An Introduction to Palaeontology
古生物學簡介

2014GLSV1

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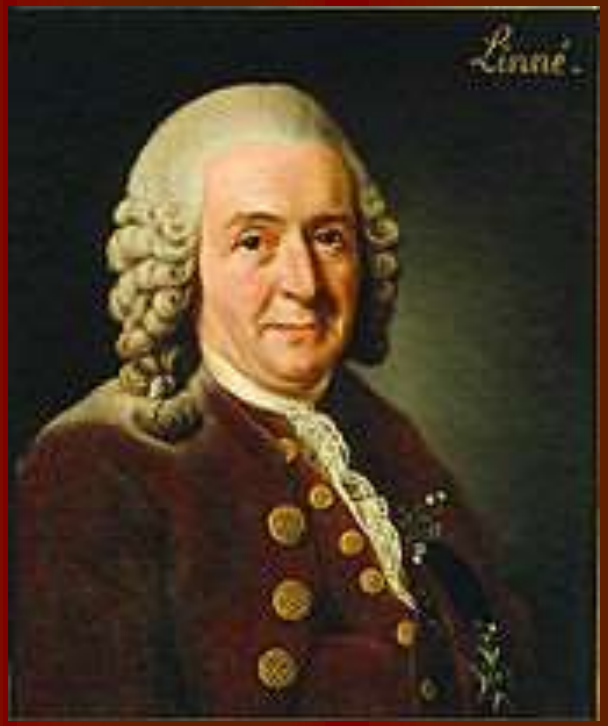
Definition

- **Palaeontology 古生物學 is the study of prehistoric life largely through fossils**
- Fossil 化石 is derived from the Latin word "fossilis" meaning "to be dug up"
- "Fossils are naturally preserved remains of once living organism 生物
- Must be at least 10,000 years old, remains less than 10,000 years are known as sub fossils. Fossils smaller than 2 mm are called microfossils
- As of today there are only 500,000 known fossil records

LIVING ORGANISM

Classification of Living Organism

- Kingdom 界
- Phylum 門
- Class 綱
- Order 目
- Family 科
- Genus 屬
- Species 種



(Taxonomic ranking 分類學：binomial system 二名法 developed by Carl Linnaeus 林奈1707-1778)

Classification Example 命名舉例

- Kingdom - Animalia
- Phylum - Molluscs
- Class - Gastropoda
- Order - Mesogastropoda
- Family - Cypraeacea
- Genus - Cypraea
- Species - vitellus*

Cypraea vitellus *linnaeus* (Binomial system)

Popular name – "Pacific Deer Cowry" 白星寶螺

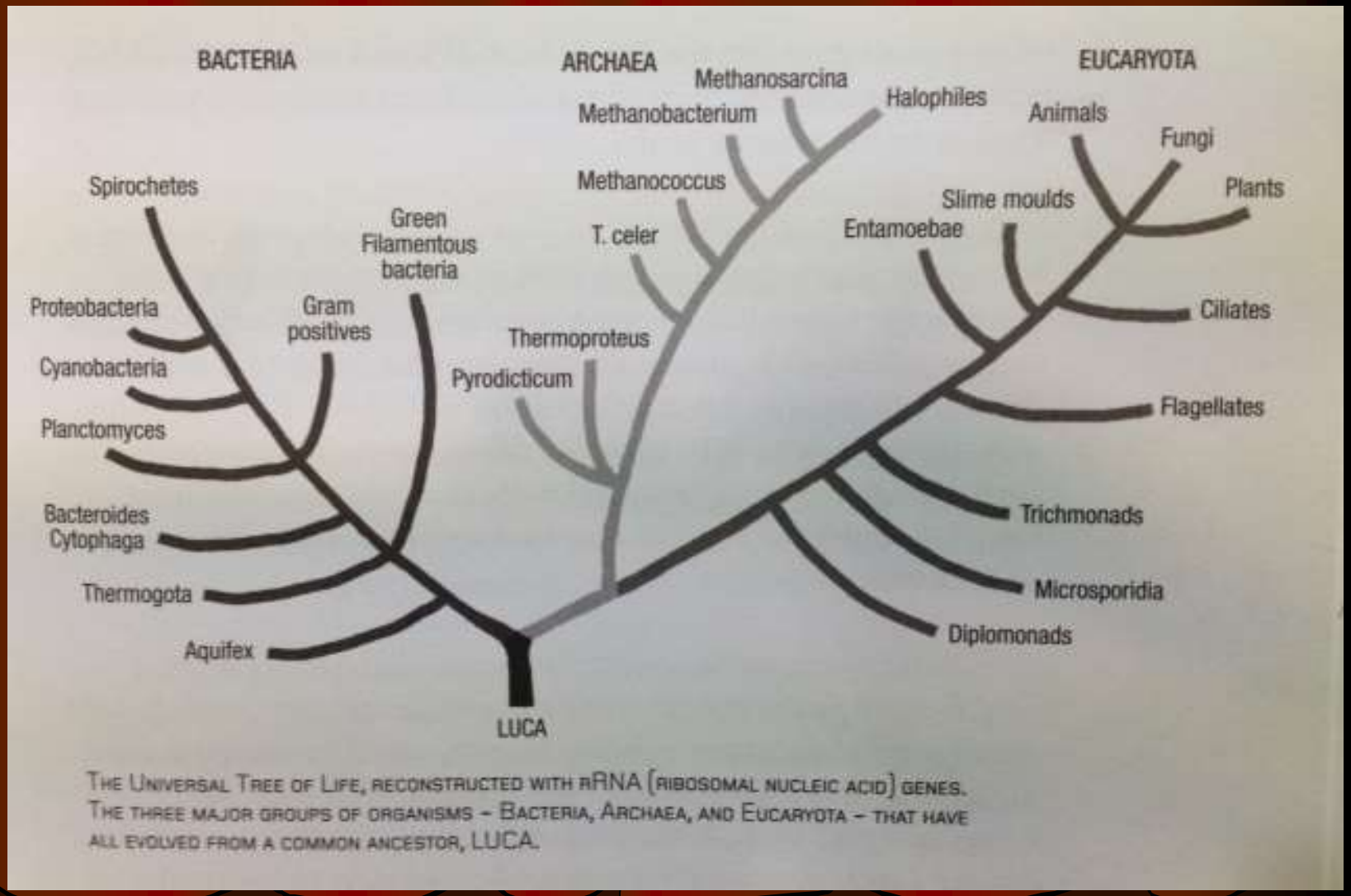
vitellus* means the yolk of an egg

- Kingdom

1. Animal (Eukaryotes) 動物界
2. Plant (Eukaryotes) 植物界
3. Fungi (Eukaryotes) 真菌界
4. Prokaryotes (Bacteria 細菌 & Archean 古生菌) 原核生物

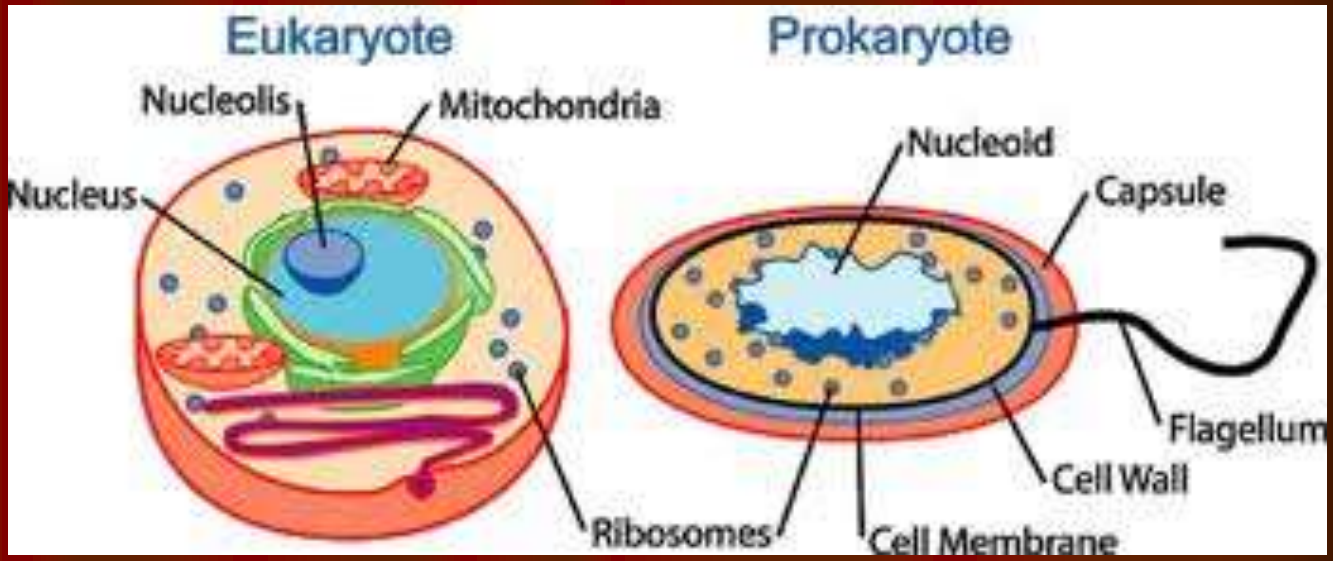
(Eukaryotes 真核生物)

Living organism



THE UNIVERSAL TREE OF LIFE, RECONSTRUCTED WITH rRNA (RIBOSOMAL NUCLEIC ACID) GENES. THE THREE MAJOR GROUPS OF ORGANISMS – BACTERIA, ARCHAEA, AND EUCARYOTA – THAT HAVE ALL EVOLVED FROM A COMMON ANCESTOR, LUCA.

Differences between Eukaryote & Prokaryote

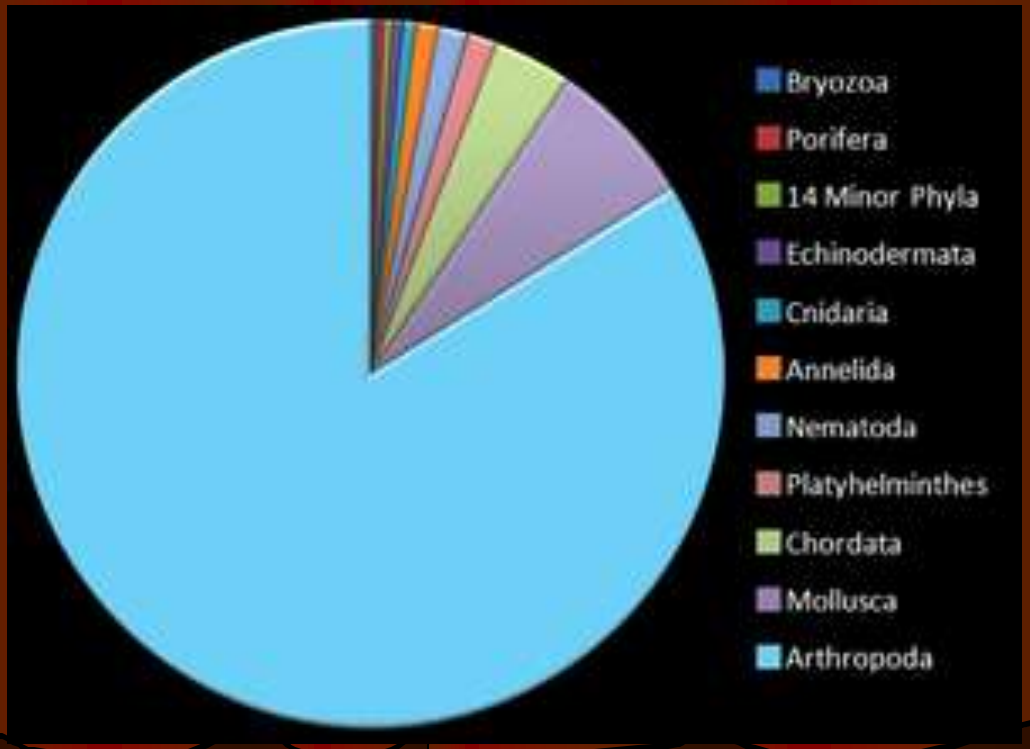


Prokaryotic Cells	Eukaryotic Cells
Very minute in size	Fairly large in size
Nuclear region (nucleoid) not surrounded by a nuclear membrane	Nuclear material surrounded by a nuclear membrane
Single chromosome present	More than one chromosome present
Nucleolus absent	Nucleolus present
Membrane bound cell organelles are absent	Membrane bound cell organelles are present
Cell division by fission or budding (no mitosis)	Cell division by mitosis or meiosis

ANIMAL KINGDOM

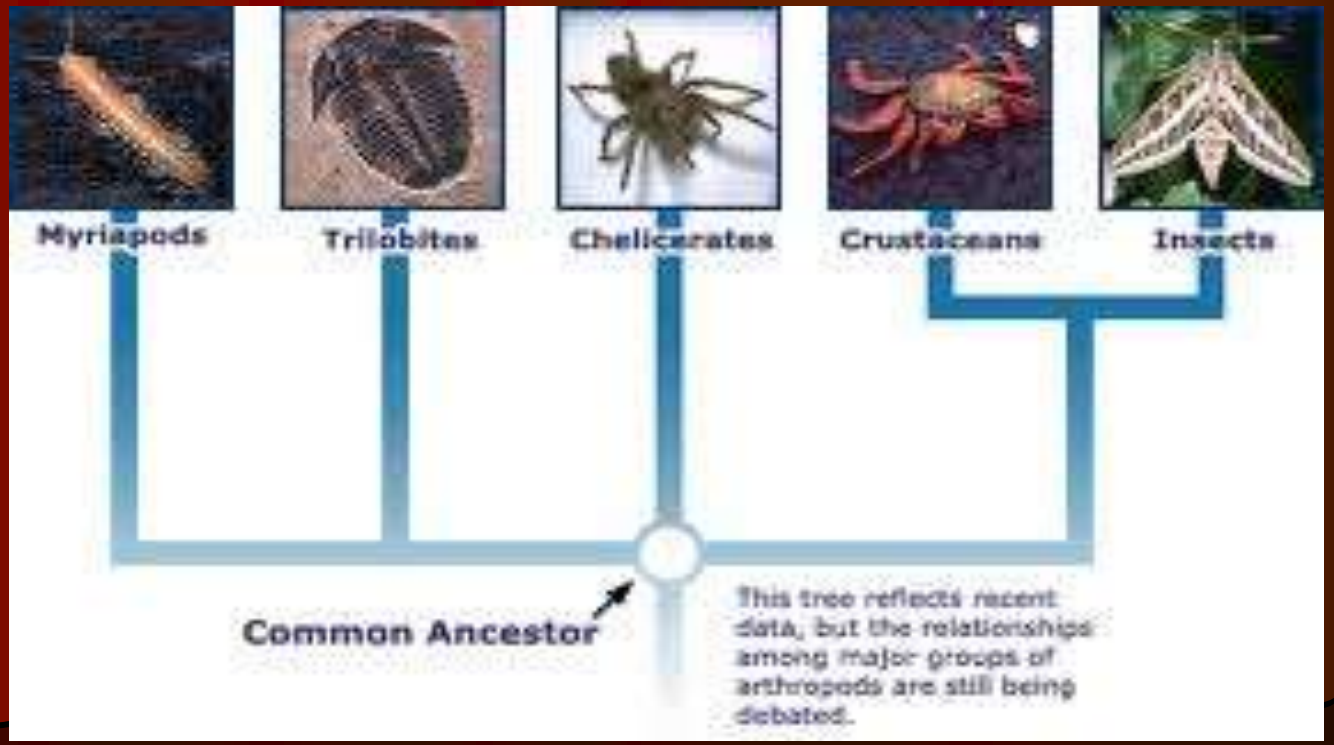
Animal kingdom 動物界

Currently 36 phyla (門) with 1.8 million named species. Total species may be as many as 10 million or more. Even so all the species we see today represents only 1% of all life existed on earth totaling at least 1 billion !

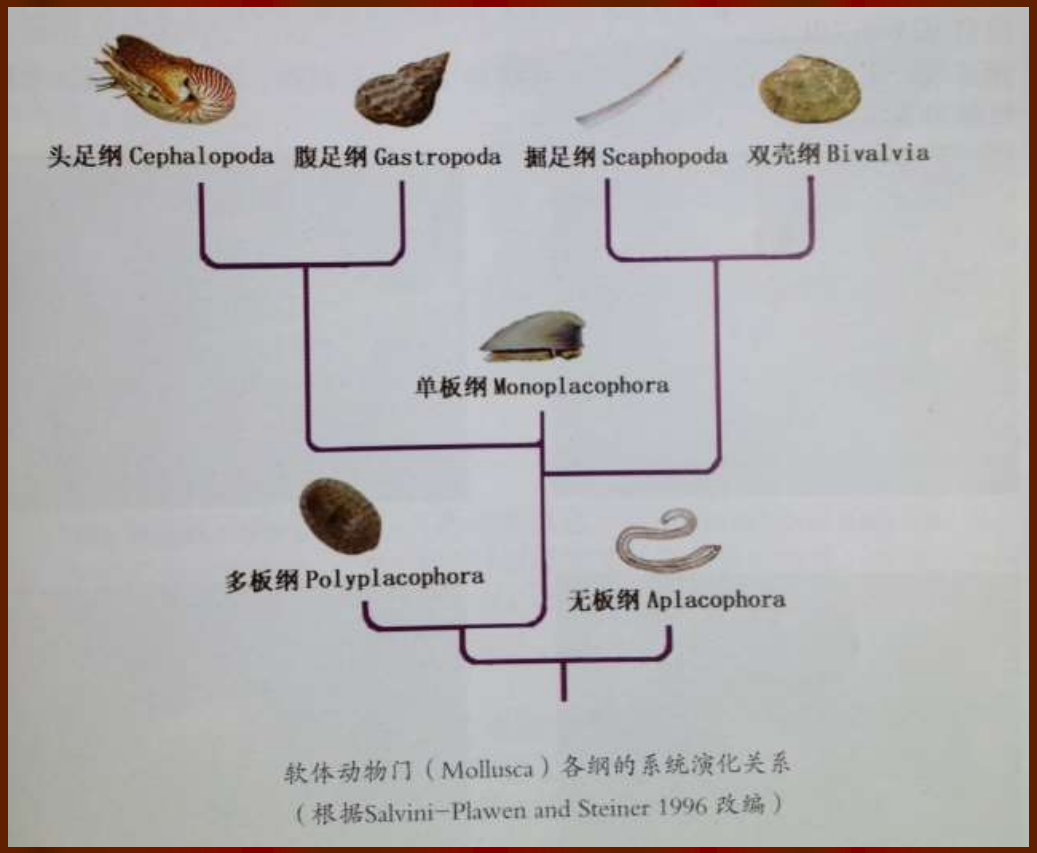


The Key Phyla 主要動物門介紹

1. Arthropoda 節肢動物門 : largest phylum totaling 1.1 million living species plus many already extinct includes Insects 昆蟲; Crustaceans 甲殼 (shrimp & crab 蝦,蟹); Chelicaerates 蛛型 (spiders 蜘蛛); Trilobites; Myriapods 多足 (millipede 蜈蚣)

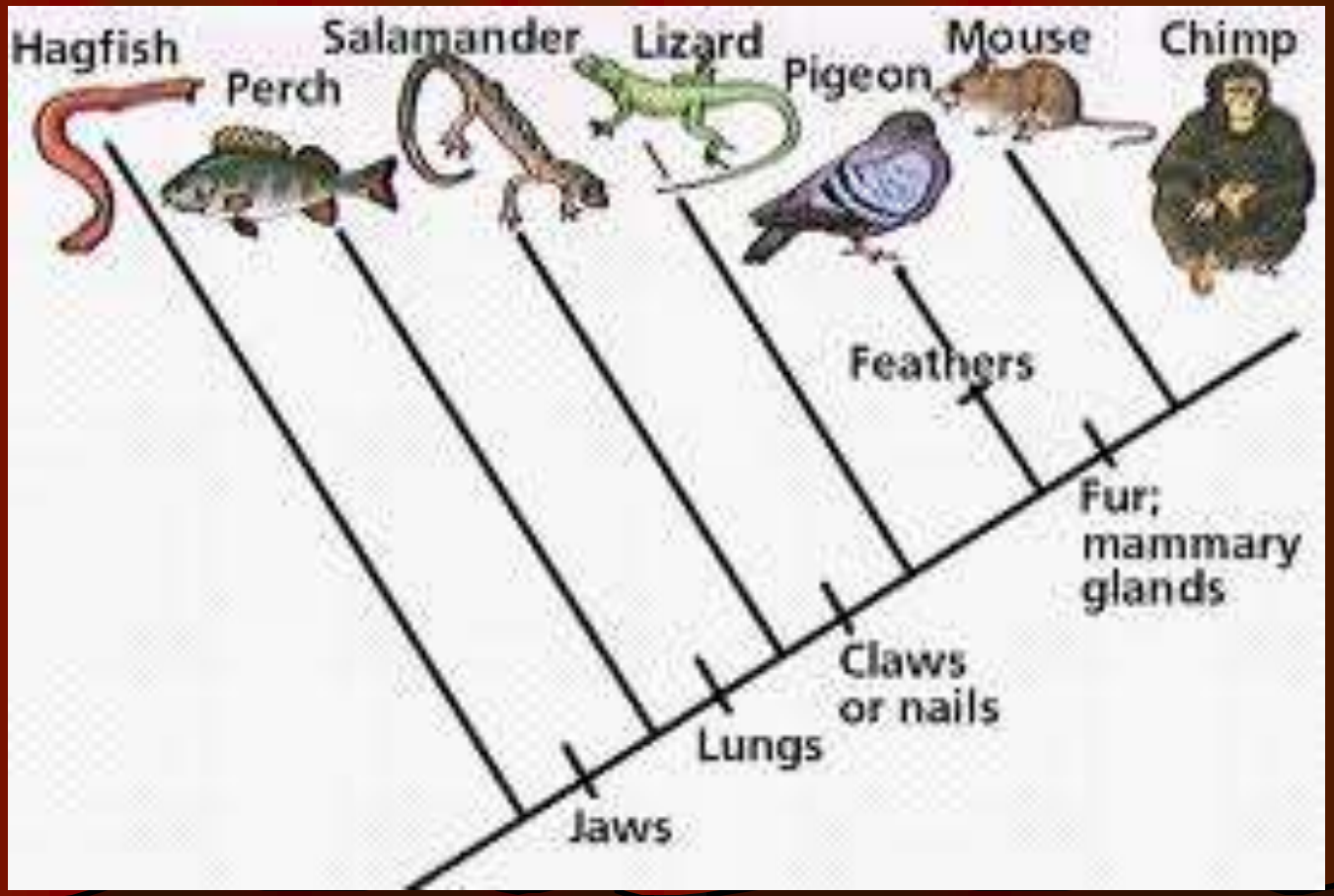


2. Mollusca 軟体動物門：7 class 112,000 species



软体动物门（Mollusca）各纲的系统演化关系
（根据Salvini-Plawen and Steiner 1996 改编）

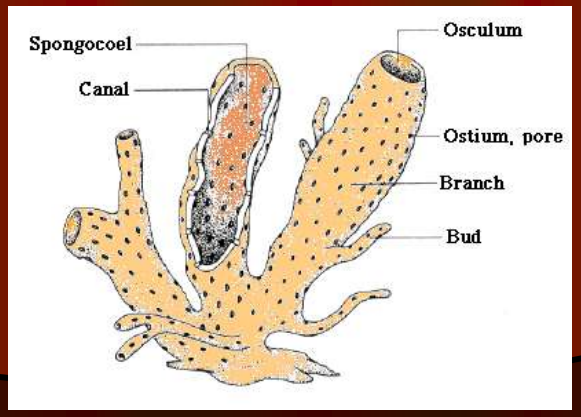
3. Chordata 脊索動物門：100,000 species (vertebrates 脊椎動物亞門 56,000 include mammalian 哺乳綱)

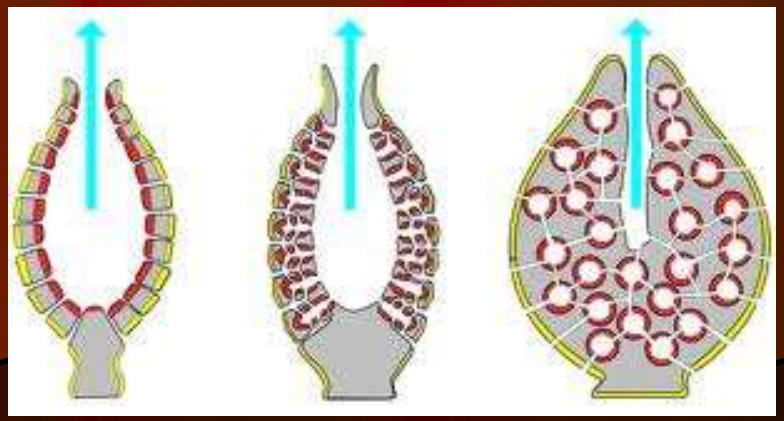


4. Porifera 多孔動物門 ：Means “pore bearer” Sponges 海綿 10,000 species Porifera is the simplest multicellular animal with no nervous, digestive or circulatory system. Oxygen & food are acquired as water flows through the body which is stiffened by spicules 骨針 made of silicate or calcium carbonate

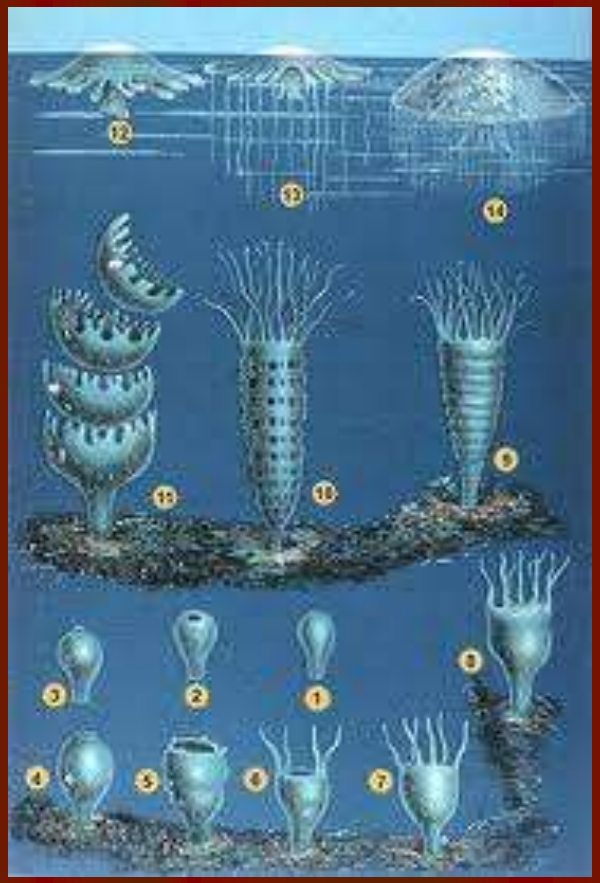


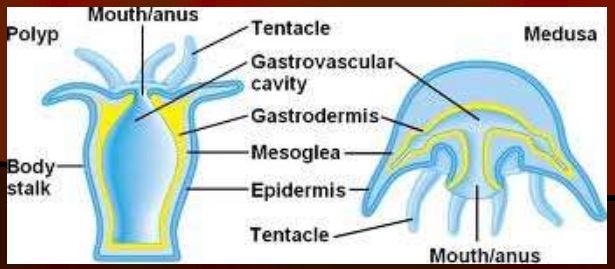




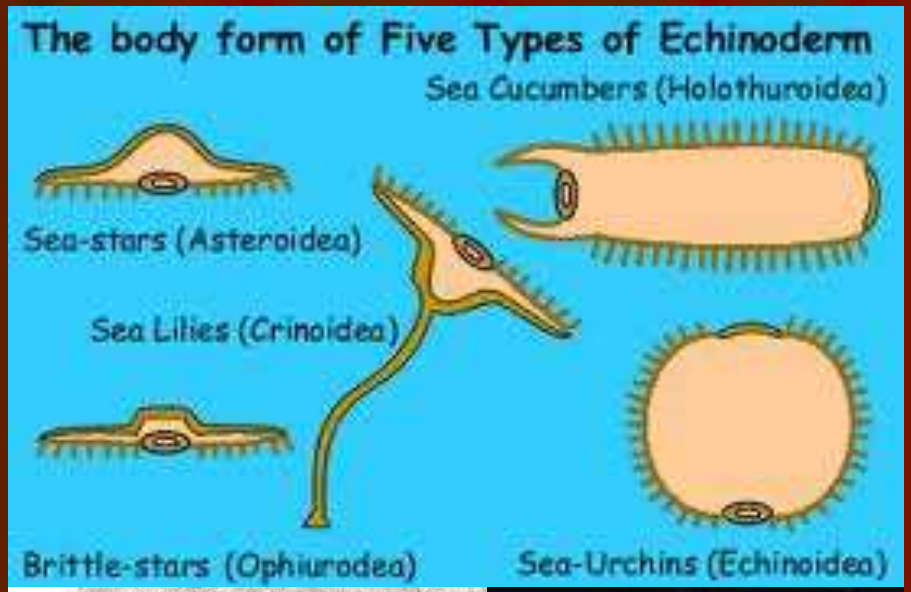


5. Cnidaria 腔腸動物門：11,000 species including corals 珊瑚，jelly fish 水母 & anemone 海葵

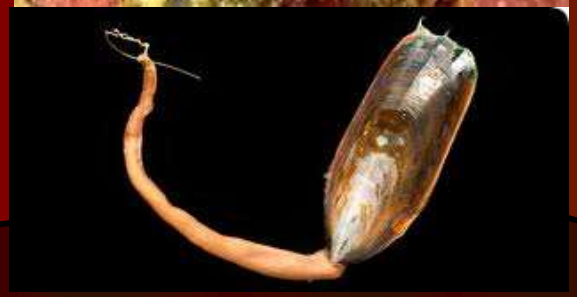


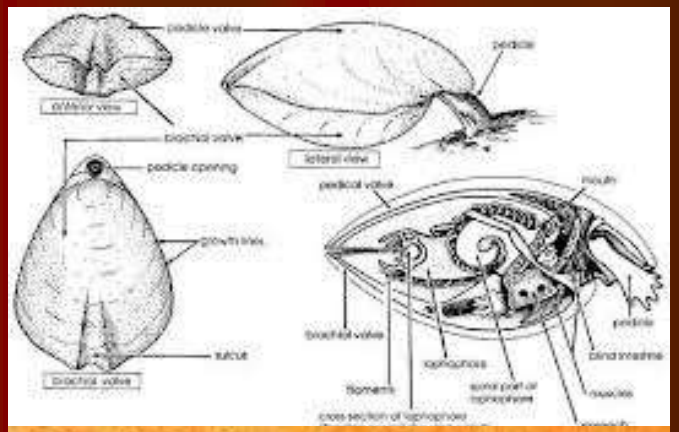


6. Echillodermata 棘皮動物門 : includes sea urchin 海膽, sea star 海星, sea cucumber 海參, crinoid 海百合
7,000 species plus 13,000 extinct ones including many types of crinoid , blastoidea & cystoid.
All have a body showing a 5 side radial symmetry



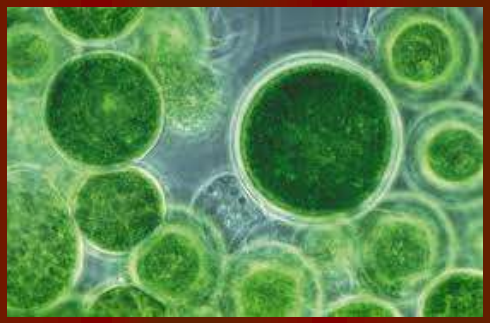
7. Brachiopoda 腕足動物門： “lamp shells” 200 living species plus 4,000 extinct ones. 1 mm to 20 cm. Have upper & lower valves vs left & right arrangement in bivalves; can be articulated or non articulated





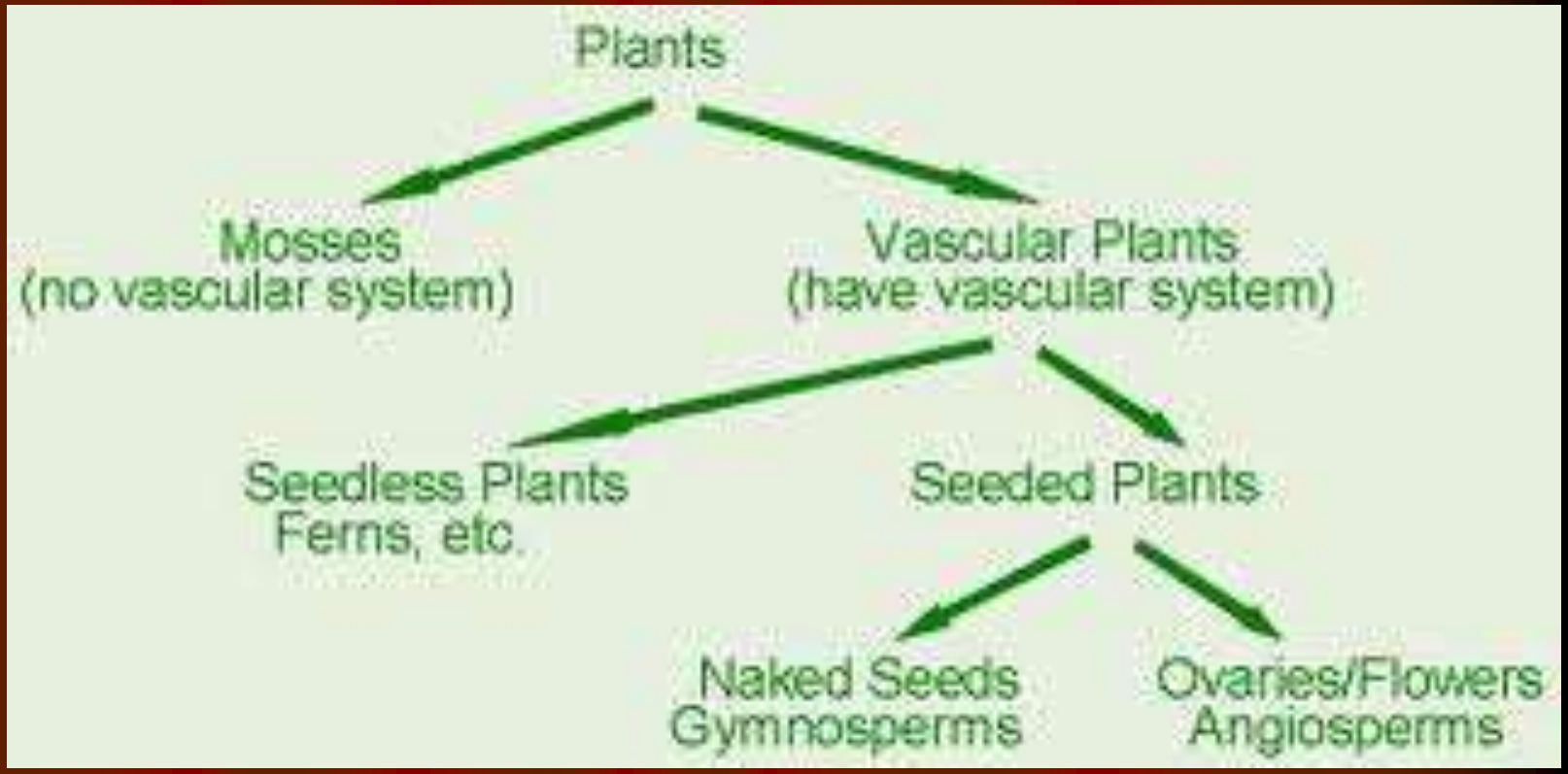
PLANT KINGDOM

- There are 12 phyla & 315,000 species of plants today
- Earliest plant is algae 藻 first living 3.6 Bya in the ancient oceans



- The first plant on land may have been around 475 Mya (Ordovician) & first flowering plant is around 140 Mya (Late Jurassic)

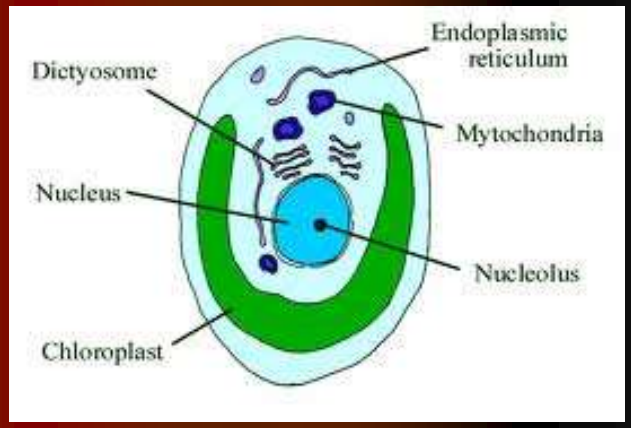
Plants Classification



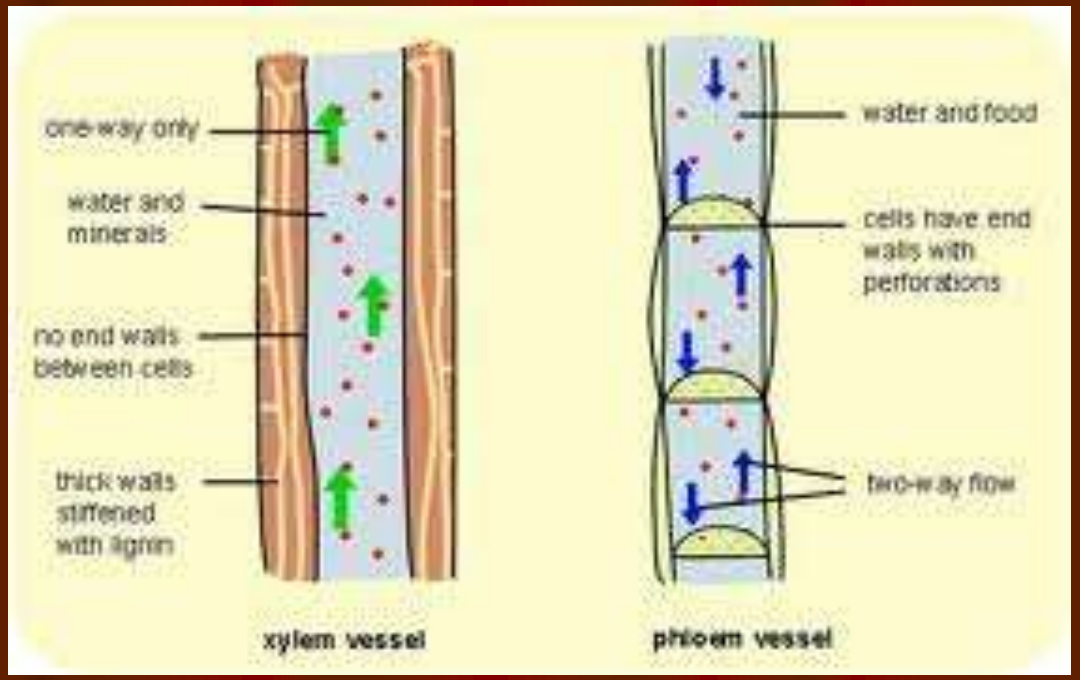
Non vascular plant 無維管植物

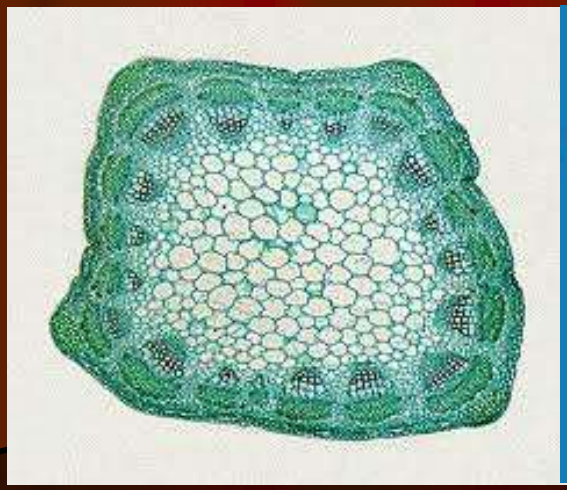
(no water conducting tissue) – mosses & lichens 苔蘚

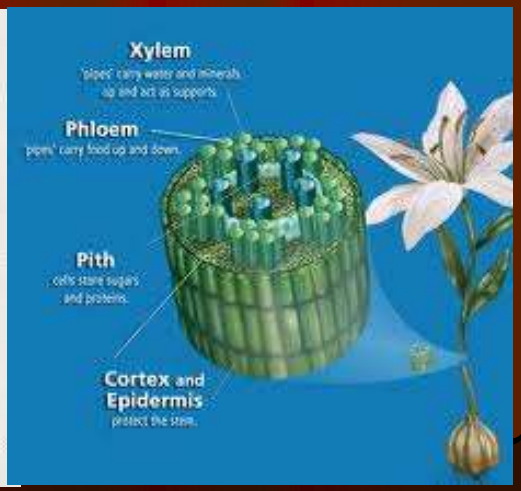
no root, no trunk, absorb water & nutrient through leaves

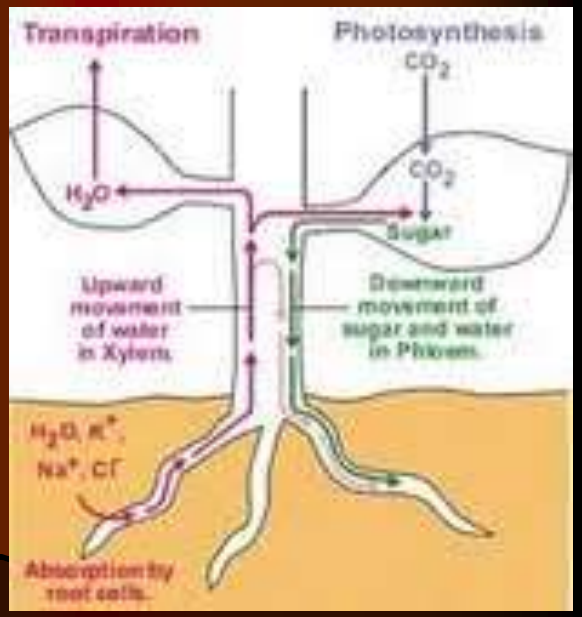


Vascular Plant 維管植物



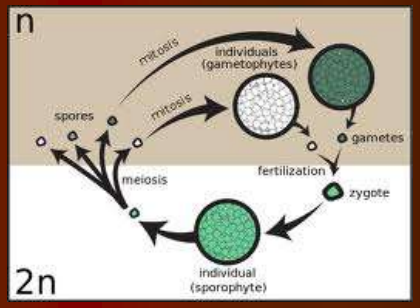






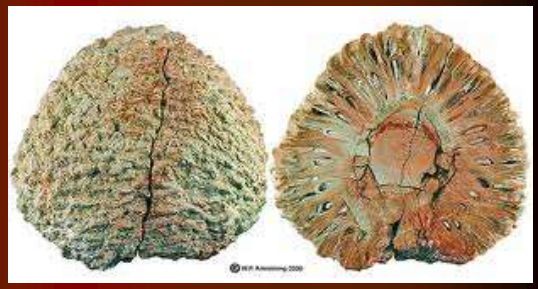
1. Seedless : reproduce by spores 孢子 eg Horsetails 木賊, Whisk Ferns, Ferns 蕨



