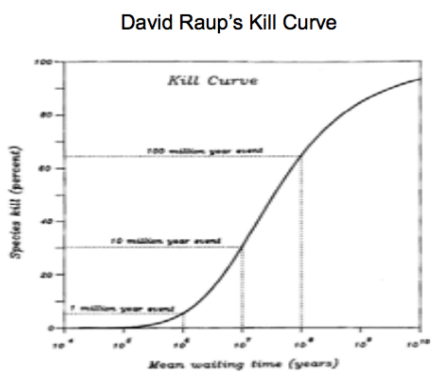
What happened to impactor?

- most likely vaporized during the blast, but possible fragment 100 trillionth of a gram found in drill core in NW Pacific.
- NE Mexico: tsunamis— believed to have been deposited by tsunamis generated by impact
- Belize: Ejecta Blanket— poorly sorted debris believed to be ejecta deposited close to crater

Other (more recent evidence for impact)

- fullerenes (molecular cage of carbon atoms)
  - also called bucky balls
  - contain ^3He (vs the more common 4He)
  - suggested to be of cosmic origin
  - elevated 3He at K-T boundary

David Raup's Kill Curve: shows magnitude of event



•Basic premise: major events occur less frequently than minor events (have greater killing power)

•Larger events, with larger effect, occur less frequently

•little events, with smaller impact, occur more frequently

Does Survival of the fittest work during a mass extinction

- in mass extinctions, the specialists lose
- early mammals inferior in their tie, when conditions were stable, but because of their generalized lie habits, had a higher chance of surviving ecological disaster than dinosaurs
- shit happens= completely random events
- when mass extinction takes place, it changes the rules… organism should be the MOST FIT in all aspects in a specific environment, however when environment changes, organism is no longer most fit. Most prone to dying out.
- mammals, amphibians, reptiles
- early mammals were inferior at the times of dinosaurs

The Other Big Four

End Ordovician Mass Extinction

- cooling due to gathering of continents at south pole (possible glaciation?)

- all tropical fauna went extinct almost immediately— organisms survived better if they already lived in cooler areas

Late Devonian Mass Extinction

- First forests
- onset of glaciation (could this be linked to first forests?)
- forests suck out CO2 from atmosphere

End-Permian: Mother of All Mass Extinctions

- coincided with final assembly of Pangaea and eruption of Siberian traps
- huge desserts- not a lot of diversity
- low sea levels

End-triassic mass extinction

- Little known about this one but possibly due to oxygen depletion in oceans.
- Coincided with extrusion of flood basalts accompanied initial spreading of Atlantic

Mass extinctions: summary of big 5

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5. Cretaceous-Tertiary extinction (65 Ma) -> victims: 47% marine genera
   - bolide impact
   - flood volcanism (Deccan Traps in India)
   - Cooling, rapid sea level fall

4. Triassic-Jurassic Extinction (199-214 Ma) -> Victims: 52% of marine genera
   - flood basalt volcanism (central atlantic)

1. Permian-Triassic extinction (251 Ma) -> victims: 84% marine genera, 95% all marine species
   - bolide impact?
   - flood basalt volcanism in Siberia
   - Assembly of pangaea (continents interconnected)
   - global cooling, major sea level fall

3. Late Devonian extinction (364 Ma) -> victims: 57% of marine genera.

- Global cooling (note: coincident with expansion of land plants)

2. Ordovician-Silurian extinction (439 Ma) -> victims 60% of marine genera
    - global cooling, then rapid warming
    - rapid sea level fall followed by rapid sea level rise

Different mass extinction, different causes

Towards the sixth big mass extinction

- we are losing many species (30 000) per year— rate much faster than any time in past many years. Almost a quarter of world mammal's face extinction within 30 years.
- Biosphere future lies in understanding of earth's system— past and present

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the advantage of being a furball: diversification of mammals

Reptiles vs mammals

Reptile

REPTILE	Mammals
• no milk • small brain case • jaw contains more than one bone • simple teeth • one ear bone • continual growth • variable temperature • scales/knobbly skin	• milk • expanded brain case • jaw contains only one bone in jaw • complex teeth • three ear bones • limited growth (stop growing at adulthood) • constant temperature • hair

Polycosaurs

- among earliest of the mammal like reptiles were the pelycosaur (evolved from anapsid by early permian)
- retina sprawling posture of primitive anapsid
- distinguished by sail

