

Geologic time scale

- Chronology of Earth's history
- 4.7 billion history of the earth from its origin to the present
- Transitions in the fossil record, found in characteristic layers of sedimentary rock
- Formulated by assessing the age of rocks and rock sediments.
- Correlates with evolutionary events

Kaibab Limestone



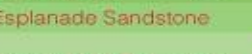
Toroweap Formation



Coconino Sandstone



Hermit Shale



Esplanade Sandstone



Wescogame Formation



Manakacha Formation



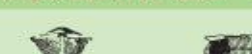
Watahomigi Formation



Redwall Limestone



Temple Butte Formation



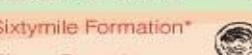
Muav Limestone



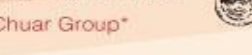
Bright Angel Shale



Tapeats Sandstone*



Sixtymile Formation*



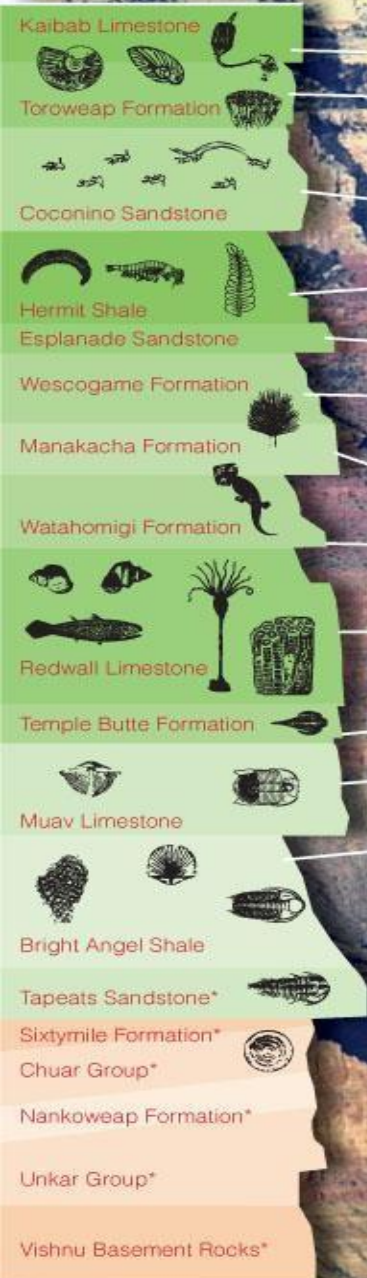
Chuar Group*

Nankoweap Formation*

Unkar Group*

Vishnu Basement Rocks*

Geologic time scale



- Based on geologic events
- the ancient period from earth's history is formulated into eons-eras-periods-epochs.
- Each division in the geological calendar is clearly identified and described.
- Incidents pertaining to earth surface, plant and animal life are neatly recorded.
- The influence of geological and climatic changes on the life and the evolution of the living organism had been well analyzed.
- Earth is 4.7 billion (4,700 million) years old.

Geologic time (4.7 billion/4,700 million)

- ❖ Divides geologic history into units
- ❖ Originally created using relative dates and more recently, radioactive dating.
- ❖ The influence of geological and climatic changes on the life and the evolution of the living organism

Divisions: four-level hierarchy of time intervals

• EONS

- First and largest division of geologic time
- Greatest expanse of time
- Four eons
 - Phanerozoic ("visible life") –most recent eon
 - Proterozoic
 - Archean
 - Hadean – the oldest eon

• ERAS

- Second division of geologic time

• PERIODS

- Third division of the geologic time.
- Named for either location or characteristics of the defining rock formations

• EPOCHS

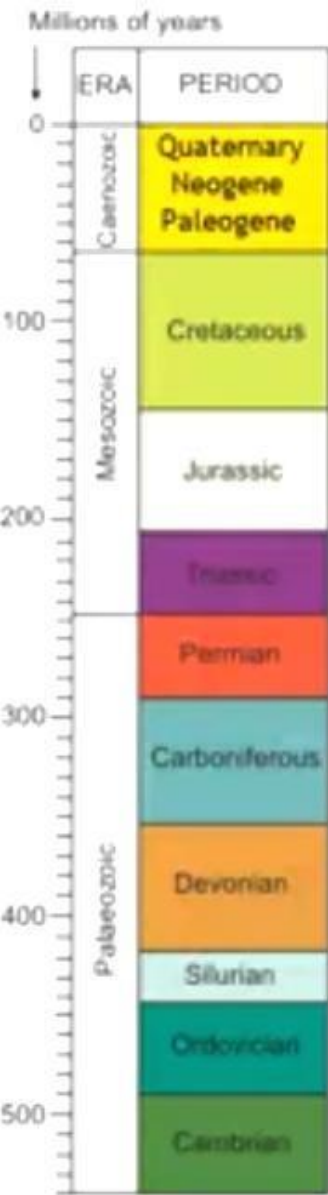
- Fourth division of geologic time
- Represents the subdivisions of a period

GEOLOGIC TIME SCALE			
EON ERA	PERIOD	EPOCH	Present
Phanerozoic	Cenozoic	Quaternary	Holocene 0.01
			Pleistocene 1.6
		Tertiary	Pliocene 5.3
			Miocene 23.7
		Paleogene	Oligocene 36.6
			Eocene 57.8
	Mesozoic	Paleocene	66.4
		Cretaceous	144
		Jurassic	208
		Triassic	245
	Paleozoic	Permian	286
		Pennsylvanian	320
		Mississippian	360
		Devonian	408
		Silurian	438
		Ordovician	505
		Cambrian	570
	Proterozoic		2500
	Archean		3800
	Hadean		4550



The geologic time scale

Eon	Era	Period	Epoch	Development of Plants and Animals	Relative Time Span of Eras		
Phanerozoic	Cenozoic	Quaternary	Holocene	0.01	Humans develop	Cenozoic	
			Pleistocene	1.8		Mesozoic	
		Tertiary	Pliocene	5.3		"Age of Mammals"	Paleozoic
			Miocene	23.8			
			Oligocene	33.7			
			Eocene	54.8			
			Paleocene	65.0			
			Extinction of dinosaurs and many other species				
	Mesozoic	Cretaceous	"Age of Reptiles"	First flowering plants			
		Jurassic		144	First birds		
		Triassic		206	Dinosaurs dominant		
	Paleozoic	Permian	"Age of Amphibians"	Extinction of trilobites and many other marine animals			
		Pennsylvanian			290	First reptiles	
		Mississippian			323	Large coal swamps	
		Carboniferous	354	Amphibians abundant			
		Devonian	"Age of Fishes"	First insect fossils			
		Silurian		417	Fishes dominant		
		Ordovician		443	First land plants		
		Cambrian	"Age of Invertebrates"	First fishes			
Trilobites dominant							
Precambrian	2500	Collectively called Precambrian, comprises about 88% of the geologic time scale	First organisms with shells				
			First multicelled organisms				
			First one-celled organisms				
Archean	3800			Origin of Earth			
Hadean				4500			