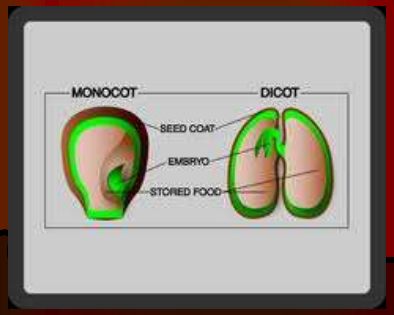


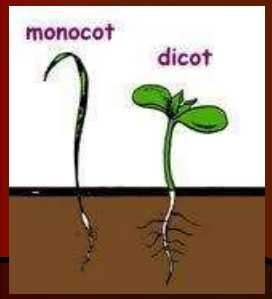
2. Seed : Gymnosperms 裸子植物 eg. Cycads 蘇鐵, Ginko 銀杏, Conifer 松柏





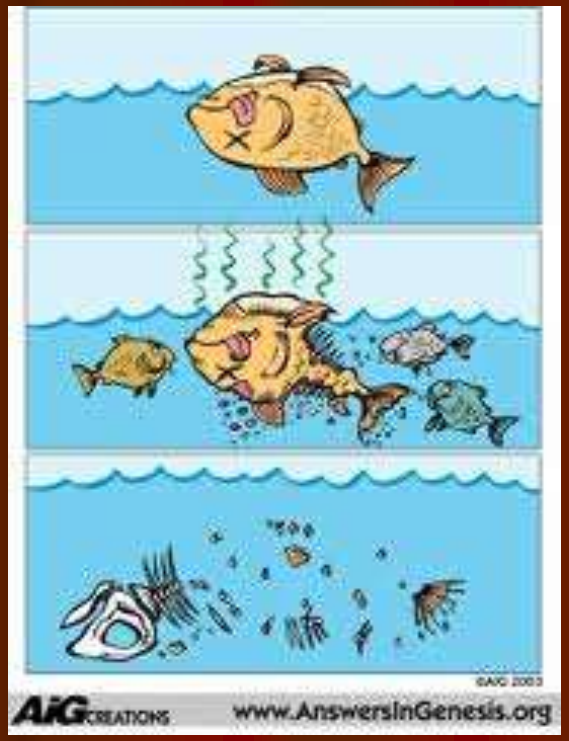
3. Seed : Angiosperms 被子植物: flowering plants – Monocotyledon 單子葉 59,300 species/ Dicotyledon 雙子葉 199,350 species

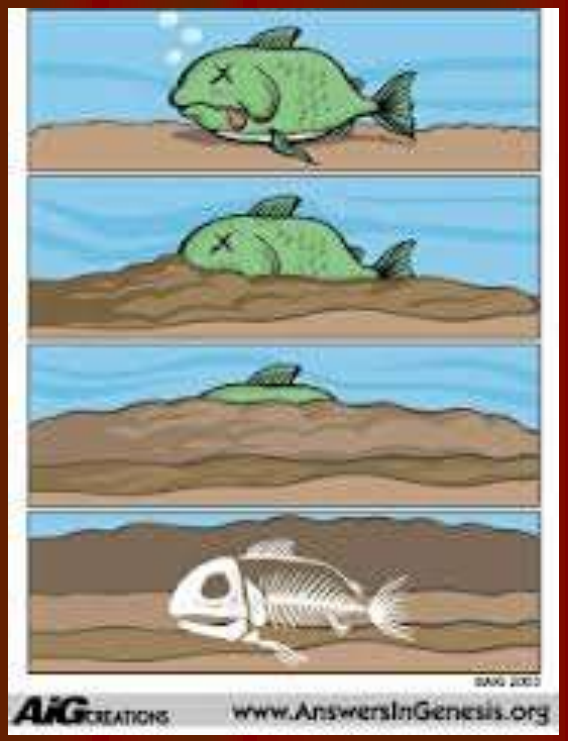


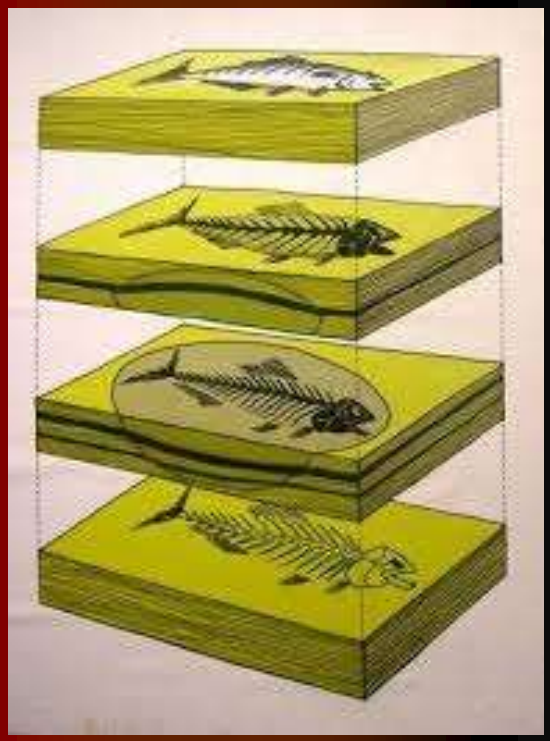


Preservation

A quick burial is the key







Taxonomy - the 7 types of preservation

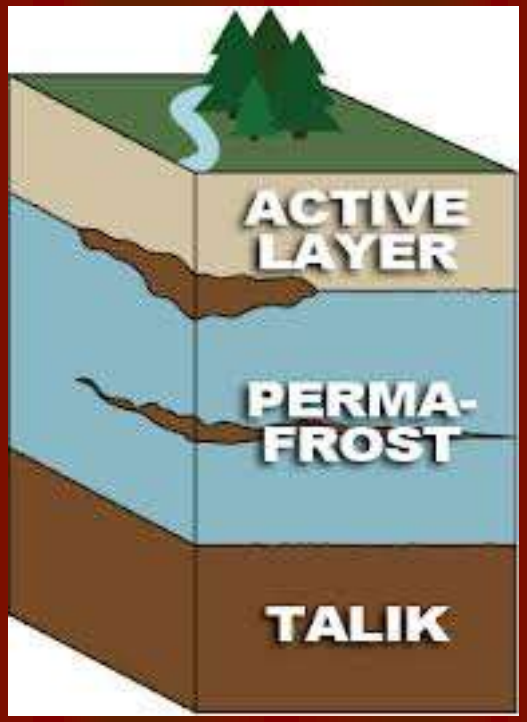
- 1. Unaltered hard parts preserved in amber, peat bog, tar or perma frost
- 2. Altered hard parts – recrystallization, replacement (Petrified by silica, pyrite, phosphate, calcium)
- 3. Carbonization (mainly plants) 炭化
- 4. Impression, Mold & Cast 模鑄
- 5. Mummification 乾化
- 6. Trace fossils 生痕 (tracks, burrows, droppings (coprolites), egg shells)
- 7. Chemical fossils or syngenetic bio markers are identifiable chemical remains of organisms eg. Steranes, Protein & DNA extracted from animals preserved in amber or tar

1. Unaltered animals preserved in fossil resin of trees
Amber 琥珀 with insect

Unaltered animals preserved in tar pits 瀝青湖

La Brea Tar Pits Los Angeles, USA (8,000 – 40,000 Ya) & Messel, Germany (Eocene 47 Ma)

“Lyuba” the Baby Mammoth 猛獁
42,000 ya preserved in Siberia perma frost 永凍土

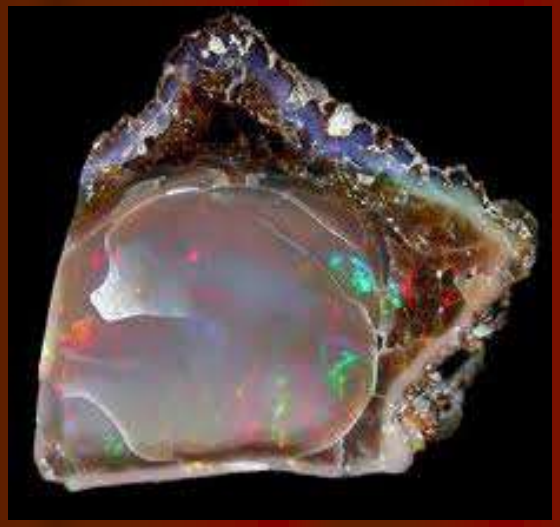


2. Altered hard parts - Petrified wood 硅化木

Petro means "wood changed to stone" (Arizona 160 ma)

Opalized wood & mollusks

Opal is a hydrated amorphous form of silica



Pyritized ammonite (FeS_2) 黃鐵礦化菊石

3. Carbonization of plants 炭化植物

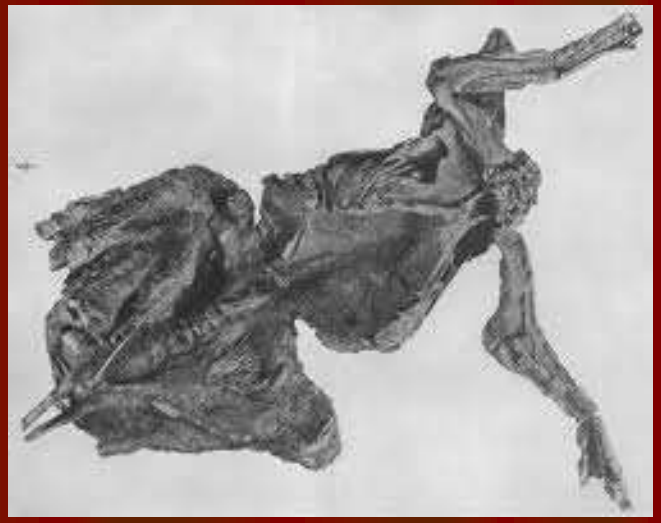





4. Mold & cast 模印

Ammonite, trilobite & branchiopod

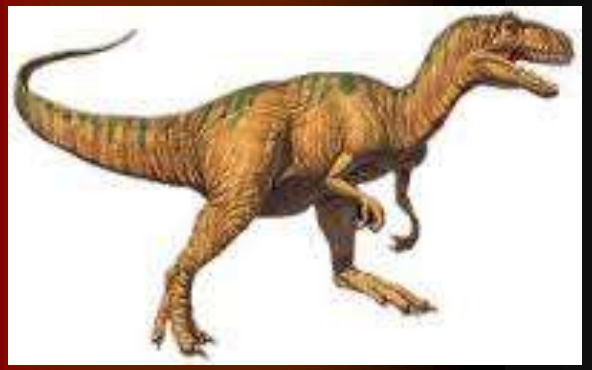
5.Mummification 乾化 : dinosaur parts & the 4th century BC Tollund Man found in Denmark



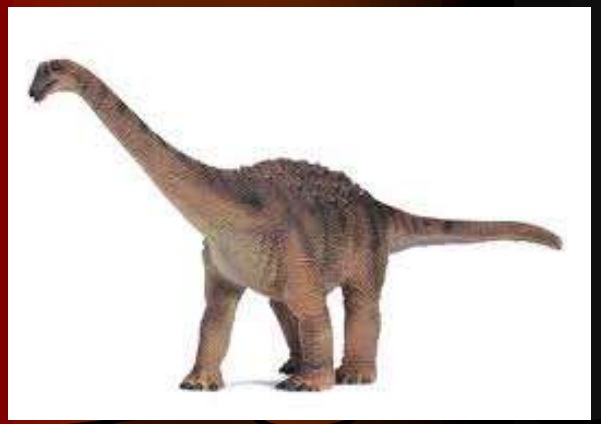
6. Trace fossil 生痕/印痕化石：burrows, gastrolith, coprolite, trilobite tracks, dinosaur footprint & egg shell

Trace fossils : dinosaur tracks
there are 2,000 sites in the world

- Theropod track mark



- Sauropod track mark



Trace fossil足跡 – a 3.6 million year old hominid foot print of *Australopithecus afarensis*. The study of footprint is called Ichnology

Where to find fossils ?

- Fossils are mostly found in sedimentary rocks particularly limestone, clays, siltstones, mudstones and shale but also available in volcanic ash/tuft
- Go for outcrops, road cuttings, quarry, mines, cliffs & beaches

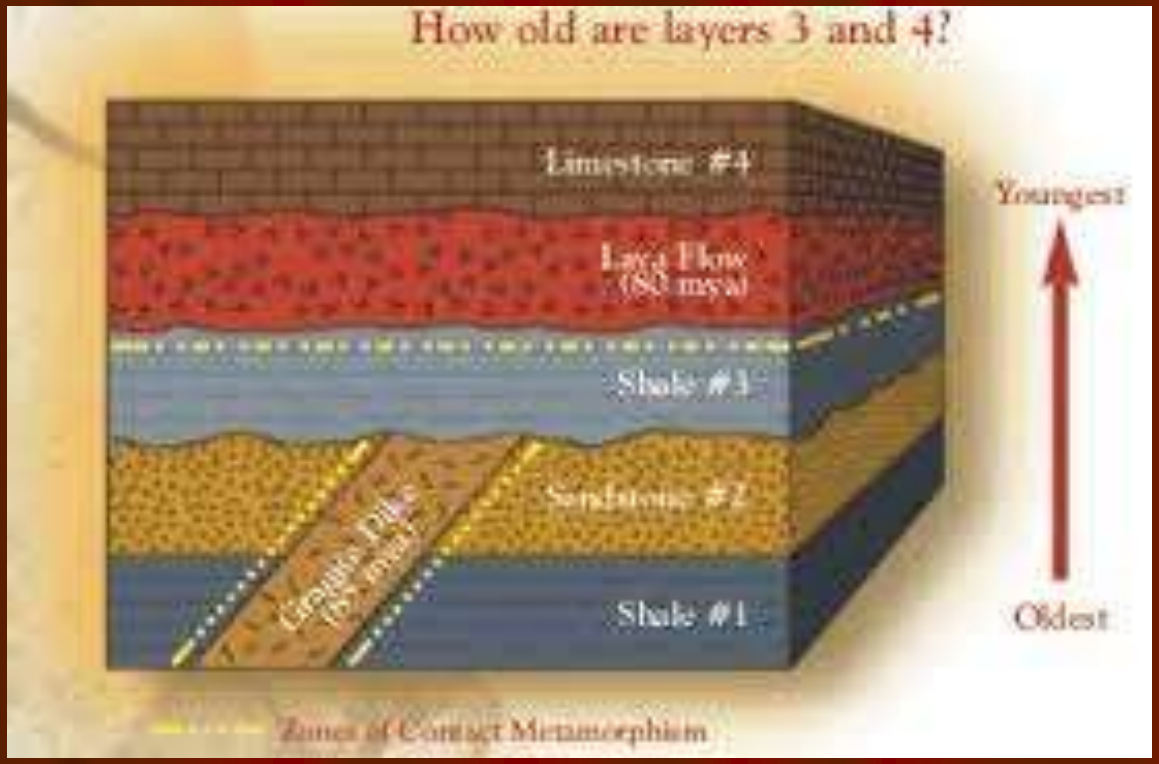





Dating Fossils

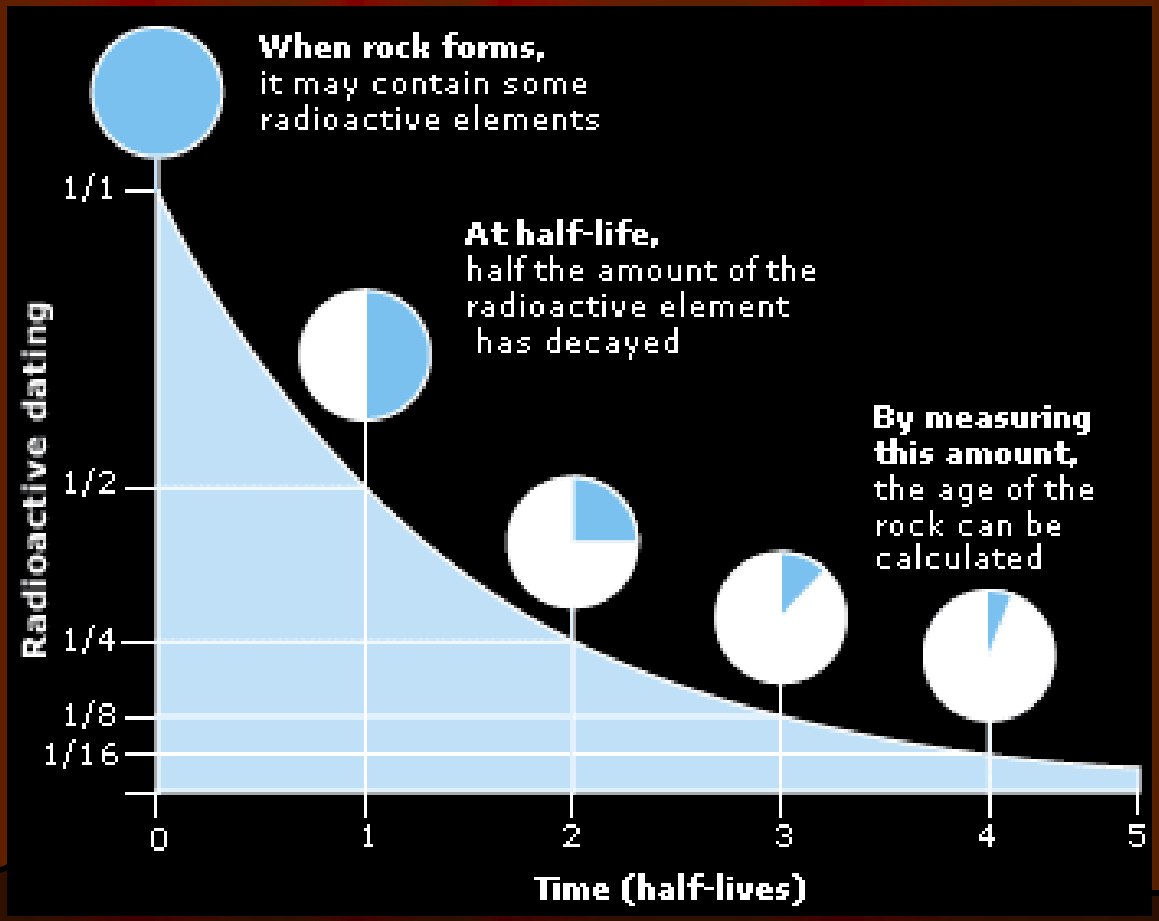
Principle of Superpoistion

Shows the Relative Age. Absolute age is mainly determined by testing the age of the igneous rocks around it as well as testing the fossil itself



Radiometric dating

Actual Age can be determined by measuring the rate of radioactive isotopes decay in certain minerals in rocks from the parent element to the daughter element



Examples of Radiometric Dating

Carbon C-14 to Nitrogen N-14 : No good for material older than 50,000 years old

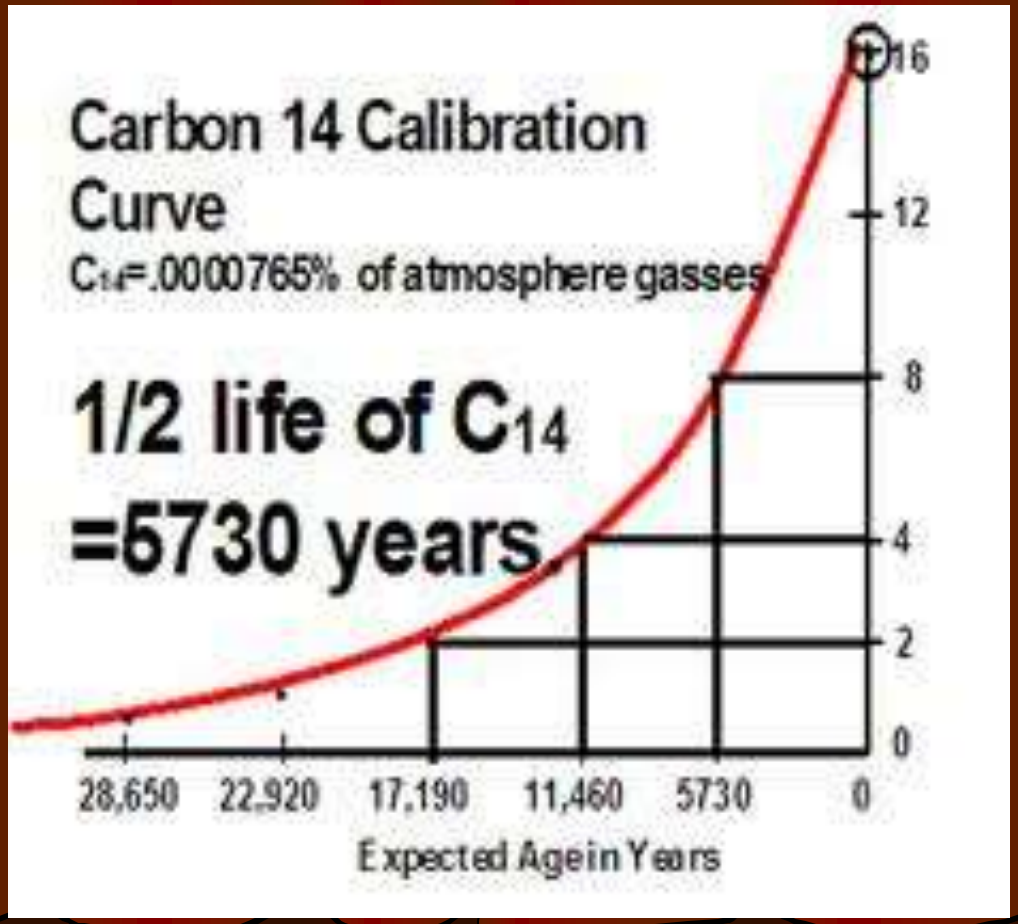
Uranium 235 to Lead 207 or U238 to Pb206 : good for 10m to 4.5 billion years

Rubidium to Strontium : 10m to 4.5 billion years

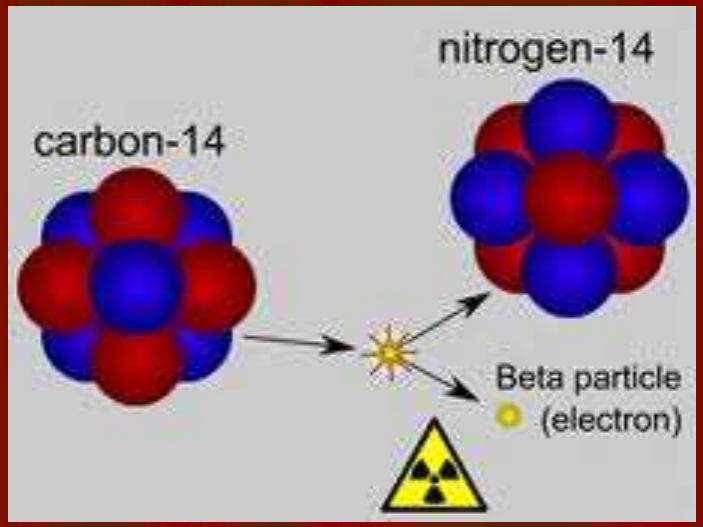
Potassium 40 to Argon gas 40 : 100,000 t0 4.5 billion yr

Radiocarbon dating

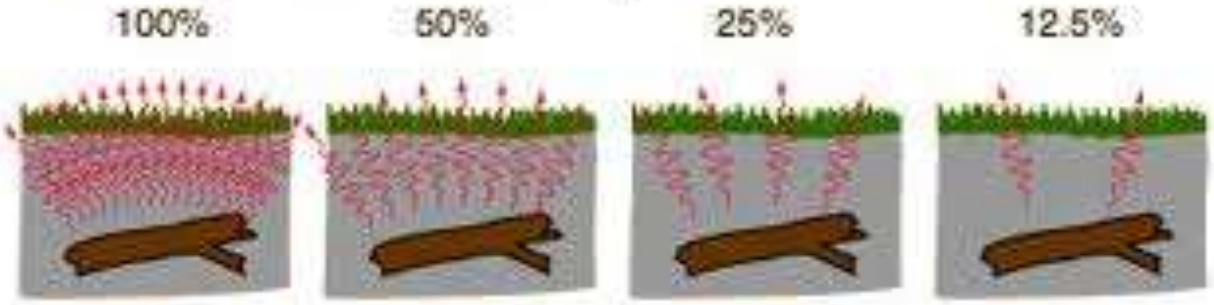
Carbon has a radio active isotope C_{14} with Half life at 5,730 years mainly use for dating organic material such as wood, leather, bones & shells



Beta counting

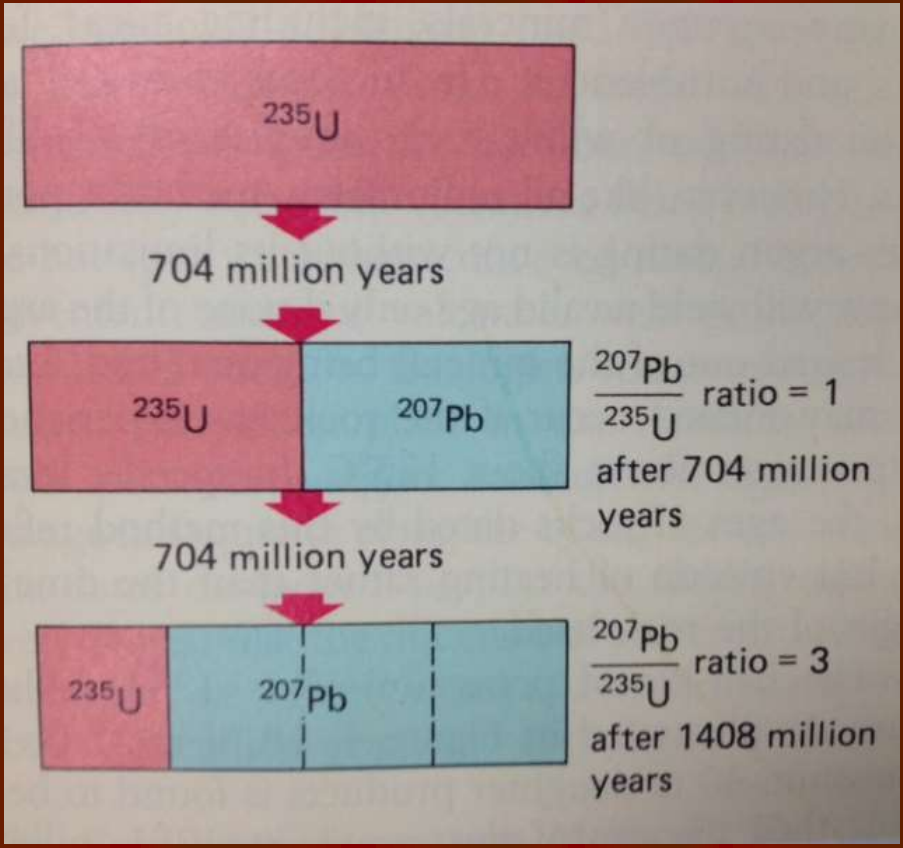


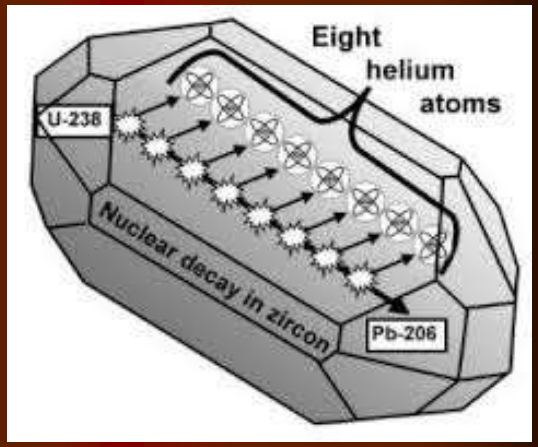
Measurement of the beta decay activity of a buried piece of wood provides a measurement of the time elapsed since it was living and in equilibrium with the atmosphere.



Uranium Lead dating

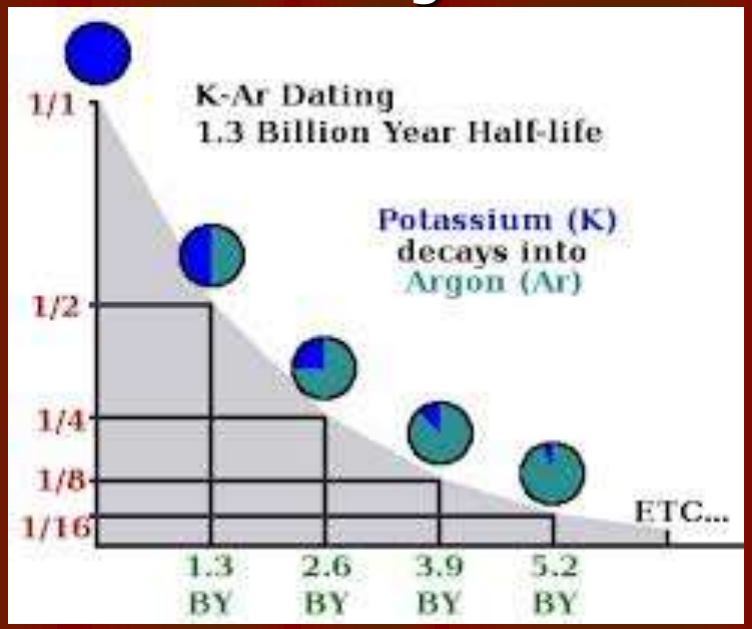
From ^{235}U to ^{207}U or ^{238}U to ^{206}U 鈾 latter usually performed on zircon (fissure track dating in volcanic tuft)



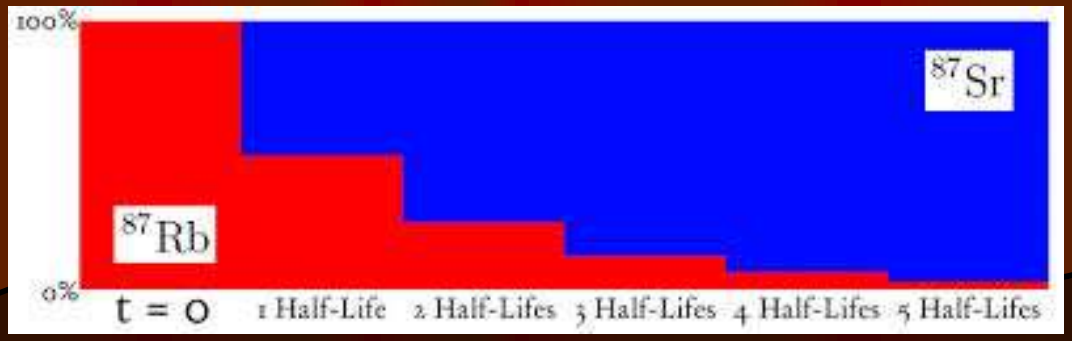


Potassium Argon aka K-Ar dating

Ideal for dating lava flow

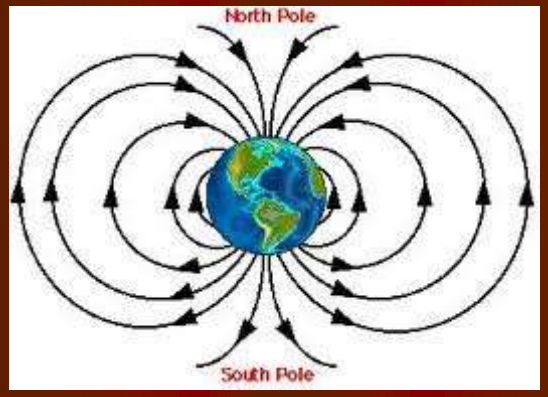


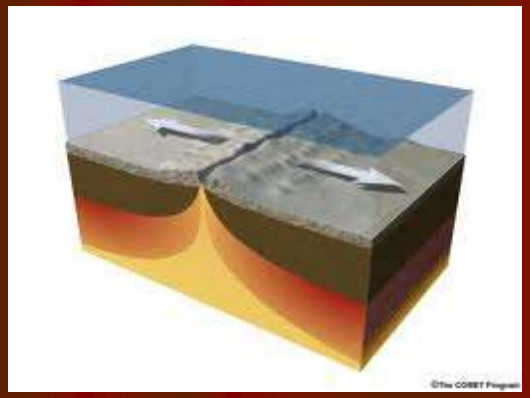
Rubidium Strontium Dating

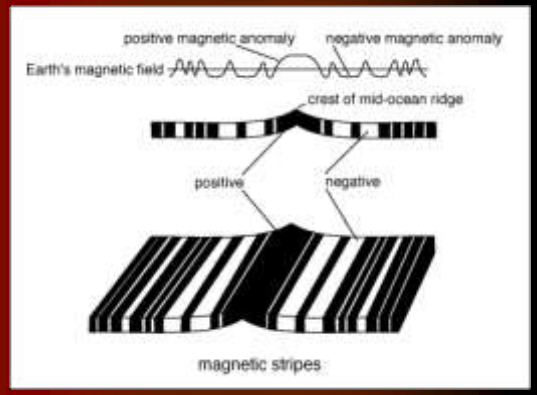


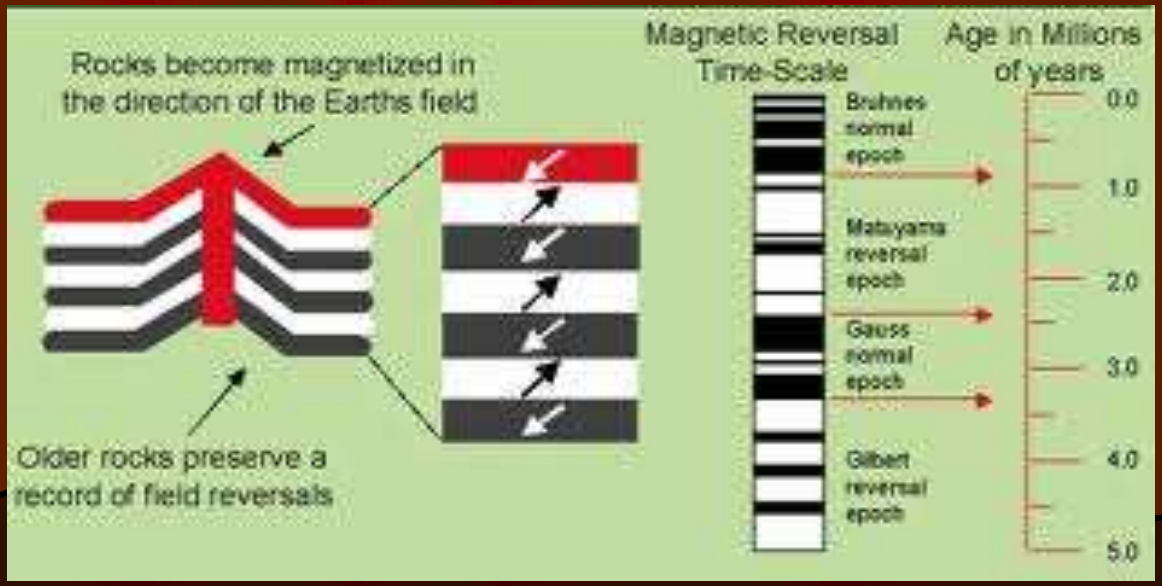
Geomagnetic dating 古地磁學

The earth's magnetic poles flipped 4/5 times per million year & minerals in rocks preserved the prevailing magnetic direction when formed. Age can be determined by comparing same to the Geomagnetic Polarity Time Scale (GPTC)





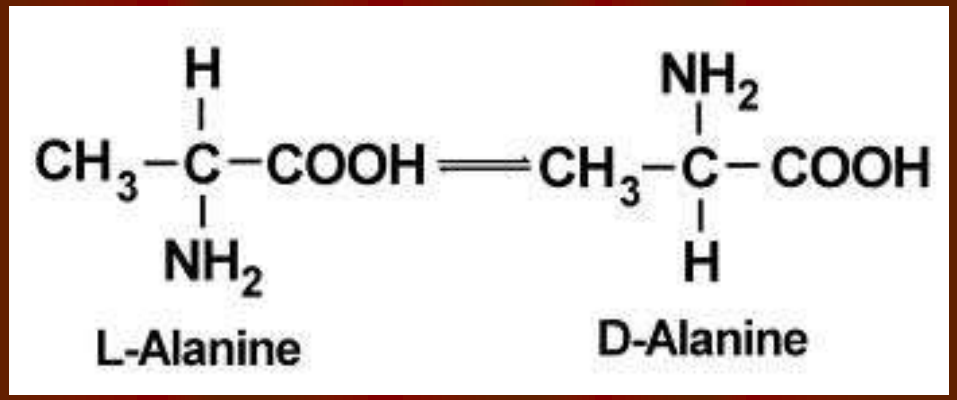


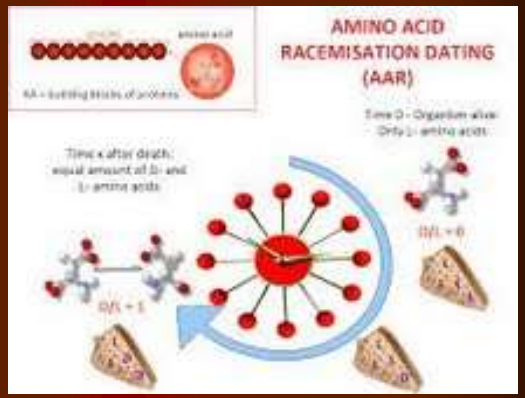


Amino acid dating

All biological tissues contain amino acid.

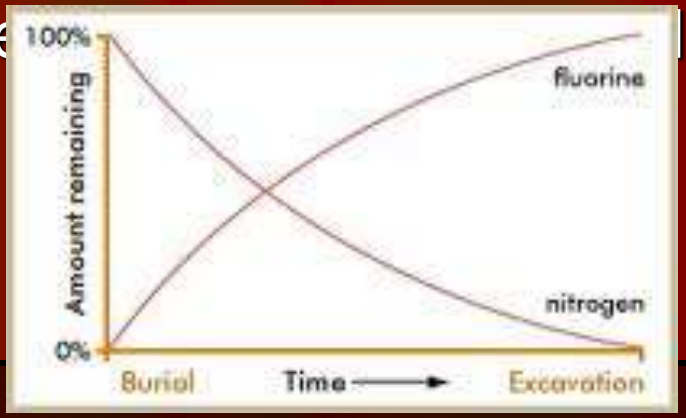
Two configurations Living "L" to Dead "D"





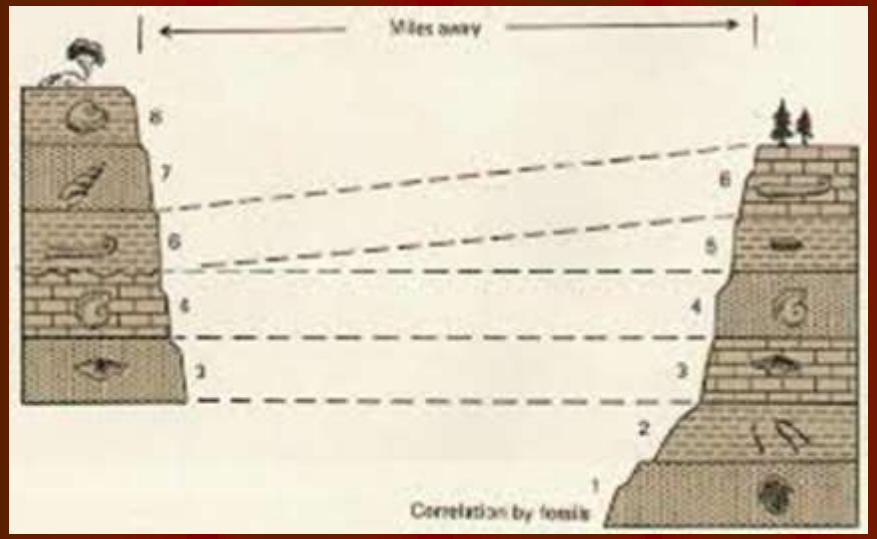
Fluorine absorption test

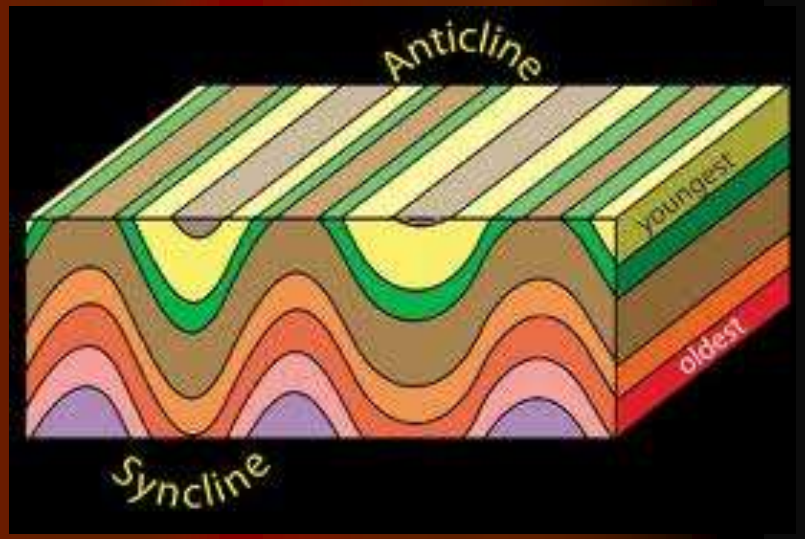
can only determine the relative age by measuring the amount of fluorine absorbed by bones from ground wate le ions

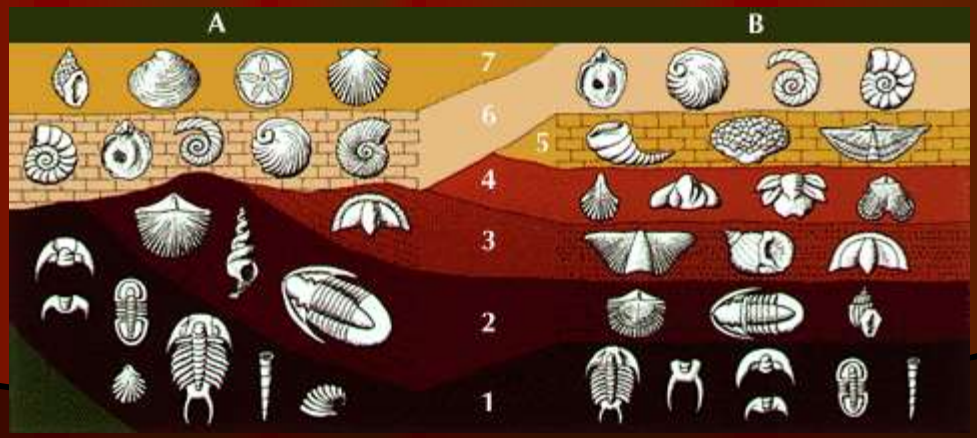


Importance of fossils

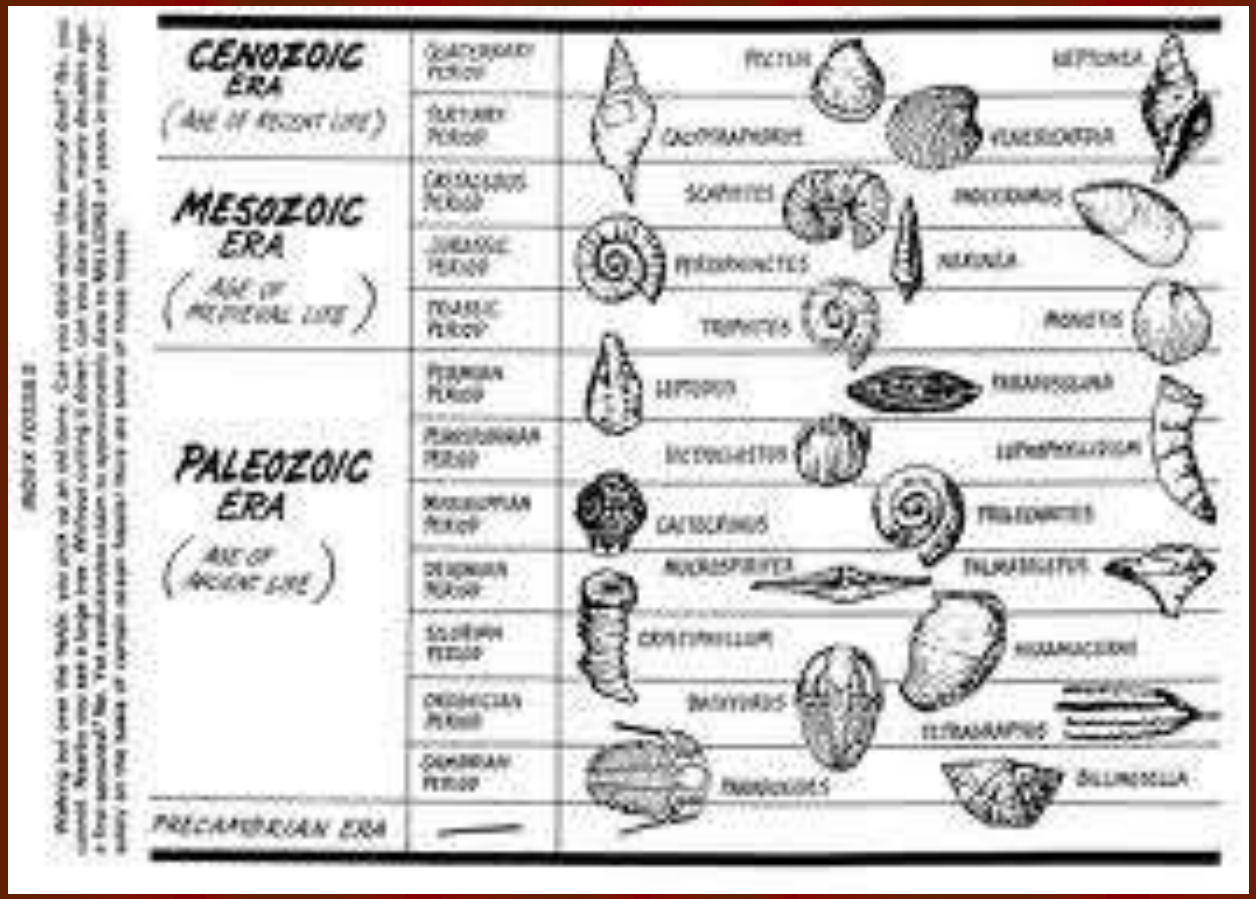
- 1. Help identify the origin, age and relationship of sedimentary rock through Biostratigraphy which is basis on the Law of Fossil Succession