- both carnivorous and herbivorous forms

Therapsids (mammal-like reptiles)

- Succeeding the pelycosaurs were the therapsids or mammal-like reptiles
- Got off to a pretty good start, diversified in the mid-to-late Permian
- Therapsids themselves hard-hit by end-permian mass extinction, then again by the End-Triassic extinction, and totally wiped out by early Cretaceous
- Primitive mammal-like reptiles had decidedly reptilian characteristics
- More advanced mammal-like reptiles have sprawling stance, but very mammal-like in many other skeletal features (pits in skulls of some forms even whiskers)

True Mammals

- by a stroke of luck, one group of therapsids give rise to mammals during the triassic
- (first true mammals appeared on earth together with the earliest dinosaurs during triassic)
- Some lived during mesozoic but went extinct by early cenozoic

The remaining group, the therian mammasl, which originated during the jurassic survive today

- 3 major living mammals

1. monotremes — egg-laying mammals
2. marsupials— pouched mammals- egg laying mammals
3. placentals— mammals with placenta

- **reptiles to mammals: hearing with jawbones**
    - articular is detached from jawbone and comes middle bone in humans
    - the quadrate bone also detach and becomes inkus in bone
- increasing sophistication of teeth as mammals evolve (teeth used to all be very similar and had the same function)

**fundamental

phylogeny of Therian mammals

- many mammals went extinct at the same time as dinosaurs
- those that survived, ancestral mammal, gave rise to the marsupials, monotremes, and placentals (that gave rise to elephants, sloths, carnivores, rodents, etc.)

- marsupials: their young is small, defenceless, and looks embryonic— young travels up to pouch after birth and during this time, females are paralyzed to prevent eating them. — underdeveloped young is external to mother, so if something happens to mother, then it does not directly affect young (vice versa: complications with young, mother can abort it).
    - were once very successful in southern continents
  - Placental animals have complications when giving birth: mother can die (causing offspring to die).
- Mammal groups show remarkable degree of evolutionary convergence especially marsupials and placentals
  - mammals that are fundamentally different can have an equivalent — like marsupial equivalent and placental equivalent (sugar glider and flying squirrel)

Mammalian Milestones

- Life recovers after major extinctions illustrated by mammalian evolution
- 2 factors:
  1. recovery is slow by ecological standards because entire ecosystems have been destroyed beyond recognition, as many or even most of their species have become extinct.
  2. The process is extremely fast by evolutionary standards, showing that exceptional conditions are in effect, promoting extraordinarily rapid evolution

The link between these two factors is that ecosystems are reconstituted anew after mass extinction— needs replacement

Post-Cretaceous Recovery

- dominant land vertebrates of the late cretaceousous (the dinaorus) Are not replaced for 5-10 million years
- during that time there are no large herbvores, and few predators of any size at all
- yet by early tertiary, there are several different lineages of 4 to 5 ton herbivorous animals, which are of different ancestry on the separate continents, and there are large carnivores birds
- no mosasaurs, ichthyosaurs, or plesiosaurs survive the K-T extinction, but by the eocene times, there were very large mammals eating fish in the oceans (whales)

The incumbency effect

- major conservative effect in evolutionary ecology
- difficult to remove an incumbent politician (i.e. one who is already in power) and in much the same way it is difficult for a species to evolve to displace a species which is already well adapted to its niche

- typically, it is invaders that displace the incumbents, rather than species evolving in the same ecosystem

the force of incumbency

- obviously the force of incumbency is much diminished if an ecosystem is drastically affected in mass extinction
- little wonder that we have subdivided the geologic time on the basis P-Tr and K-T extinction marking the ends of eras.

Mass extinctions reset the clock

- so mass extinctions indirectly bring about major renewals in the history of life by bringing about major catastrophes
- in particular, the process of renewal after mass extinctions are overdue for studies as detailed as this have been devoted to the extinctions
- likely the major item on evolutionary agenda one next 20 years

Relative abundances of large land animals

note:

- mammal-like reptiles suffer from T-J extinction, replaced by dinos
- took a mass extinction to oust dinos and replaces them with diminutive mammals that evolved from mammal-like reptiles

Land vertebrates: a little more complex

- mesozoic world was warm with poorly defined latitudinal climatic variation
- land bridges were widespread despite many inland seas(sea level fall at end of cretaceous aided in and bridge formation too)