PRECAMBRIAN SUPER EON

1. HADEAN EON (PRE-ARCHEAN EON)

4.6 to 3.8 billion years ago



~4.6 BYA -- Formation of Earth and Moon
(as indicated by dating of meteorites and rocks from the Moon)

~4 BYA -- Likely origin of life
-- indirect photosynthetic evidence of primordial life
-- evidence of materials created by organic decay

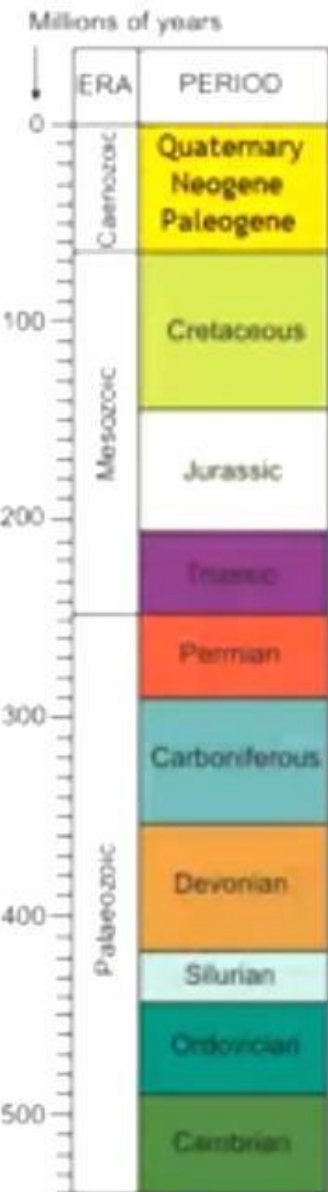
This is the "hidden" portion of geologic time as there is little evidence of this time remaining in Earth's rocks.

PreCambrian SuperEon (4.6 BYA – 545 MYA)

Hadean Eon (4.6 BYA – 3.8 BYA) – Primordial life at the end of this Eon

Achaean Eon (3.8 BYA – 2.5 BYA) – Cratons stabilize

Proterozoic Eon: (2.5 BYA – 545 MYA) – Protists & green algae appear, Ediacaran biota



PRECAMBRIAN SUPER EON

2. ARCHEAN EON - 3.8 to 2.5 billion years ago

The eon of first life

~3.8 BYA -- Oldest known rocks

~3.5 BYA -- Oldest known fossils (single celled organisms resembling bacteria)

- Prokaryotes were the Earth's sole inhabitants
- Evidence of **stromatolites**- created by colonial cyanobacteria
- Earliest types of photosynthesis did not produce oxygen
- Oxygenic photosynthesis probably evolved in cyanobacteria



PreCambrian SuperEon (4.6 BYA – 545 MYA)

Hadean Eon (4.6 BYA – 3.8 BYA) – Primordial life at the end of this Eon

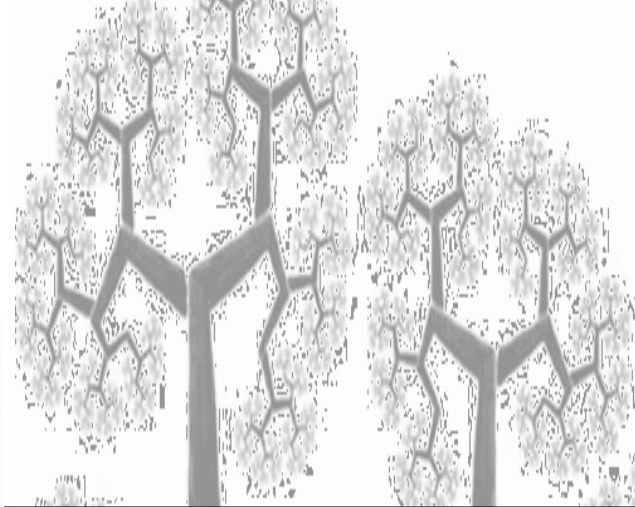
Achaean Eon (3.8 BYA – 2.5 BYA) – Cratons stabilize

Proterozoic Eon: (2.5 BYA – 545 MYA) – Protists & green algae appear, Ediacaran biota

PRECAMBRIAN SUPER EON

3. PROTEROZOIC EON - 2.5 Billion to 570 Million years ago

The eon of the first multi-celled life



- Emergence of protists, green algae and ediacaran biota
- Evidence of oxygen producing bacteria begin to change the atmosphere
- Life turned from anaerobic to aerobic
- simple algae, protozoans, poriferans, annelids

(End of the Pre-Cambrian -- a period at least five times longer than all the geologic time that follows.)

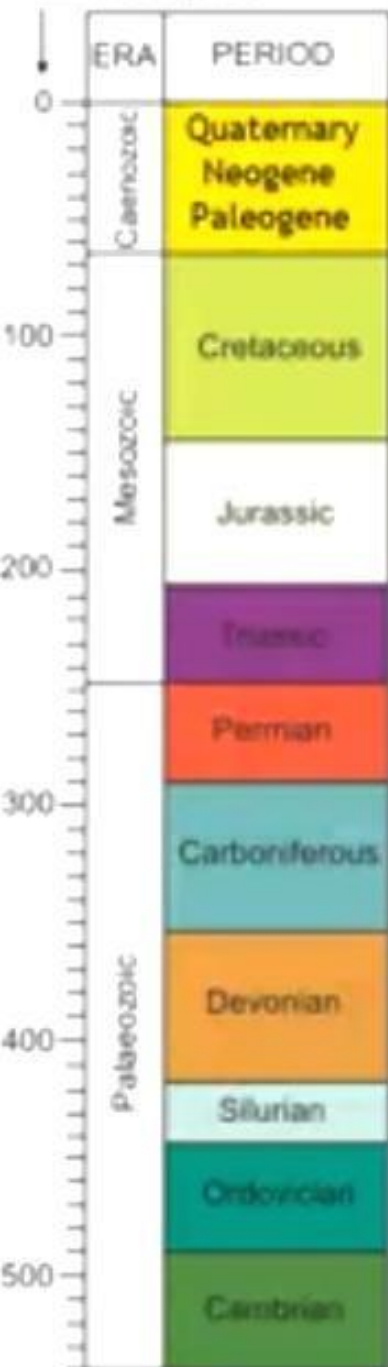
PreCambrian SuperEon (4.6 BYA – 545 MYA)