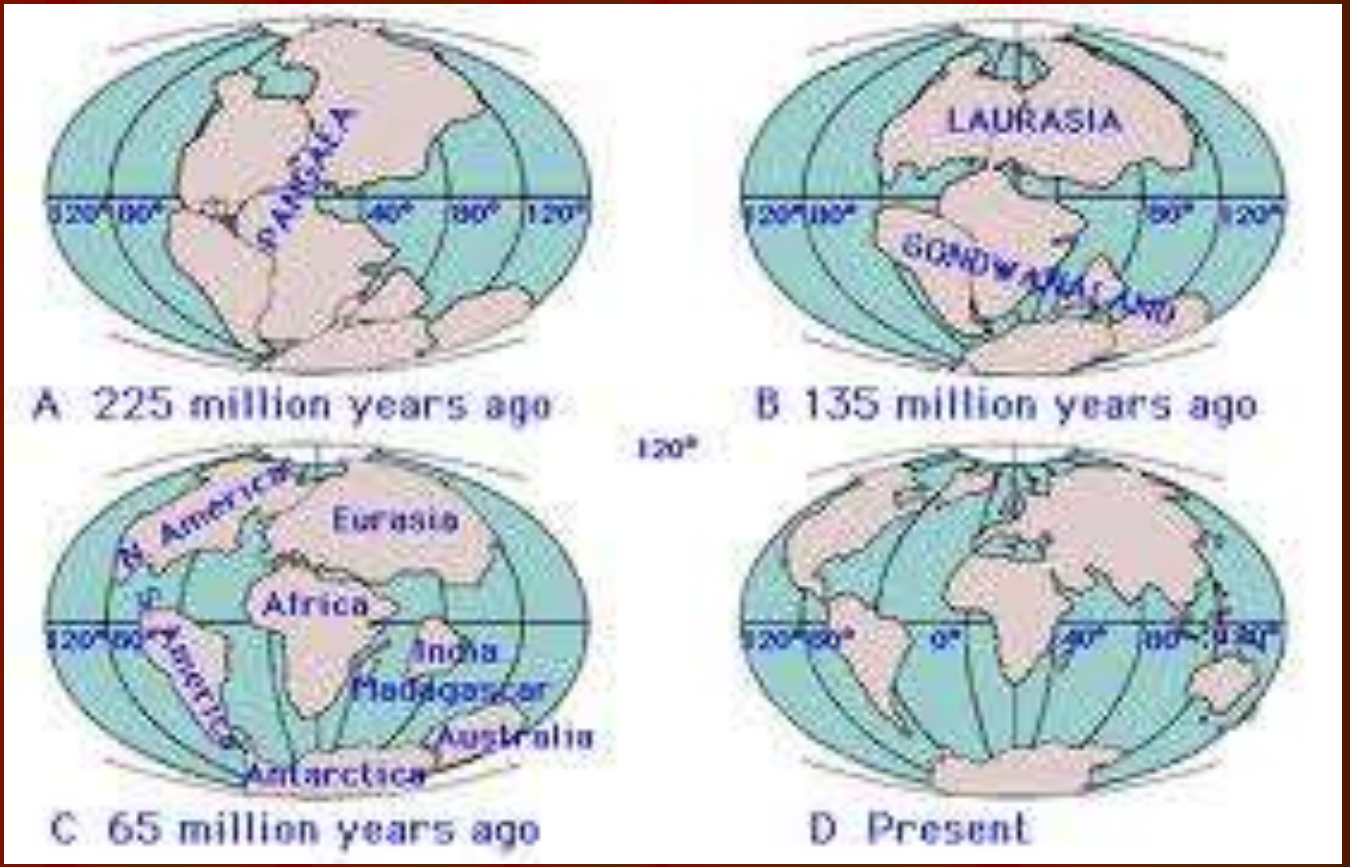




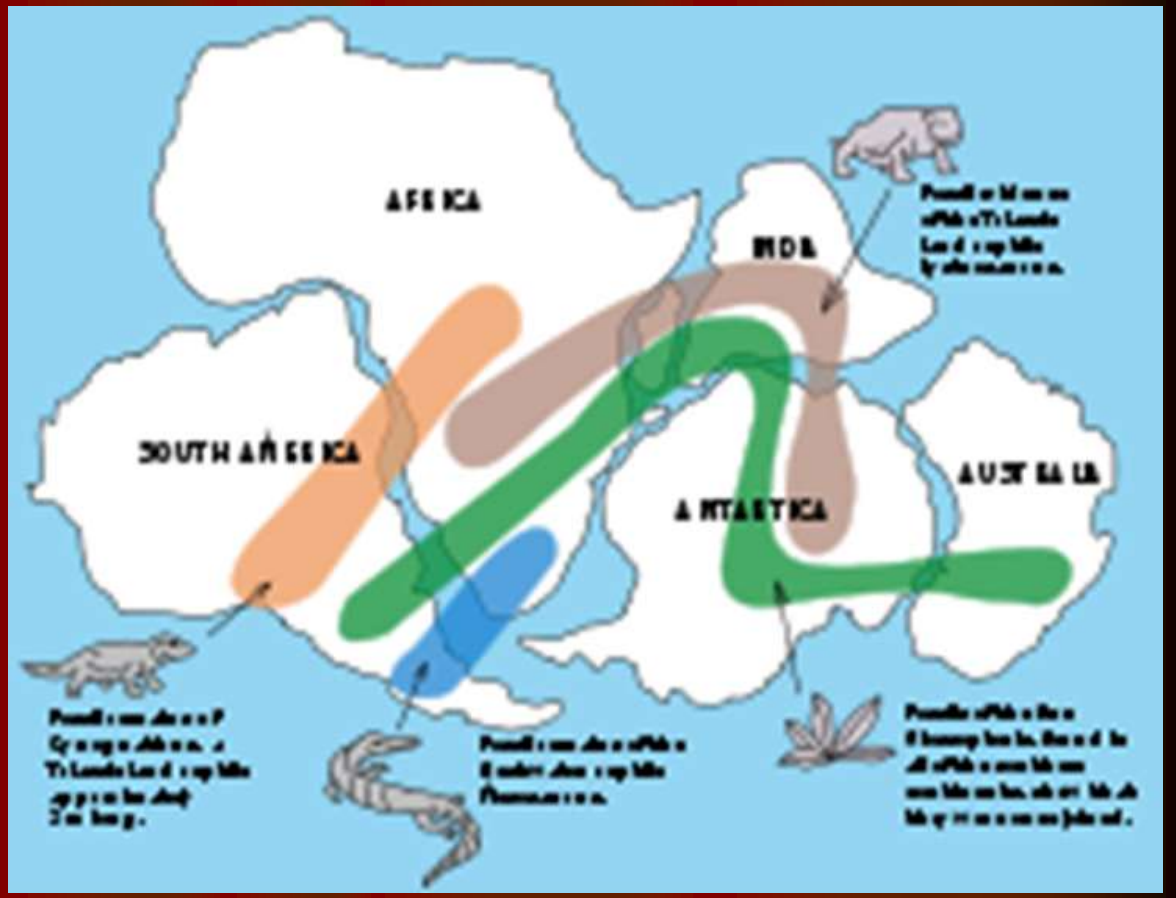
Biostratigraphy relies on the usage of
"Index fossils" or "Zone fossils" 指標化石 to know the relative age
(common index fossils: graptolite/trilobite/brachiopod/ ammonite)



2. Support Alfred Wegener's Continental Drift theory in 1912 as well as the theory of Plate Tectonic

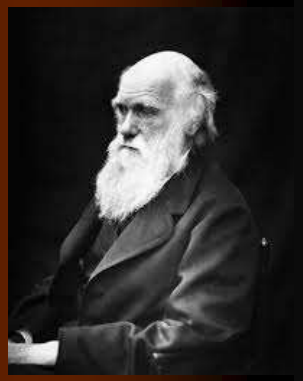


Similar plant & animal fossils across the continents eg. Mesosaurs 中龍 & Lystrosaurus 水龍獸



3. Support Darwin theory of Evolution

Evolution of living organism is changes through time by mutation 基因突變 with natural selection 天擇 eliminating the harmful ones whilst favorable ones are preserved & passed down by heredity 遺傳 – "Survival of the fittest "

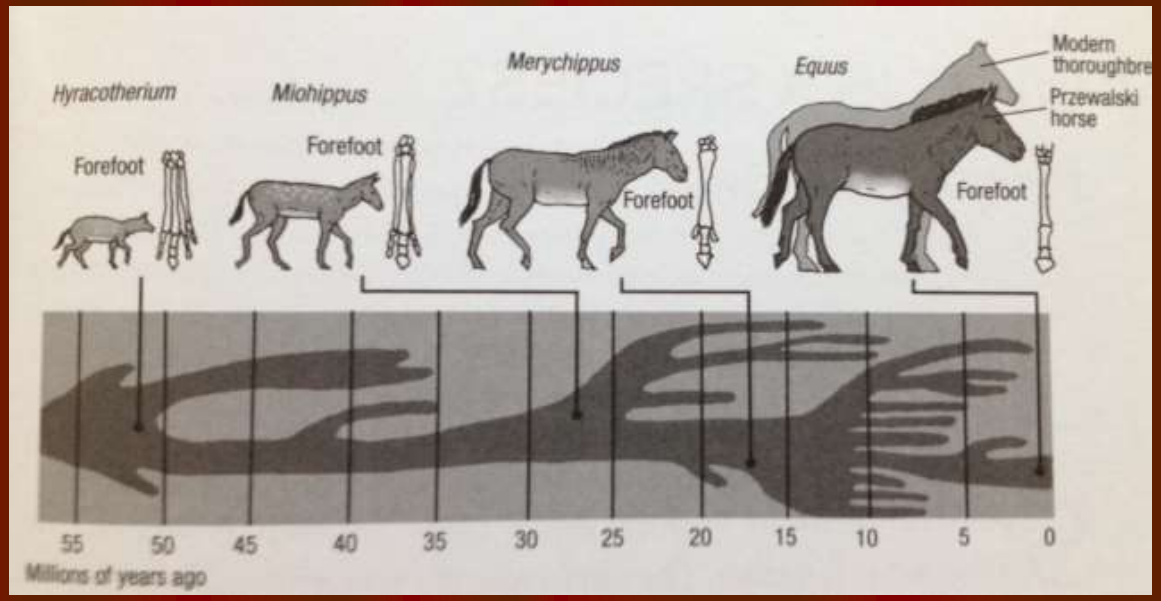


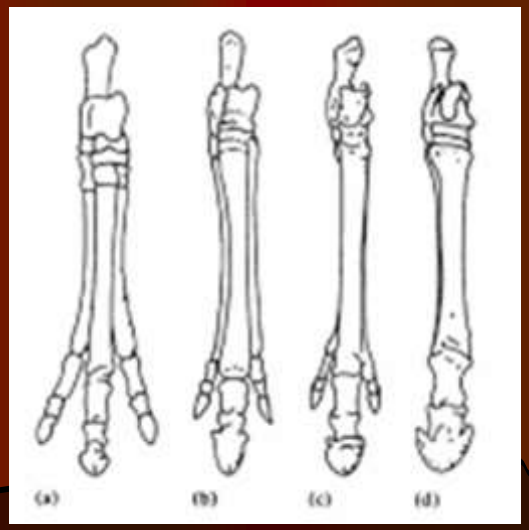
Mutation is to a large extend triggered by the change in the living environment (eg. climate, food; space & chance to mate)

All living things descend from a common ancestor. Did not address where the common ancestor (LUCA) come from – Game of Chance or Divine Creation ?

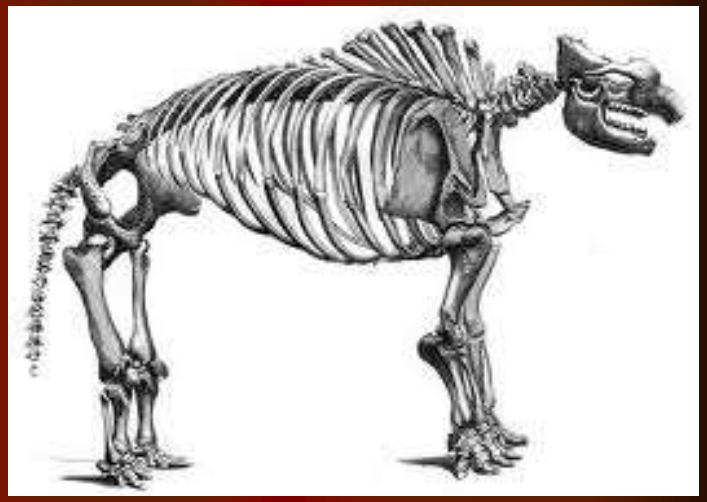
Some Evidence of evolution through fossils

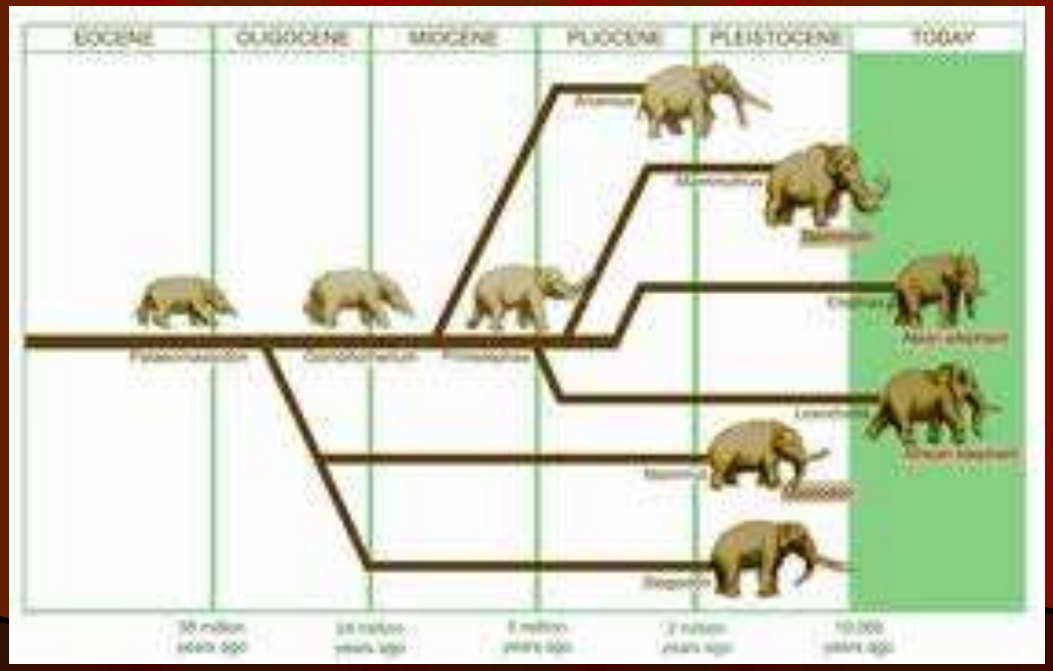
a. Horses - from toes to hoofs over 55 ma

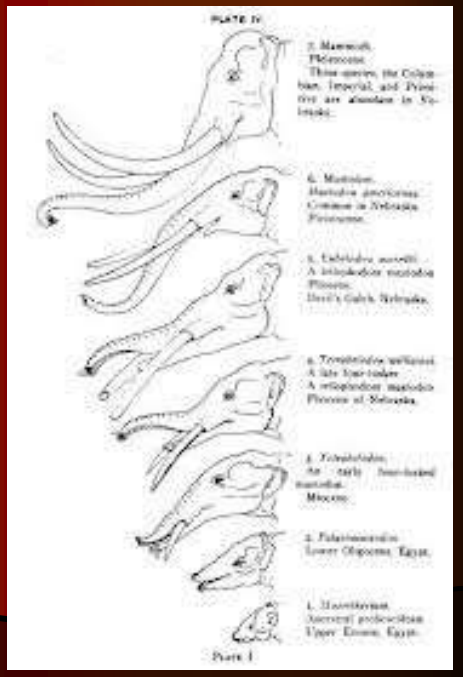




b. 60 million years of Elephant Evolution

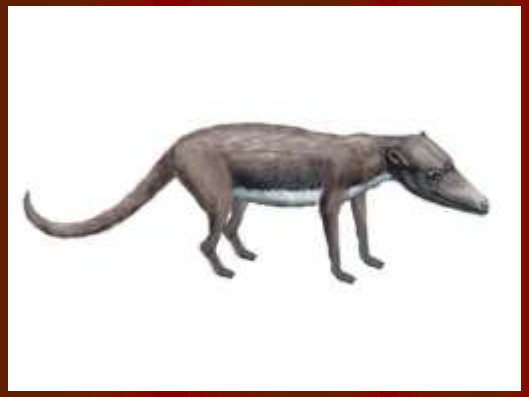


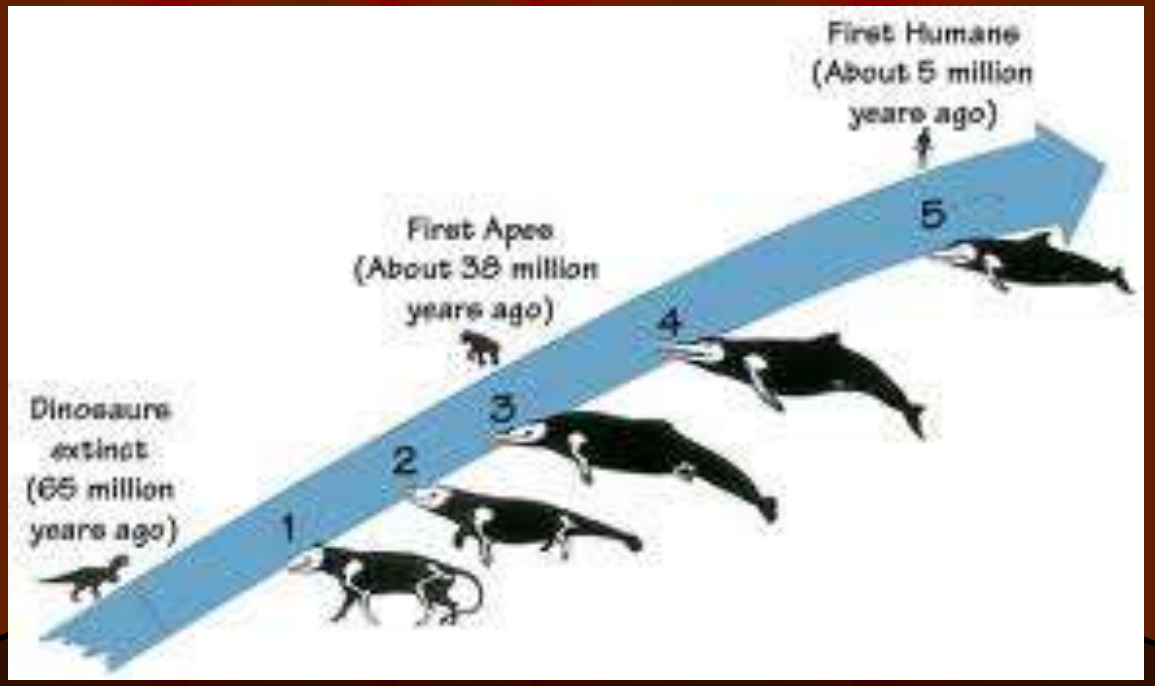




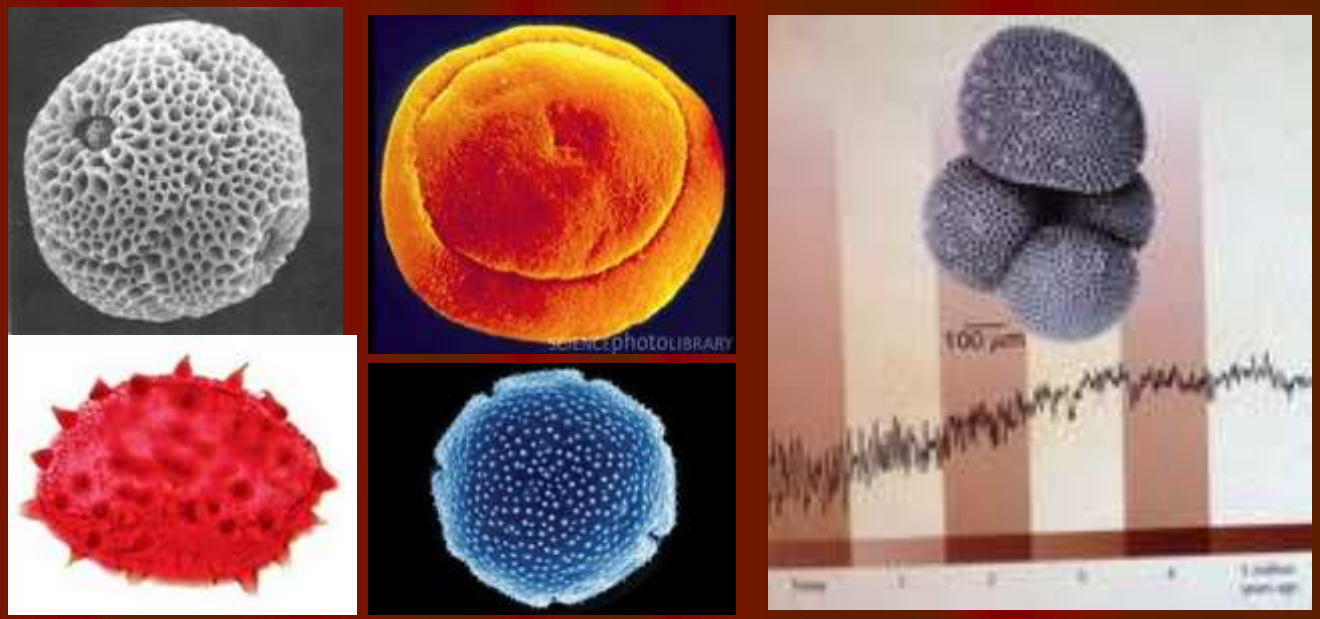
c. Mammal returning to the sea -Dolphin

哺乳類回歸海洋





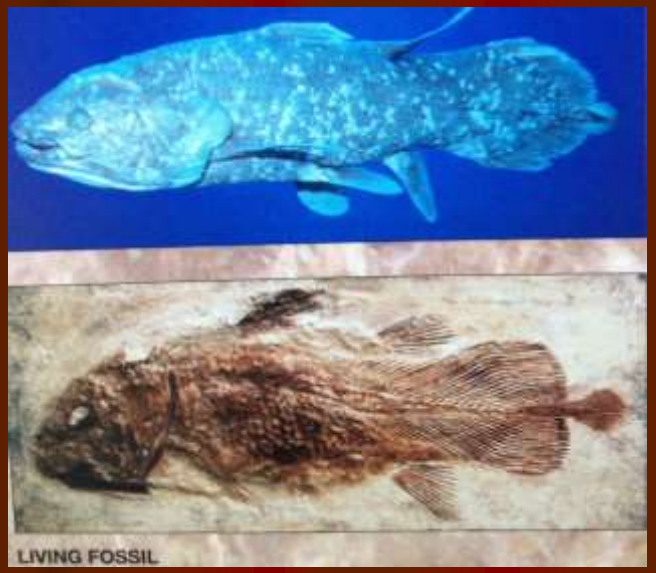
- 4. For the study of Paleoclimatology 古氣候學, Paleoanthropology 古人類學 etc. Palynology which is the study of ancient pollen 花粉 can indicate ancient environmental conditions including temperature and rainfall by analyzing the isotopic composition



- 5. Help to locate natural resources like oil & gas particularly with micro fossils like Foraminifera

Living fossil 活化石

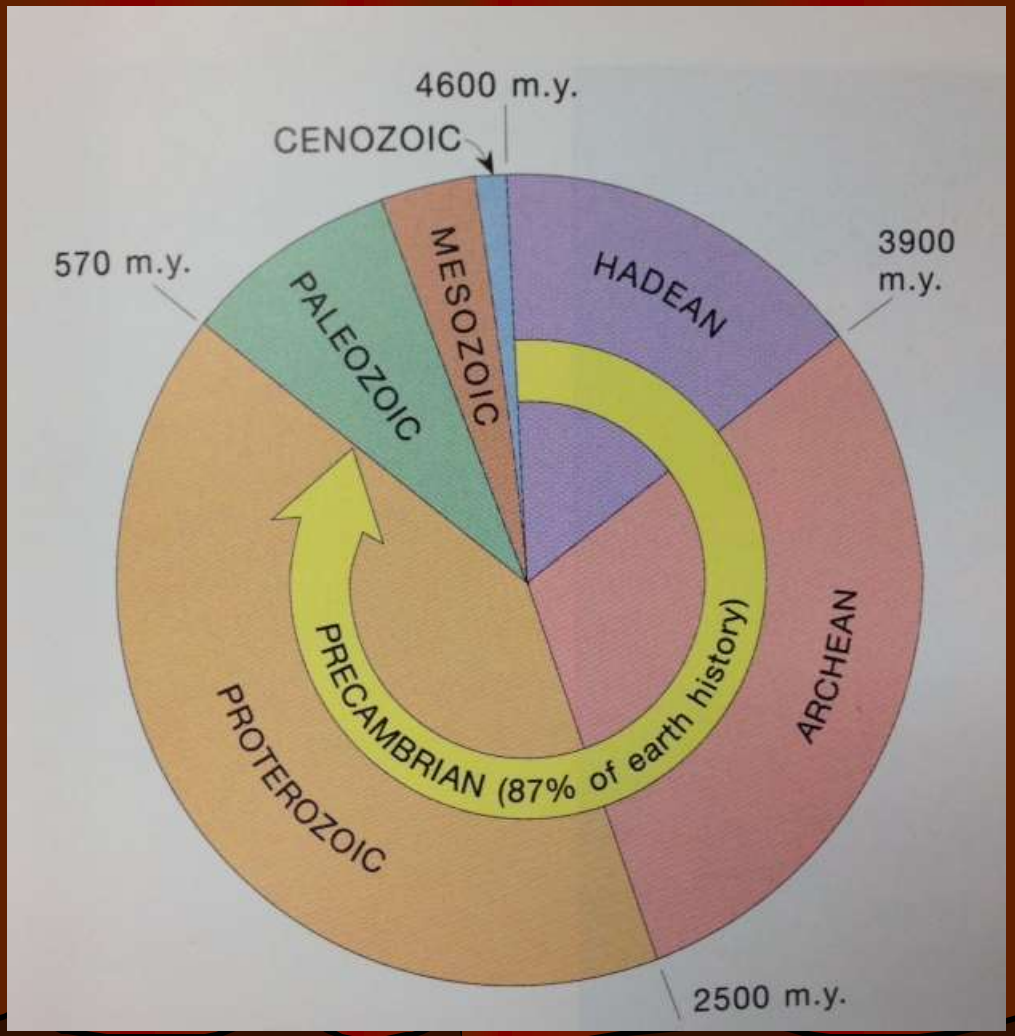
Coelacanth 腔棘魚, Nautilus 鸚鵡螺, Lingula 舌形貝/海豆牙, Horse shoe Crab 鱟 & Gingko tree 白果



Development of life on earth
Paleontology is a Journey through time

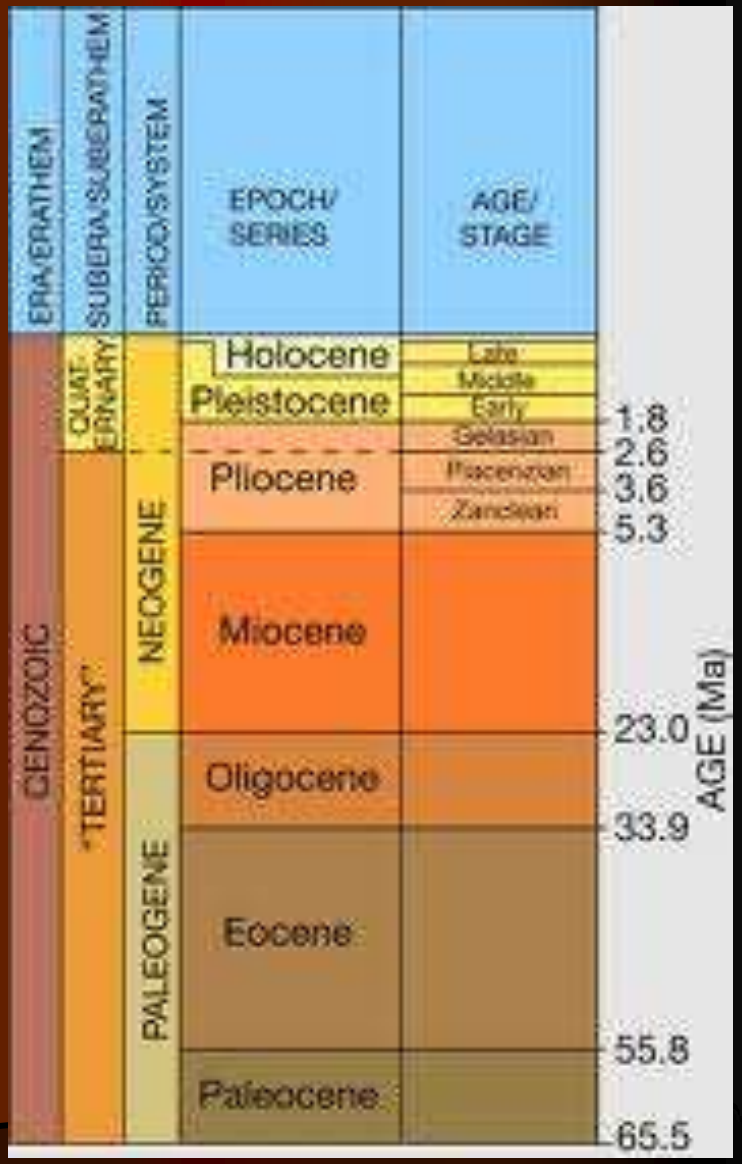
Geological Time Table 地質年代表

Eon 宙, Era 代, Period 紀, Epoch 世, Age 期



Geological Time Table 地質年代表

宙 Eon	代 Era	紀 Period	百萬年 m.y.
顯生宙 Phanerozoic 複雜的多細胞生物大量出現的時代 An era when numerous complicated multicellular organisms appeared	新生代 Cenozoic 哺乳類時代 An era of mammals	第四紀 Quaternary 人類出現 Appearance of human beings	2.6
		第三紀 Tertiary 哺乳類繁盛 Boom of mammals	65
	中生代 Mesozoic 爬蟲類時代 An era of reptiles	白堊紀 Cretaceous 恐龍滅絕	145
		侏羅紀 Jurassic 恐龍繁盛，鳥類出現 Boom of dinosaurs and appearance of birds	201
		三疊紀 Triassic 爬蟲、恐龍、哺乳類出現 Appearance of reptiles, dinosaurs, mammals	251
	古生代 Paleozoic 魚類、 兩棲類時代 An era of fish and amphibians	二疊紀 Permian 大滅絕 Extinction	299
		石炭紀 Carboniferous 兩棲類出現 Appearance of amphibians	359
		泥盆紀 Devonian 魚類出現 Appearance of fishes	416
		志留紀 Silurian	444
		奧陶紀 Ordovician	488
		寒武紀 Cambrian	542
元古宙 Proterozoic 單細胞生物至簡單多細胞生物 Unicellular organisms developed into simple multicellular organisms			2500
太古宙 Archean 原始生命誕生 Birth of primitive lives			3850
冥古宙 Hadean 地球形成的初期階段 Early stage of the earth			4600



The Development of Life on earth

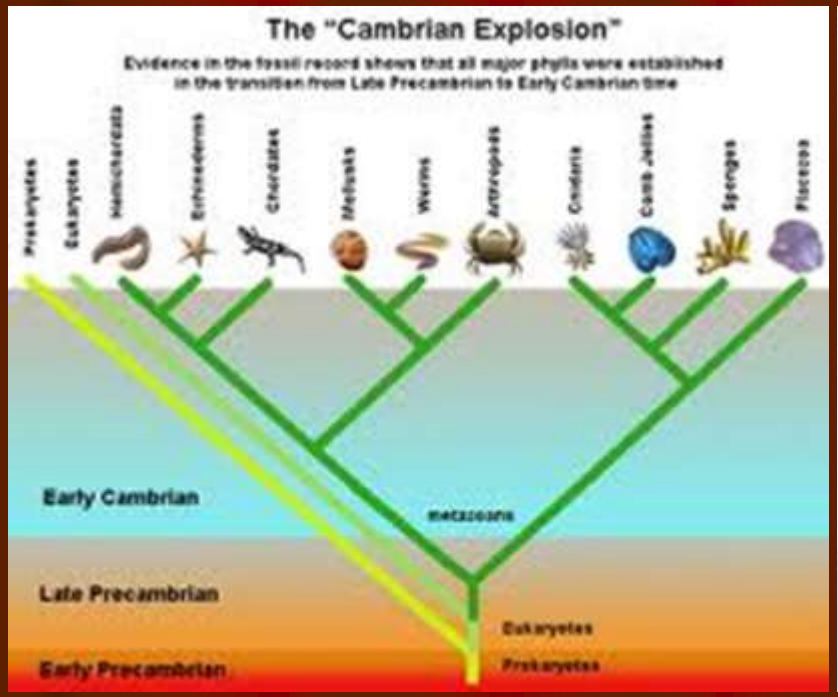
- 13.82 Ba : The Big Bang & creation of the Cosmo
- 4.56 to 3.6 Ba : Earth formed, no signs of life, hot with poisonous gas
- 3.85 Ba : Heavy Bombardment by meteorites = "water"
- 3.6 Ba : simple cells (prokaryotes)
- 3.4 Ba : Blue green algae 藍綠菌 (cyanobacteria), the source of O_2 through photosynthesis
- 1.8 Ba : Earliest multiple cell fossil (eukaryotes)
- 600 Ma : Snow Ball earth

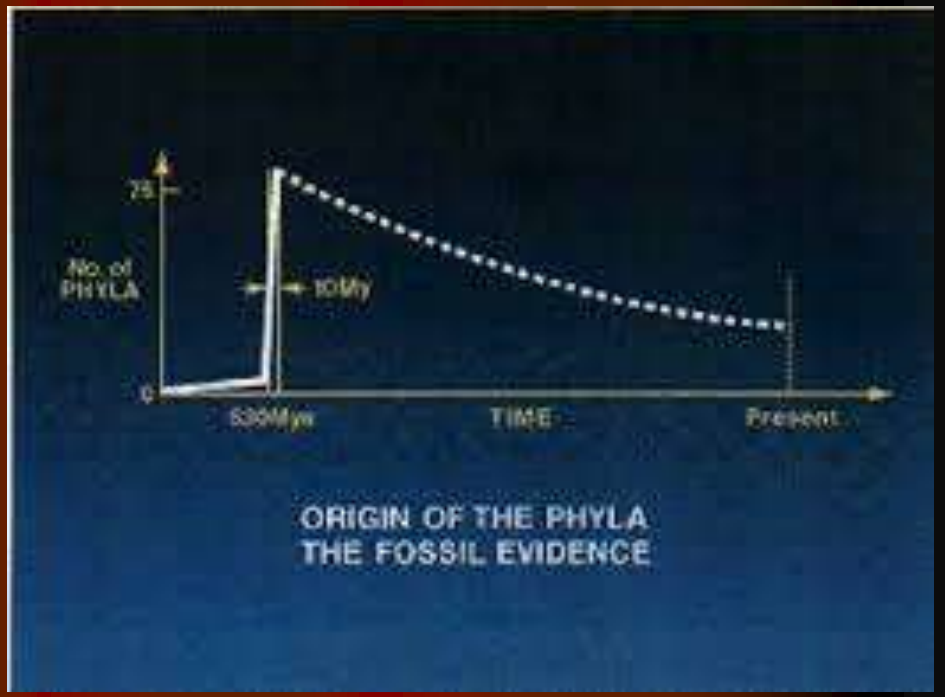
Ba: billion years ago Ma : million years ago

- 570 Ma : Beginning of the Phanerozoic 顯生宙
- 570–250 Ma : Paleozoic 古生代
- 545 Ma : The **Cambrian Explosion**

  50 phyla within 10 million years !

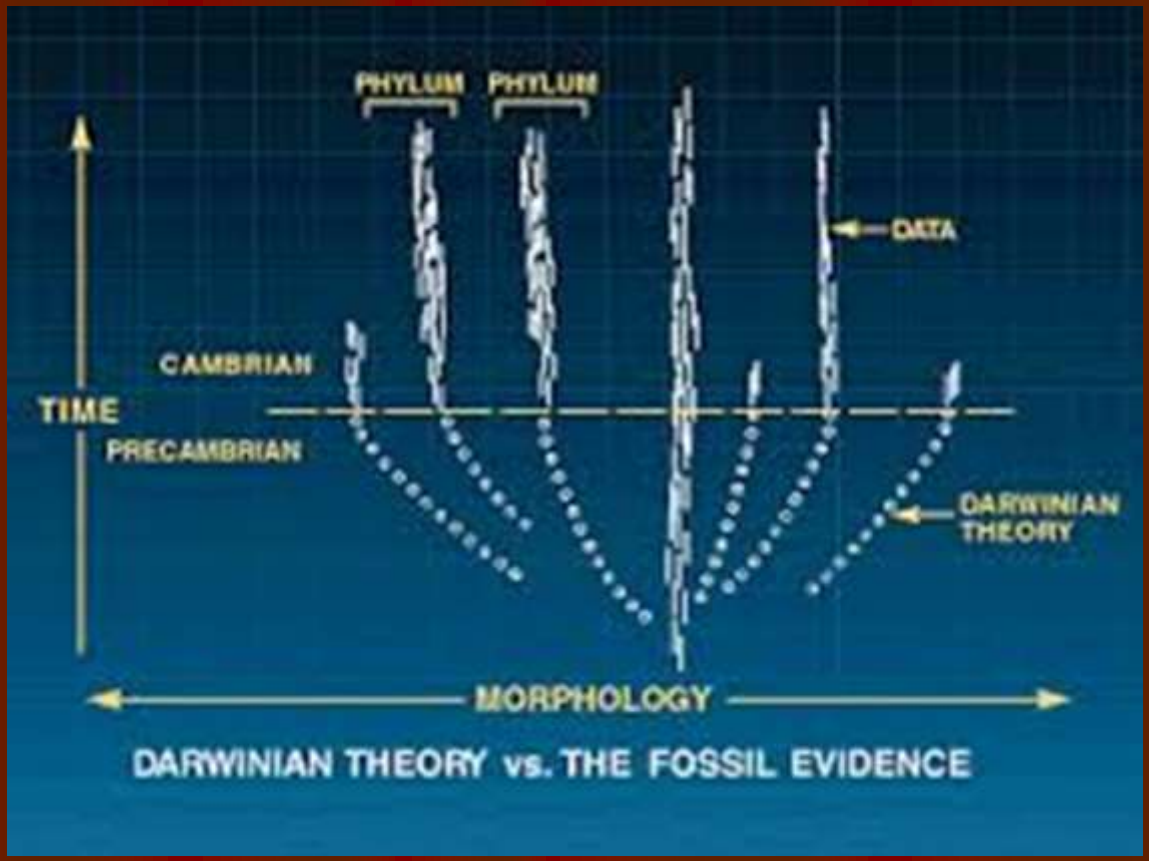
  寒武紀生命大爆發





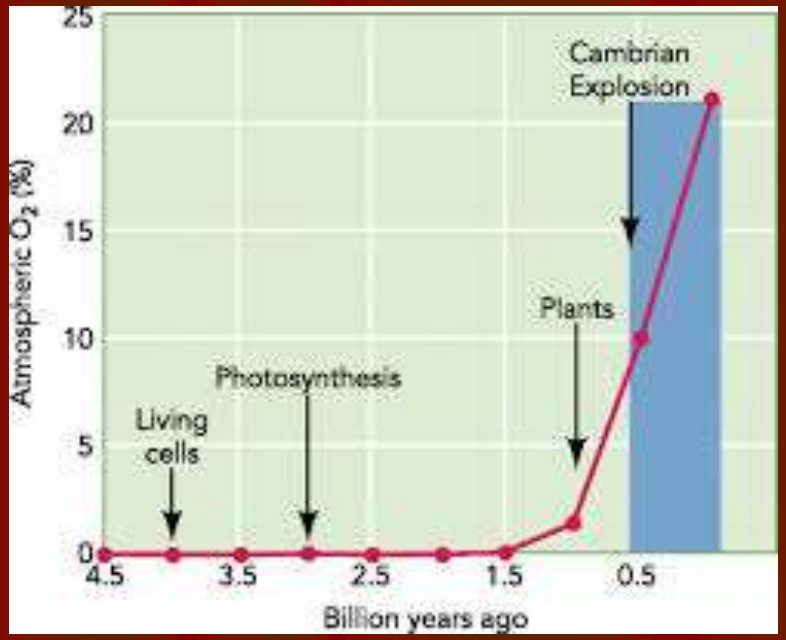
The Cambrian Explosion is counter Evolutionary

No fossil support for pre Cambrian evolution?