Brontotheres and other big brutes: evolution of large mammals

the tertiary

- the tertiary witnessed the diversification of many mammalian and bird groups, fluriosing in the tropical conditions
- During the early Tertiary the continents were isolated by shallow seas, and different lineages of mammals evolved on each one (but not before a bit of a lag in replacement in the earliest Paleocene)

Earliest tertiary

- on land, many new types of mammals appear in a dramatic evolutionary radiation, filling the ecological roles vacated by the dinosaurs

- but compared the cretaceous megafauan, these animals were very small
- dominant forms were hold-overs from the cretaceous and quickly died out as large scale replacement commenced

——————

- By eocene, mammals included many giant, yet small-brained rhinoceros (asiamerican uintatheres and brototheres)
- uintatheres, brontotehres, and other rhino-like mammals: tertiary ecological equivalents to the large herbivorous dinosaurs.
- huge, flightless , carnivorous birds (phorusachids) - 2 meters tall with curved beaks that mimicked theropod dinosaurs of mesozoic.
- end of paleogene: large carnivorous animals came in

Late tertiary

- during late tertiary modern mammals and flowering plants (angiosperms) evolved as well as many strange mammals that are no longer around
- shrinkage of inland seas plus plate movement create land bridges (esp between eurasia, then north and south america— great american biotic interchange)
- most astonishing thing to happen during late tertiary was the evolution of grass. this led to the evolution of long-legged running animals adapted to life on the savana and prairie
- horse family- equine- was a successful story during the late tertiary. horses and there grazing mammals evolved in high-crane teeth to cope with a diet of abrasive grass.

Horses: browsers to grazers

- originated in north aemrica, migrated to south america and europe, went extinct in north america
- horses went from walking on shorter legs with feet, and over time, they evolved to walk on one toe and legs get longer so they can run quicker to escape predators

Late tertiary (pliocene)- great aermcain biotic interchange

- land bridge between north and south america — brought land mammals of different origins into competition (with winners and loesrs)
- nothern fauna won out and successfully invaded south america
- only marsupial is opossum (very strong animals)

Significance of plate tectonics to

- Pangaea initially split into northern supercontinent Laurasia and southern supercontinent Gondwanaland (note mammals appear in around the Triassic)
- Each supercontinent developed its own types of land mammals (dominated by placentals in Laurasaria and by marsupials in Gondwanaland)
- Supercontinents further split into smaller continents Smaller continents came into contact, allowing interchange of Laurasian and Gondwanan faunas
- Some extinction due to competition of two faunas

another late event in late tertiatery

- meanwhile during the late tertiary hominids appeared in the africa savanna , the austraolothicines

Late Tertiary (Pleistocene)— Initiation of last Ice Age, climate much cooler !

- More extinctions as climate cooled, culminating in ice age
- Episodes of continent-scale glaciation in Northern and southern hemisphere with interludes of warmer interglacial conditions
- There were still many forest animals however. For examples, the mastodons lived on every continents except australia

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Evolution of primates

How and where did primates originate

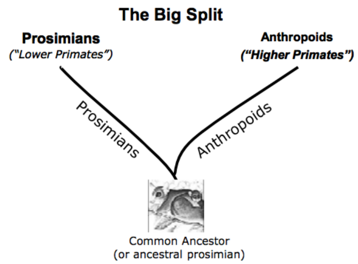
- arboreal theory:
  - primates became primates by adapting to life in trees
  - enhanced depth perception
  - grasping hands and feet
- Visual predation hypothesis
  - binocular vision, grasping ands and feet, reduced claws because they facilitated the capture of insects
  - first adapted to life in the bushy forest undergrowth and low tree branches

Oldest primates

- earliest primates date to at least the paleocene (65-54 million years ago) but possibly appeared as early as late cretaceous
- eocene (54-38 million years ago) was epoch of prosimians with at least 60 different genera in 2 families

The Big Split

Major differences between prosimians and anthropoids



Anthropoid line split from Prosimian line by Paleocene or Eocene

- anthropoid eyes are rotated more (*inward??)compared to prosimians
- Anthropoids have a fully enclosed bony eye socket
- anthropoid have a flatter, dry nose separate from upper lip
- Anthropoid molars more complex than prosimians
- prosimians incl. lemurs, lorises

Early Anthropoids Parapithecines (e.g. Aegytopithecus)

- By olivine (38-23 millions ear ago), anthropoids dominated over lemurs and relatives
- Beginnigs of anthropoid group are traced to generalized forms like parapithecines