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Millions of years



4. Phanerozoic eon (600 MYA – present)

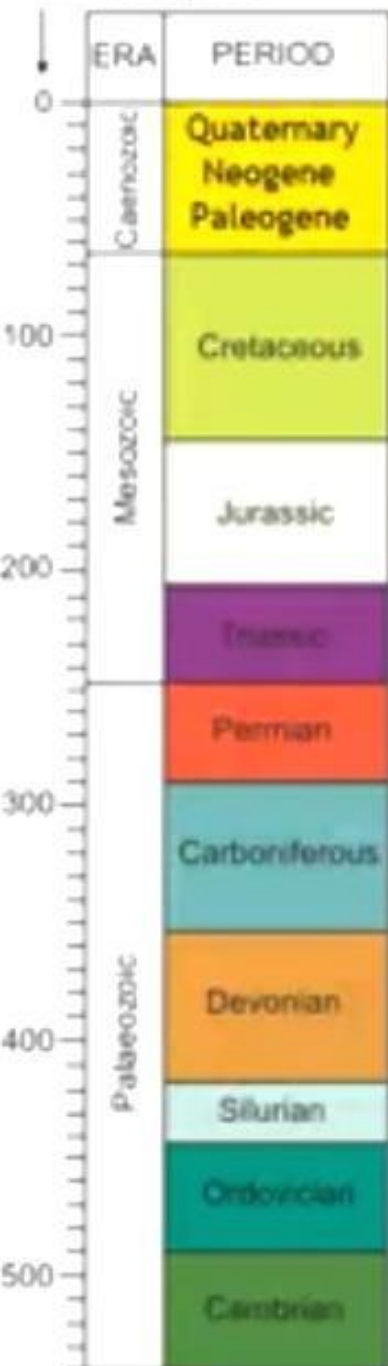
1. Paleozoic era(600-210 m.y.a)

- produced revolutionary changes in the biosphere.
- known as the **Cradle of ancient life**
- Restricted to seas
- Vertebrates had not yet evolved
- Life consisted of several invertebrate groups

Trilobites
Brachiopods
Cephalopods



Millions of years



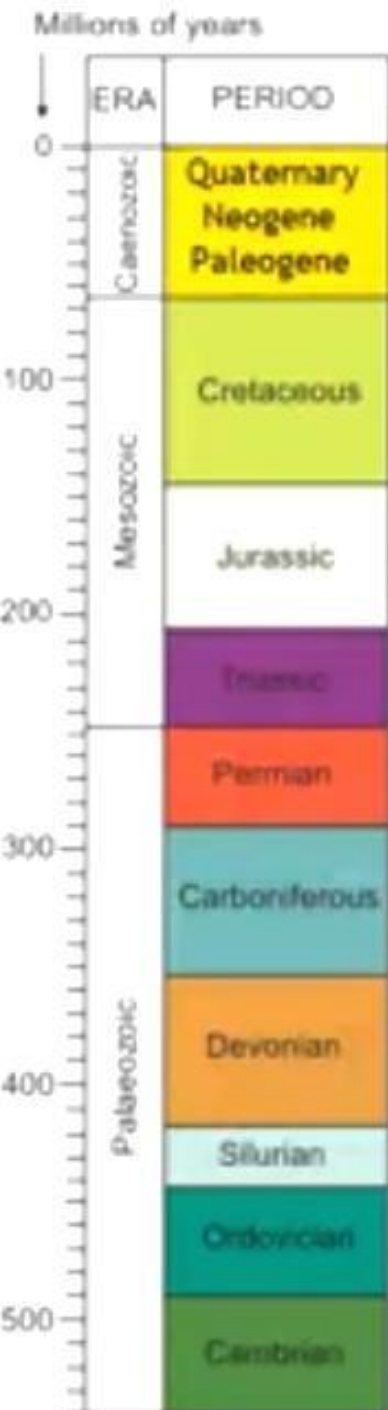
4. Phanerozoic eon (600 MYA – present)

1. Paleozoic era(600-210 m.y.a)

1. Cambrian period (600 to 440 m.y.a)

- Cambrian Explosion: age of marine inverts
- Cambrian: among plants thallophytes were well established.
- They diversified into various groups (Chlorophyceae, Rhodophyceae etc.,).
- Among animals the aquatic arthropods and echinoderms came to prominence.
- End of the Cambrian denoted by the appearance of fish.



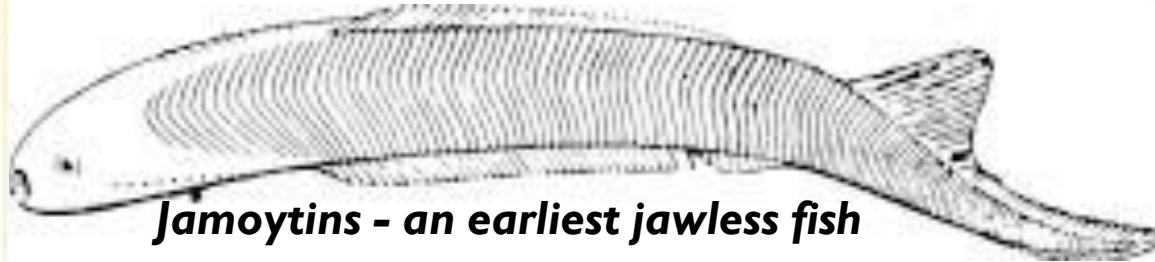


4. Phanerozoic eon (600 MYA – present)

1. Paleozoic era(600-210 m.y.a)

2. Ordovician period (440 to 350 m.y.a)

- Green plants (Bryophytes) and fungi first appeared on land
- formation of coral rocks and molluscs and echinoderms.
- First vertebrate: Jawless fishes,
- Among arthropods, the trilobites were more prominent during this period.