Some speculations accounting for the Cambrian Explosion

- Life did evolve but all soft bodied leaving no fossil record
- Upsurge in the oxygen level



- Global warming after Snow Ball Earth
- Appearance of Predators led to rivalry development between the hunters & the hunted
- Divine Creation

- 440 Ma : Late Ordovician Extinction killed 27% of all genus
- 417/354 Ma : Devonian is the "Age of Fish" 魚類世界 & **from sea to land** - amphibian, insects & plants. Late Devonian Mass Extinction at 360 Ma also killed 50% of all genus
- 354/290 Ma : Carboniferous , formation of coal
- 290/248 Ma : Permian Mass Extinction termed the "Great Dying" at 251 Ma killed 83% of all genus & 96% of all life including all Trilobites

- 250 to 65 Ma : Mesozoic 中生代 Age of the Reptile 爬行類世界

  Flowering plants 140 Ma

  The Triassic – Jurassic Mass Extinction at 205 Ma killed 48% of all genera. The K-T Mass Extinction at 65 Ma killed 50% of all genera including the dinosaurs & ammonites

- 65 Ma to now* : Cenozoic 新生代
  Tertiary : Age of Mammals 哺乳類世界
  Quaternary : Age of Man 人類世界

(* now = 1950 the year Radiometric dating was introduced)

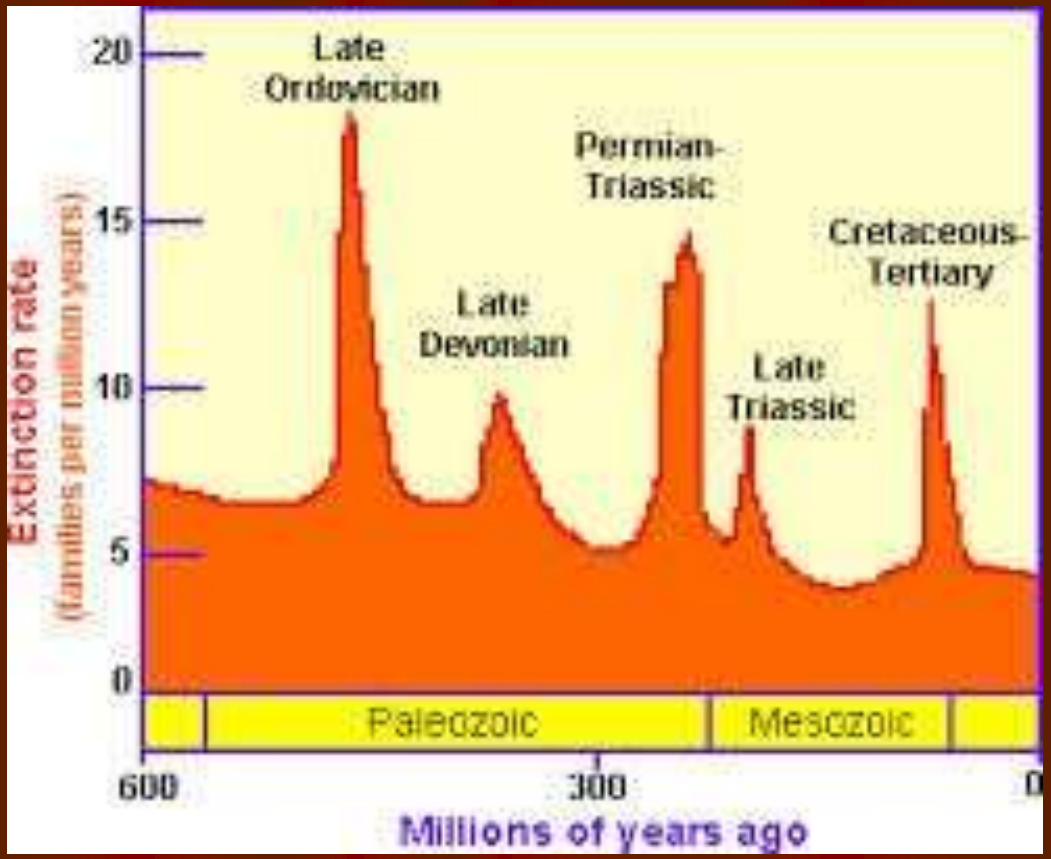
The Development of Life on Earth

- 570 million years of arthropods
- 500 million years of fish
- 475 million years of land plant
- 400 million years of insect & seeds
- 360 million years of amphibians
- 300 million years of reptiles
- 200 million years of mammal
- 150 million years of birds
- 130 million years of flowers
- 66 million years since the dinosaurs died out
- 20 million years of Hominid
- 200,000 years of Homo sapiens !

The Mass Extinctions
生命大滅絕

The 5 major Mass Extinctions 物種滅絕

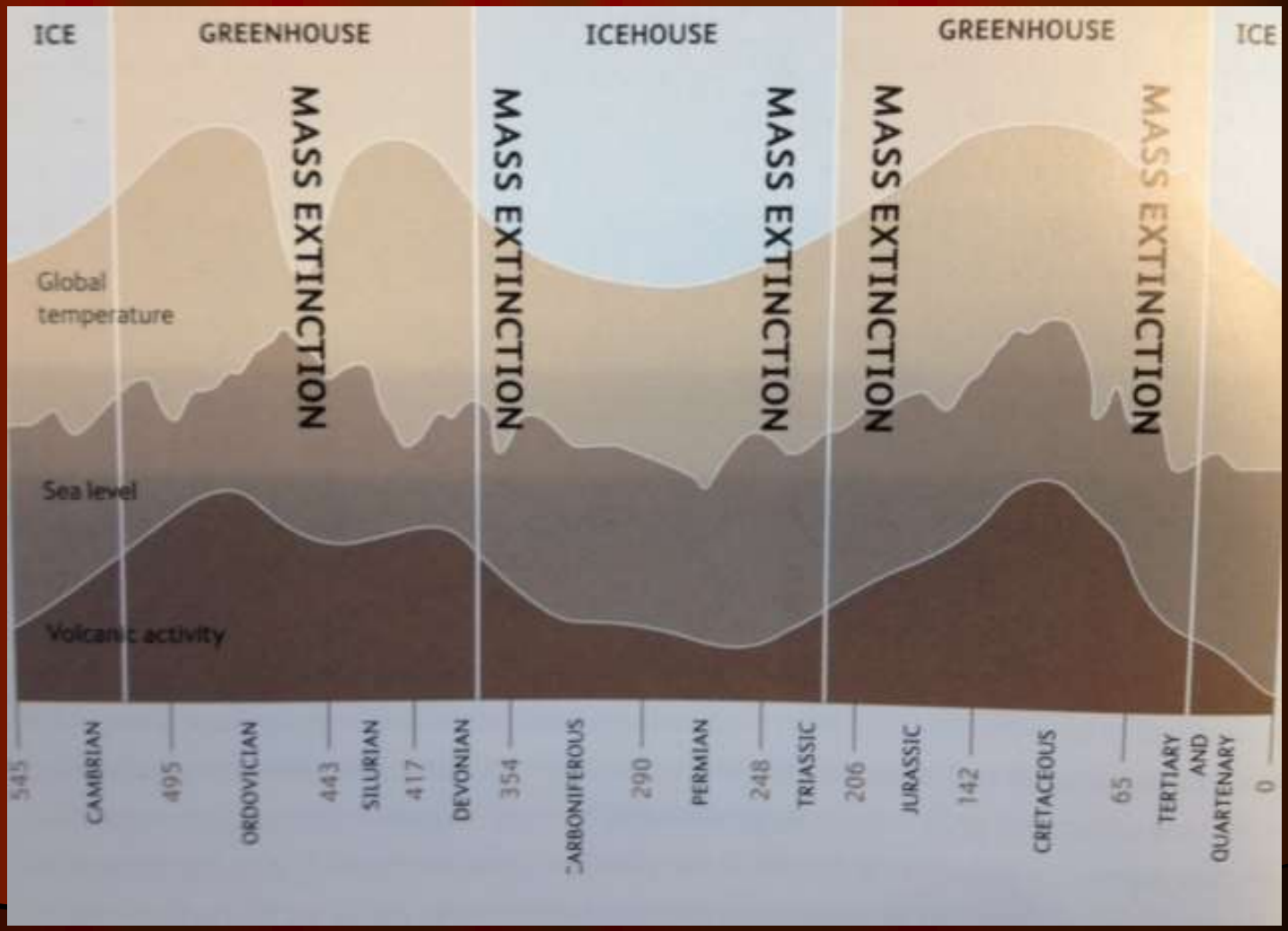
Ordovician 440 Ma, Devonian 365 Ma, Permian 251Ma, Triassic/Jurassic 205 Ma , KT 65Mya



Some possible reasons for the Mass Extinctions

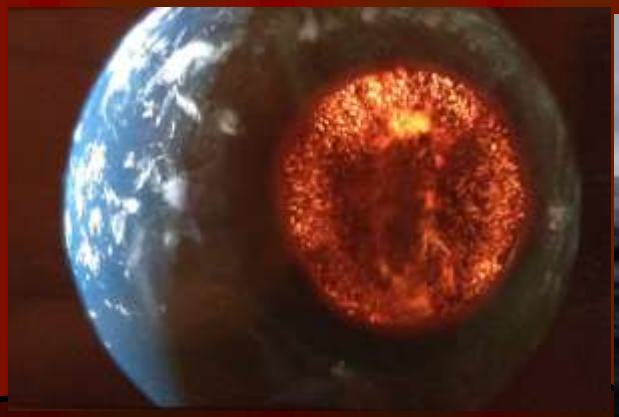
- Fall of sea level (Glaciation/Ice Age)
- Asteroid impact (K-T boundary: iridium, hit quartz)
- Global warming/ cooling
- Volcanic activities (Flood basalt eg. Deccan plateau India)
- Effect of H2S, methane 甲烷, ocean overturn
- Diseases
- Solar flare 日焰
- A combination of some of the above

Relationship between the 5 major mass extinction with temperature, sea level & volcanic activities

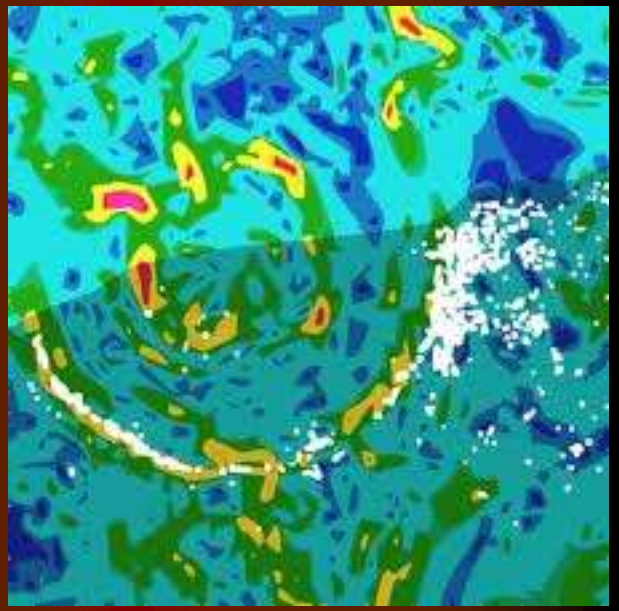


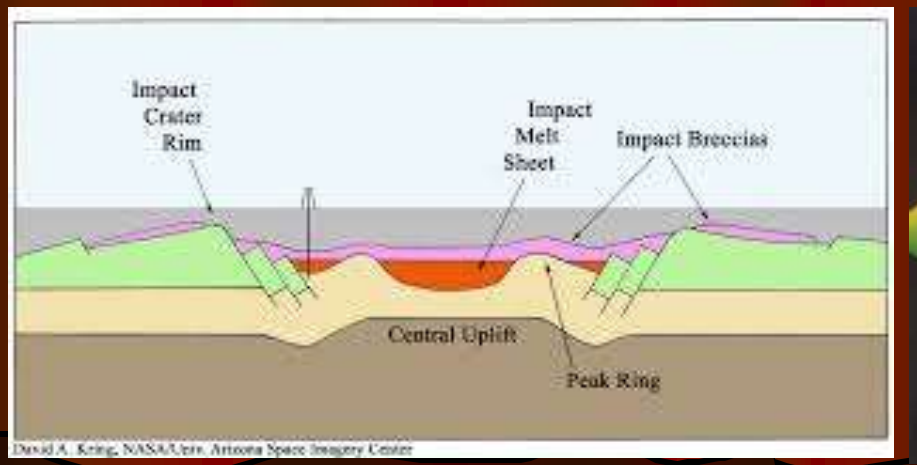
Asteroid strike

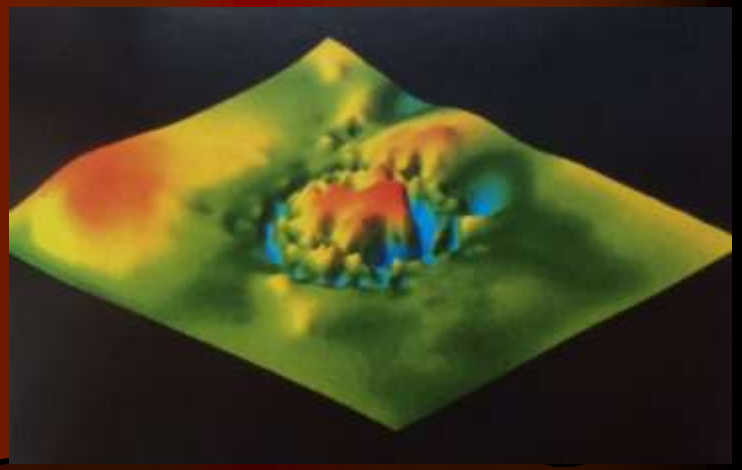
K-T Event at 65 Ma：An asteroid 10km in diameter moving at 40 times the speed of sound created a scale 11 earthquake & 300 m high tsunami. Its immediate destructive power is equivalent to 100 trillion tons of TNT !



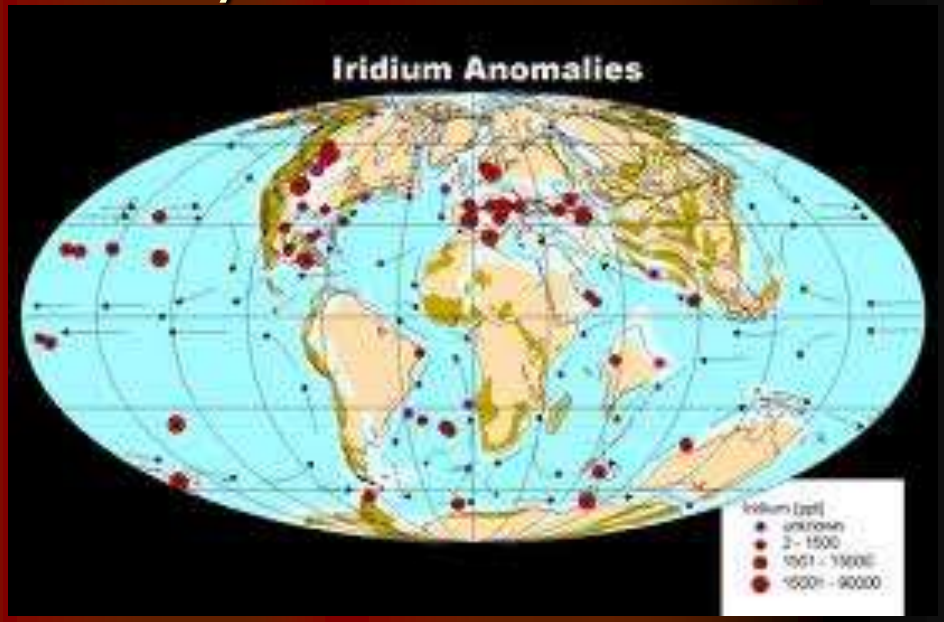
The asteroid strike at Yucatan created the Chicxulub Crater. All animals larger than 25 kilo could not survive

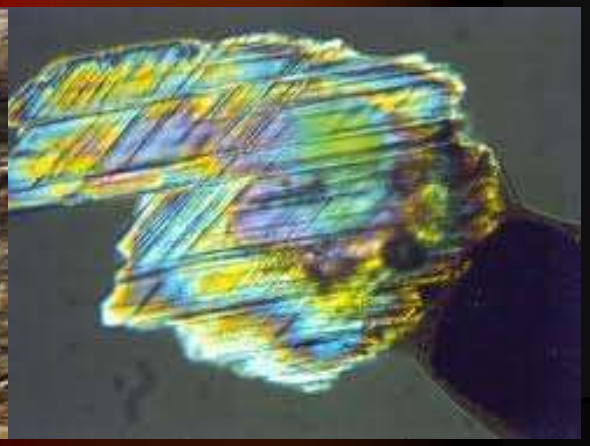






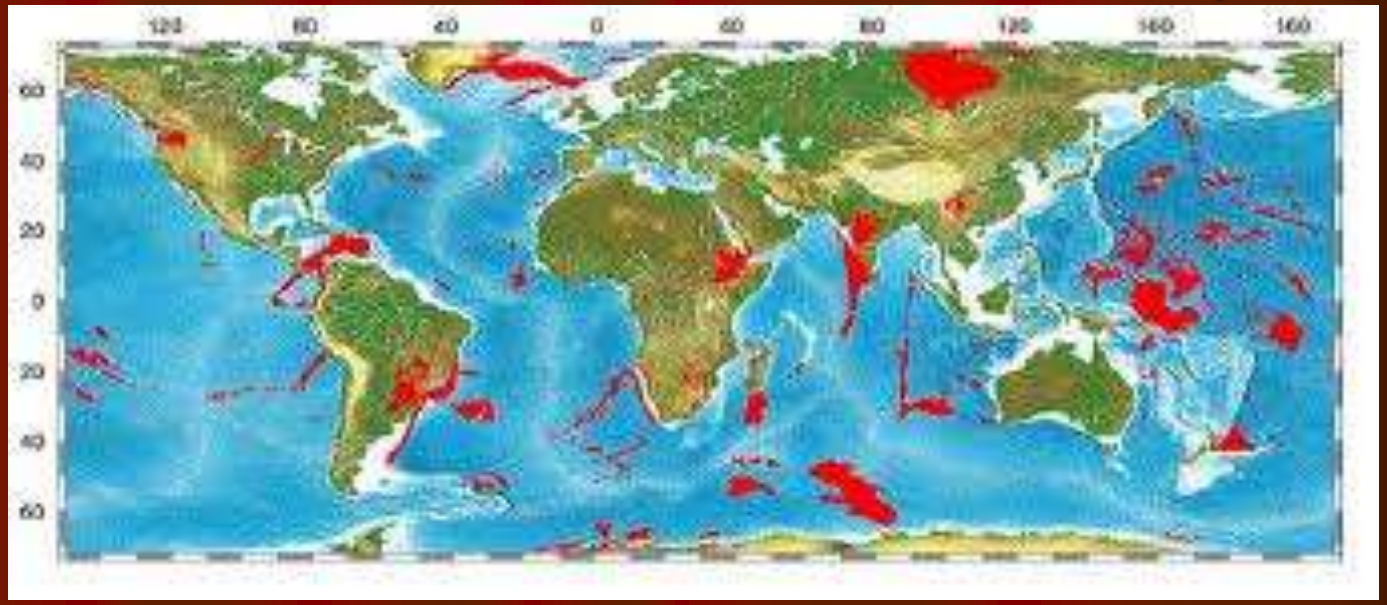
Iridium 銥 is a very dense metal rarely found on the Earth's crust but a layer of this sediment was located globally at the KT Boundary



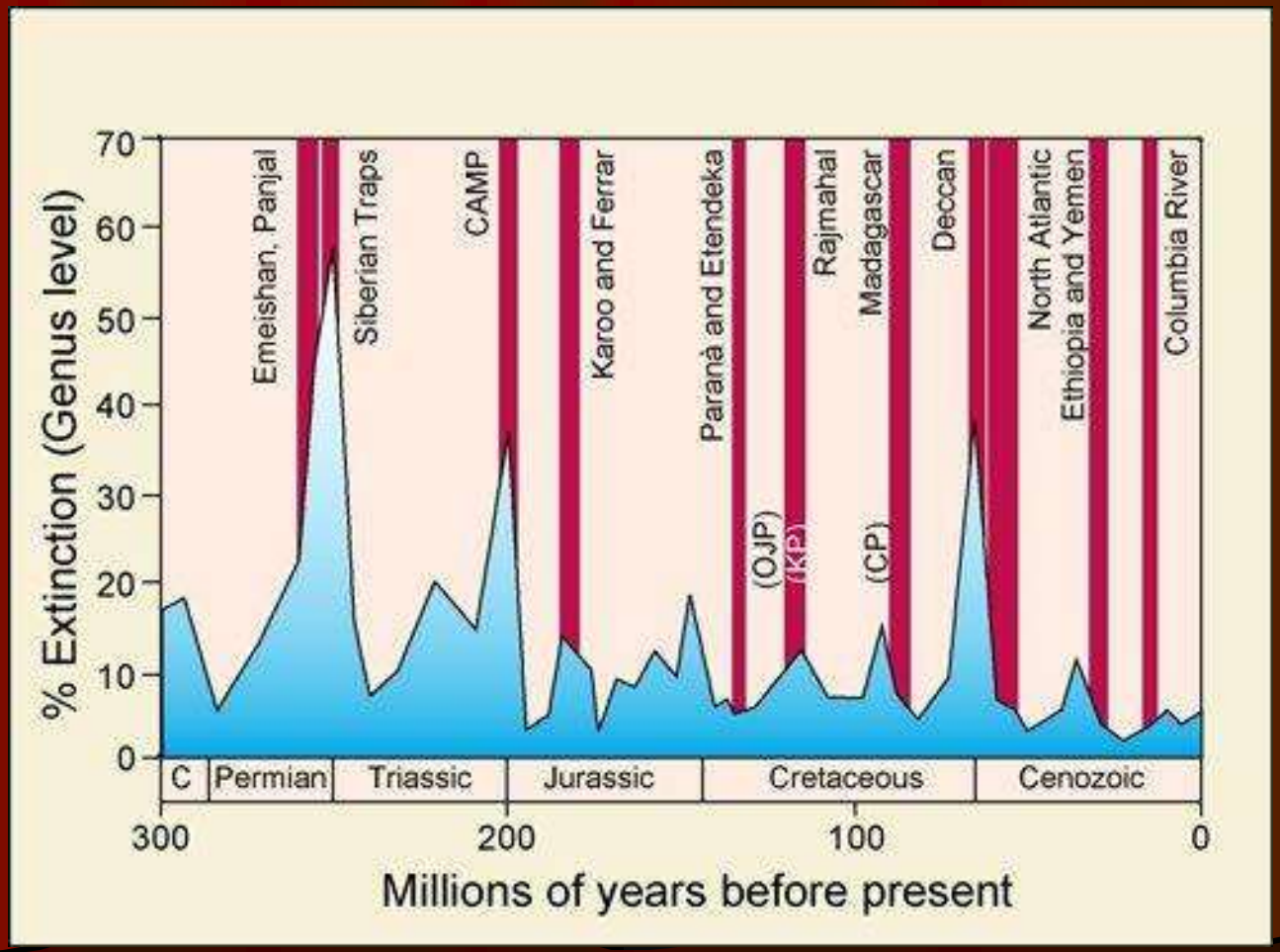


Flood Basalt

can be 2,000 cubic kilometer deep. Famous sites Siberia, Deccan Plateau & the Africa Rift Valley

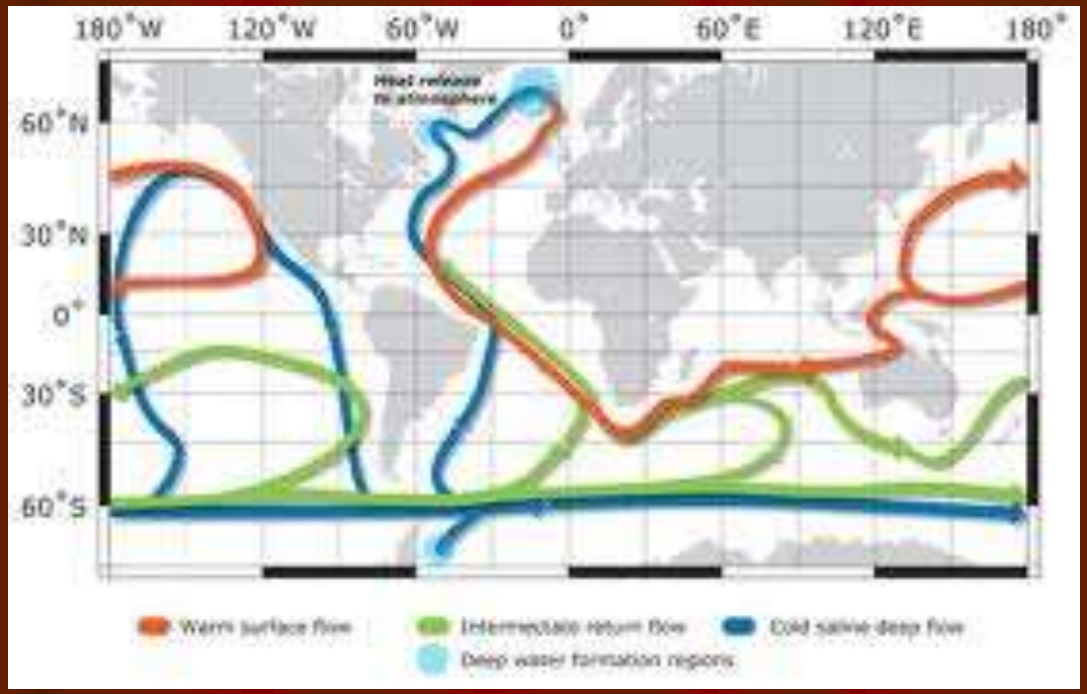


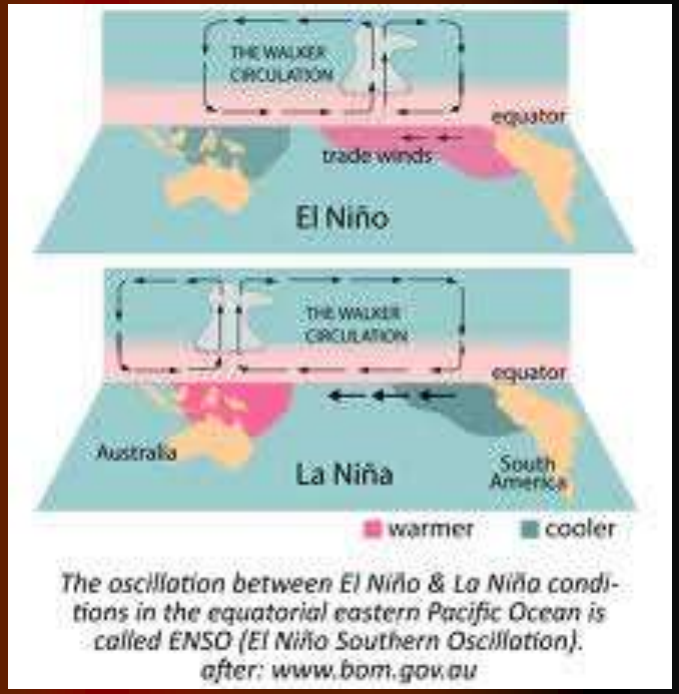
At least 3 Mass Extinction coincided with 3 Flood Basalt by producing a "Volcanic Winter" thru the production of large quantity of sulfur dioxide, carbon dioxide & aerosol.



Ocean overturn

Refers to the disruption of the Thermohaline circulation in our oceans which can have serious effect on climate. Modern example is the El Nino in Central South America

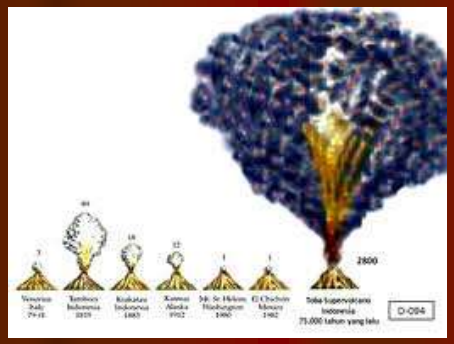




The oscillation between El Niño & La Niña conditions in the equatorial eastern Pacific Ocean is called ENSO (El Niño Southern Oscillation). after: www.bom.gov.au

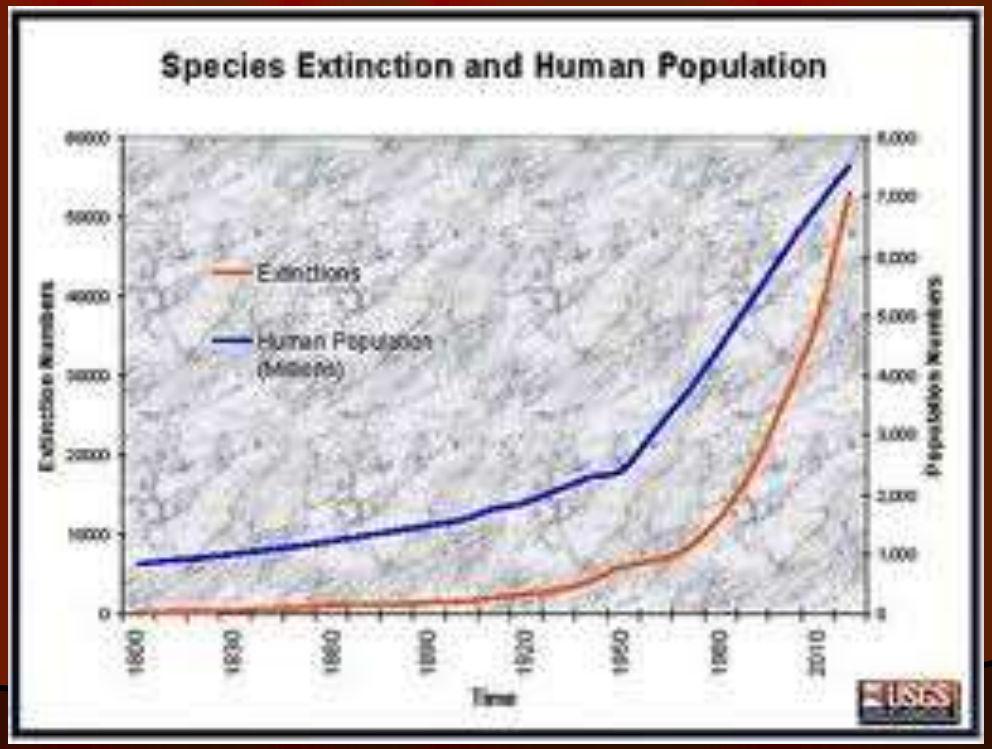
The near extinction of Human

74,000 year ago the super volcano Toba eruption in Sumatra, Indonesia which is over 5,000 times that of Mount St. Helen. With 2500 km3 of magma being nearly twice the size of Mt. Everest, it created a "Volcanic Winter" that lasted 6 years and almost wiped out the entire human population !

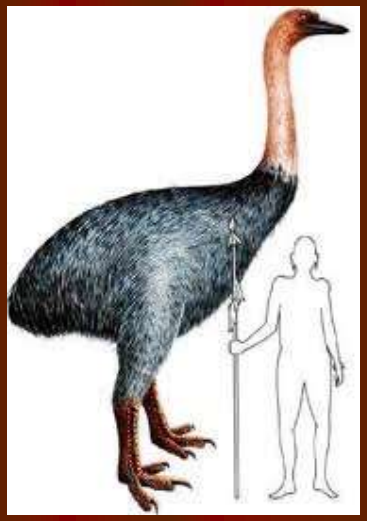


The 6th Mass Extinction is underway which is to a large extend due to human activities !

Within the 20th century human have caused the extinction of 593 species of birds, 400 species of animals & 209 species of reptiles by direct slaughtering, destruction of habitat & introduction of foreign species eg cats/dogs/goat



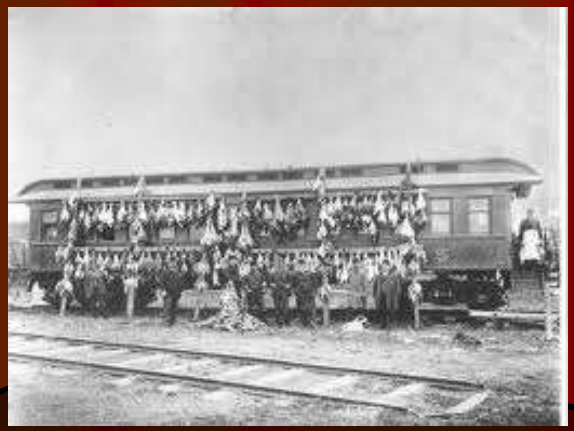
Some species that became extinct largely due to the action of man – mammoth, moa, elephant bird, Tasmanian tiger, giant kangaroo & Do Do Bird



The demise of the Passenger Pigeon

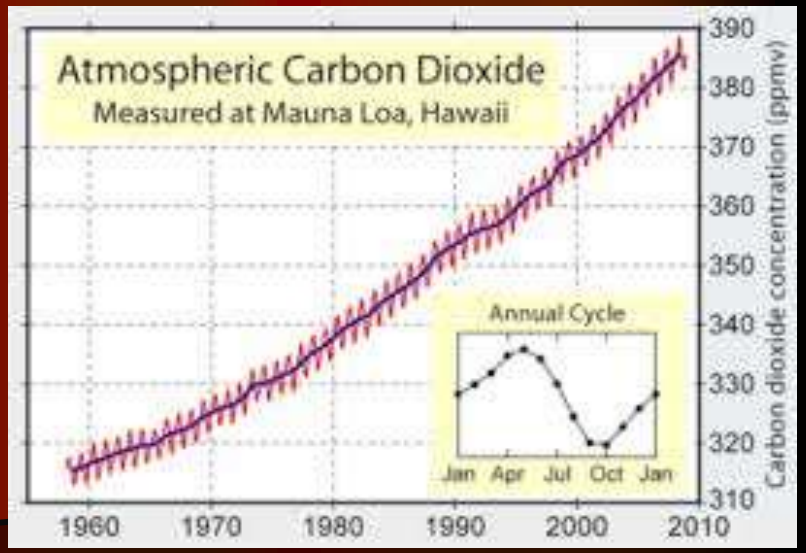
(*Ectopistes migratorius*)

- Used to be in the billions in USA until European arrived. Slaughtering started from 1884 & extinction in 1914



What are we doing to our habitat ?

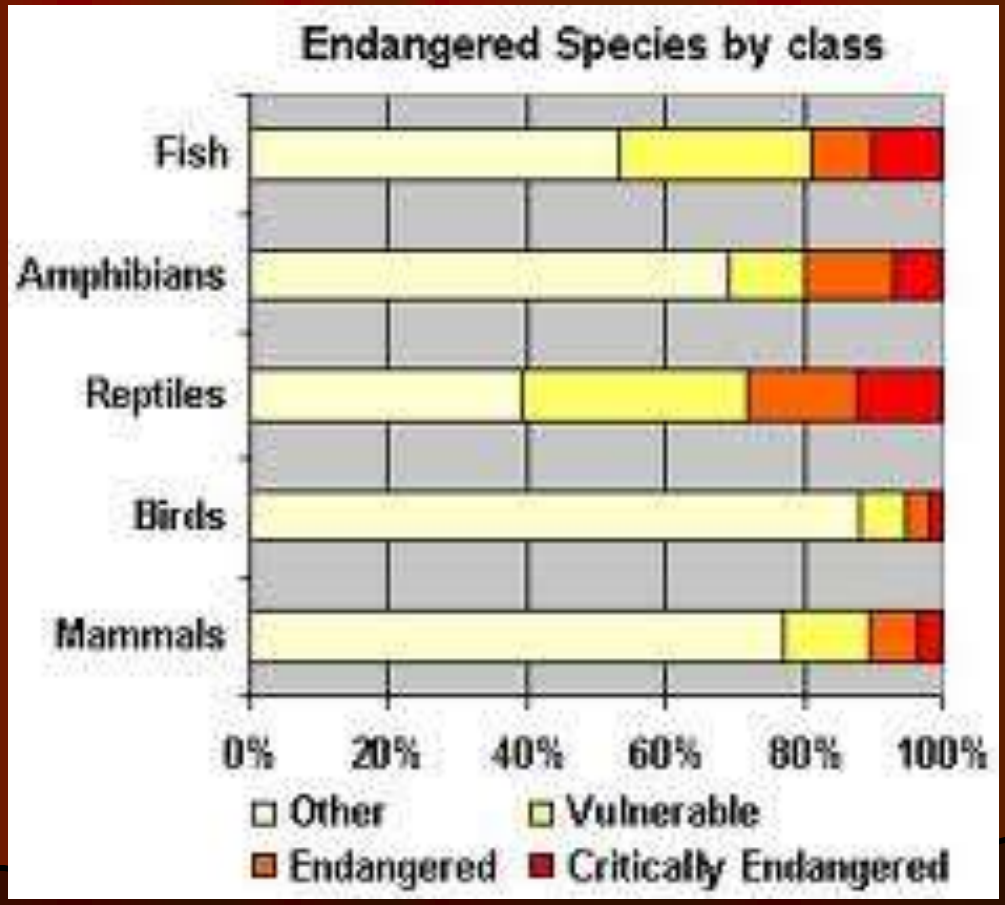
Deforestation & carbon emission – 2013 : 400 ppm predict will reach point of no return at 450 ppm by 2038



How serious ?

Latest*IUCN Red List reported that 21,286 species are now threatened with extinction. It is estimated that 50% of all species will disappear in the next 100 years. Once its gone its gone forever !

(*International Union for Conservation of Nature)



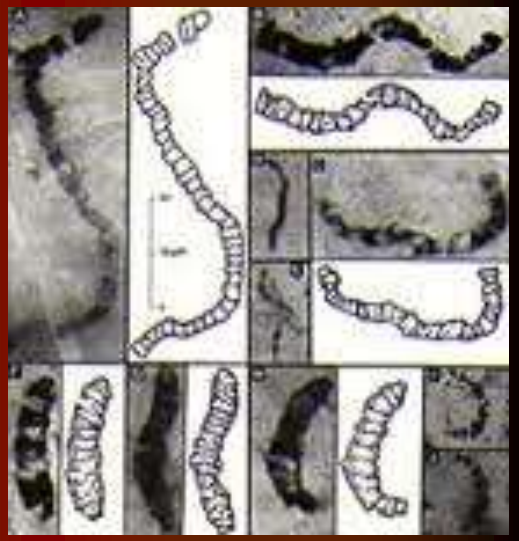
Animal Fossils

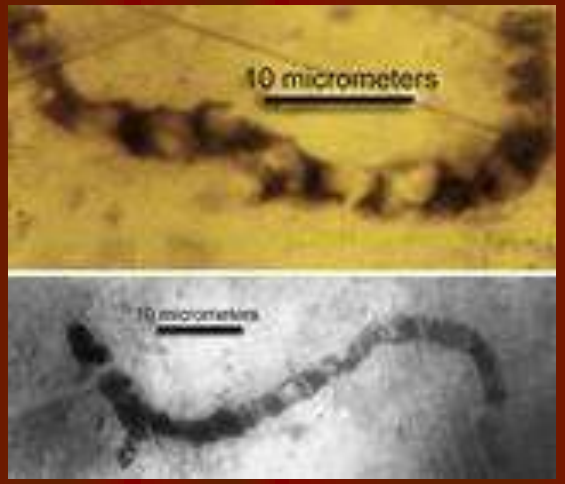
PRECAMBRIAN LIFE 前寒武紀動物

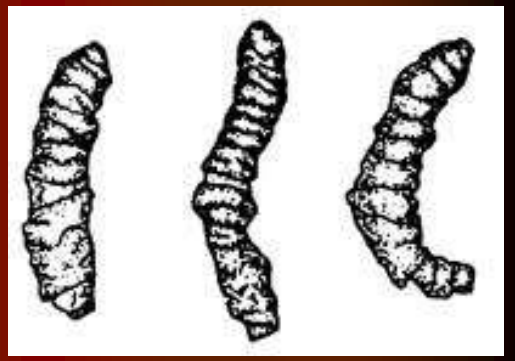
- Before 540 Ma
- From nothing to something simple but important
- All marine

3.5 billion years old fossilized bacteria living in water at 40-50C and air full of methane & no oxygen

Micro fossils composed of spores & other organic structures & bacteria filaments in 3.46 Ba found in Apex Chert in West Australia

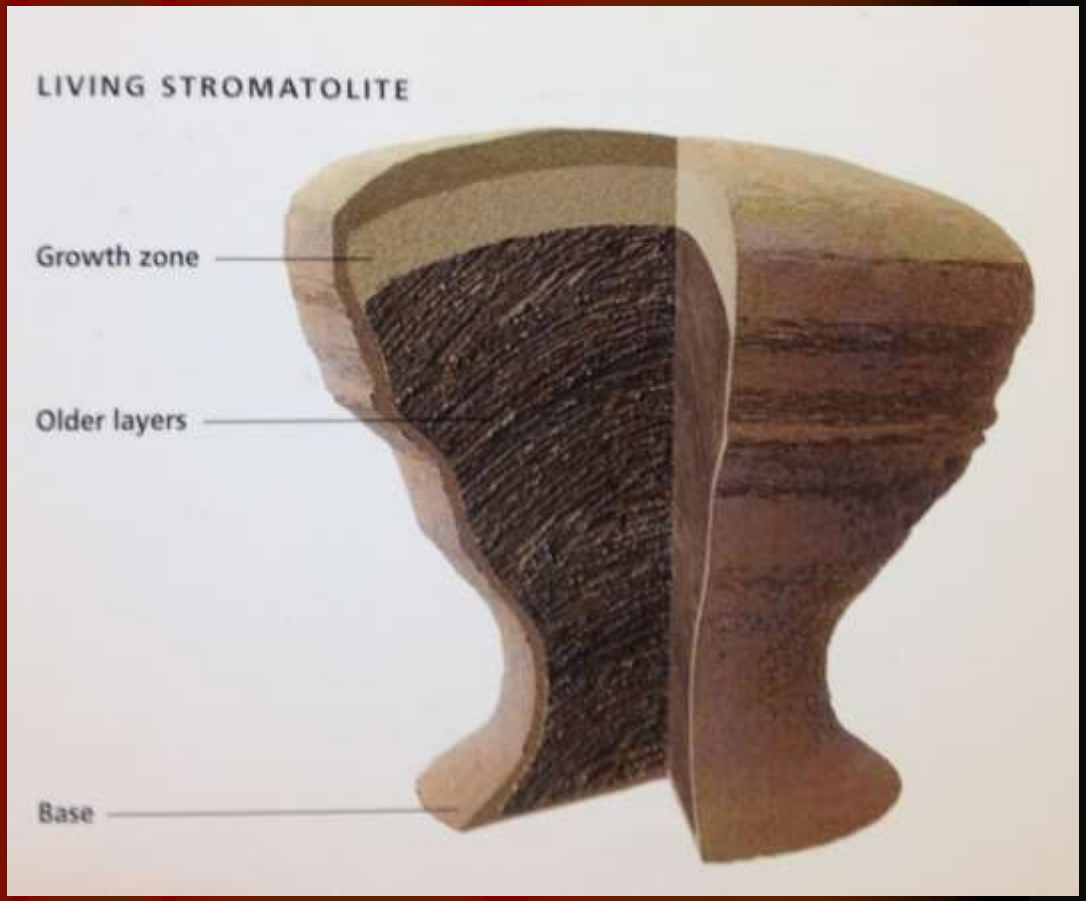






Blue Green Algae & Stromatolite 疊層石

3.35 billion years ago cyanobacteria the "Oxygen Maker" trapping sediments to form stromatolite

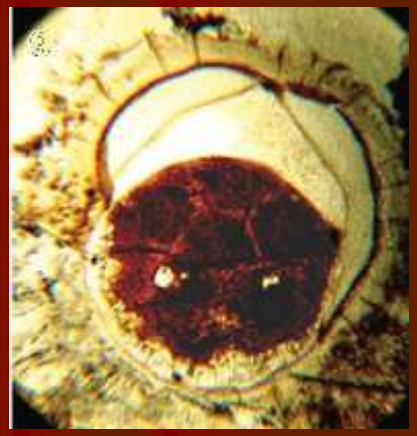


Stromatolite 疊層石 past & present

Banded iron, signs of oxygen
formed 2.8 – 2.5 billion years ago

Precambrian Microfossils

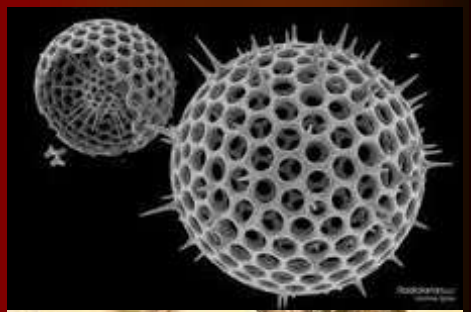
Animal embryo & egg fossils, Doushantuo 陡山沱
Guizhou 635 -551 Ma



Protozoans 原生動物

Diversified group of unicellular eukaryotic organisms with animal behavior such as movement. Including foraminifera 有孔蟲 & radiolarian 放射蟲 , mostly microscopic

(Star sand : *Foraminifera baculogypsine sphaerulata*)



The Ediacara Biota or Vendian Fauna

埃迪卡拉生物群

100 plus Precambrian species ranging from 1 cm to 2 m all marine 635 - 541 Ma first discovered in Ediacara Australia thence also located in Canada; Namibia & UK. Perhaps Nature's first failed experiment ?