Aegyptopithecus

- body of aegyptopithecus resembled that of a _____ but teeth more anthropoid-like
- aegyptopithcus or released form is though to be the common relative of the new world monkeys and old world monkey-hominoid group

Living Representatives (Anthropoids)— new world monkeys

- marmosets, tamarins, spider monkeys
- tail acts like a fifth limb— very agile

Early Anthropoids- Dryopithecines (e.g. Proconsul)

- Dryopithecines thought to be common ancestor of Old World Monkeys and Ape-Human Line
- Proconsul's teeth have similarities with modern apes, but bellow the neck, skeleton is more monkey-like (fairly slender)

Living Representatives (Anthropoids) Old World Monkeys

- baboons, macaques, mandrills
- Distinct body and long face
- Can live in trees and on land

Living Representatives (anthropoids) Hominoids (apes, humans, and related forms)

- lesser apes, panids, pongids,

Plate Tectonics and Isolation

- here is the placement of the continents in the early centozoic.
- New world monkeys and old world monkey-hominoid grows become isolated as continents were splitting apart
- applied to prosimians (e.g. esp. lemurs which nearly went extinct)

Primitive hominoids

- Common ancestor of gibbons, apes, and hominids is believe to have resembled pierolpithecus which lived during the miocene.

Misconceptions

1. ancestors were apes. Contrary to popular belief, evolutionists do not claim we evolved directly from apes. We evolved from a common ancestor and are related to apes— did not evolve from them
    - Contrary to popular belief, evolutionists do not claim we evolved directly from apes. We evolved from a common ancestor and are related to apes— did not evolve from them
2. hominid evolution progressed along a single near linear track directly from primitive ancestor to modern form.
    - most evolutionists acknowledge assert that hominids evolved several branches and that some of these branches overlapped in time and space

- Last ancestral population held common by humans, gorillas, and chimpanzees is known as Hogopans (after the genus names of these three); this is a hypothetical ancestor
- Lines of orangutans, gibbons, and siamangs having split off several million years early, the hominid line almost certainly diverged from this chimps and gorilla late in the Miocene epoch, between 7-5 million years ago.
- Hogopans probably split into the 3 separate lines leading to gorillas, chimpazees, and humans no more than 8 million years ago, with each group moving into separate niches: equatorial forest (gorilla), woodland (chimp), and open grasslands (hominids)
- Which leads us to attempt to reconstruct our family tree.

Recipe for Disaster: Rise of the Hominids

Continuing from last lecture

- from hogopans (or similar common ancestral group)
- apes took one road (e.g. chimps, gorillas, and extinct relatives)

- hominids (lead to humans) took another (oldest hominid: *Sahelanthropus tchadensis)*

Misconceptions (repeated)

1. ancestors were apes— did not evolve directly from apes but had common ancestor

2. Hominid evolution proceed along single linear track from primitive ancestor to modern form.— Evolutionists acknowledges that hominids evolved several branches that overlapped

Morphological Trends

- ape-like ancestors to australopithecines:
- pelvic becomes shorter and flatter, pelvic canal expands.
- Legs longer, arms shorter
- Digits sorters ad straighter
- Foramen magnum (attachment area at

Bipedal Locomotion

- footprints of australopithecus in volcanic ash (about 4 million years ago

Australopithecus Africanus

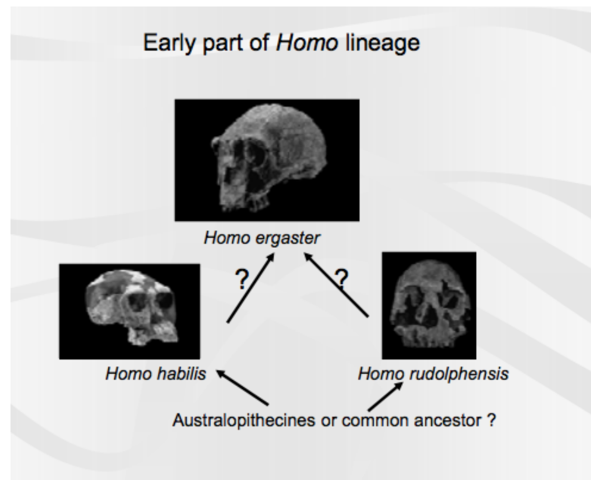
- Robust austrolopithicus
- like grey still australopithceces
- huge jaw/teeth, show that they were specialized herbivores
- chest on top of skull, dividing line of muscles on skull (responsble for chewing) needed a lot of biting power
- died out when homo came in
- first homo 2.5 million y/a