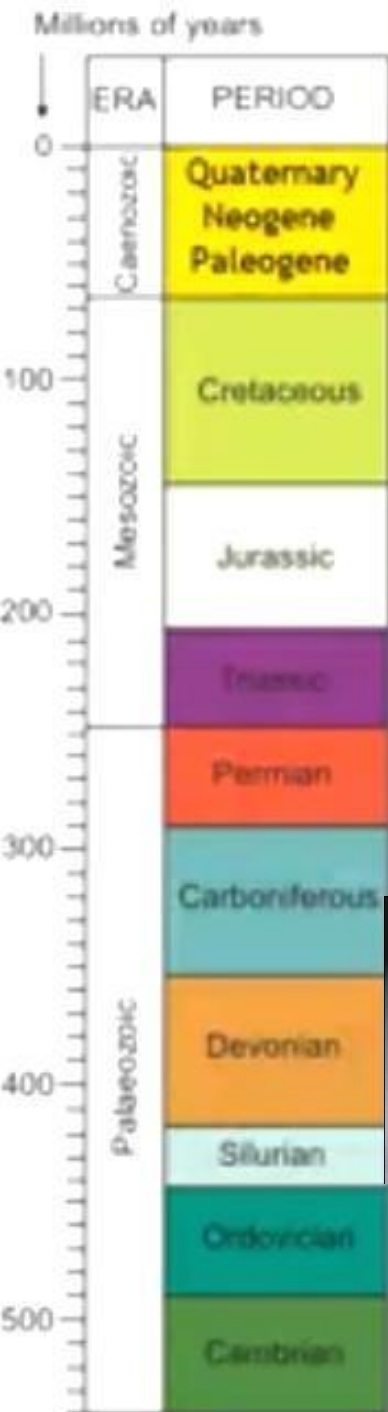


Jamoytins - an earliest jawless fish



The origin of early vertebrate: major event in the evolution of animals.



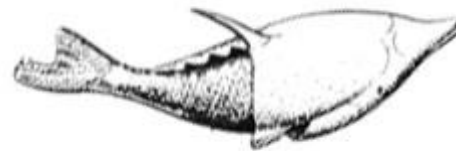


4. Phanerozoic eon (600 MYA – present)

1. Paleozoic era(600-210 m.y.a)

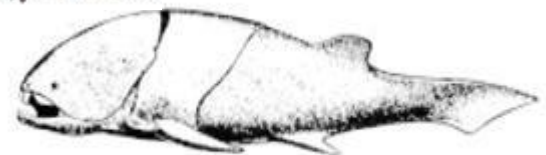
3. Silurian period (350 to 315 MYA)

- The oldest land plant conducting tissue (vascular plants) originated and colonized the land.
- Brachiopods and mollusks flourished.
- The corals diversified.
- Jawed fishes originated (scales and paired fins developed)
- Origin of paired fins and jaws: major events in chordate evolution.



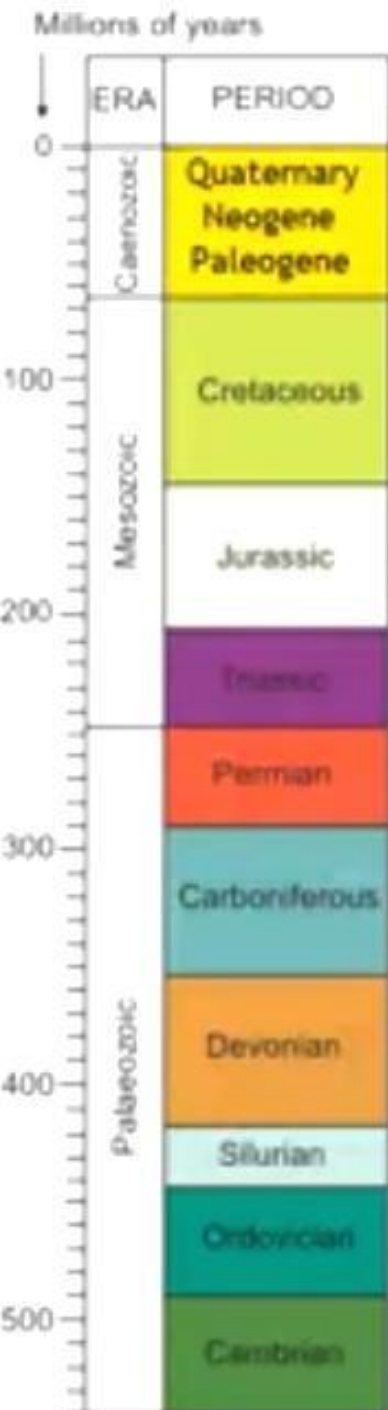
Pteraspis (Ostracoderm)

Ostracoderms - the early armoured, jawless fishes



Coccosteus (Placoderm)

Placoderms - the early jawed fishes.



4. Phanerozoic eon (600 MYA – present)

1. Paleozoic era(600-210 m.y.a)

4. Devonian Period (315 to 275 MYA)

- Land living plants have become more successful.
- The forests were filled with varieties of ferns and cycads (non-flowering plants).
- Among aquatic animals fishes became dominant.
- The forefathers of almost all modern fishes lived **(Age of fishes)** – the sharks
- First aquatic/marine amphibians probably emerged

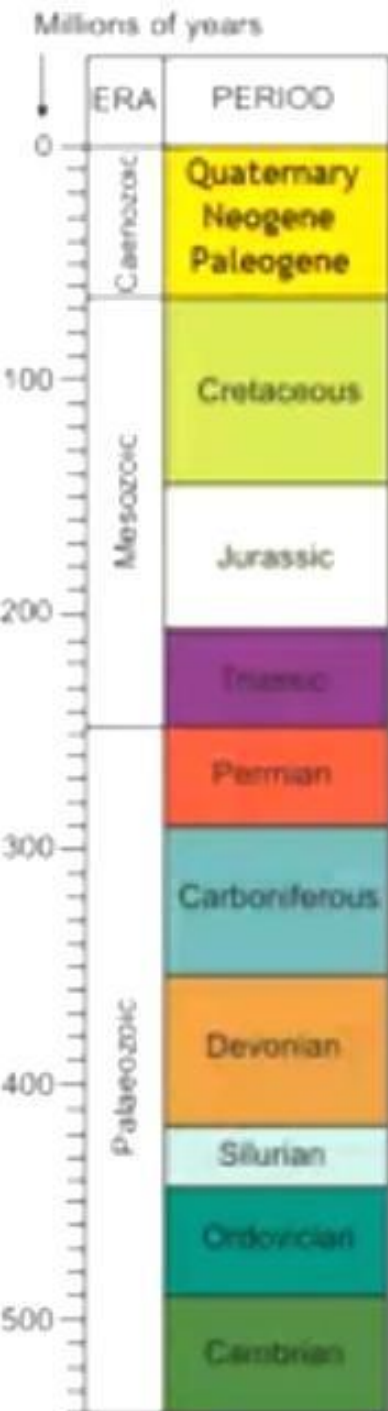
Kellwasser Extinction and the Hangenberg Extinction Event



19% of all families

5% of all genera went extinct





4. Phanerozoic eon (600 MYA – present)

1. Paleozoic era(600-210 m.y.a)

5. Carboniferous Period (275 to 235 MYA)

A. Mississippian Period (275 to 255 MYA)

- Massive upraising of land : formation mountain ranges.
- Huge water bodies were broken into smaller lakes: cause the origin of lungs (to live temporarily on land) in fishes.
- encouraged the origin of the **amphibians** – very first land vertebrates (tetrapods).
- The origin of land living amphibians were further increased by the proliferation of several land living insects.