Charnia masoni 恰尼海鰓

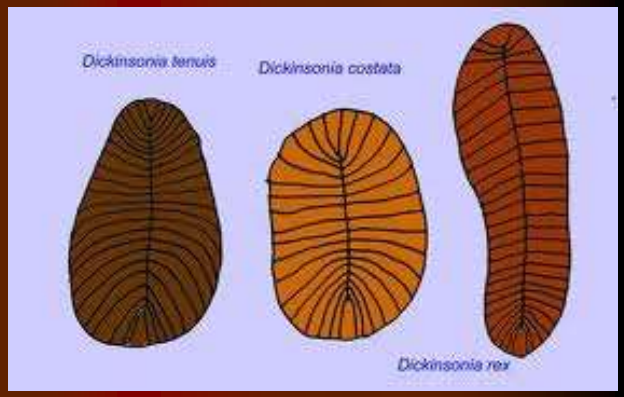
640 Ma first known from the Charnwood Forest in England. It resembles the modern Sea Pen

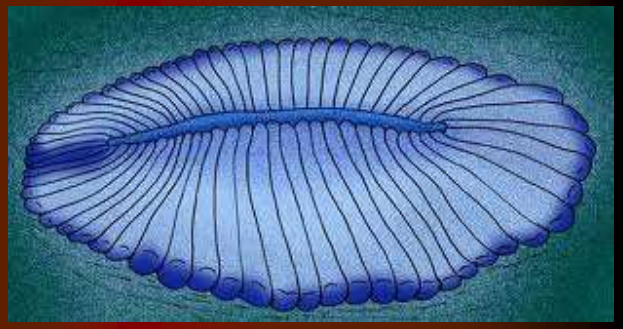
Ivesheadia – "pizza disc"
565 Ma Mistaken point, Nova Scotia





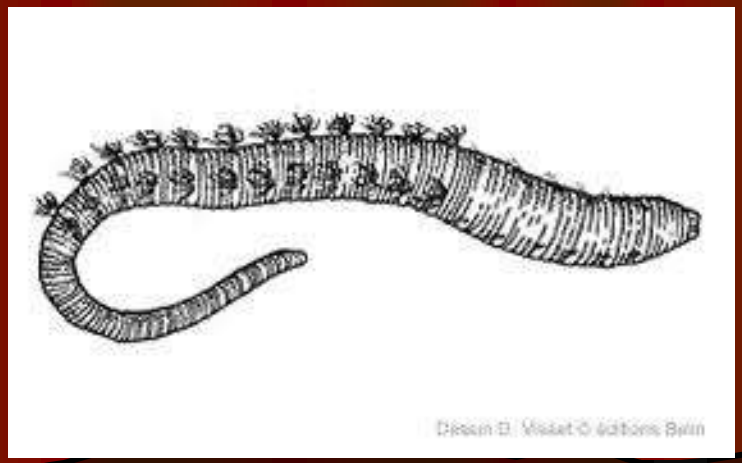
Dickinsonia costata : jelly fish ?





Spriggina floundersi 枝沙蠶

580 Ma, 3.5 cms showing bilateral symmetry



Mawsonite spriggi , ancestor of Jelly Fish ?

THE PALAEOZOIC LIFE 古生代動物

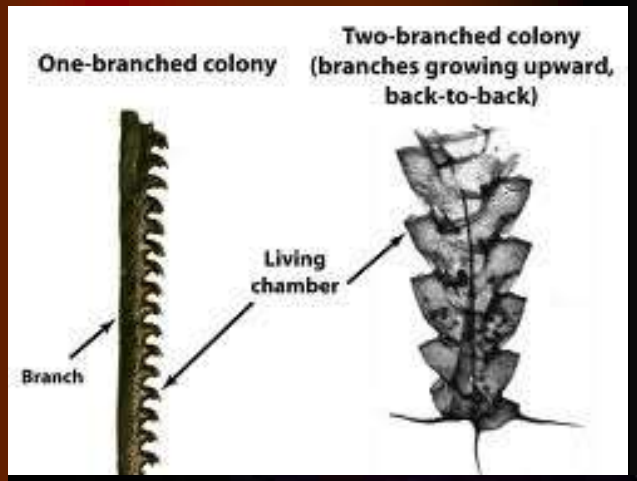
(540 to 250 Ma)

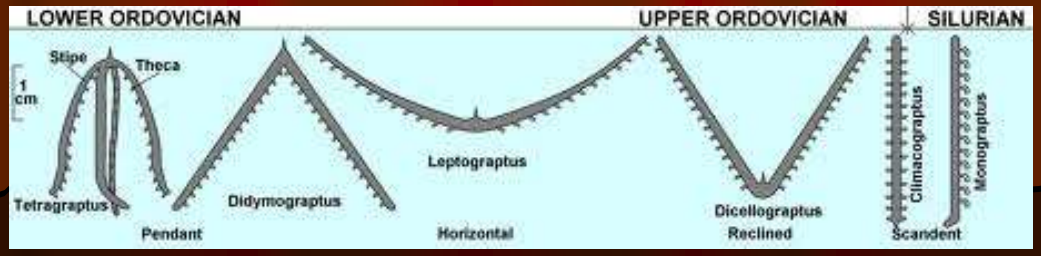
- The Cambrian Explosion: 50 phyla in one go !
- From ocean to land : Invertebrates, fishes, amphibians, early reptile & mammal
- Some Carboniferous giants

Fossil sponge & coral

Graptolite (*Didymograptus*) 筆石 550 Ma

Means "rock writing". These are colonial filter feeding invertebrate animal living in the ancient seas with an organic skeleton. Graptolites are excellent Index Fossil





Important Cambrian Fossil Finds

- Chengjiang Bio group 雲南澄江生物群 : 520-515 Ma in Maotianshan Yunnan China over 180 species

- Bergess shales 伯吉斯生物群 : 505 Ma 172 species discovered by Charles Walcott of Smithsonian Institute

Eldonia 依爾東缽

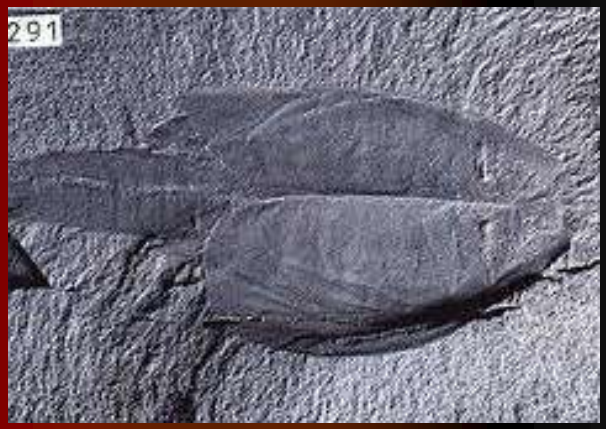
The 0.88 mm jellyfish like shape suggests a pelagic lifestyle

Opabinia regalis 歐巴賓海蠍： 70 mm long

Hallucigenia 怪誕蟲

26 mm with 7 pairs of spines & legs

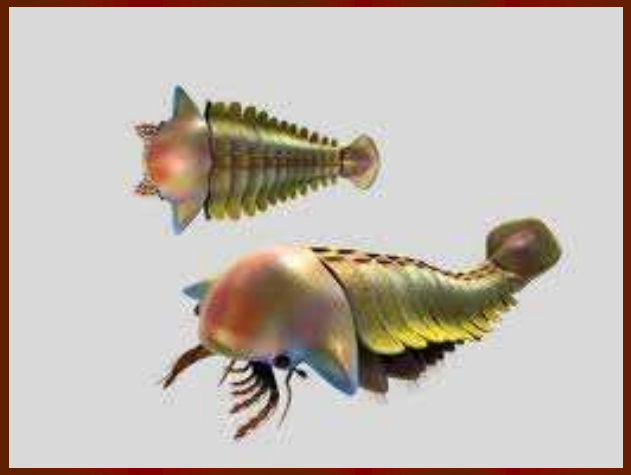
Canadaspis

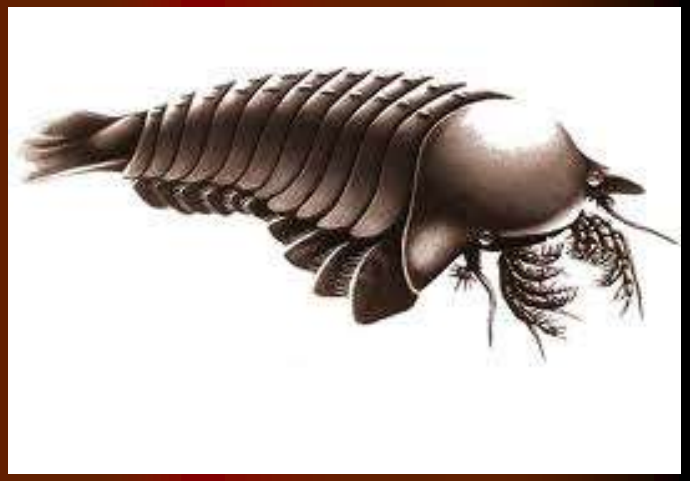


Marrella 馬瑞拉蟲 19 mm

Wiwaxia 微瓦霞蟲：50 mm

Sanctacaris : 100 mm

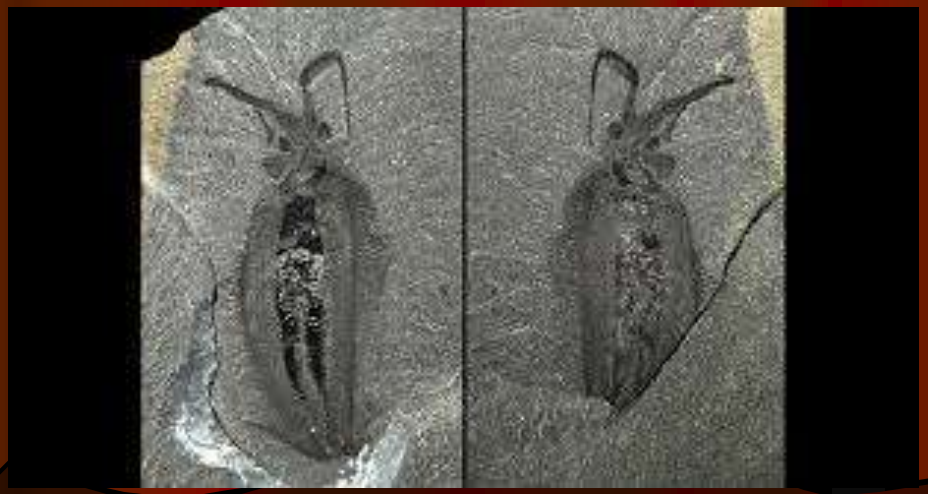


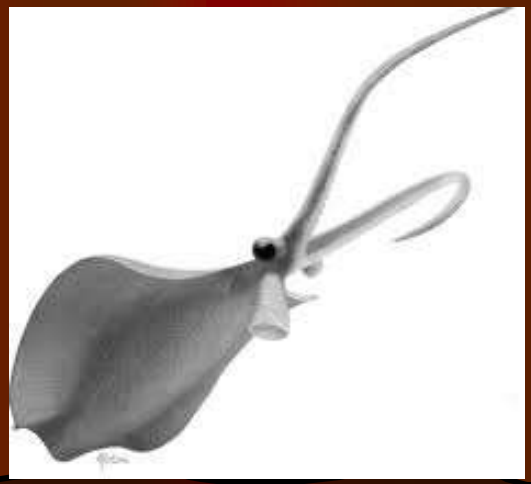


Yohoia tenuis

Aysheaia : 50 mm

Nectocaris



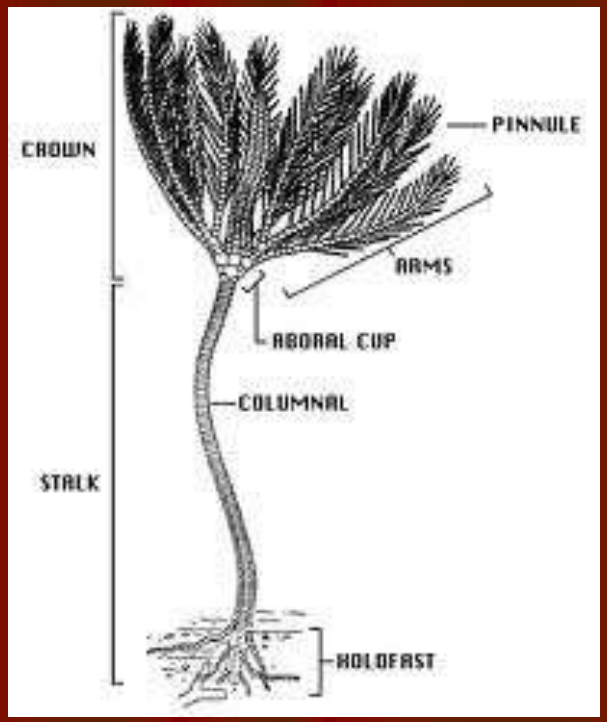


Microdictyon 微網蟲

Anomalocaris 奇蝦

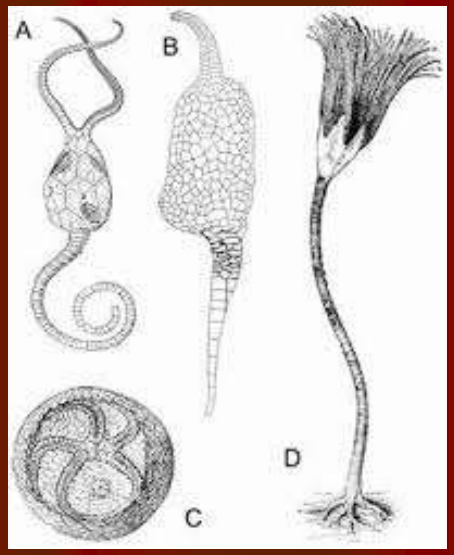
At 600 mm this fearsome looking animal is the largest predator in the Cambrian Seas

Echinoderm
Crinoid - Sea lily 海百合



Echinoderm
Sea lily crown & stalk

Echinoderm
Cystoid 海林檎



Echinoderm
Sea urchin 海膽









Echilloderm
Sea star & Brittle star (ophiuroida)






Worms 蠕蟲

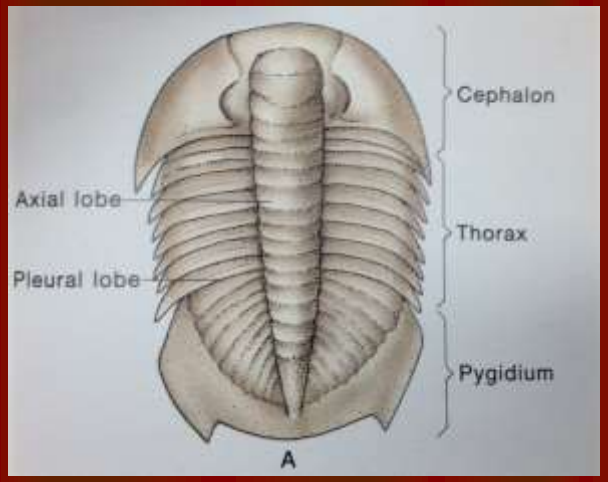
Conodonts 牙形石

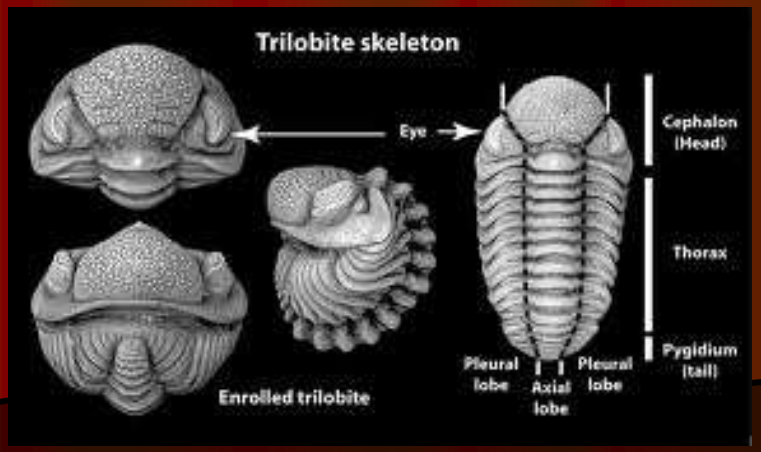
Meaning “cone teeth” only 1 to 4 mm long composed of calcium phosphate (apatite). Ordovician. A mystery until 1980 being teeth of a eel like predator. Some scientist consider it as the earliest vertebrae

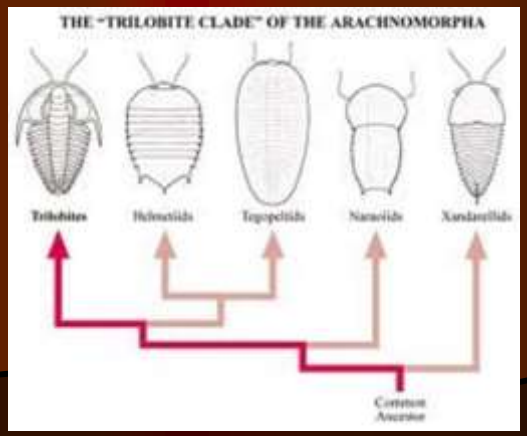
Trilobite

Trilobite 三葉蟲

Extinct marine arthropods 10 orders 150 families 5000 genera over 20,000 described species first appeared in the Cambrian period and disappeared with the Permian Mass Extinction. Note the curled up body when under threat

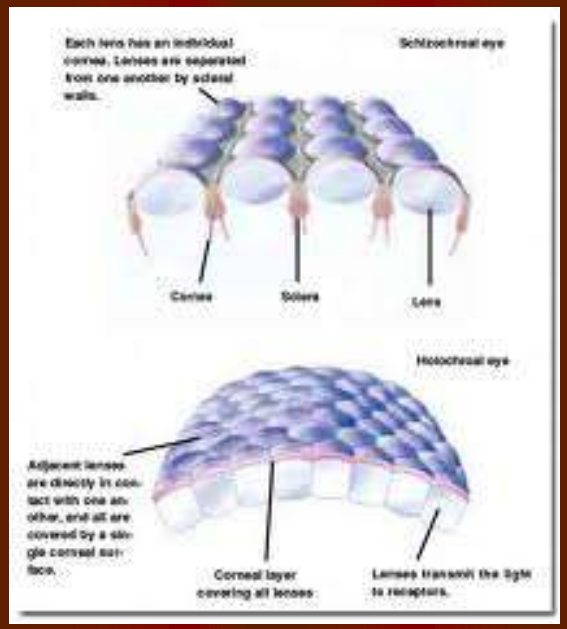


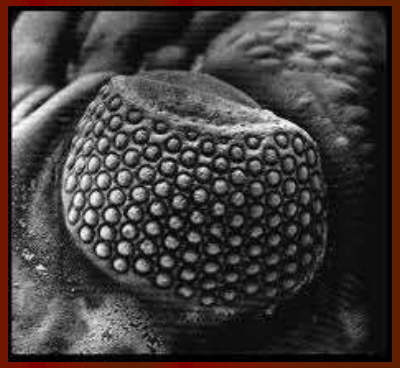




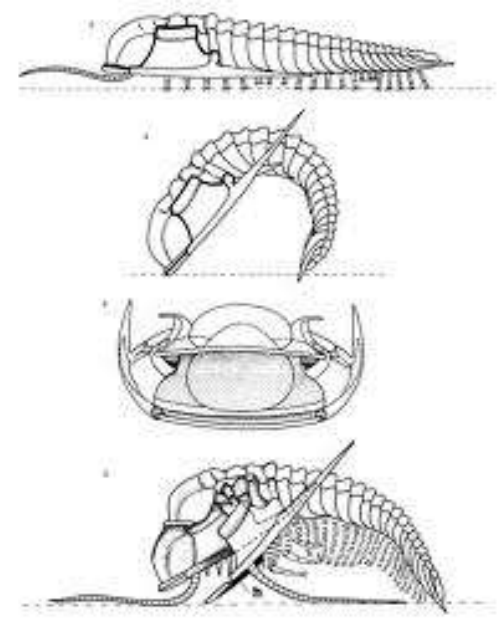
Trilobites' calcspar compound eyes 鈣質複眼

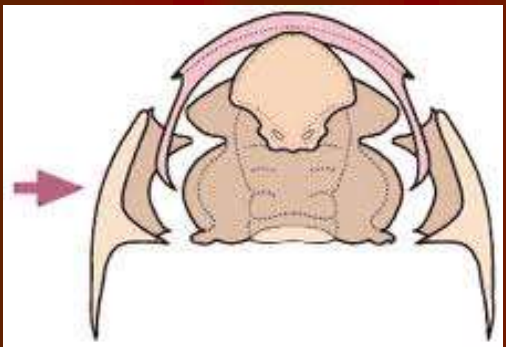
transparent but inflexible can have up to 15,000 rigid crystalline lenses

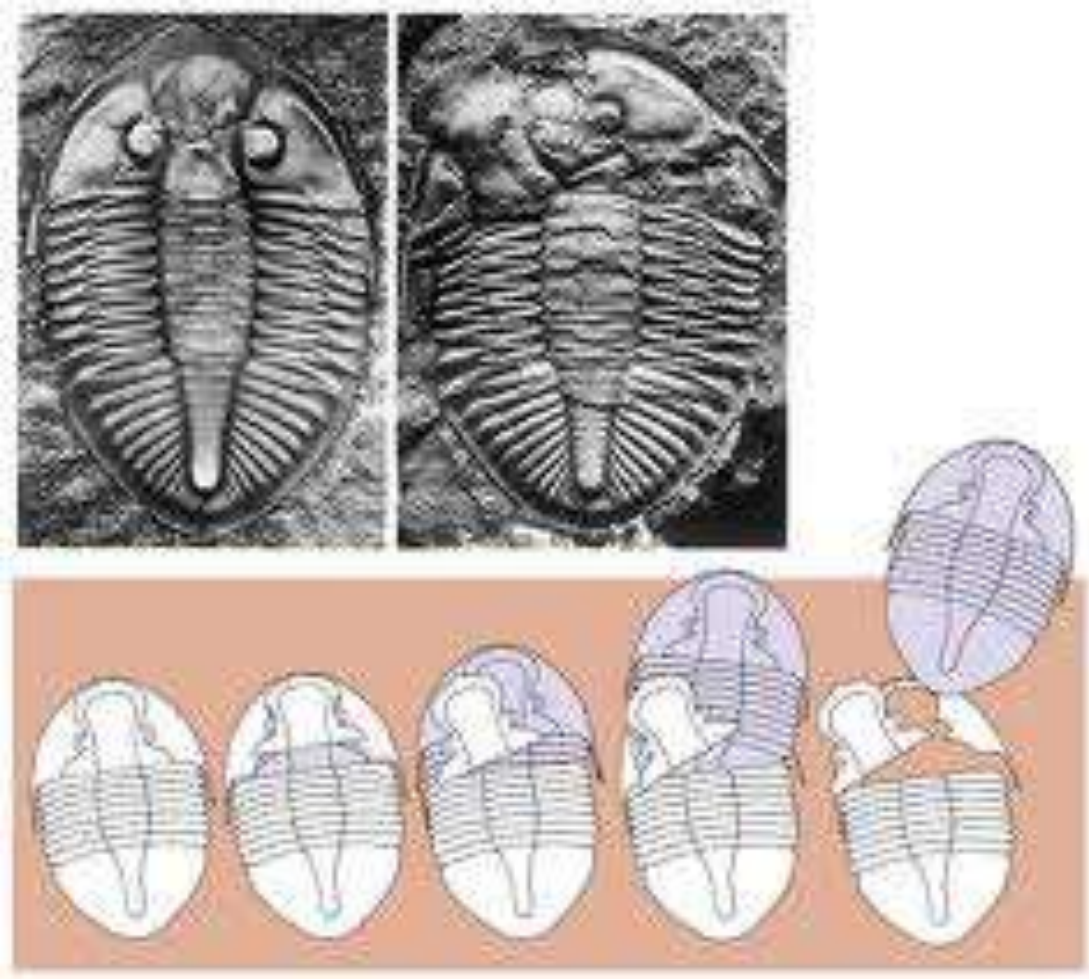




Trilobites moulting : trilobite shed its skeleton like other arthropod







Trilobite

(*Peronopis interstricta* 球接子三葉蟲)

510 Mya probable ancestor to all trilobites

Trilobite : Djebel Oufaten Morocco







Trilobite - Morocco












Trilobite - Russia






China Trilobite

Zheungjiajie Hunan Province

Largest trilobite : *Isotelus rex* length 720 mm
width 400 mm
Smallest trilobite : 1 mm

Early Cephalopod 頭足類

Orthocerus 角石 (Ordovician 450 Ma) & Goniatite 棱菊石 (350 Ma)

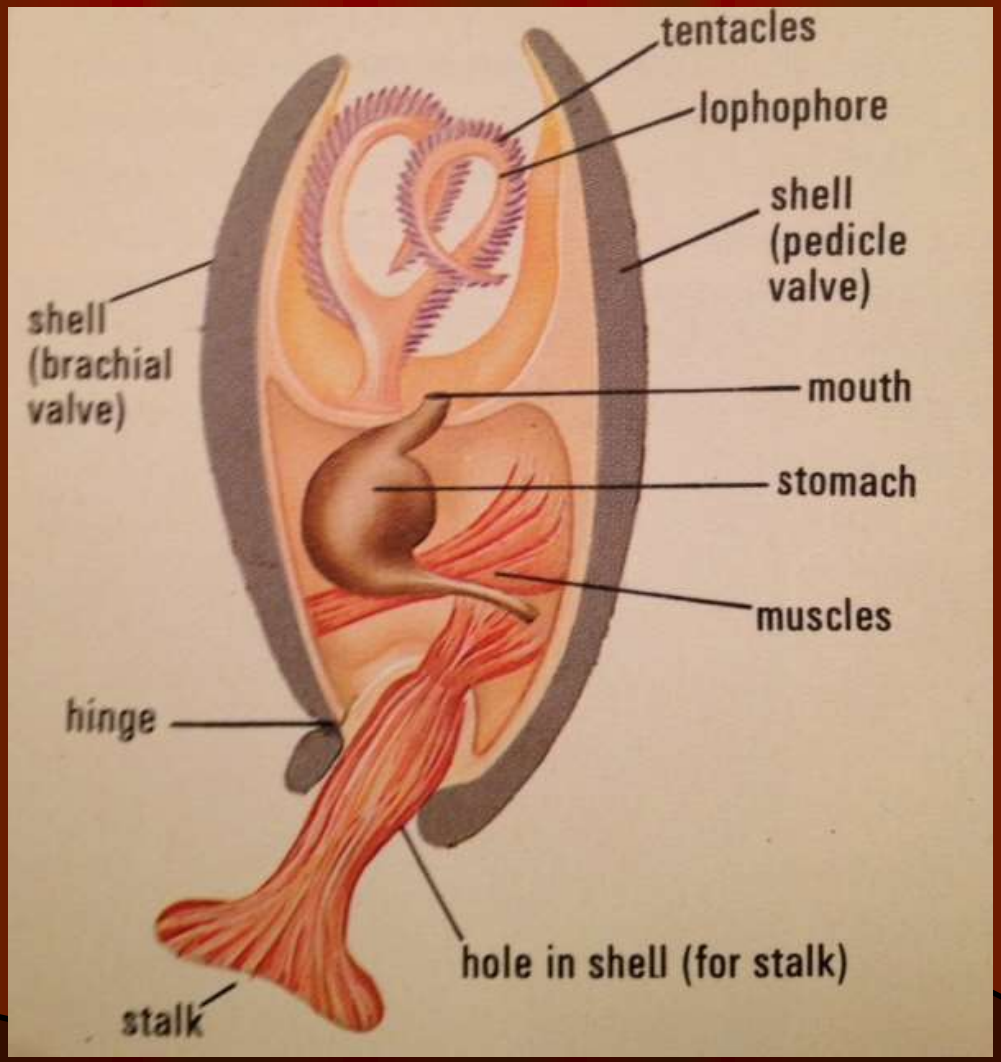


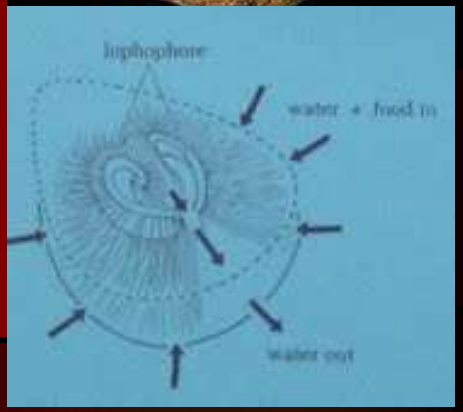




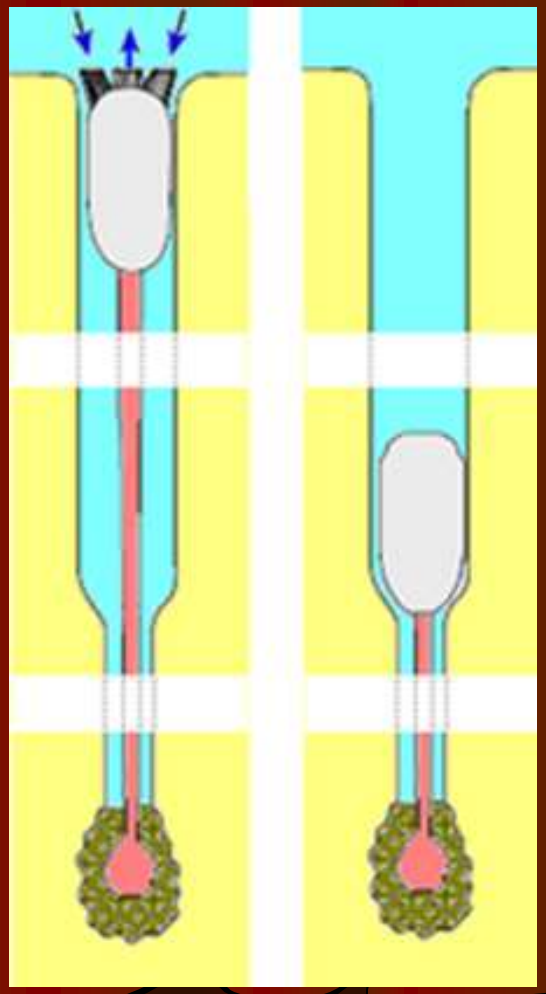

Brachiopod 腕足類

Small marine invertebrates - Living 200 fossils 30,000; use a pump & sieve mechanism called lophophore for feeding





Living & fossil lingula 海豆芽, an unarticulated Brachiopod first appeared 400 Ma. *Lingula anatina* is the oldest animal living on earth & has not changed much !



Brachiopod can appear in many different shapes & sizes

Brachiopod - spirifer 石燕

540 ma










Bivalves
clams & scallops

Graphea 捲嘴蠣
“devil’s toenail”, an ancient oyster

Crustacean 甲殼動物

Crab & Lobsters

Story of the fish

Evolution of fish

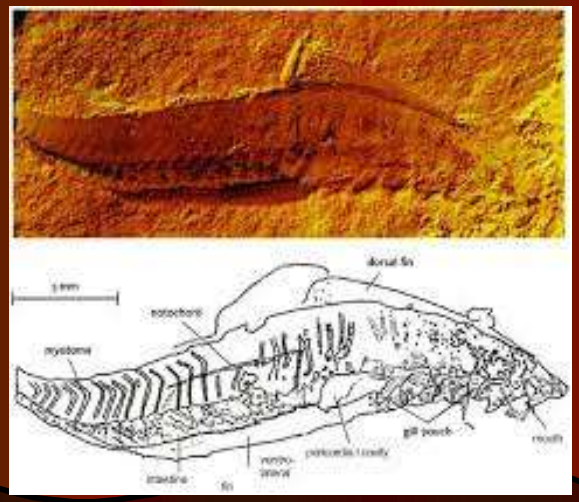
- Protofish
- Ostracoderms : jawless fish 無顎綱
- Placoderm :plated skin fish 盾皮綱
- Chondrichtyes : cartilaginous fish 軟骨魚
- Ostteichtyes : bony fish 硬骨魚

Early Fish

Protofish all jawless

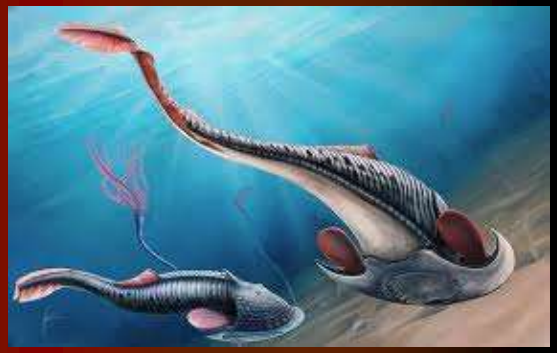
- Pikaia 皮克魚：Cambrian (Burgess shale) at 5 cm long it is one of the earliest known chordate 脊索類 & relative of the ancestor of all vertebrate animal 脊柱類

- Haikouichthys 海口蟲：518 Ma primitive chordate



Ostracoderms 無顎綱：Armored jawless fishes

- Cephalaspis
  斗甲魚



- Hemicyclspis

- Pteraspis 鰭甲魚 20 cm

Placoderms 盾皮綱 (Plated skinned)

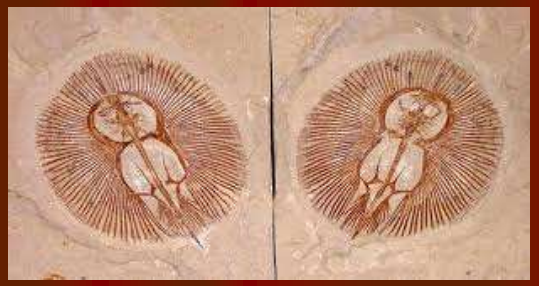
These are armored jawed fish eg. Bothriolepis 溝鱗魚 discovered by Dr. C. M. Lee 李作明教授 in Plover Cove in 1980 dated to be Devonian (410 Ma)

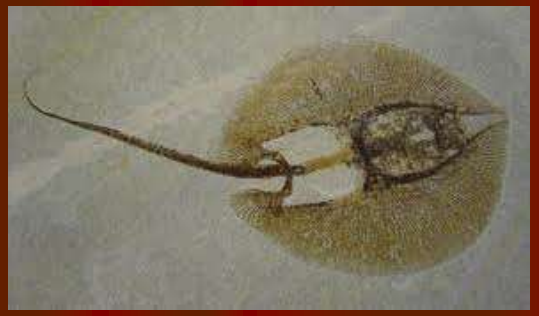
Dunkleosteus 鄧氏盾皮魚 (恐魚)

Late Devonian 380 – 360 Ma 10 m long weighing 3.6 tons possessed two pairs of bony plates instead of teeth. A smaller China species is called 江油魚

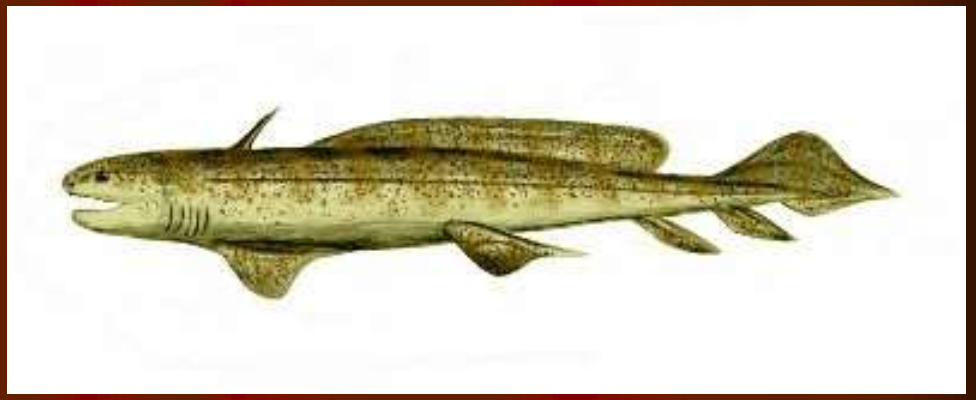
Chondrichthyes 軟骨魚

Cartilaginous fishes with open gill slits including sharks, rays & skates. Most of the time only the teeth were fossilized



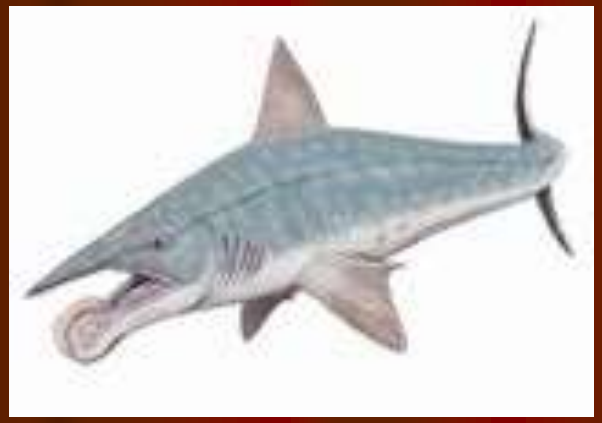


- *Orthacanthus* : a Devonian fresh water shark



- *Cladoselache* : another Devonian shark

- *Helicopion* 輪齒鯊：Carboniferous shark

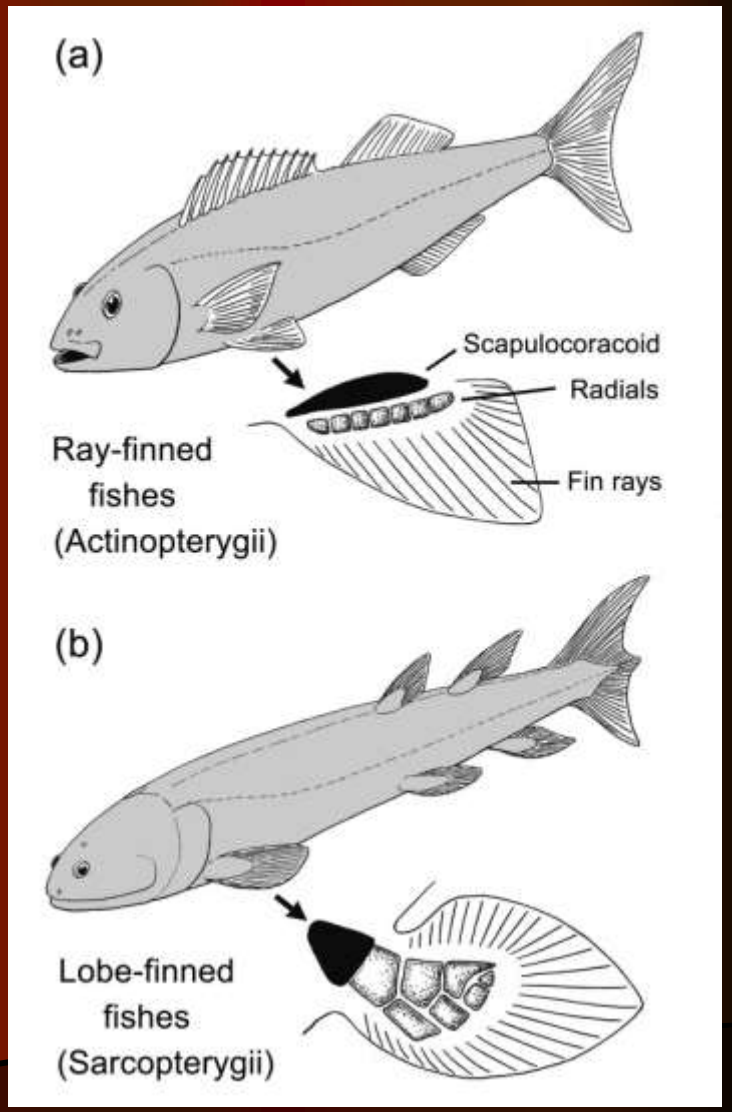


- *Stethacanthus* 胸脊鯊：another Carboniferous shark 70 cm long with distinct ironing-board-like structure at the back of males


Osteichthyes :硬骨魚 Bony fishes

- Ray finned fishes 蝠鰭魚 (*actinopterygii*)

- Lobe finned fishes 掌鰭魚



The Carboniferous Giants

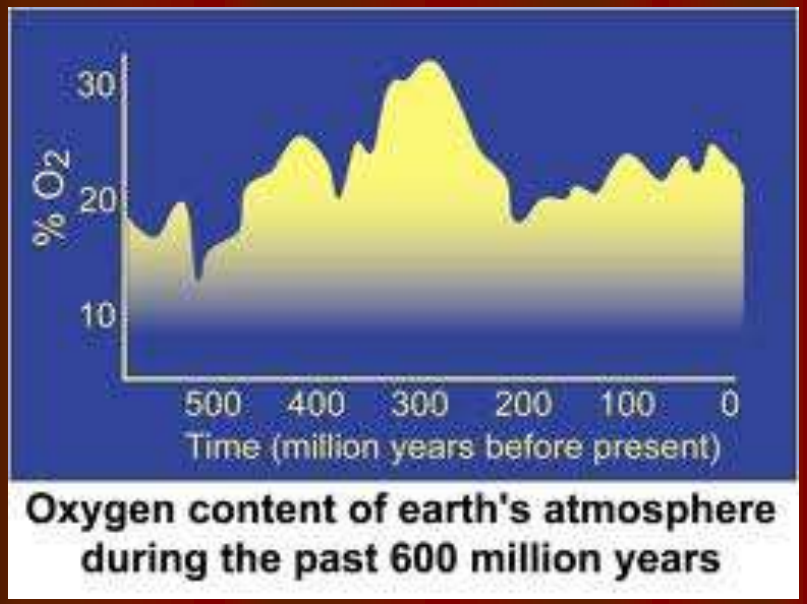
The Carboniferous "Giants"