Australopithecus to Homo

- Body size increases
- change from largely herbivorous to omnivorous diet
- bony facial does progressively reduced
- upper/lower jaw protrude less
- tooth size reduced
- tooth morphology changes: sharp molars

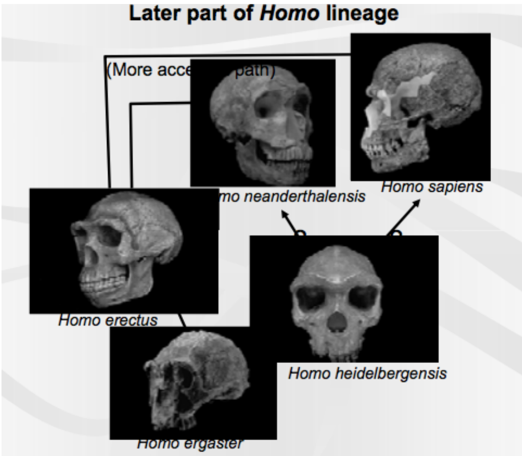
- cranial capacity increases— more brain power
- habitat changes from woodland to savanna
- tool use
- discovery and increase use of fire
- development of language
- development of prolonged parental care
- show these relate to life in open areas: upright posture helps with running in grass

Early part of homo lineage



a lot of disagreement with homo nearederthal— are they separate species?

Later part of homo lineage



Early Technology

- Oldowan tools (2.4 -1.5 Ma)— primitive chopping tools
- homo erectus because of change in habitat
- Acheulean tools (1.5-0.2 Ma) homo ergaster, H. erectus. H. Heidelbergensis
  - more refined tools — bifaces edge— use of fire

Later Technology

- Mousterian tools (200 000— 40 000 yrs)— homo sapeins, homo neanderthalensis
  - tools with maximized cutting surface
- paleolithic tools (40 000 -12 000) — homo sapiens
  - sophisticated spear points- cave drawings appear by 30 000 years

Development of Homosapiens

- 2 main modelst o explain development/dsitribution of homo spins

1. replacement model
2. regional continuity model

Replacement Model

- By christopher stringer and peter andrews
- envisages modern humans evolving from archaic homosapeins 200 000 - 100 000 years ago in africa
- though that modern homo sapiens migrated from africa into rest of old world replacing neanderthals and other archaic homo sapiens
- if correct, then all modern humans have african ancestry
- According to this model, the regional anatomical (e.g. racial) differences that we see among humans today are recent developments--evolving only in the last 50,000-40,000 years.
- If so, all other lines of humans that had descended from Homo erectus presumably went extinct

Regional Continuity Model— multi regional model

- modern human survived simultaneously on different continents of ld world
- if we held some connection between populations
- e.x. modern chinese evolved from chins archaic homi sapiens and ultimately from chinese homo erectus
- mean that east asian and some other people in old world have origin of great ____
- Advocates of this model beleive that ultimately common ancestor was an early homo erectus that arose in africa but rapidly dispersed to other regions
- Further suggest that there was sufficient gene flow among european, african, asian populations to prevent long term reproductive isolation and the subsequent evolution of distinct regional species
- argued that these people would have intrebred to kept humans single species
- sufficiently separated to produce racial differences

Which makes more sense?

- oldest known modern homo sapien come from africa and adjacent areas of southwest asia.
- elsewhere in asia and europe, modern h. sapiens appears about 50 000 years alter
- unless modern homo sapiens remains 100 000 years or older are found in europe, or east asia, the REGIONAL MODEL best explains available data

Genetic evidence

- Geneticists argue that the geographic area where modern humans have resided the longest should have the greatest amount of genetic diversity.
- This is based on the premise that the rate of mutation is more or less constant everywhere (so long-lived populations would show greater diversity from mutations)

- Through comparisons of mitochondrial DNA sequences (remember that mitochondria have their own DNA, distinct from that of the cell nucleus) from people in different modern populations, it was concluded that Africa has the greatest genetic diversity and therefore must be the homeland of all modern humans
- Assuming a specific rate of mutation, the common ancestor of all modern humans was a woman who lived 200,000 years ago (mitochondrial Eve)

Fossil Evidence in Favour for Regional Continuity Model

- Proponents of the regional continuity model is claim that there has been some continuity of some anatomical features from archaic Homo sapiens to modern humans in Europe and Asia