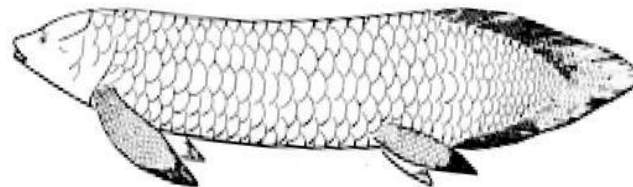
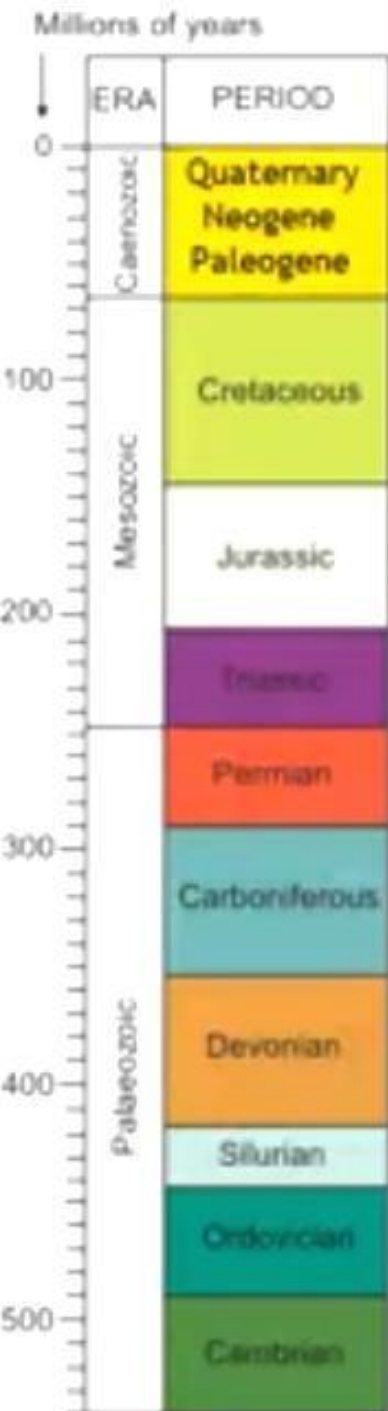


Fig.7.2.3 The Australian lung fish - Neoceratodus



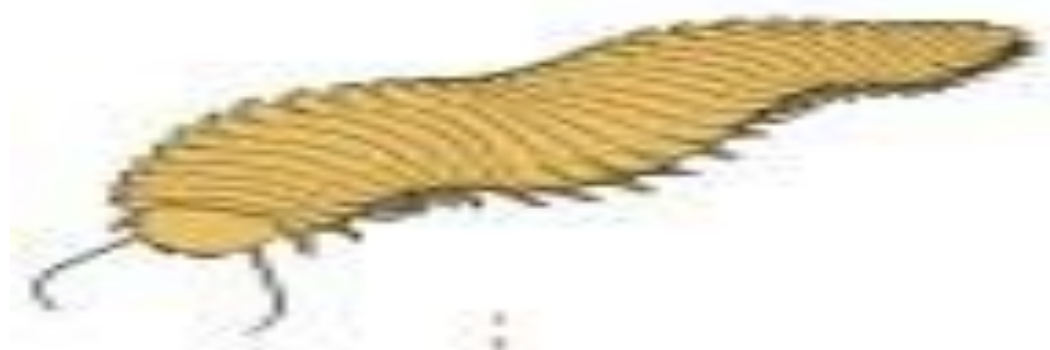
4. Phanerozoic eon (600 MYA – present)

1. Paleozoic era(600-210 m.y.a)

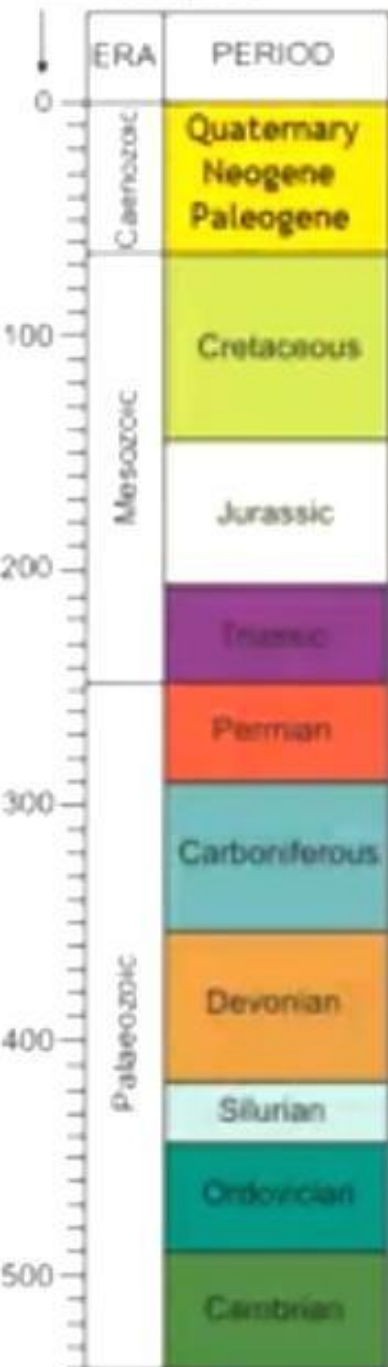
5. Carboniferous Period (275 to 235 MYA)

B. Pennsylvanian (255 to 235 MYA)

- Giant arthropods populate the land
- collectively known as **Carboniferous (carbon bearing) period.**
- Due to geotectonic changes : several forests got buried under the soil.