A. Sea scorpion (*Eurypterid eurypterus*) 海蝎子

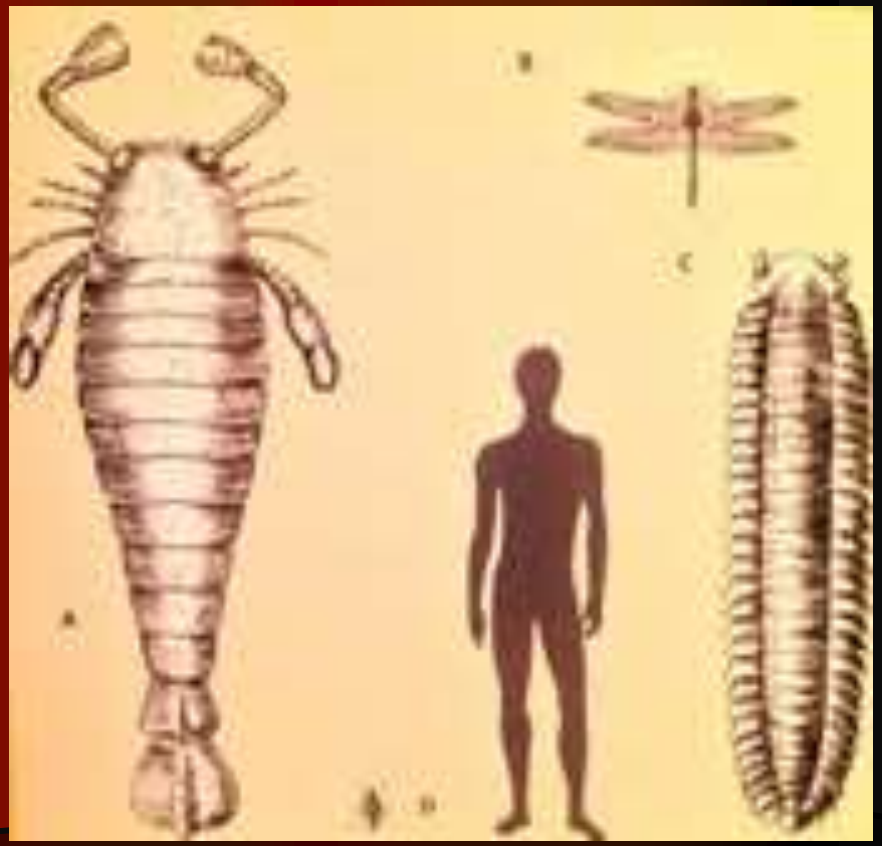
B. Cockraoch

C. Dragon fly (Meganeura) 巨蜻蜓

D. Centipede 馬陸

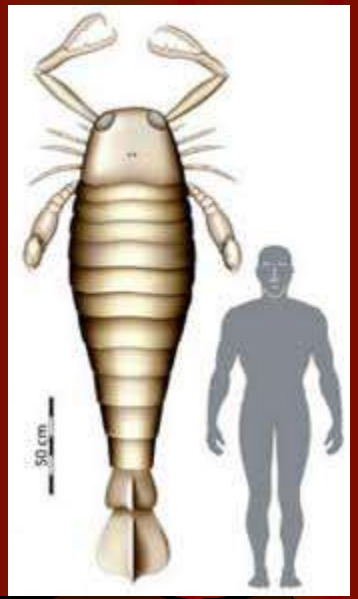


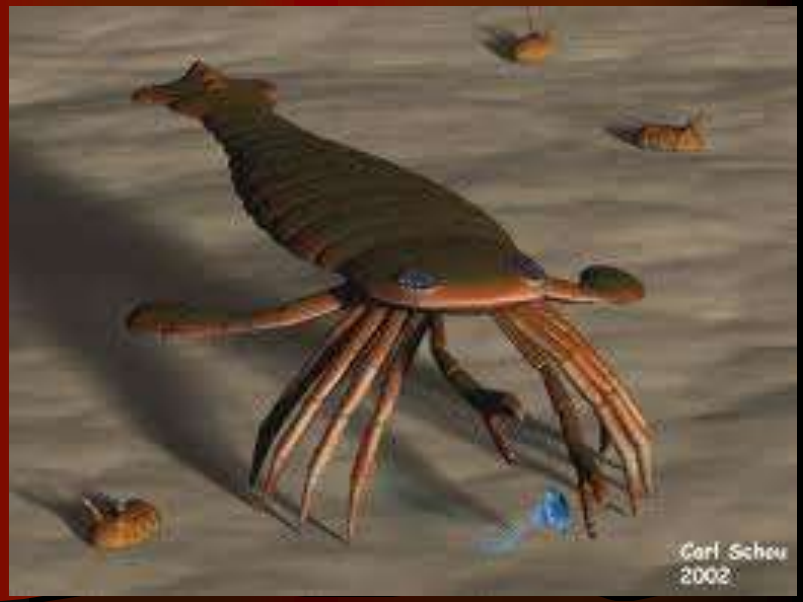
Oxygen content of earth's atmosphere during the past 600 million years



Sea scorpion（Eurypterids）海蝎子/板足鱟

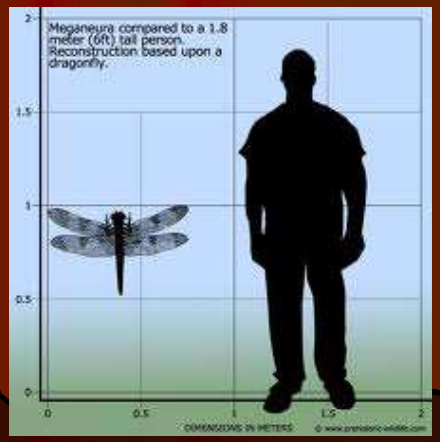
Maximum size 2.7 m



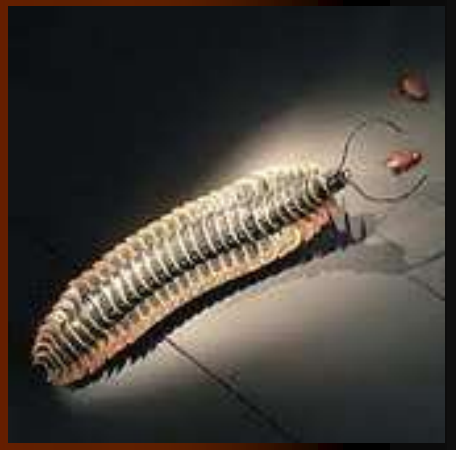


Monster Dragonfly 巨蜻蜓

(*Meganeura* 300 Ma – over 2.5 ft wide wing tip to wing tip)



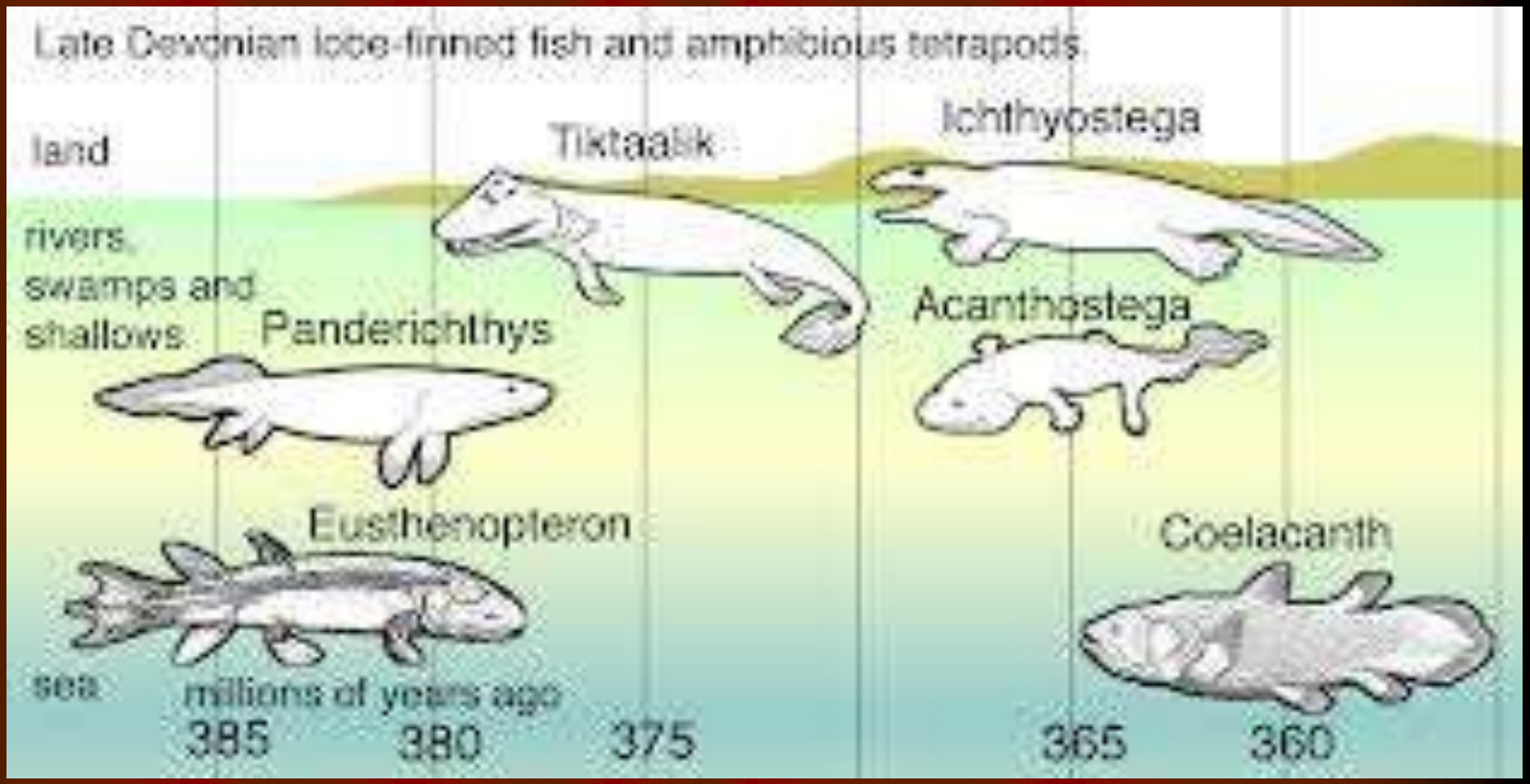
Giant centipede



Giant cockroach

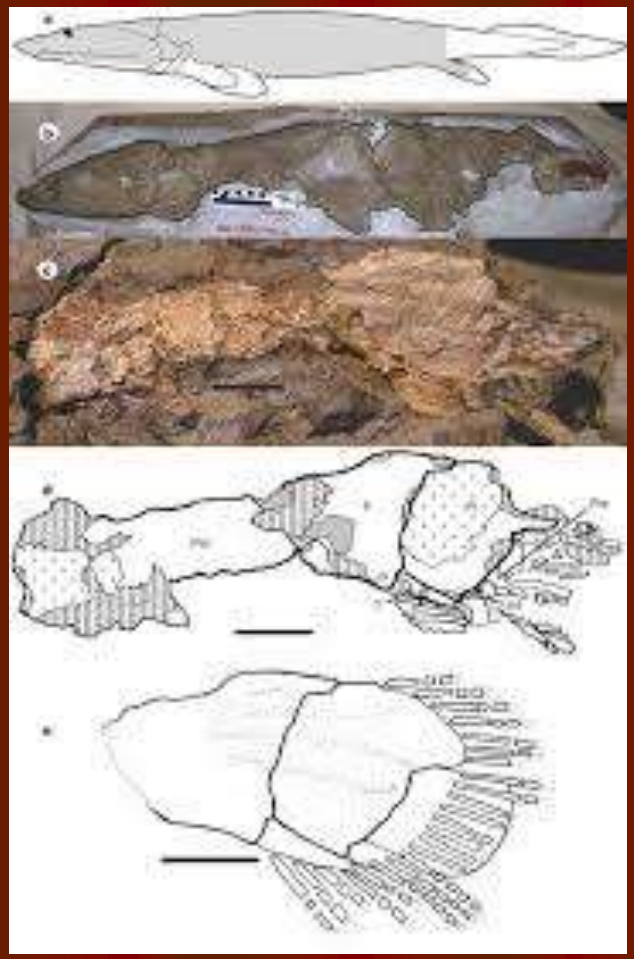
From Fish to Tetrapod

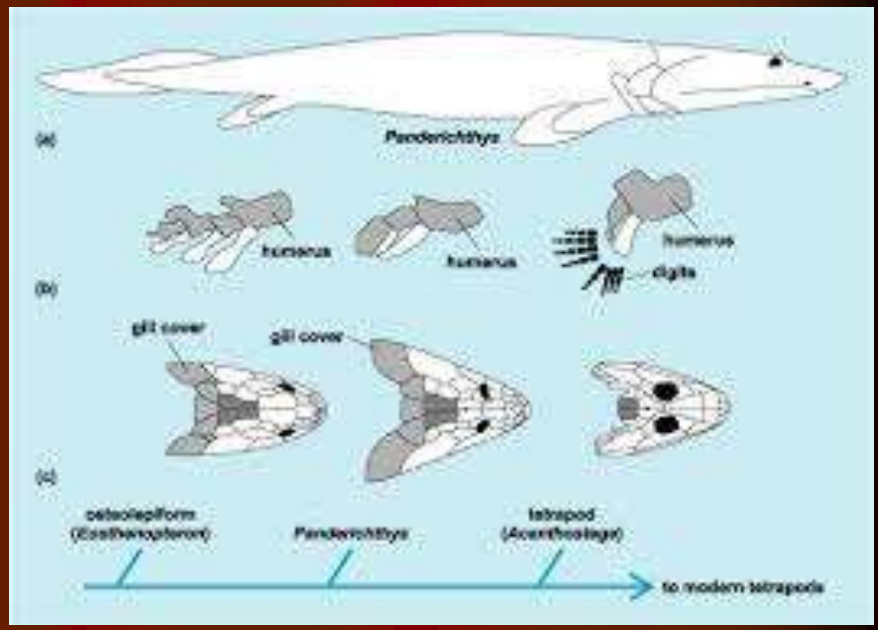
Devonian Evolution of amphibian tetrapods
兩生類演化



Panderichthys 潘德魚

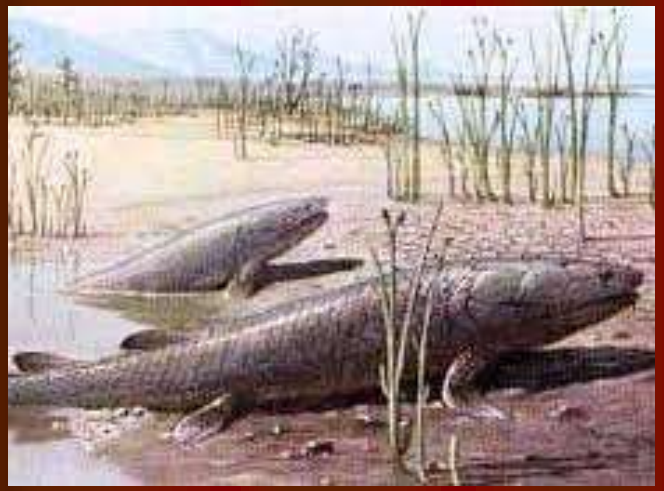
- A 380 Ma 130 cm lobe fin fish living in the Devonian

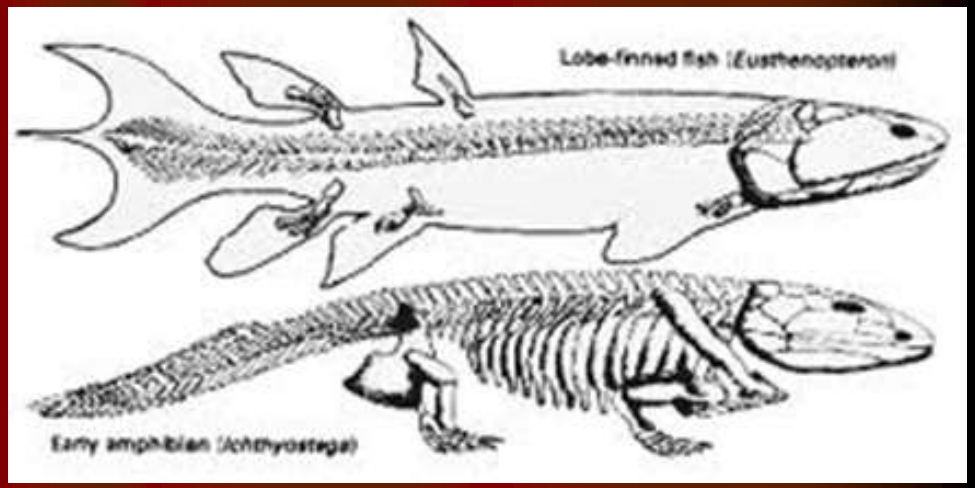




Eusthenopteron 真掌鰭魚

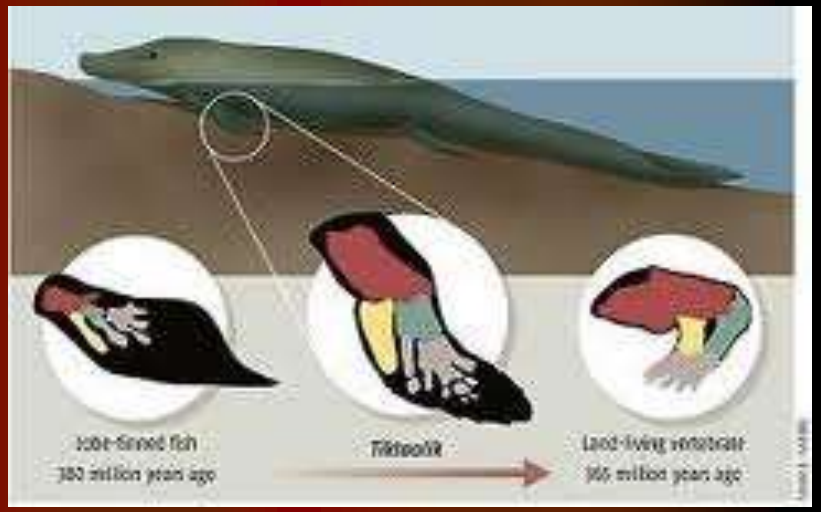
- 385 Ma a fresh water lobe finned fish living in the Late Devonian

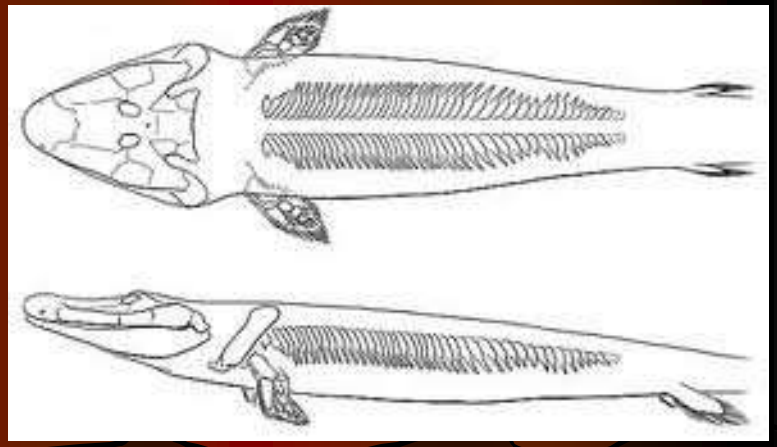




Tiktaalik roseae 提塔利克魚

- 380 Ma late Devonian "Fishapod", a Missing Link between fish & tetrapod (animal with 4 limbs) discovered in 2006



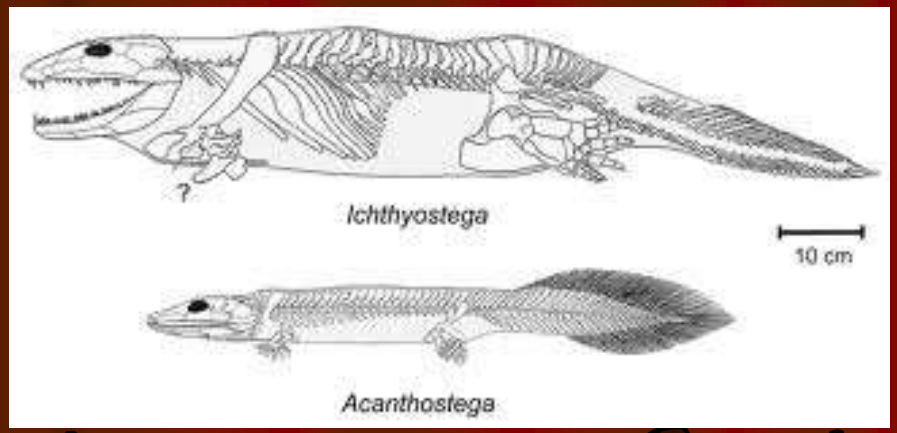


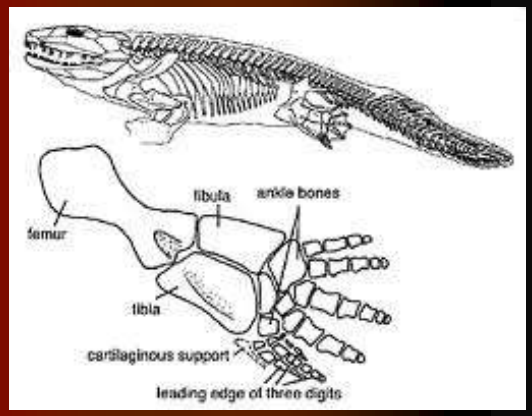
Acanthostiga 棘螈

- 365 Ma : the first vertebrate to have recognizable limbs, one of the earliest tetrapod

Ichthyostiga "Fish Roof" 魚石螈

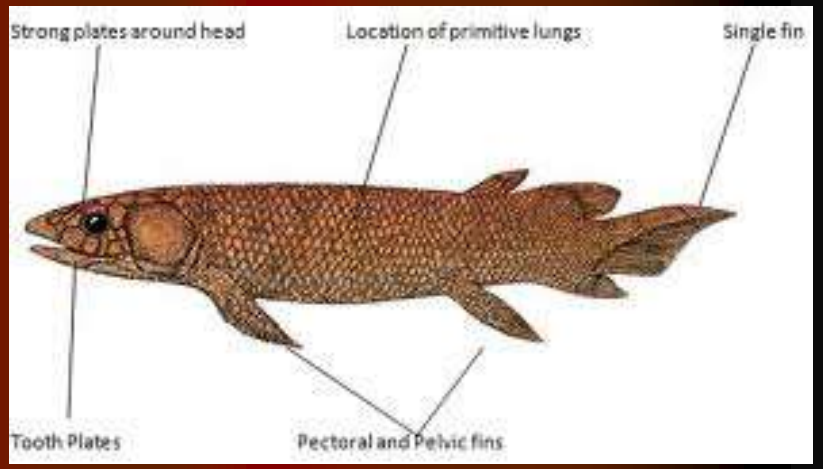
- 374 Ma : transitional between fish & tetrapod that possessed gills, lungs & limbs living in the upper Devonian. One m long discovered in Greenland

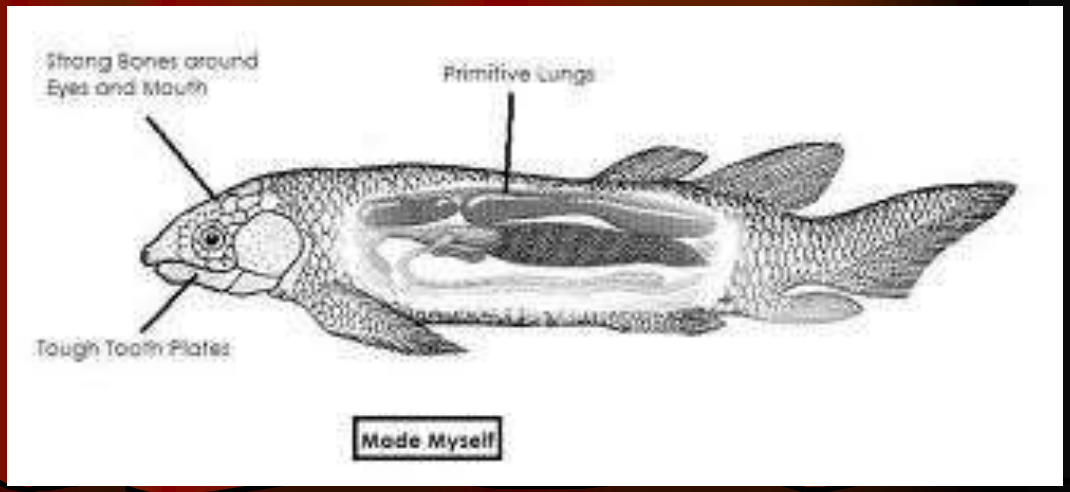




Dipterus

A 35 cm long extinct lung fish closely resemble modern lung fish 肺魚

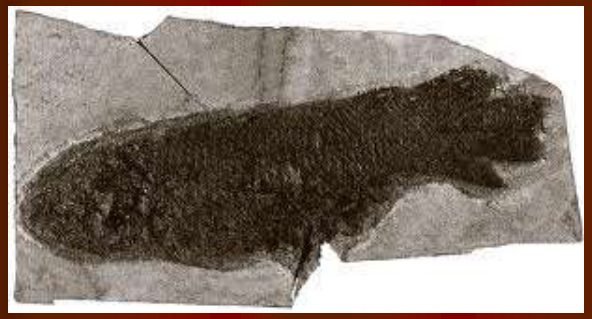


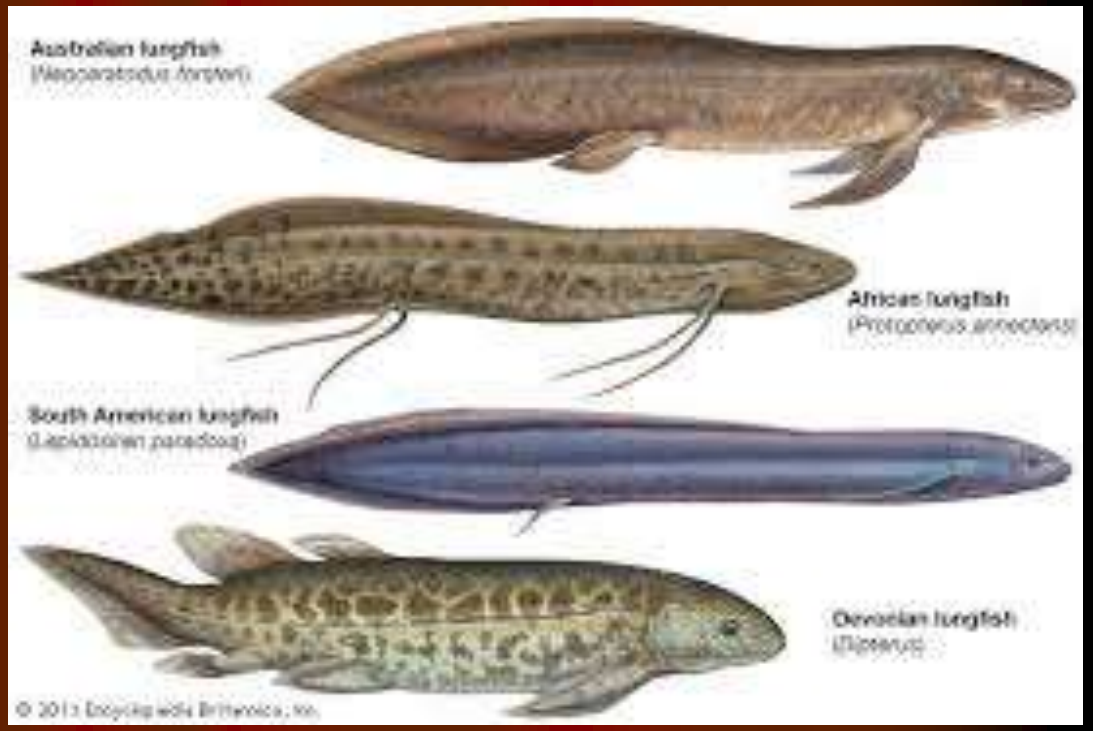


Lung fish (*Dipnoi*)

An air breathing bony fish. Had their heydays 380 Ma.

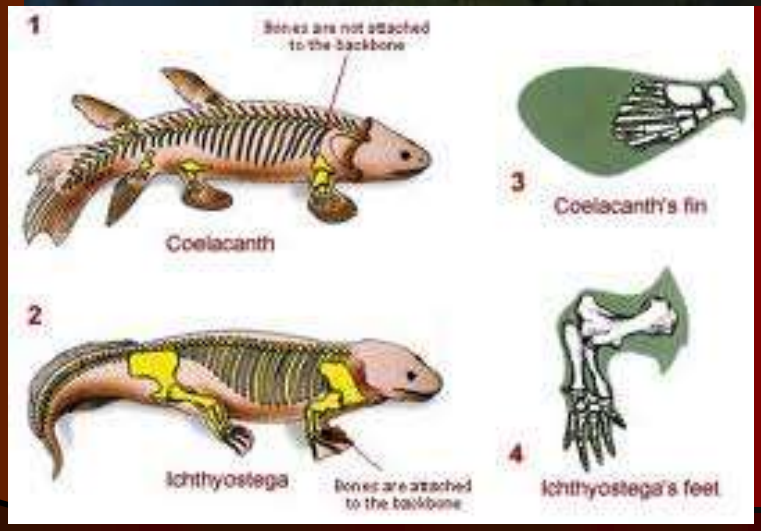
Now only living in Australia, S. America & Africa





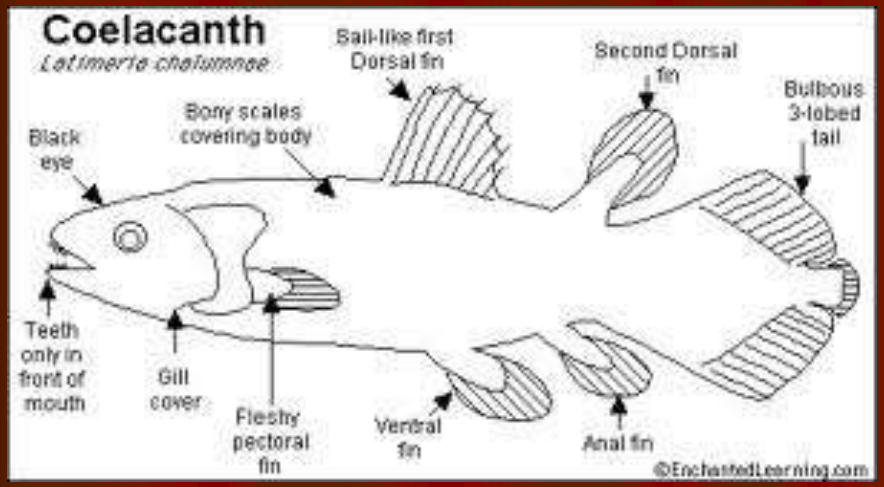
Coelacanth 腔棘魚 A fringe fish & a living fossil

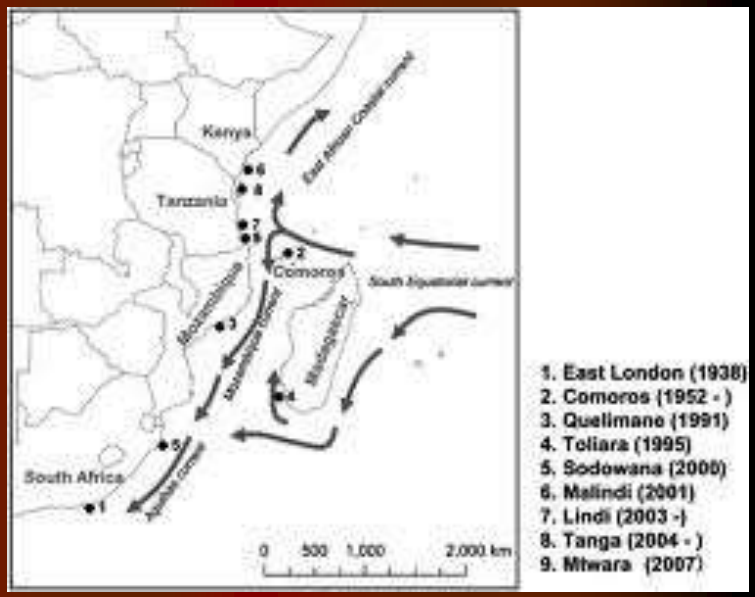
This 365 Ma lobe fin fish survivor thought to have extinct 65 Mya in the late Cretaceous was rediscovered in 1938



Coelacanth

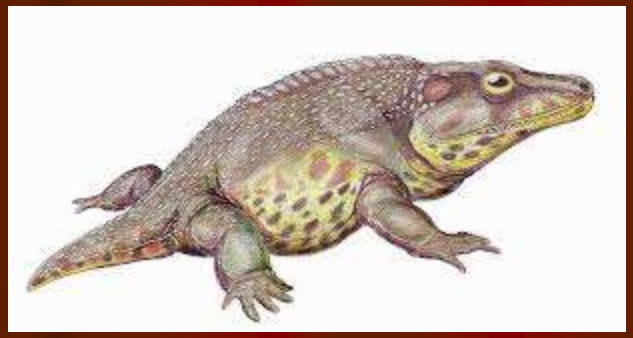
A living fossil living off South Africa & Indonesia

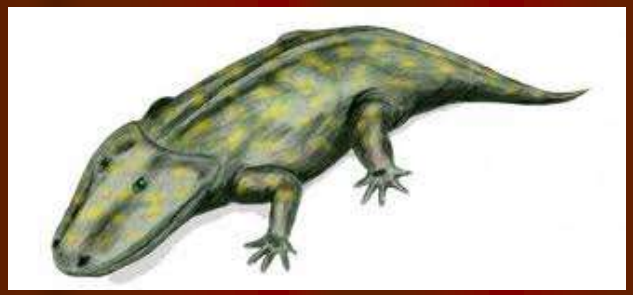


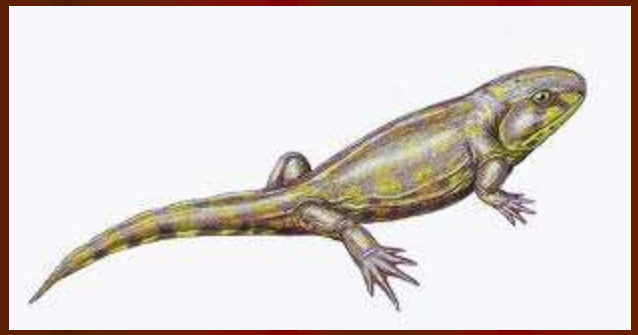


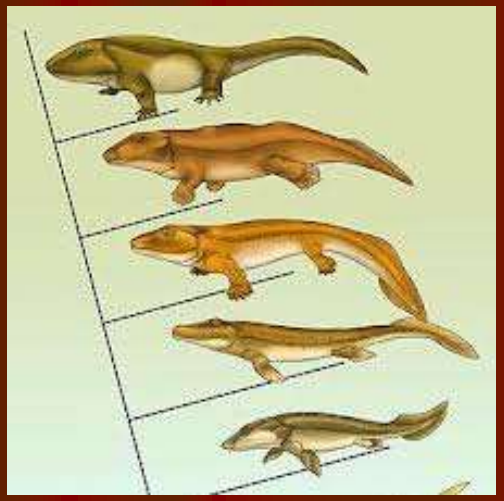
Early amphibians to reptiles

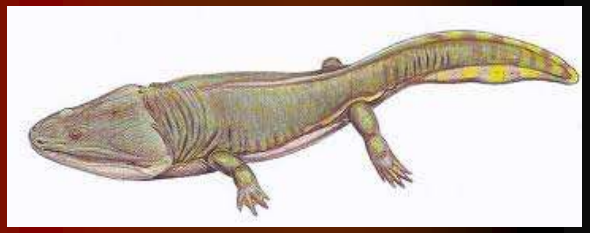
迷齒螈到爬行類

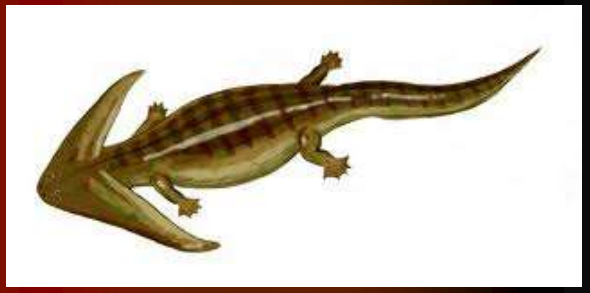






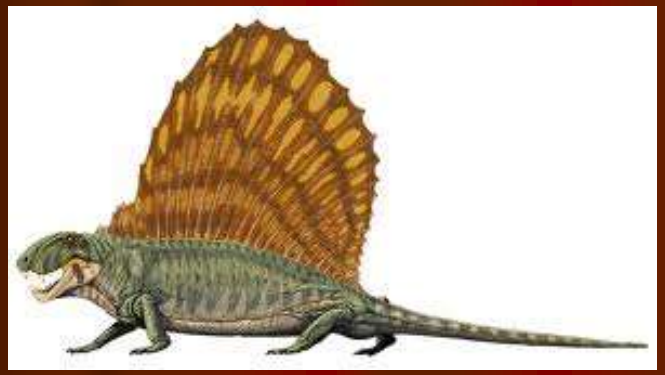


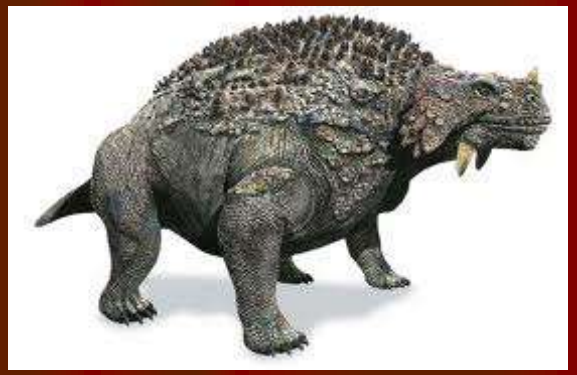


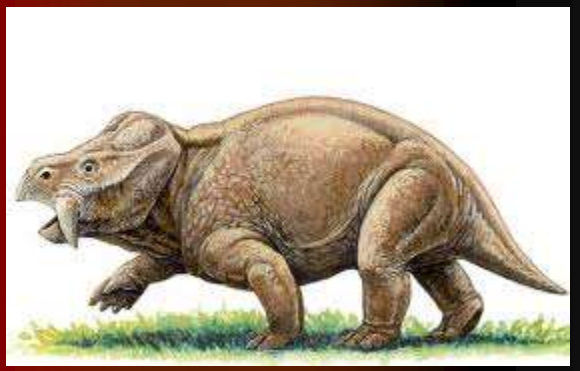


Some early Mammal like Reptiles, Permian

Dimetrodon 異齒獸, Sinokannemeyeria 中國肯氏獸(二齒獸)





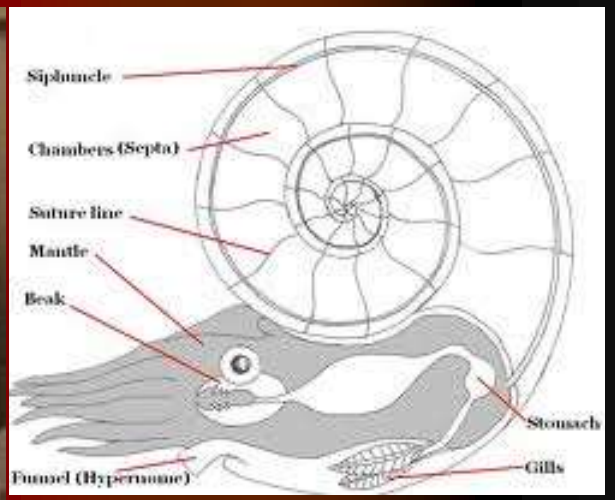


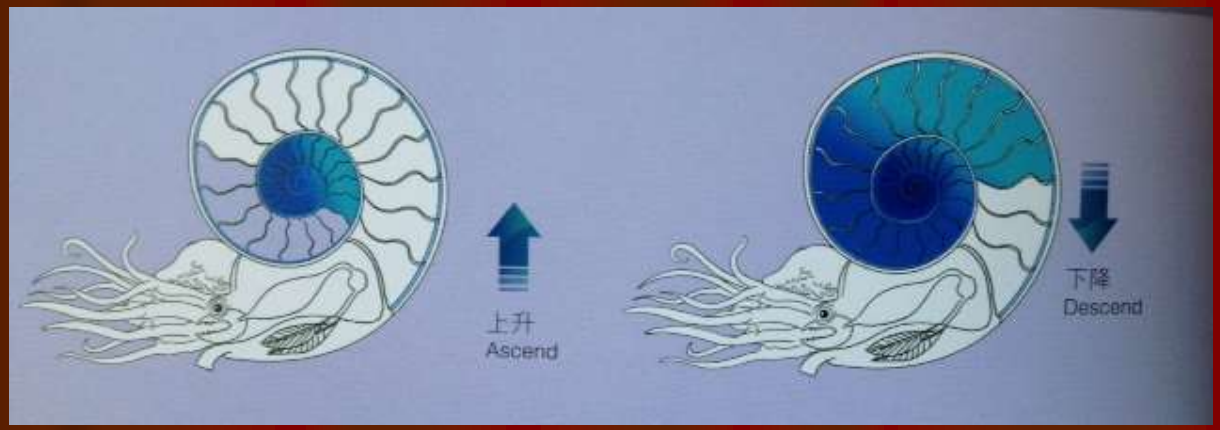
MESOZOIC LIFE 中生代動物

- 251 to 65 Ma
- Heydays of Ammonites
- Age of the Reptiles : at sea, on land & in the air

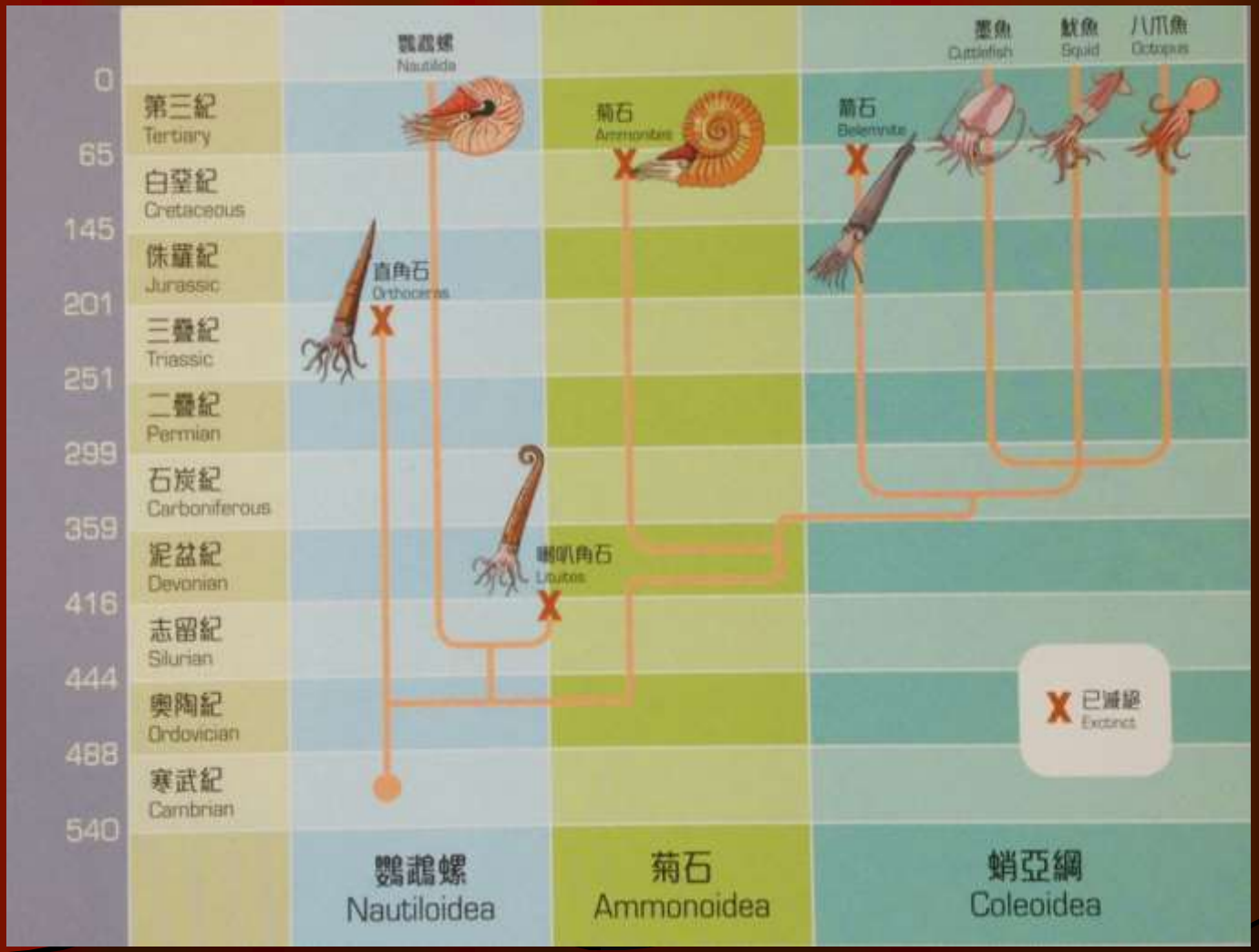
Ammonite 菊石

Extinct cephalopod named after the Egyptian God Ammon





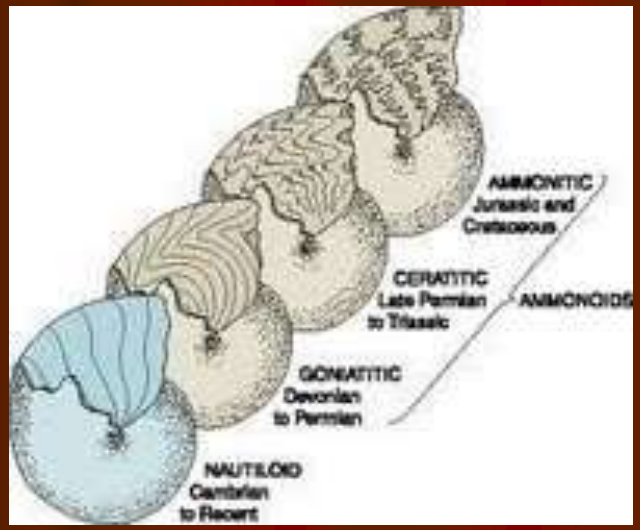
Evolution of Cephalopod
Orthoceras, Ammonite, Belemnite