1. heavier brow in europeans relatve to other populations (brow shape similar to that seen in neanderthals)
2. facial characteristics in oriental people can be see in asian archaic homo aspens dating 200 000 years ago
3. east asian common have shovel-shaped incisors (similar to homo erectus) while africans and europeans rarely do

- seem that there is a direct local linage between asian homo erectus and modern asians and that there are sufficient differences between them among other populations to suggest a multi regional origin

Morphological Differences: homo neanderthalensis vs. homo sapiens

- how close are we to neanderthals?
- If subspecies of H. aspens could have interbred with other subspecies (in which case all of us could contain a little neanderthal)
- If they were separate species, then homo sapiens out competed them and then the neanderthals went extinct due to competition

Neandertals had a bad rep

- they have a sophisticated level of intelligence
- apparently had somer respect for members f their groups (burial sites include evidence of flowers being buried alongside the deceased)
- There is evidence of long term care for injured individuals (injuries sufficiently severe to have normally been fatal)

Were neanderthals religious?

- evidence that neanderthals practiced burial rituals
- evidence includes the position of the remains (e.g. head cradled in hand), presence of flower pollen in grave, and animal remains (which some think was food for the individual in their journey to afterlife

- hwoever these interpretations have been doubted by many researchers

Hobbit People

- On Flores, an island of undonesia, scientists have found skeletons of a diminutive species of humans that grow no lager than a 3 year old modern child (1 metre high).
- Homo floresiensis

Who were they and where did they come from

- homo floresiensis is believed to be a long term, isolated descendent of large-bodied Javanese H. erectus, though it could be a recent divergence
- once on flores, ancient humans could have assumed a dwarfed form in response to ecological pressures of land (limited food)
- used stone tools and coexisted with dwarf elephants, giant rodents, and komodo dragons
- estimated tat H florensiensis loved on flores between 95 000 years ago until 13 000 years ago
- Means that their time rage overlapped with mainland— homo sapiens.

Implications of new discovery

- discovery of this new species has thrown yet another complication into current understanding of human evolution

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What goes around comes around: humankind, environmental crisis, and future life on earth

How will we go on and when?

- since microbes began pumping O2 in atmosphere in Archaean, humans are the only other group of organisms that has heavily affected earth's conditions
- scientists are increasingly concerned that our consumption of resource and disregard for consequences of this consumption will bring an end to the age of humans
- others suggest that humans might be wiped out in a spectacular way, by natural events over which we have no control

Events we have no control over

- Bolide Impact (impact from comet/asteroid)
- To cause serious affect on human civilization, it must be 1.5 km in diameter. It has been estimated that impacts by objects of this size occur once in a million years— the one that wiped out earth before was 10.0km in diameter

- Supervolcano— every 50 000 years or so, a volcanic eruption capable of injecting enough ash and sulphur dioxide into the atmosphere to cause a dramatic effect on global climate for a few years
- 74 000 years, Toba erupted enough ash to dramatically cool earth's atmosphere. Freezing conditions existed in tropics for 5-6 years. Humans teetered as the edge of extinction, barely made it through

Factors we hav control over

- Climate change: biggest/most complex concern. Average global temperatures increasing since mid-1800s with an accelerated increase from 1960 onward
- Habitat destruction (forest cover used as a measure)— destruction of habitat means lower biotic diversity and in the case of forests, decreased consumption of atmospheric carbon dioxide
- overpopulation and competition for reseources and human have a very high demand for food/energy
  - humans carrying capacity is still up for debate
  - inequality of resource use

Resource supply and demand

- Current estimates for the total amount of conventionally recoverable oil on the planet is around 2 trillion barrels.
- We have consumed almost 1 trillion of this - so roughly half the oil is gone.
- The rest will last another 40 years at current consumption rates.
- But demands for oil will not stay at current rates.
- It continues to rise steadily

is the past the key to the present:

negatively affected life in past

Climate Change, Competition for resources, Overspecialization, Spread of disease, Reduction in habitat diversity, Acid Rain, Ozone Depletion

Our closed system: The state of the Earth at any given time are the sum of the interactions between processes of the four spheres. In our closed system, we're stuck with what we've got (unless we master colonization of other planets), so we'd better take care of it.

Animals that would survive next mass extinction will be very generalized

we will eventually have pangaea 2

Whoever survives next mass extinction