Millions of years



4. Phanerozoic eon (600 MYA – present)

1. Paleozoic era(600-210 m.y.a)

6. Permian Period (235 to 210 MYA)

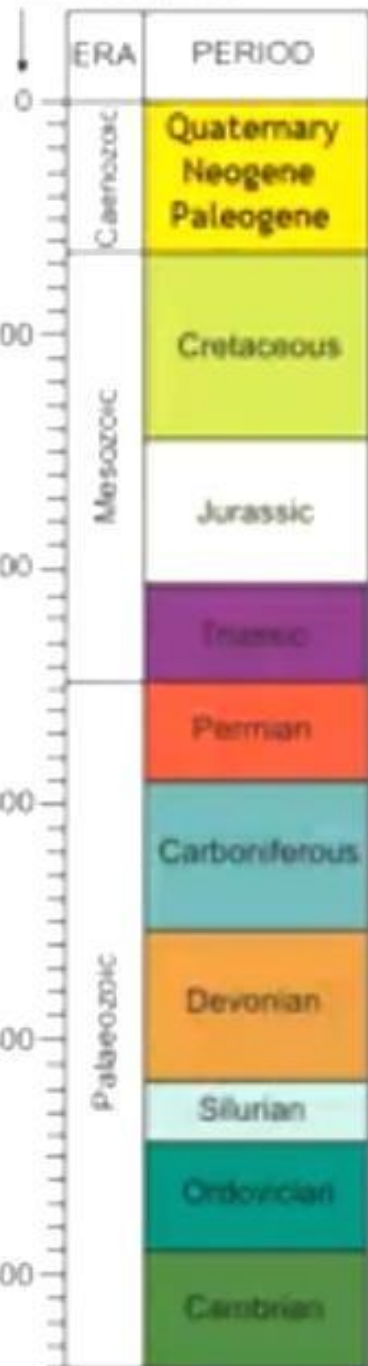
- last period in the Paleozoic
- Represented by early cone bearing gymnosperms and mosses
- Beetles and flies already appeared
- Some amphibians dramatically laid land eggs (cleidoic eggs).
 - Specifically the group of organisms that laid such eggs are identified as Seymouria.

Permian-Triassic Extinction

- Nearly 60% became extinct
- Extinction of Trilobites

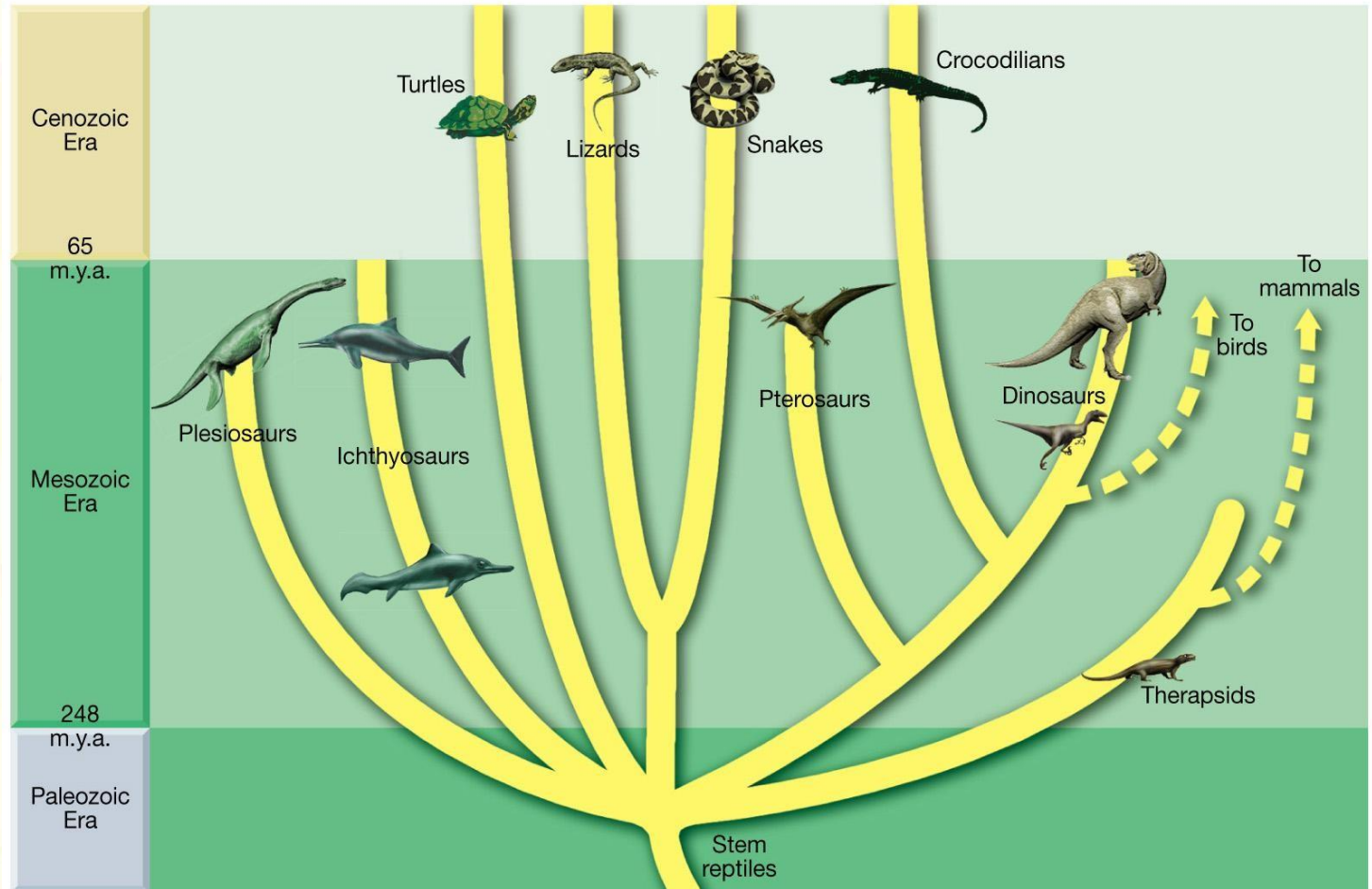


Millions of years



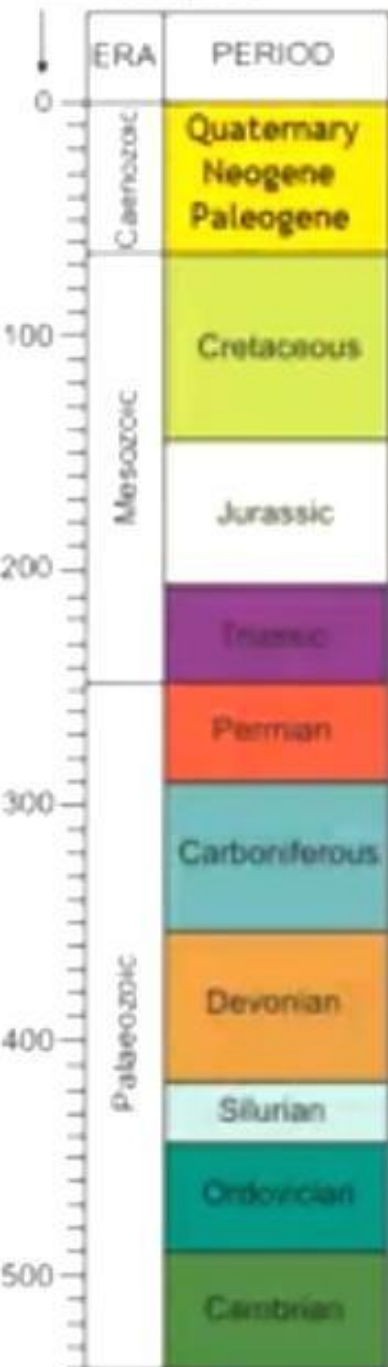
4. Phanerozoic eon (600 MYA – present)