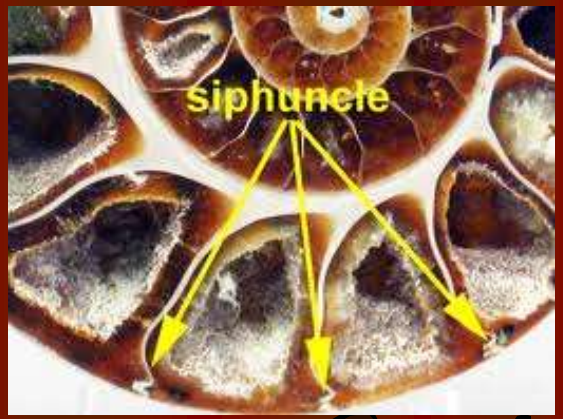
Restoration models of Ammonites

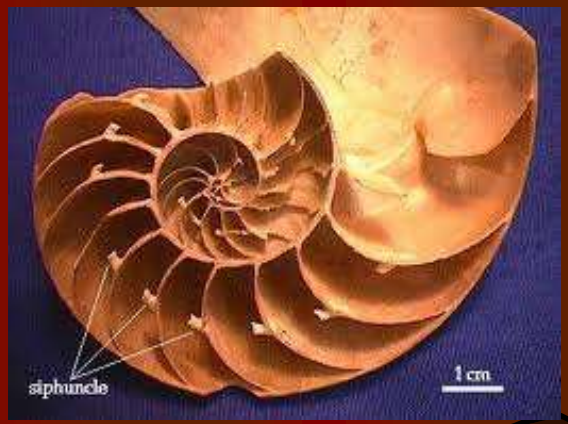
Ammonite fossils in UK

Ammonite showing complex seam or suture lines (growth lines) 縫合線 compared to much simpler nautilus



Cut section of Ammonite showing scepters & position of siphuncle relative to nautilus





Ammonite crioceratites
120 Ma

A beautiful ammonite *Audoliceras* : (Cretaceous 75Ma)

Ammonite mold & cast

European Ammonite

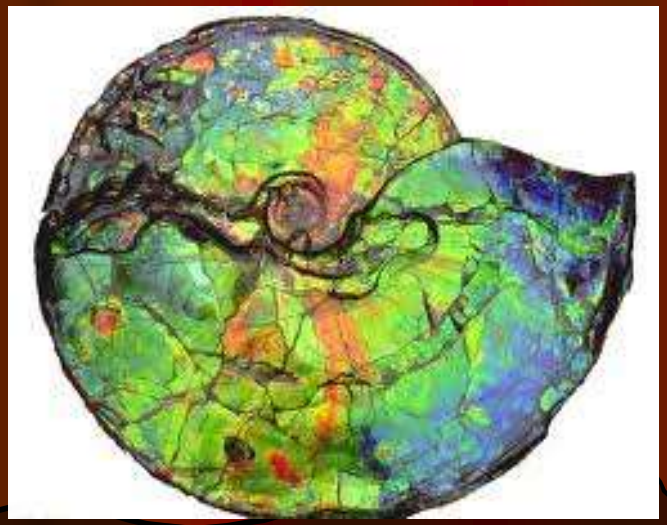
Asteroceras obtusum & Promicroceras

Found at Lyme Regis, the Jurassic Coast in Dorset UK

My Ammonite collections with missing body chambers

Iridescent Ammonite from Madagascar

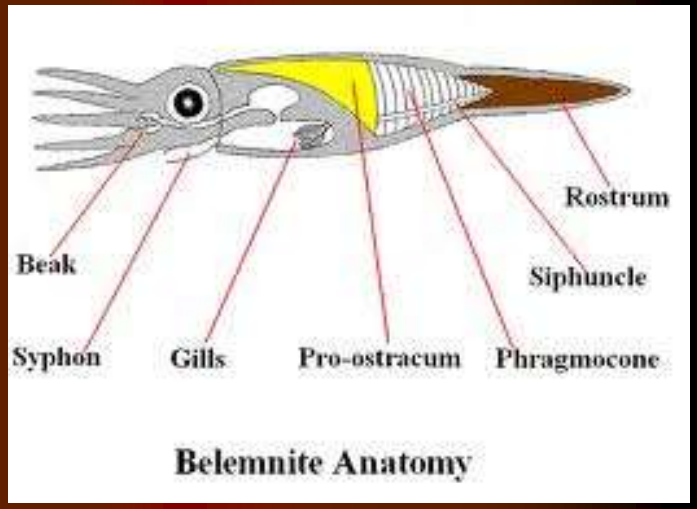


香港菊石
Hongkongites hongkonggensis Grabau
Tolo Channel

Belemnite 箭石

An extinct squid (coleoidea) which was the favorite food of Ichthyosaur. Some belemnites can be 30 cm long eg. Megatheuthis



Belemnite Anatomy

Lycoptera davidi 狼鰭魚

Liaoning China Early Cretaceous Index fossil with 16 species

Leedsichthys

A Jurassic bony fish up to 27 m long with 40,000 small teeth which is a filter feeder like the modern day whale shark but twice as large !

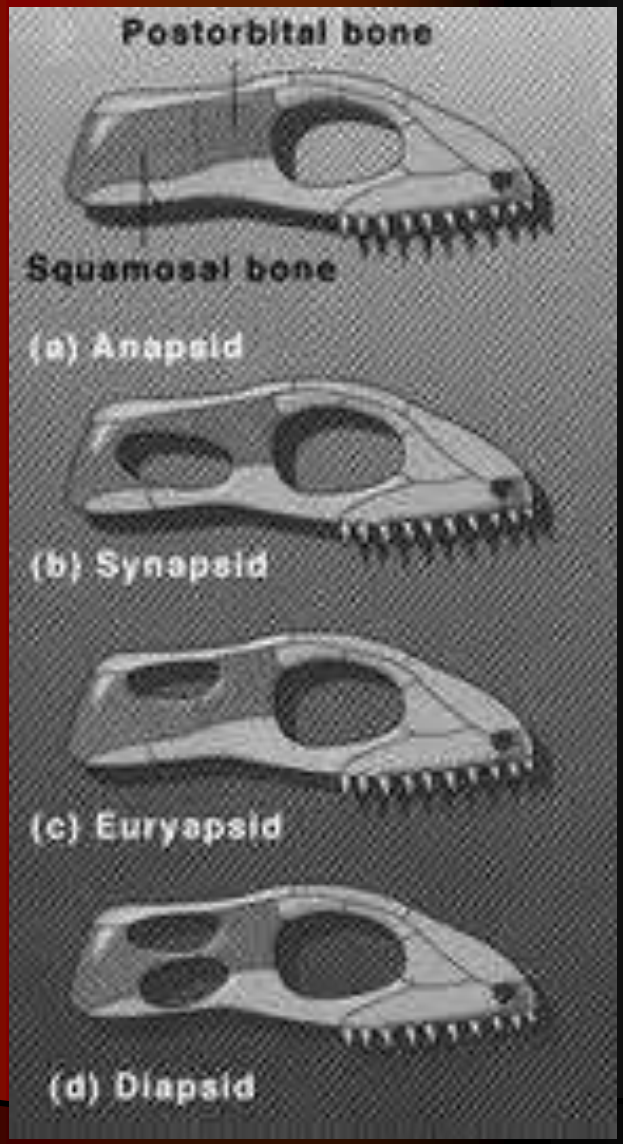
REPTILES

The Mesozoic was dominated by reptiles on land, at sea and in the air. Reptiles are cold blooded, upright crawling, fertilized internally & laid eggs on land

Early reptiles 爬蟲類

- Anapsid 缺弓類：turtles
- Synapsid 單弓類：mammal like reptiles
- Euryapsid 闊弓類：ichthyosaurs, plesiosaurs & placondonts
- Diapsid 雙弓類：dinosaurs & crocodiliformes

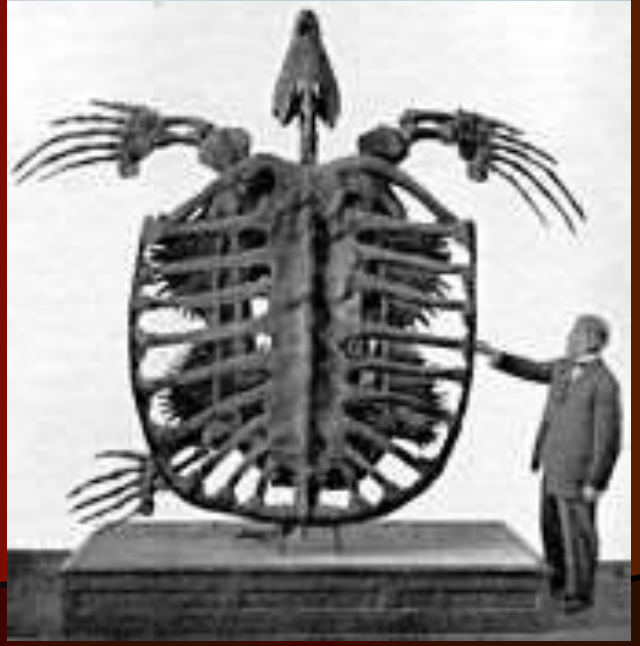
(Only one Synapsid remained to become Therapsids 獸孔類 which eventually evolved into Protomammal.弓 =顳顬孔)



Anapsid 缺弓類

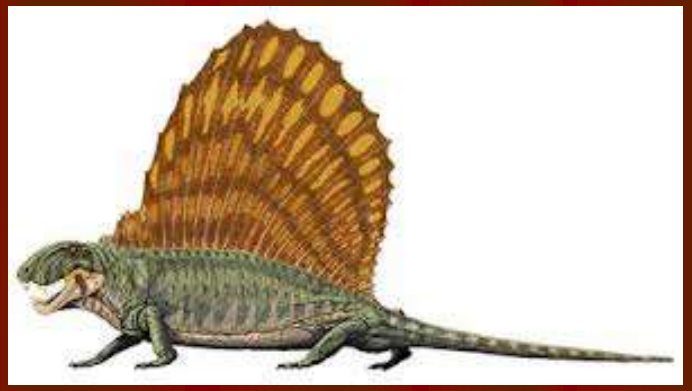
Archelon 始海龜 (*Archelon ischyros*)

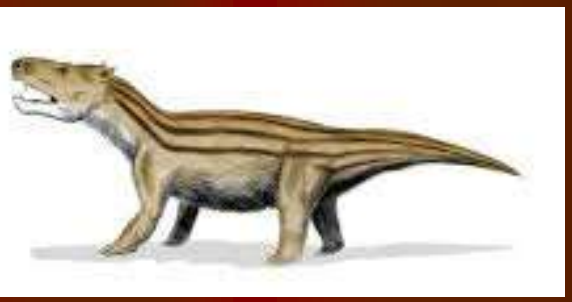
Extinct sea turtle 4 m long 4.9 m wide, 80 Ma Cretaceous

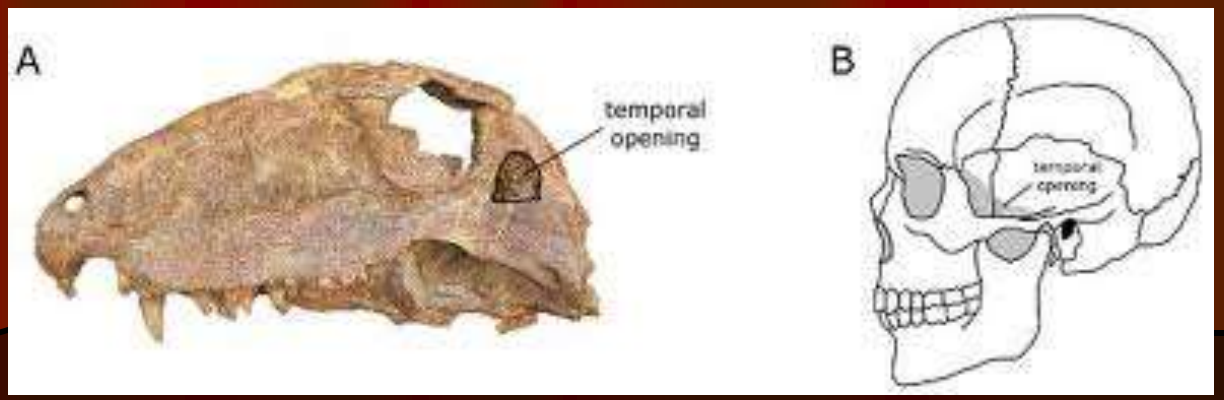


Synapsid 單弓類

- Permian synapsid eg. Dimetrodon 異齒獸 & Lystrosaurus 水龍獸 eventually evolved to therapsid which includes mammals



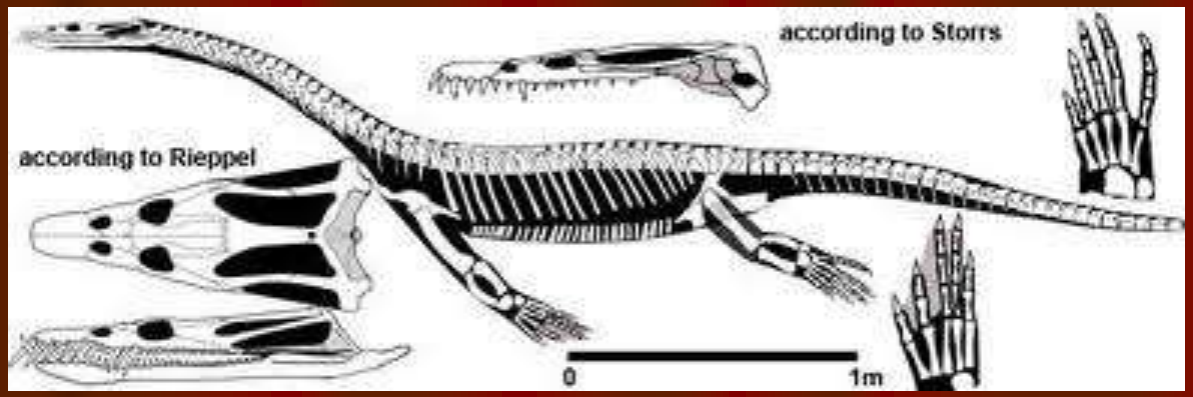


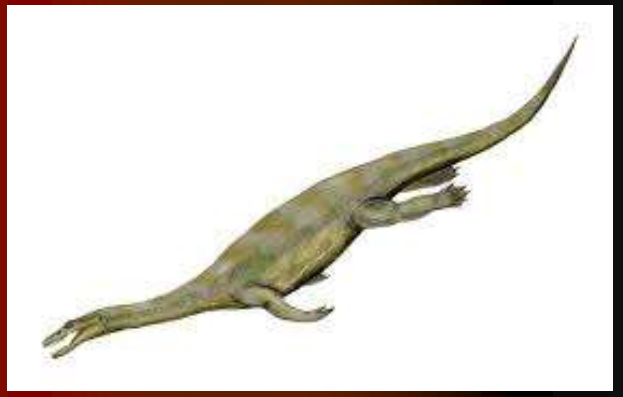


Euryapsid 闊弓類

1. Nothosaurs 幻龍

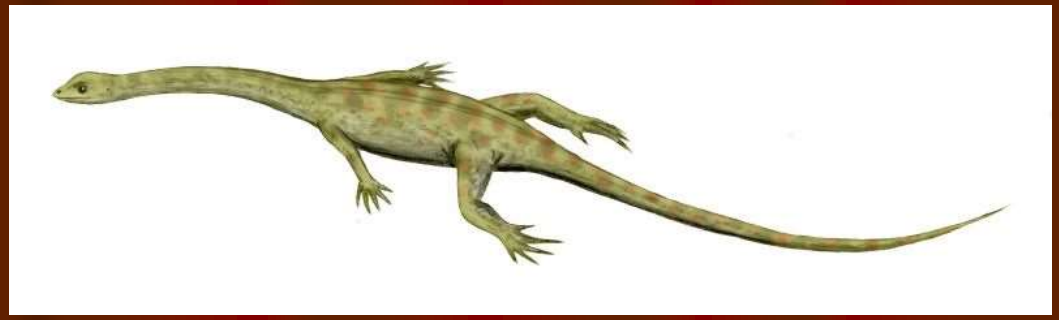
Triassic slim fish eating amphibious reptile probably ancestral to the plesiosaur





2. *Hyphalosaurus*

Liaoning Jehol Biota meaning "submerged lizard"
A fresh water aquatic reptile. Early Cretaceous



3. Placodonts 楯齒龍

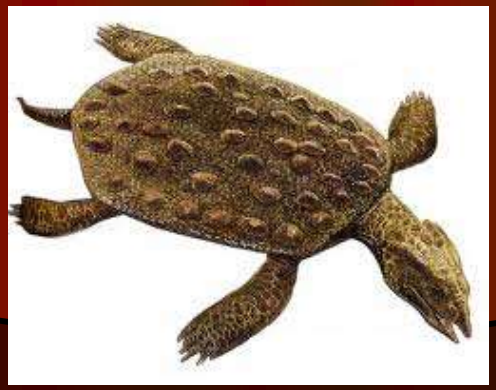
A group of Triassic marine reptiles between 1 to 3 m

- *Placodus*


- *Psephoderma*

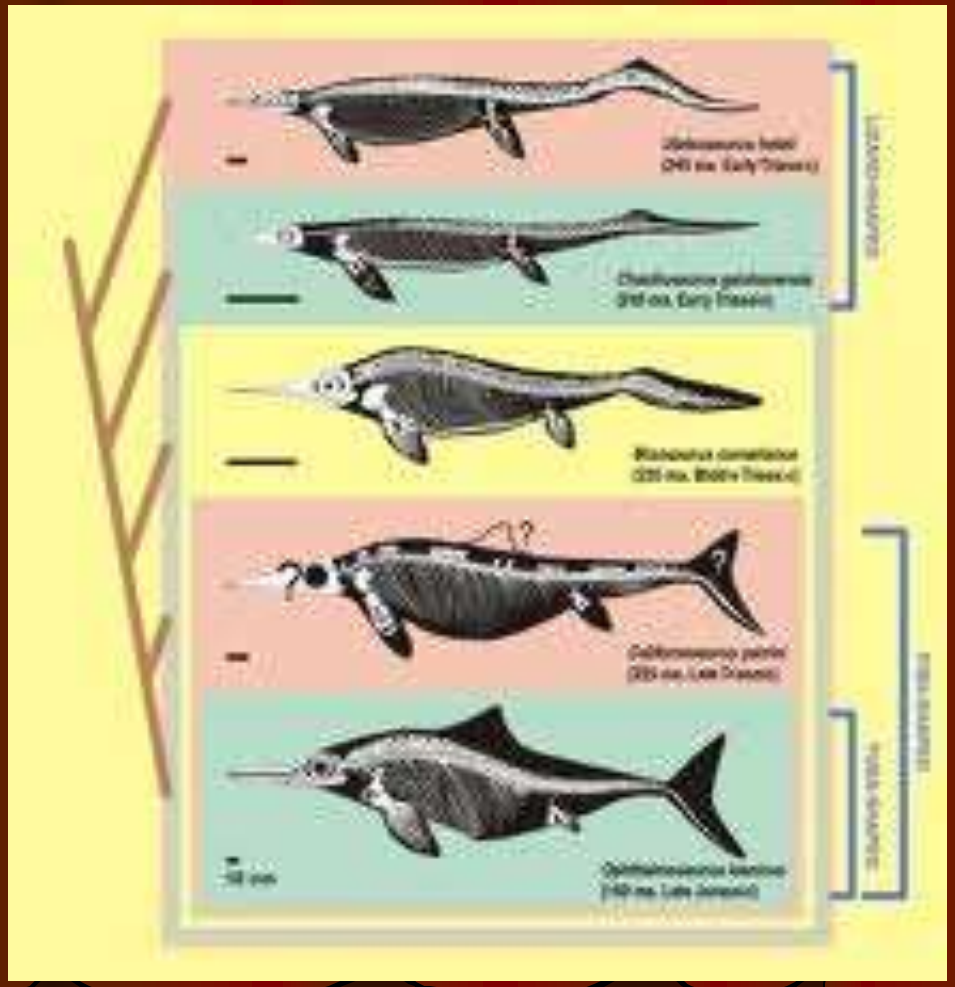
  礫甲龍


- *Placohelys*

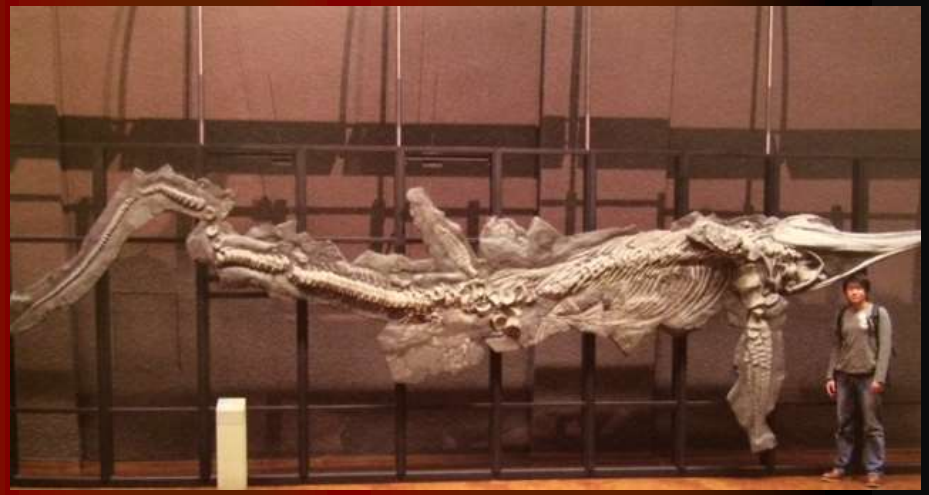


4. Ichthyosaur 魚龍

First appeared in the Triassic the carnivorous "Fish lizard" have many different body design & can be as long as 23 m



Ichthyosaurs is the most successful marine reptiles existed for 155 million years & died out 90 million years ago. They also have the largest eyes ever measuring 25 cm



5. Plesiosaur 蛇頸龍

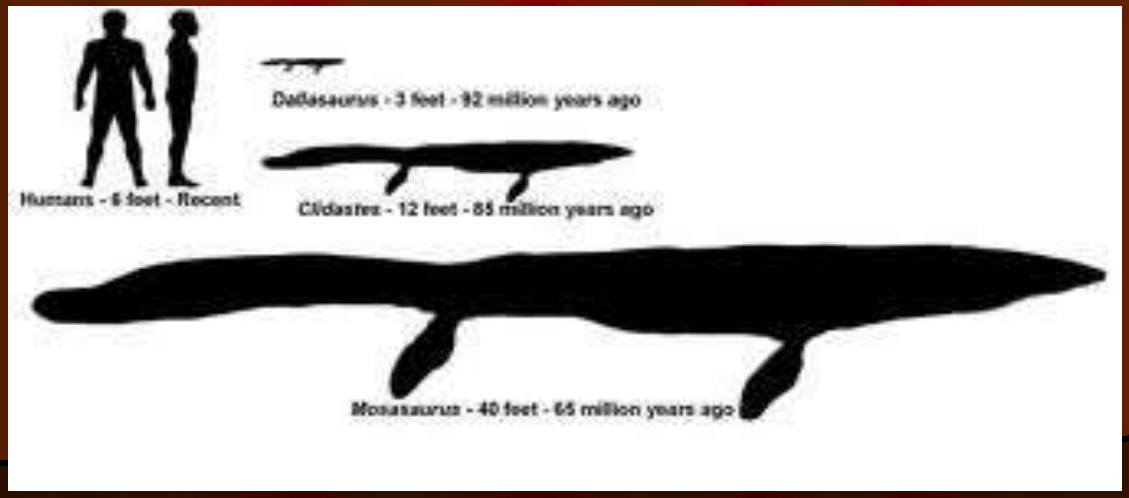
Upto 80 species of Marine carnivores some with long necks & some with short necks length varies between 5 to 15.6 m. First appeared in Early Jurassic & died out in Cretaceous

6. China Plesiosaur 澄江渝州上龍

Short necked form of fresh water plesiosaurs from 5 - 10 m
Late Jurassic

7. Mosasaurs 滄龍

This 13m "Sea Serpent" replaced ichthyosaurs & plesiosaurs to be the dominant marine predator in Late Cretaceous & extinct at the end of the Mesozoic

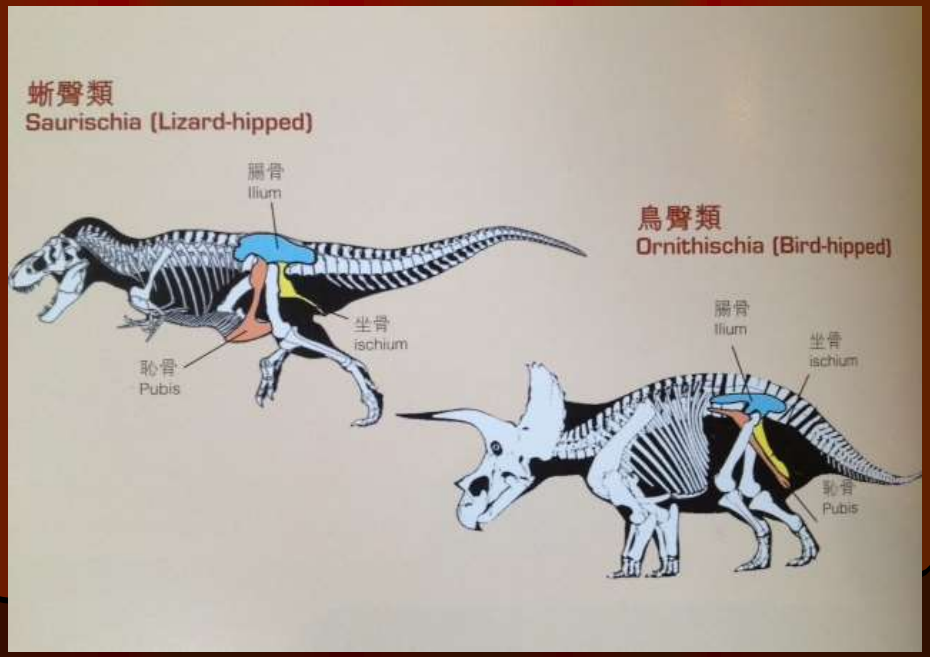


Diapsid 雙弓類

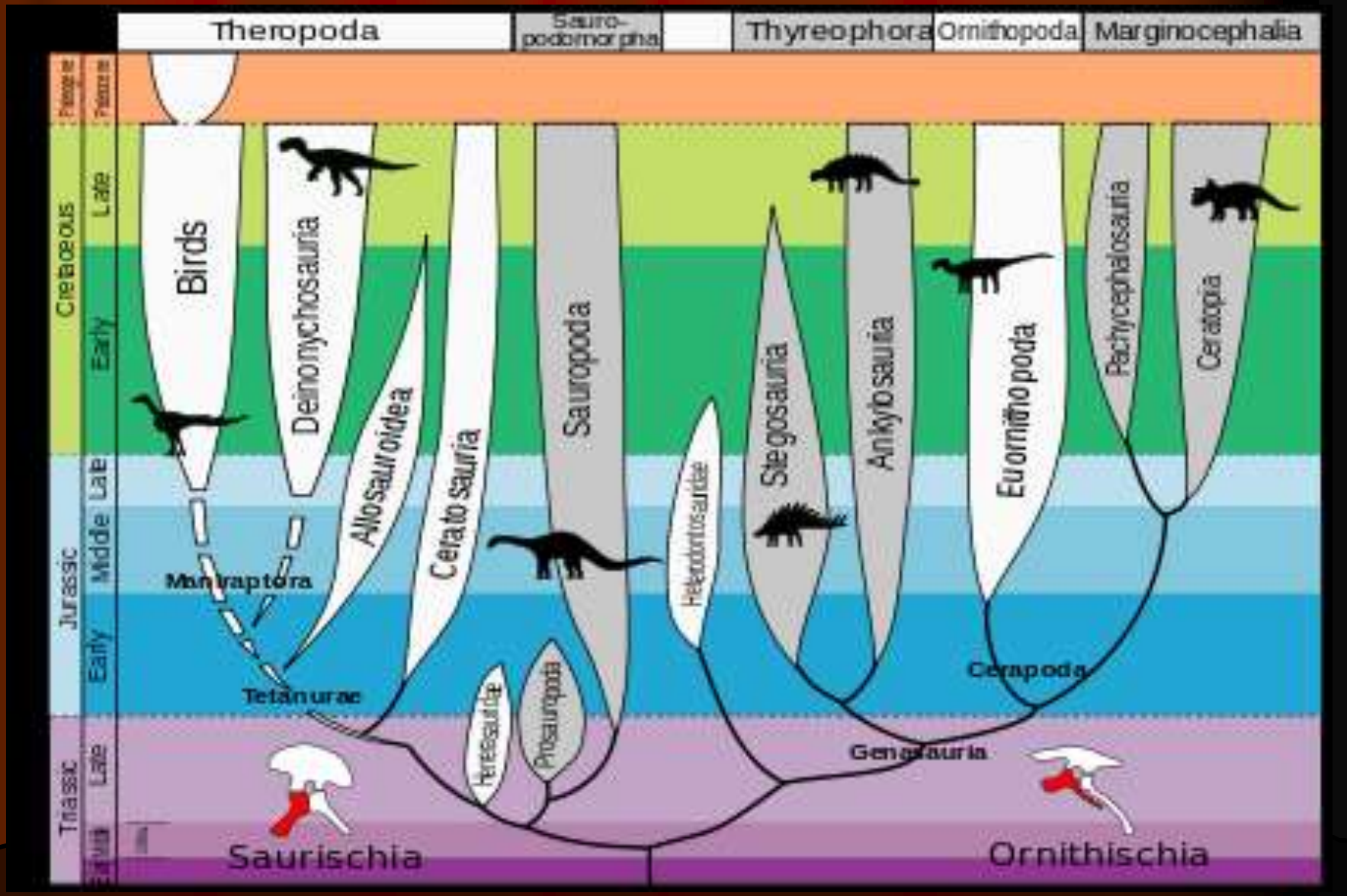
Dinosaurs meaning "Terrible Lizard" 恐龍 all descended from Anchisaurus 800 plus known species of which China has 170. Most successful animal on Earth dominated 135 million years from late Triassic to late Cretaceous

Two main orders basis on their pelvic structure :

- Lizard hipped 蜥臀目(Saurischians) - both herbivore & carnivore
- Bird hipped 鳥臀目(Ornithischians) - all herbivore

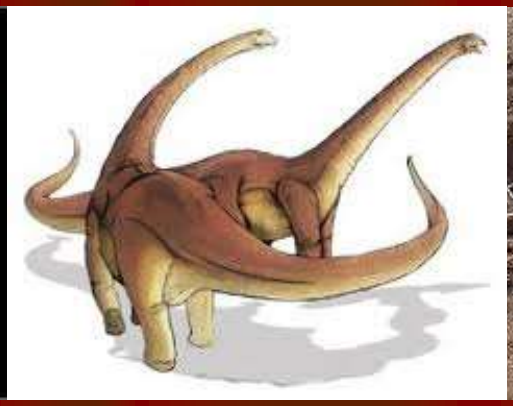


Dinosaurs evolution



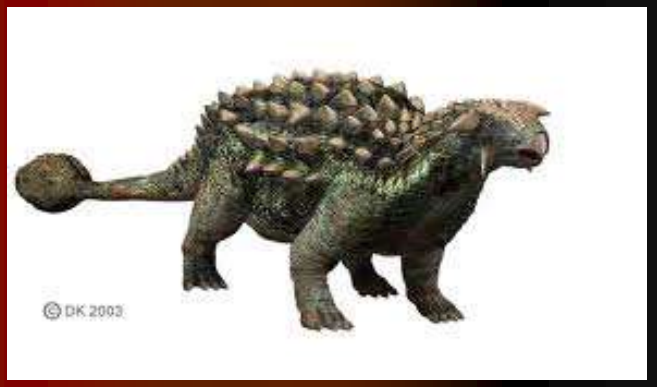
Dinosaurs

- Saurischians 蜥臀目

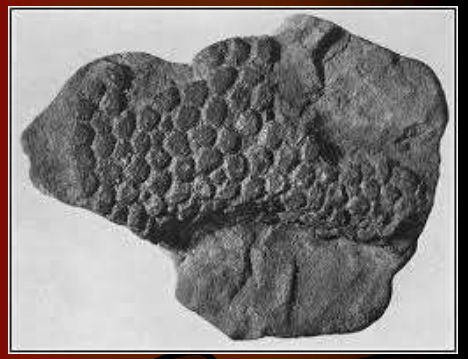




- Ornithischians 鳥臀目





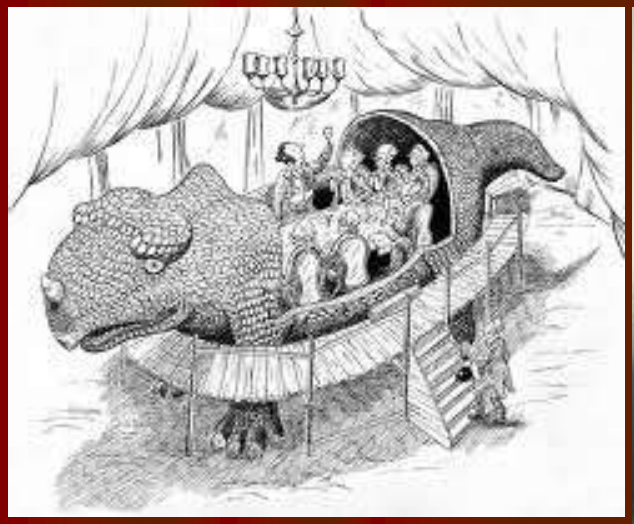
Dinosaur bone & skin



- 中國恐龍之父楊鐘健教授

The story of the spike – *Iguanodon* 禽龍

It is the first dinosaur bone being discovered in 1821



Dinosaur eggs

Key difference with amphibians by laying eggs on land instead of in water. 2 basic types : Elongatoolithidae or Spheroolithidae






Dinosaur eggs from China

The largest dinosaurs so far discovered

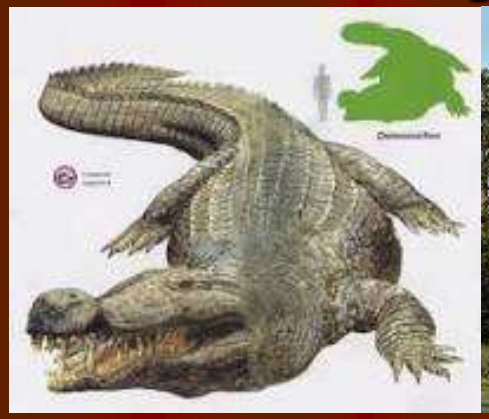
- *Spinosaurus* 棘背龍 : largest carnivorous dinosaur

- *Argentinosaurus* : largest dinosaur 80–100 tons !

Crocodiliformes

A diapsid originated in the Triassic with descendants surviving today

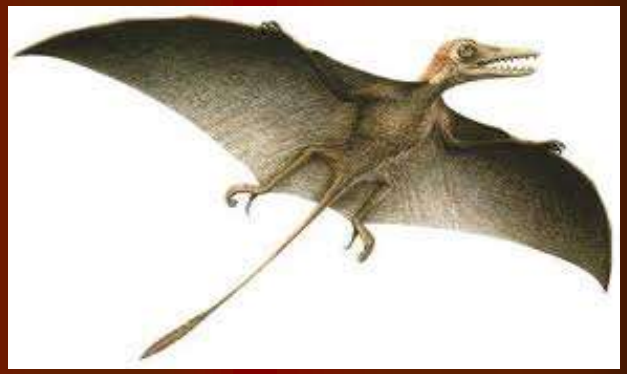
- *Deinosuchus* 帝鱷：at 15 m long living in the cretaceous, it is the largest crocodile ever !



Flying Reptiles

Flying reptile – pterosaur 翼龍

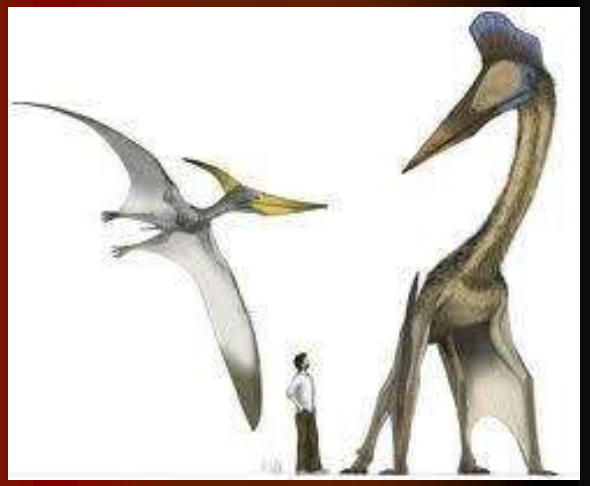
- *Rhamphorhynchus* 喙嘴翼龍：Late Jurassic 1.7 m

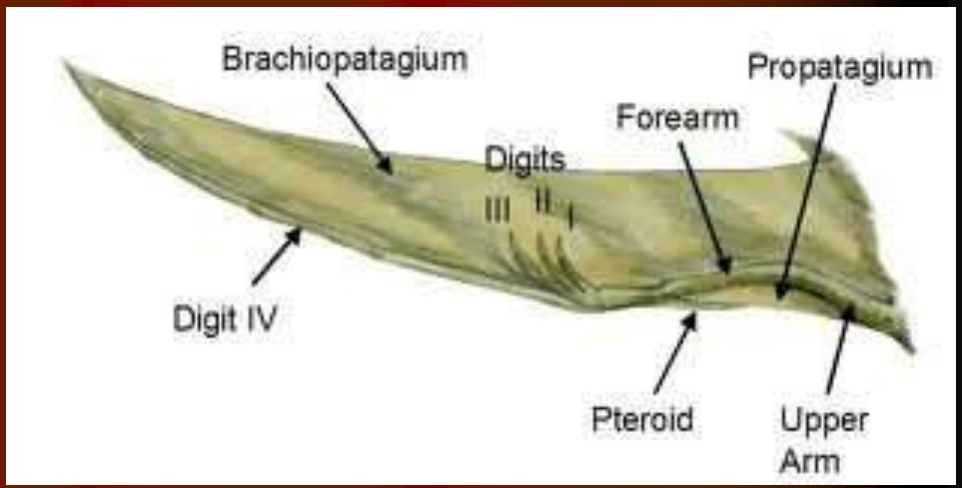


Flying reptile – pterosaur 翼龍

- *Pterodactylus* 翼手龍：Late Jurassic 2.5 m

Quetzalcoatlus 風神翼龍
The largest flying reptile with a wing span of 12 m





The Dino - Birds

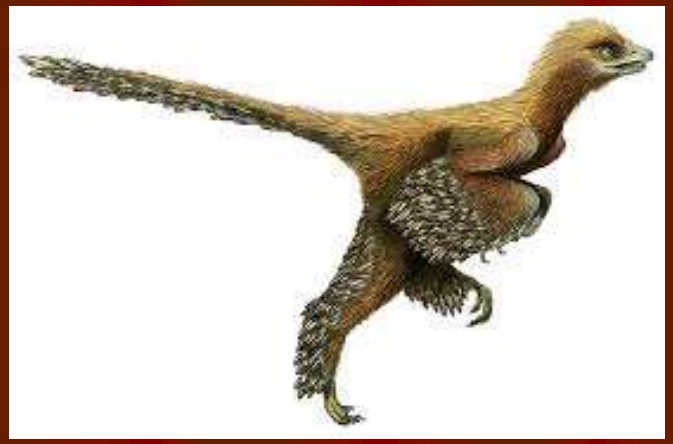
Archaeopteryx 始祖鳥

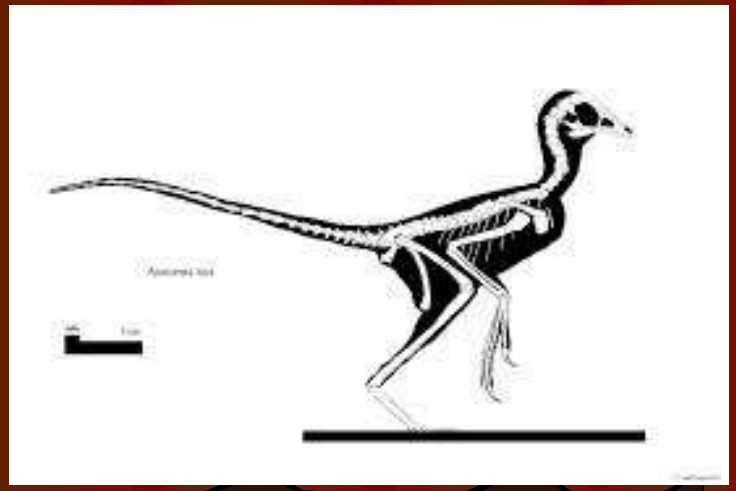
150 Ma Late Jurassic

Earliest known "bird" discovered in Solnhofn limestone Germany in 1861 body length 60 cm likely glide rather than fly

Aurornis xui the "Dawn Bird"

160 Ma contender for the oldest bird title. Total length 50 cm. Discovered in Yaoluguo, Liaoning





Anchiornis huxleyi 赫氏近鳥

Late Jurassic. The oldest feathered dinosaur



Microraptor Gui 顧氏小盜龍

Small about 1 m long 4 winged paravian dinosaur probably only good for gliding Early Cretaceous 125-120 Ma

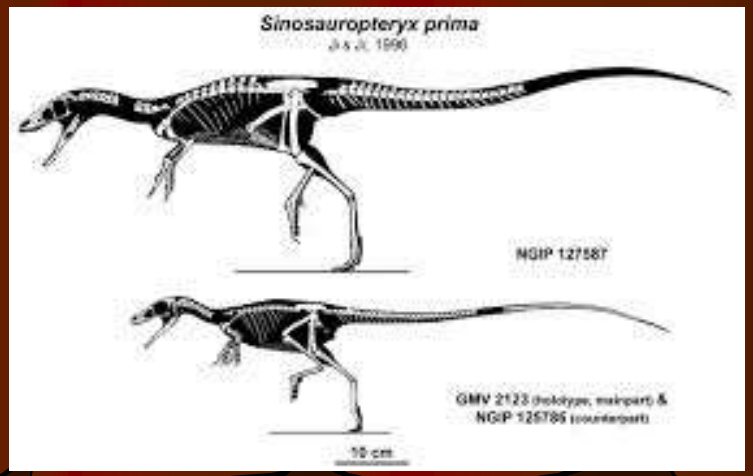


Sinosauropteryx 原始中華龍鳥

150 Ma Early Cretaceous

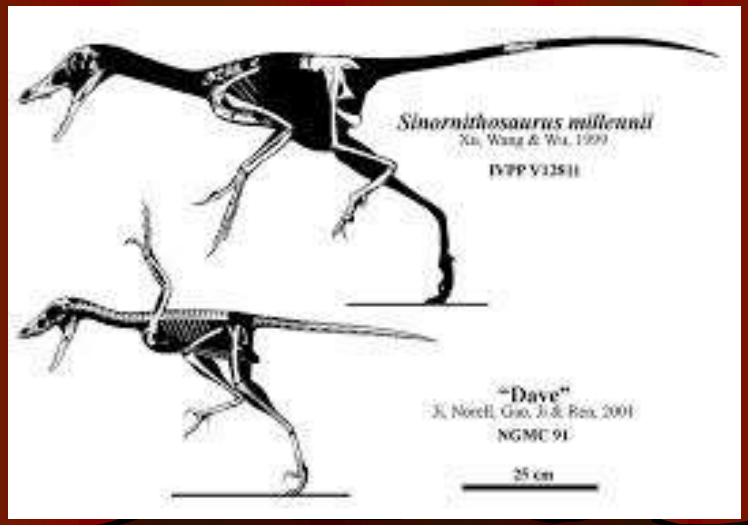
Earliest known feathered non avian theropod dinosaur in the world

around 80 cm long weighed 0.55 kg



Sinornithosaurus

千禧中國鳥龍 Liaoning Early Cretaceous



Sapeornis chaoyangensis 朝陽會鳥

Early Cretaceous, largest cretaceous bird found with very sharp teeth



Xinghaiornis lini 林氏星海鳥：

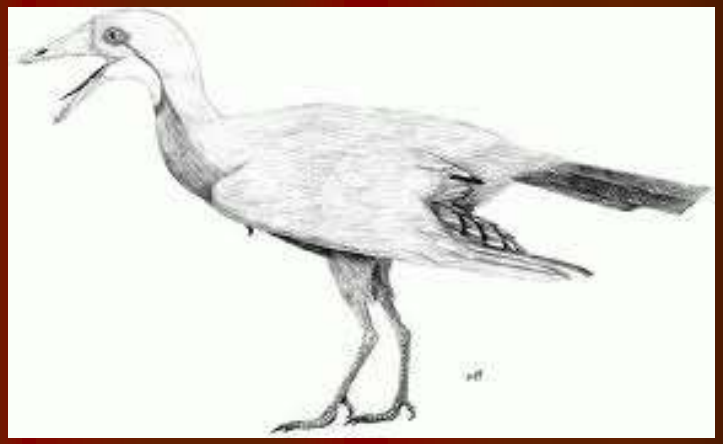
A relatively large toothless bird in the Early Cretaceous


Confuscornis sanctus 聖賢孔子鳥

125 Ma Early Cretaceous, first beaked bird & first flying bird we know of with long wings, 3 claws & some having longtail feather. Length 60 cm

Cathayornis yandica

120 Ma Early Cretaceous Jiufotang formation



Sinornithosaurus haoians 郝氏中國鳥龍

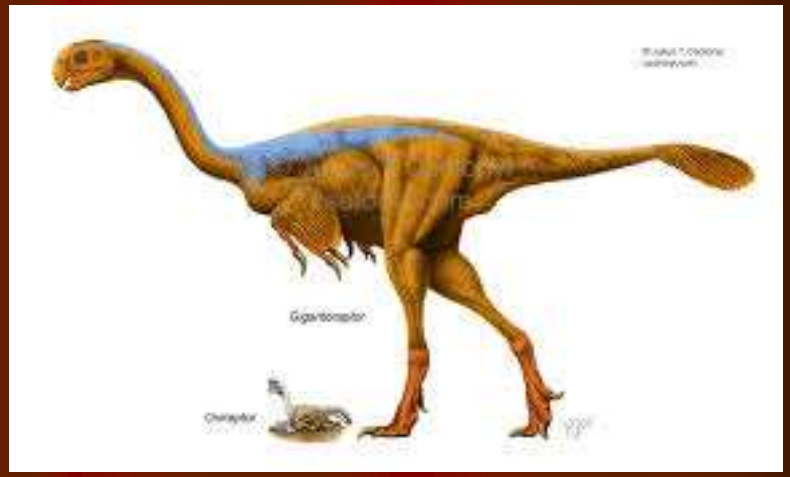
Early Cretaceous

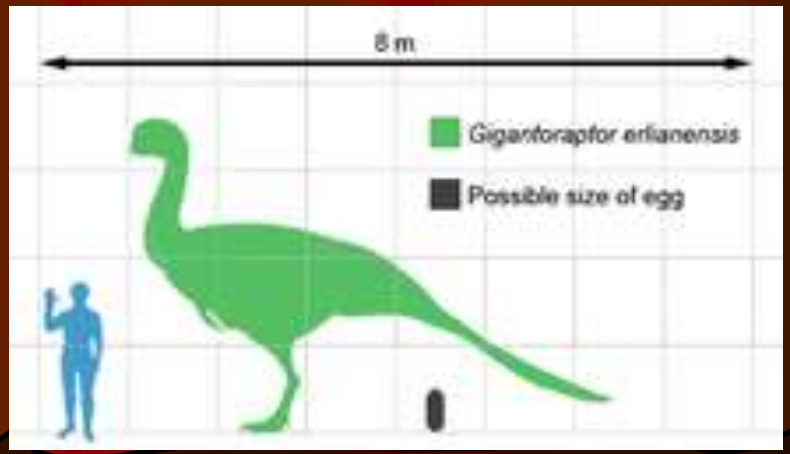
Shenzhouraptor sinensis 中華神州鳥

Early Cretaceous

Giganticraptor

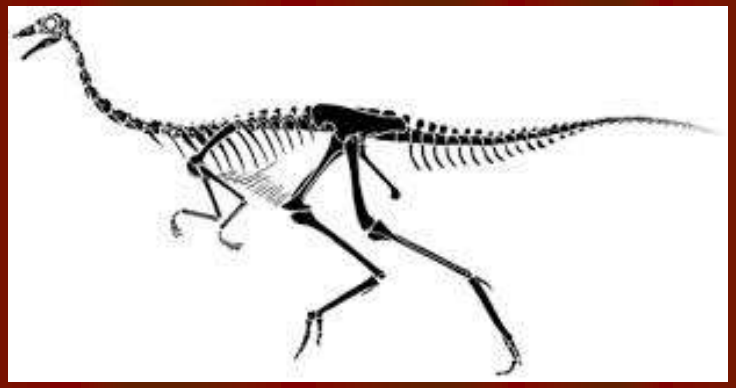
70 Ma Late Cretaceous. Length 8 m weight 1400 kg. At 45 cm their eggs are the largest dinosaur egg ever

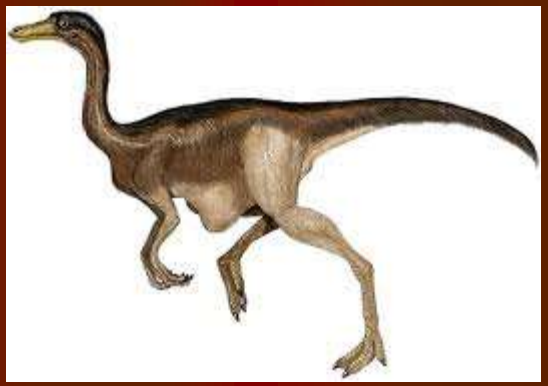




Gallimimus 似雞龍

An 8 m long Late Cretaceous dinosaur with back feathers





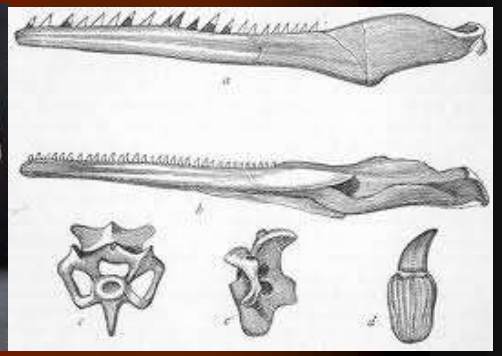
Oviraptor 偷蛋龍

A 3 m long dinosaur living in Late Cretaceous

Ichthyornis 魚鳥

A Cretaceous tern like fish eating bird preserved with teeth

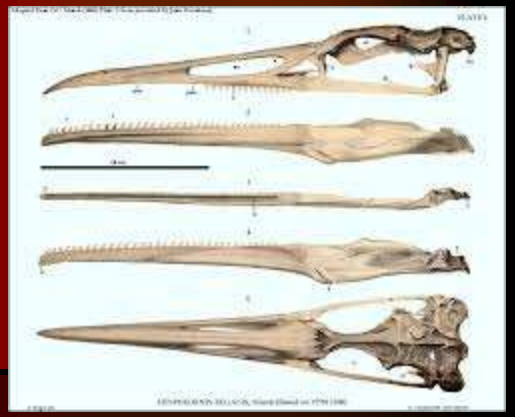




Herperornis 黃昏鳥

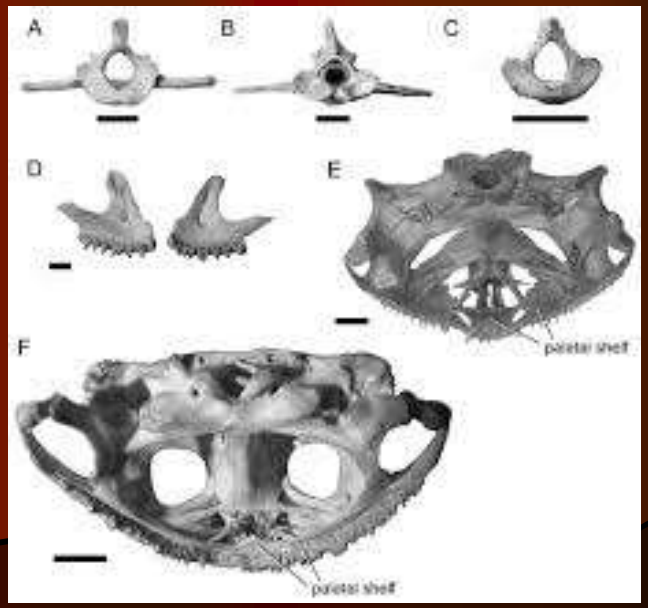
A flightless toothed aquatic bird of the Late Cretaceous well adapted for swimming & diving. Maximum length 3m





Beelzebufo

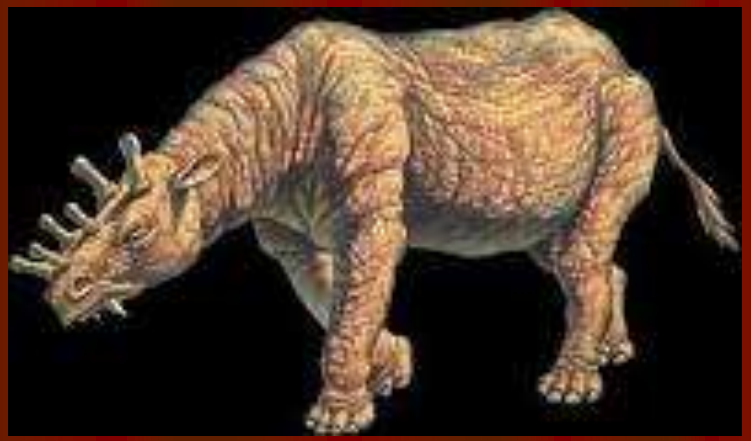
Late Cretaceous Madagascar - the "Devil Frog" or "Frog from Hell"
16 inches high weigh 10 lbs probably the largest frog ever existed



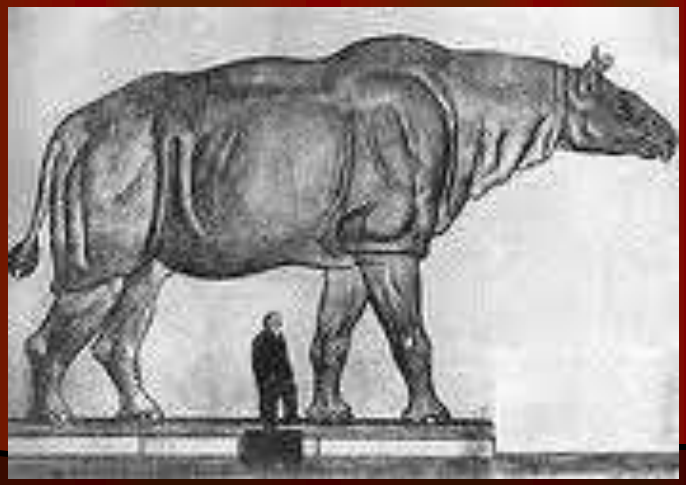
CENOZOIC LIFE 新生代動物

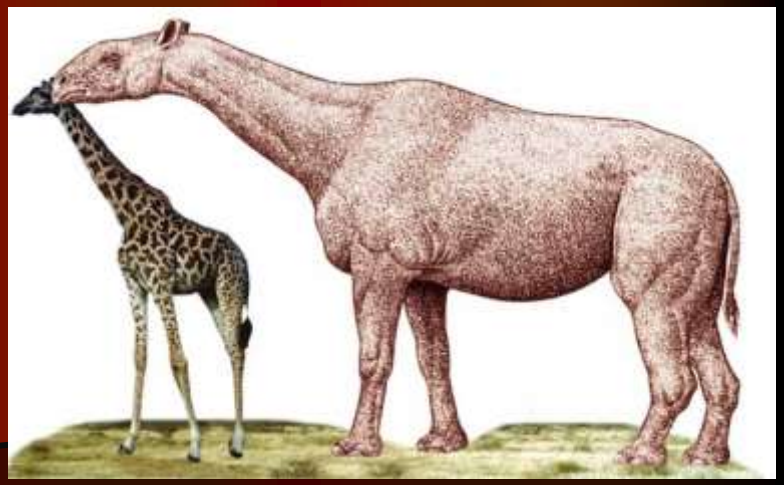
- 65 Ma to now
- Age of the Mammal
- Mega fauna
- Mammal returning to the sea
- More birds
- Bony fish excel
- Arrival of Human

- Uintatherium 雷獸：a 4 m long Eocene horned mammal which is herbivorous



- Baluchitherium 巨犀：a 6 m high rhinoceros, the largest land mammal ever





- Brontotherium : a 2m high North American grazing animal living in the Oligocene

Giant sloth (*Megatherium*) 大地獺

Pleistocene. Reached a height of 7 m

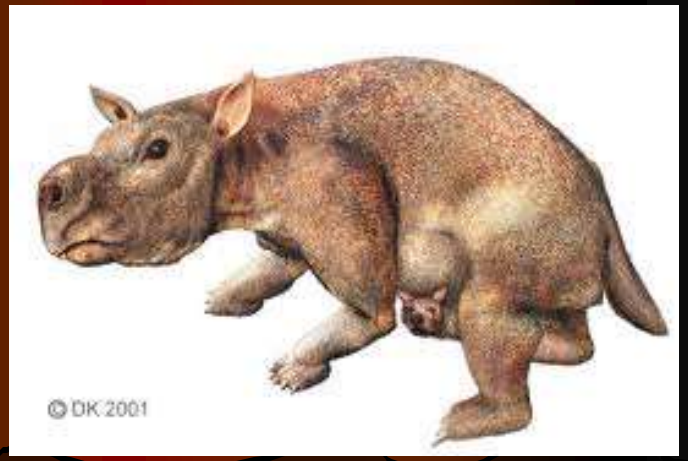
Cave lion 穴獅 (*Panthera spelaea*)

Living in Europe during the Pleistocene & extinct around 12,500 years ago

Saber tooth tiger 劍齒虎 (*Smilodon*)

Upper Pleistocene. Armed with two 20 cm long upper canine teeth it is much larger than a Bengal tiger !

Giant Armadillo (*glyptodon*), Irish Elk (*megaloceros*) & Giant Kangaro (procoptodon)



Extinct ancient elephant species

Woolly Mammoth 猛獁/長毛象 (*Mammuthus primigenius*)

Pleistocene 5 m high with 4 m tusks

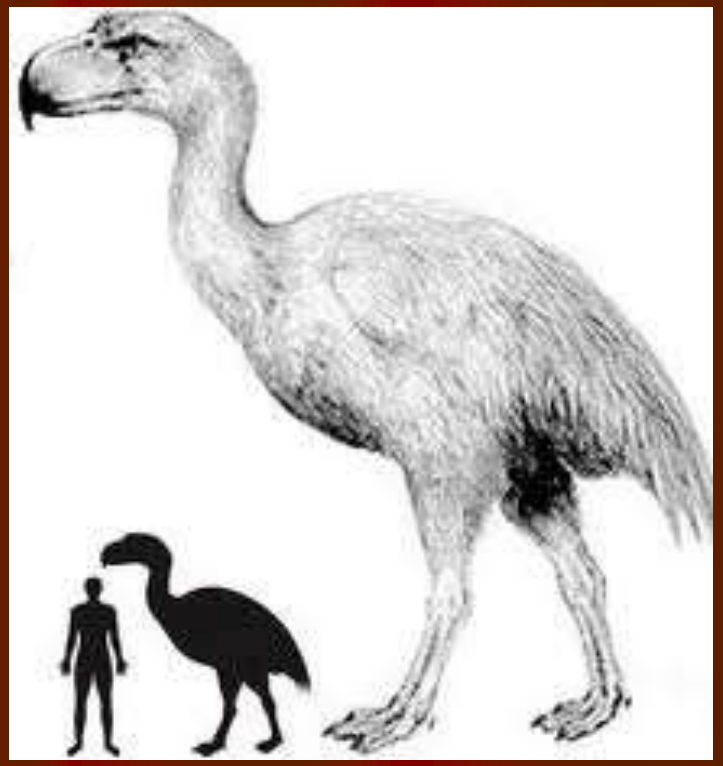
Woolly Rhinoceros 披毛犀 (Coelodonta)

6 foot high Ice Age rhino

CENOZOIC FLIGHTLESS BIRDS

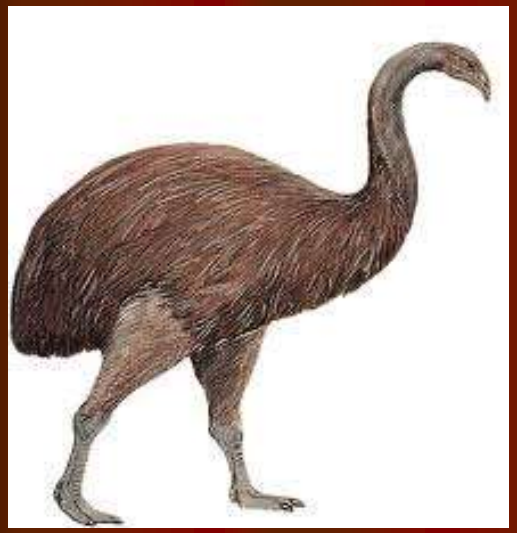
Terror Bird

Phorusrhacus 恐鳥 of South America & *Titanis* 泰坦鳥 of Florida are large carnivorous flightless birds during the Pliocene



Dinorinis “ MOA” 隆鳥

9 species endemic to New Zealand largest reached 3.6 m weighed 200 kilos died out in 1400 AD due to over hunting by man & loss of habitat



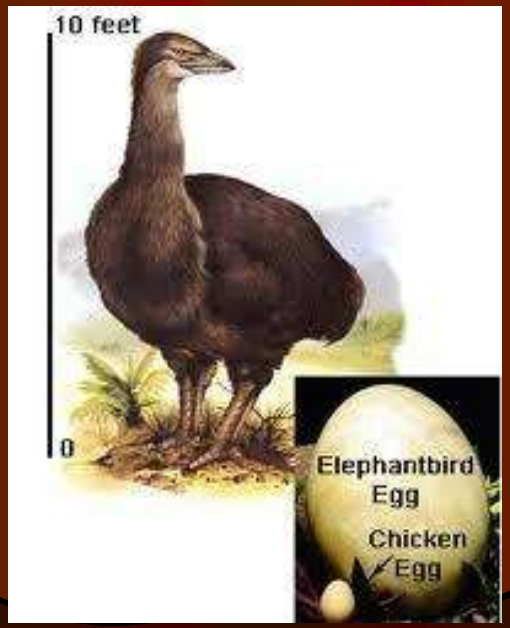
Aepyomis maximus 象鳥

Existed 60 million years ago, endemic to Madagascar & also the largest bird ever lived. Totaling 4 species, 10 ft tall & weighs 900 lbs. Related to ostriches & emus , it is a herbivore. Became extinct around the 17th century

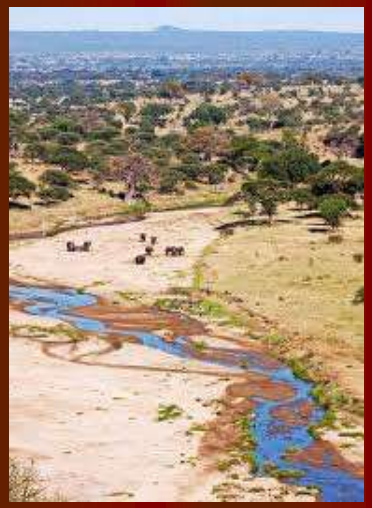
Elephant Bird's Egg is so far the largest egg ever discovered on earth

FACT FILE

- A saucepan the size of a paddling pool would be needed to poach the egg, which is 300 times the size of a hen's egg
- It could make 100 omelettes (or need 2,400 toast soldiers to soak up the yolk)
- It would have contained around 22,000 calories, while the average hen's egg has 74
- One elephant bird egg would last the average diner more than a year – we consume 172 eggs each every 12 months



Broken Elephant Bird's Egg shells are all that can be found in the southern shore of Madagascar



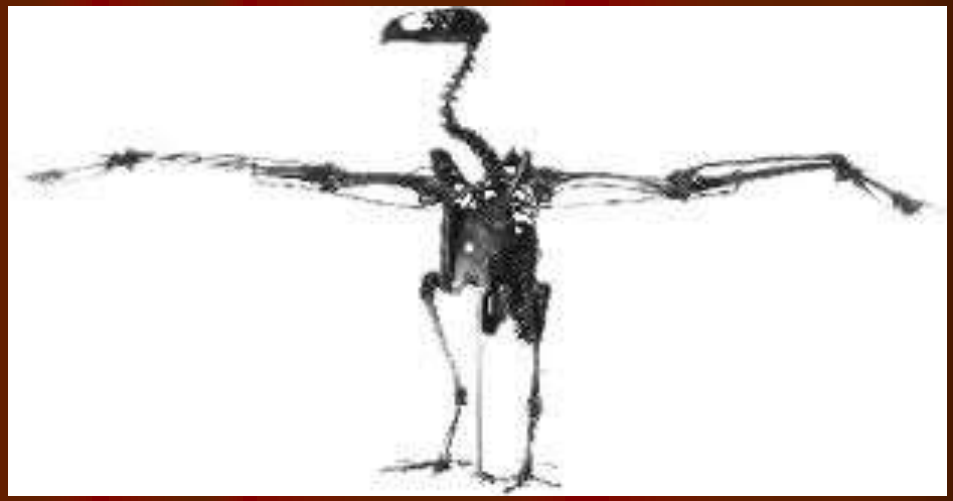
Dodo Bird (*Raphus cuculatus*) 渡渡鳥

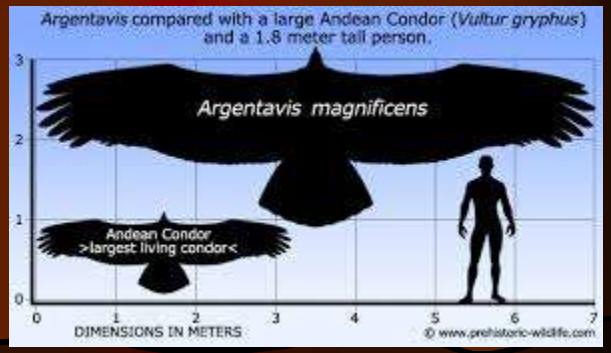
Dodo is a flightless pigeon endemic to Mauritius. 1 m tall weighed 10 -18 kg first appeared in Mauritius 4 million years ago extinct around 1662 mainly due to man's activity

Egg on face: the cast of the only alleged dodo egg in the world (left) is much bigger than it ought to be (right)

Argentavi magnificens

Also called the "Giant Teratorn" this largest bird ever discovered was living in Argentina 6 Ma during the Miocene & have been extinct for at least 10,000 years. This giant predator had a wing span of 7 m and weighed 70-78 kg

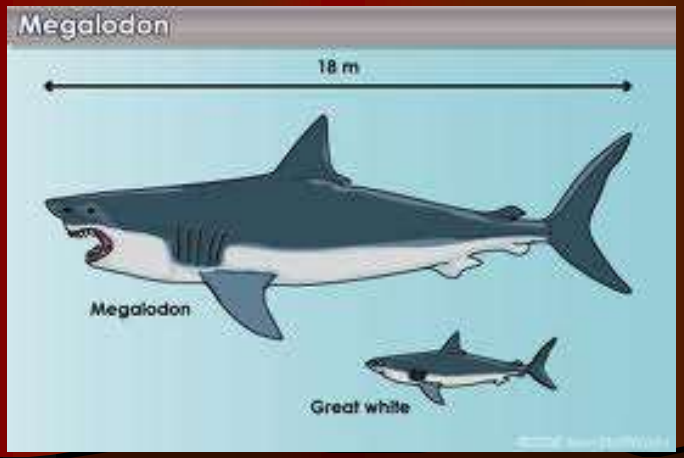




CENOZOIC SHARKS & WHALES

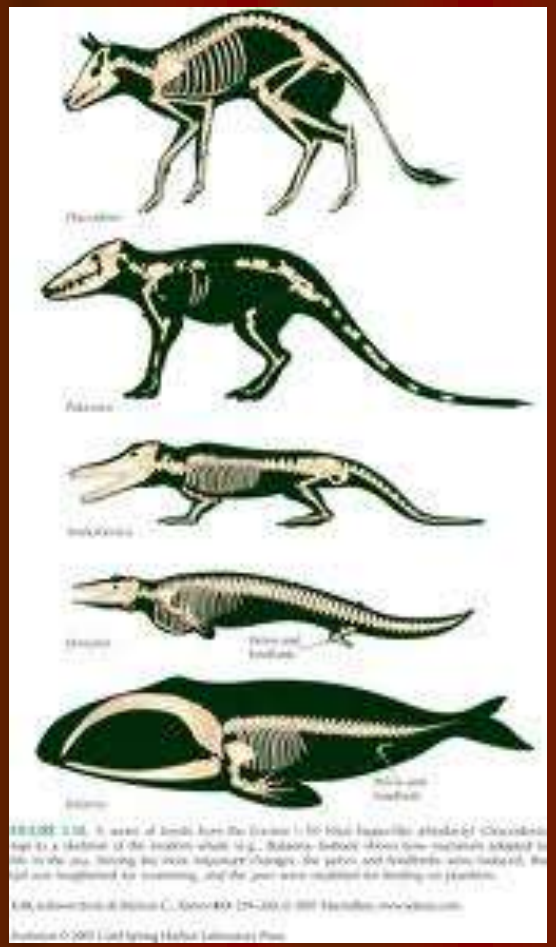
Carcharocles Megalodon 巨齒鯊

Lived 28 to 1.5 mya Oligocene to Pleistocene measured 16 m long with 15 cm teeth



Returning to the sea (55 -34 ma Eocene)

From *Mesonychians* a hoofed carnivorous mammal to whales (cetaceans)



- Pakicetus
  巴基鯨

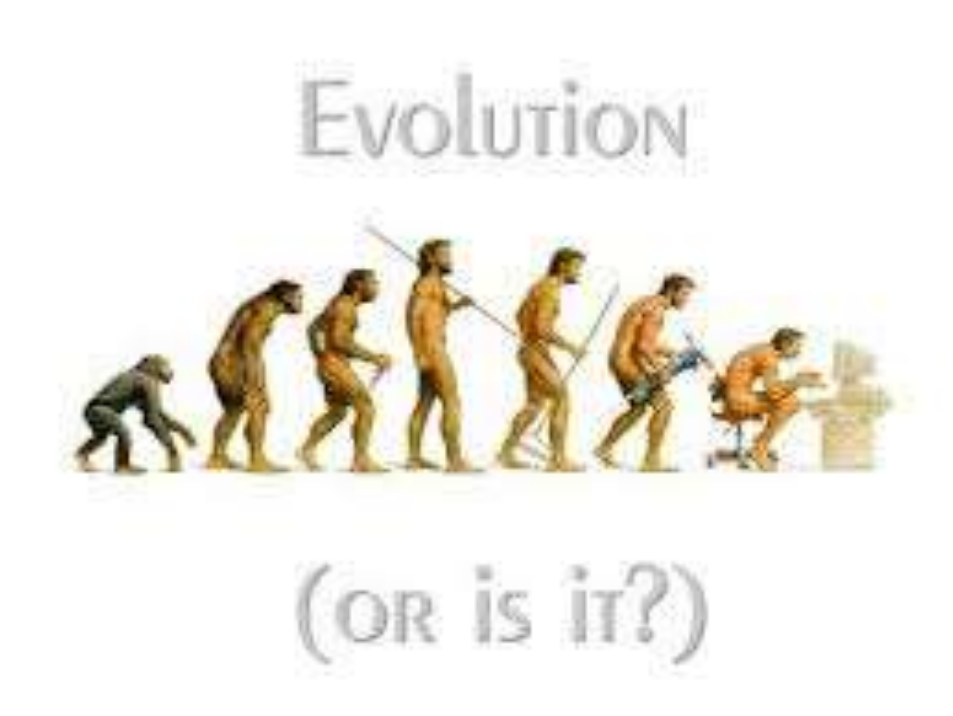
- Rodhocetus
  羅德侯鯨

- Ambulocetus
  陸行鯨

- Dorudon
  矛齒鯨

- Basilosaurus
  龍王鯨 18m

THE ORIGIN OF MAN ?

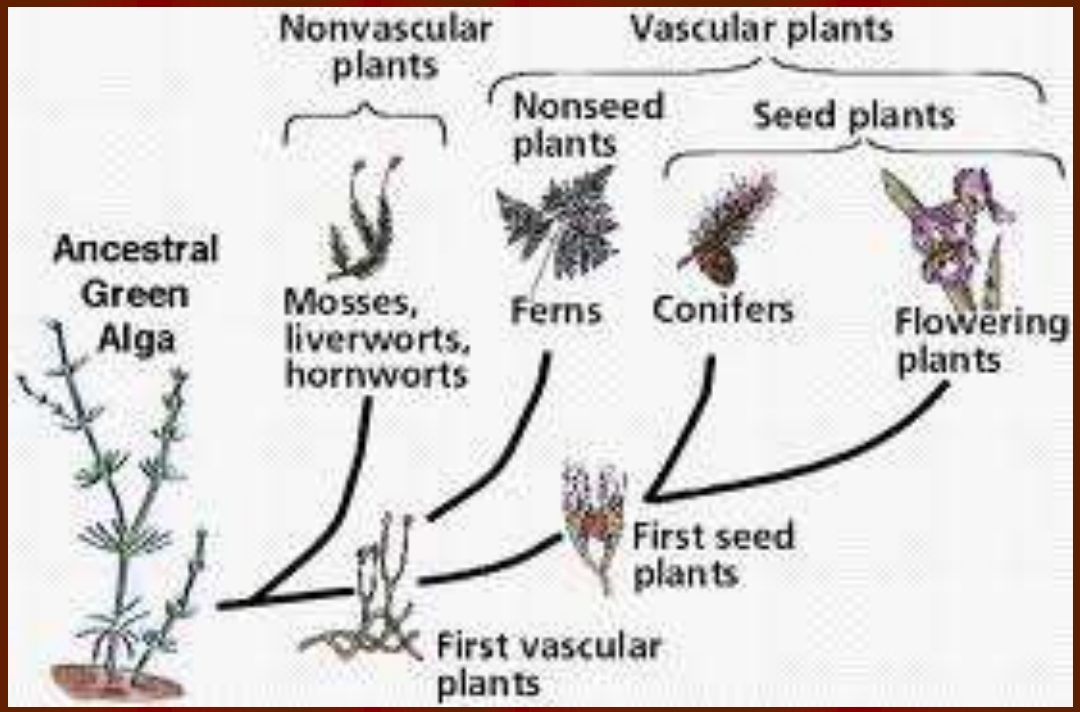


Content

- Prelude – the Development of Life on Earth & concept of Evolution
- The Origin & Evolution of Man
- The Human Explosion
- History of Hominids
- Identification of Hominids
- The Key Fossil Records
- Human Race today, what is wrong with the term ?
- Recap
- Early Man in China

PLANT FOSSILS

Evolution of Land plants

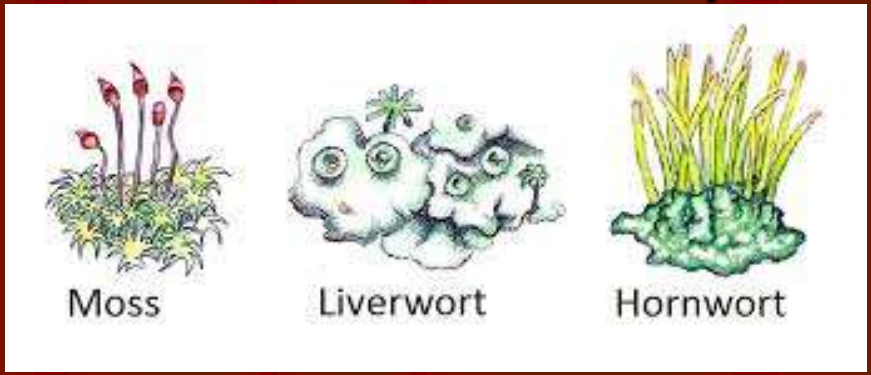


Embryophytes: The Land Plants						
Nonvascular Plants "Bryophytes"			Vascular Plants			
			Seedless Plants		Seed Plants	
			Lycophytes	Pterophytes	Gymno-sperms	Angio-sperms
Liverworts	Hornworts	Mosses	Club Mosses	Whisk Ferns		
			Quillworts	Horsetails		
			Spike Mosses	Ferns		

Development of Plants

- Precambrian over 570 Ma: cyanobacteria/stromatolite 藍綠菌– first photosynthesis
- Silurian 534-410 Ma: water bound algae 藻, Liverworts 地錢, first vascular land plant Cooksonia 庫克遜蕨 & Psilotum (Whisk Fern 松葉蕨)
- Devonian 410-290 Ma: first gymnosperm, 30 m tall Giant Club mosses 石松, seed fern, plus moss & Liverworts
- Carboniferous 360-290 Ma: Ferns, seed ferns, primitive Cycads 蘇鐵 and Conifers 松柏 appeared with giant Club mosses & Horsetails 木賊 flourished in extensive swamps. Fossil fuel formed
- Permian to Cretaceous 290-65 Ma: Seed plants replacing non seed plants. First angiosperms – *Archaefrutus sinensis* & magnolia
- Tertiary 65 Ma to now: great diversification of flowering plants

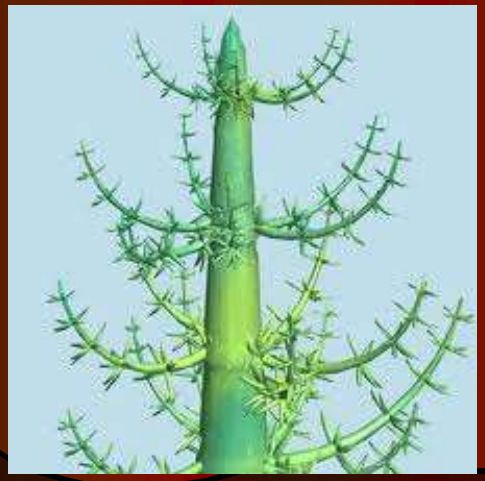
Non vesicular land plant

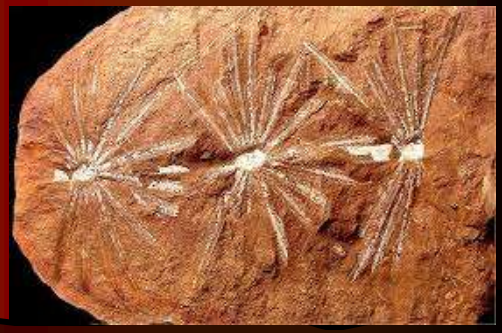


Cooksonia 頂囊蕨

The first vascular land plant flourished during the Silurian & extinct at early Devonian

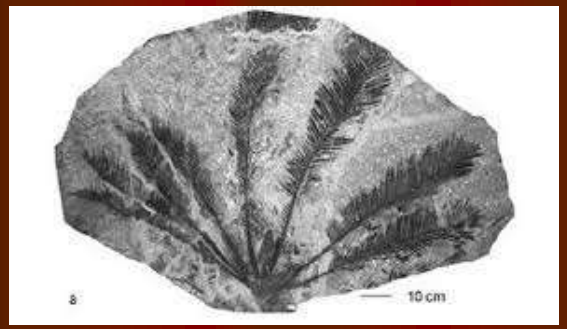
Horsetail plant 木賊





Cycads 蘇鐵

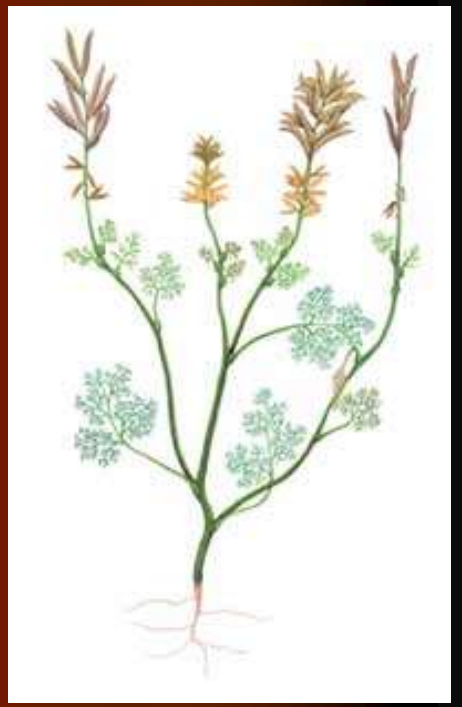
An ancient group of seed plants with no branches & no flowers



Oldest flowering plant so far discovered

Archaefrutus sinensis 遼寧古果

Discovered in Liaoning in 1996 & stood 51 cm tall dated back to 147 Ma. The plant lived in water with thin stems extended above the surface

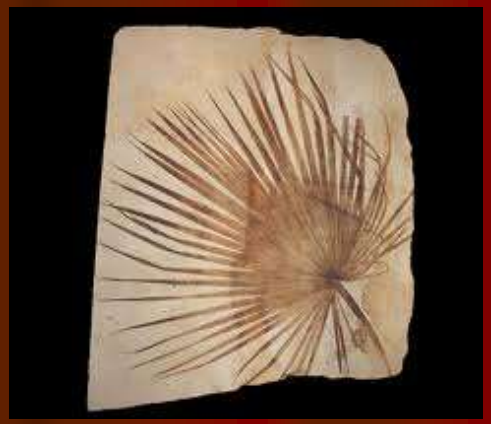


Magnolia 木蘭

This flowering plant is known to have first existed during the Cretaceous 95 Ma

Fossilized seeds

Fossil leaves

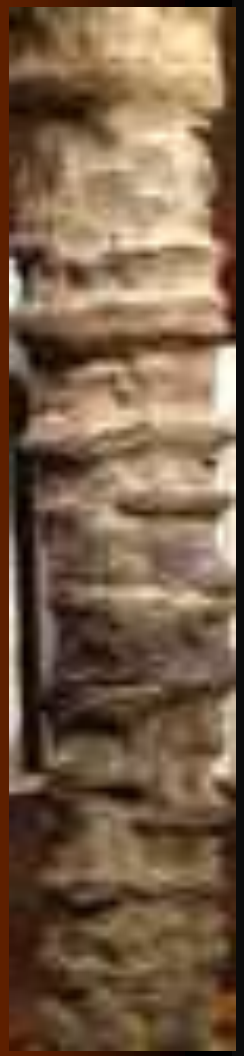









Petrified wood 矽化木

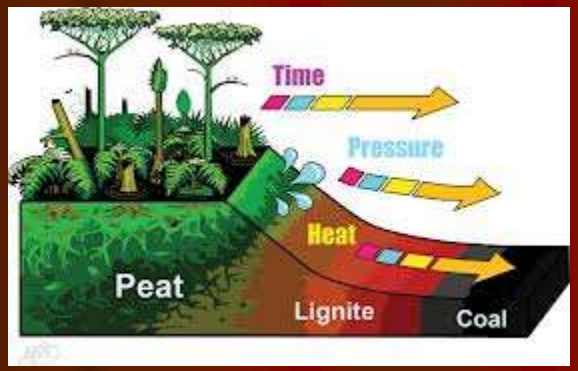


Fossil bark of Seed moss

The formation of coal from plants

- Period one – Carboniferous (359-299 Ma)
- Period two – Jurassic (201-145 Ma)
- Period three – tens of thousand years ago

From peat to lignite, bituminous & anthracite



Some important fossil sites

- Australia : Ediacara fauna (Late Precambrian 700mya)
- Canada : Burgess shale, BC (Late Precambrian)
- China : Yunan Chengjiang Maotianshan fauna (Late Precambrian) 雲南澄江帽天山
  : Szechuan Zigong - 自貢 dinosaurs
  : Liaoning Jehol biota – feathered dinosaurs
  : Xinjiang – tyrannosaurus, ceratpos
- Mongolia : Gobi Desert - Dinosaurs
- Germany : Messel Pit, Solnhofen (Mesozoic/Cenozoic)
- UK : the Jurassic Coast (Portland , Lime Regis to Exeter)
- USA : Green River Formation, Wyoming

International Museums

- The British Museums of Natural History
- The Smithsonian Museum Washington DC
- The Natural History Museum of New York
- The Chicago Field Museum
- Zigong Dinosaur Museum
- National Museum of Science Taichung

Museums in HK

- HKU Stephen Hui Geological Museum : Monday to Friday 1300 – 1800
- Bank of China – The Living Earth exhibition: Closing September 2013
- H K Museum of History Shatin
- Rock Garden at Lion's Nature Education Center, Saikung
- Nina Fossil Garden – 127 pieces of petrified wood
- HK Science Museum "Legends of the Giant Dinosaurs" 8.11.13 – 9.4.14

The End