2. Mesozoic era (210-65 m.y.a)



Major reptile groups in the Mesozoic era

Millions of years

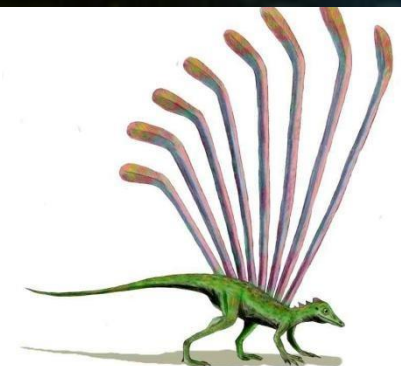


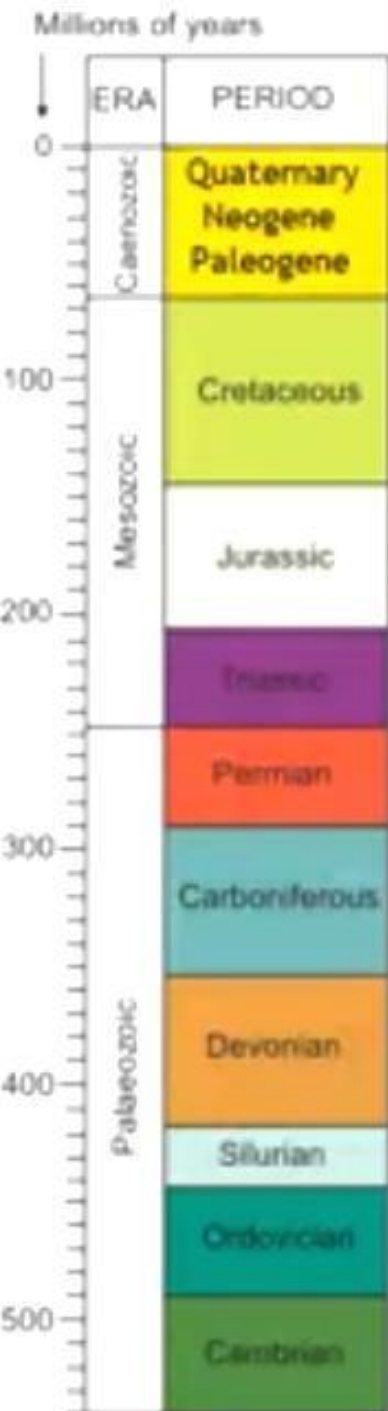
4. Phanerozoic eon (600 MYA – present)

2. Mesozoic era (210-65 m.y.a)

1. Triassic Period (210 to 160 MYA)

- Archosaur- protodinosaur
- First fossils of turtles, crocodiles, and dinosaurs obtained
- Fossil evidences : aquatic and flying reptiles thrived
- The mammals originated from reptiles
- 4th major mass extinction: 23% of all the families and 48% of all the genera went extinct.





4. Phanerozoic eon (600 MYA – present)

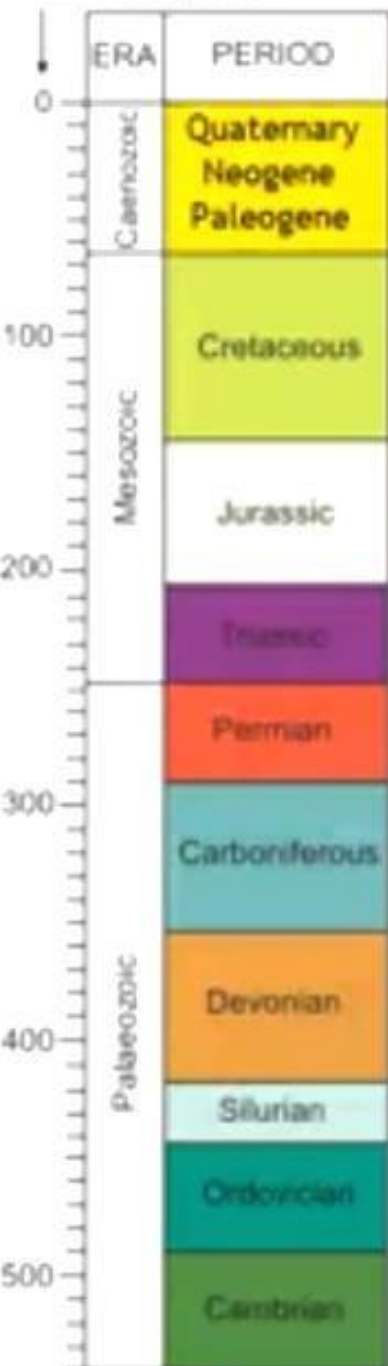
2. Mesozoic era (210-65 m.y.a)

2. Jurassic Period (160 to 130 MYA)

- A marked adaptive radiation among dinosaurs. (diversified into carnivorous and herbivorous forms)
- first birds originated from reptiles.
- Archeopteryx : The earliest bird
- origin of birds: major physiological change among animals (poikilothermic condition through feathers the birds became homeothermic)
- The modern bony fishes diversified into several groups



Millions of years



4. Phanerozoic eon (600 MYA – present)

2. Mesozoic era (210-65 m.y.a)

3. Cretaceous Period (130 to 65 MYA)

- Emergence of a very first flowering plant
- K/T Extinction
- larger marine molluscs became extinct
- Dinosaurs of the Mesozoic era abruptly became extinct
- Several reasons are given for the extinction of the dinosaurs.
- Fossils of dinosaurs were not obtained from later periods.

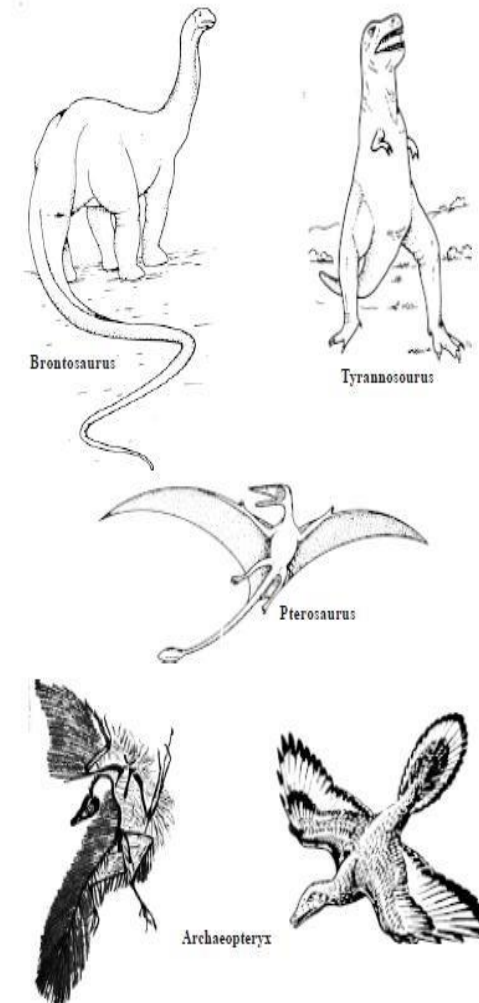
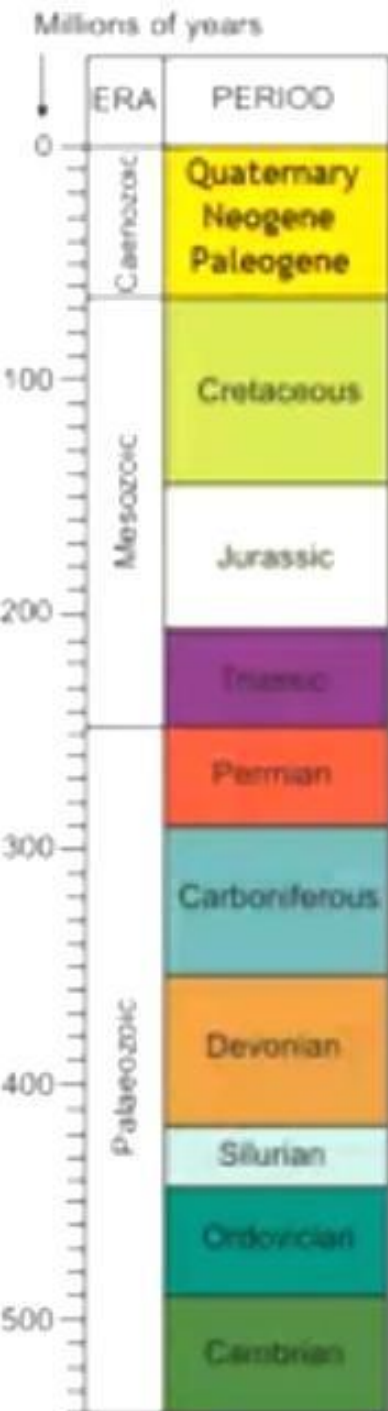


Fig.7.2.4 Mesozoic Birds and Reptiles



4. Phanerozoic eon (600 MYA – present)

3. Cenozoic era (65 MYA to date)

- Plenty of fossils (all modern animals and plants)
- subdivided into Tertiary (Paleogene & Neogene) and Quaternary periods.
- Further this era contains seven epochs
- Through fossils: The origin and evolution of independent groups of animals and man



Ptilodus was a mammal the size of a squirrel that lived during the Paleocene.



Pyrotherium was a South American ungulate that lived during the Early Oligocene.



Millions of years

ERA	PERIOD
Cenozoic	Quaternary
	Neogene
	Paleogene
Mesozoic	Cretaceous
	Jurassic
	Triassic
Palaeozoic	Permian
	Carboniferous
	Devonian
	Silurian
	Ordovician
	Cambrian

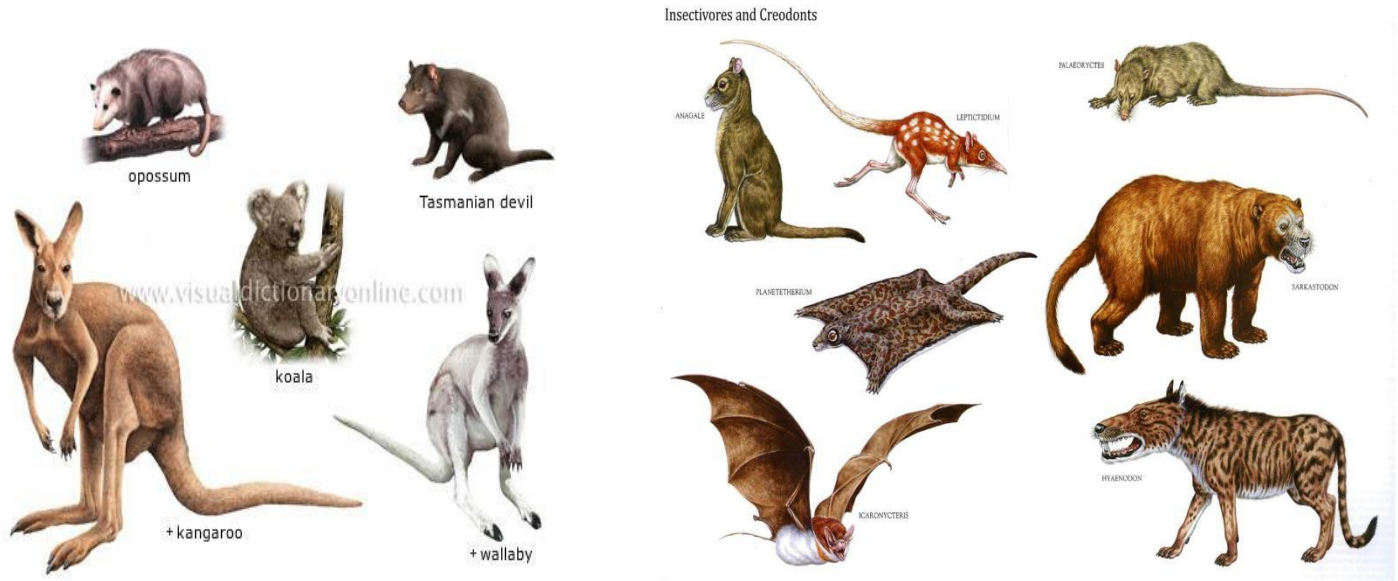
4. Phanerozoic eon (600 MYA – present)

3. Cenozoic era (65 MYA to date)

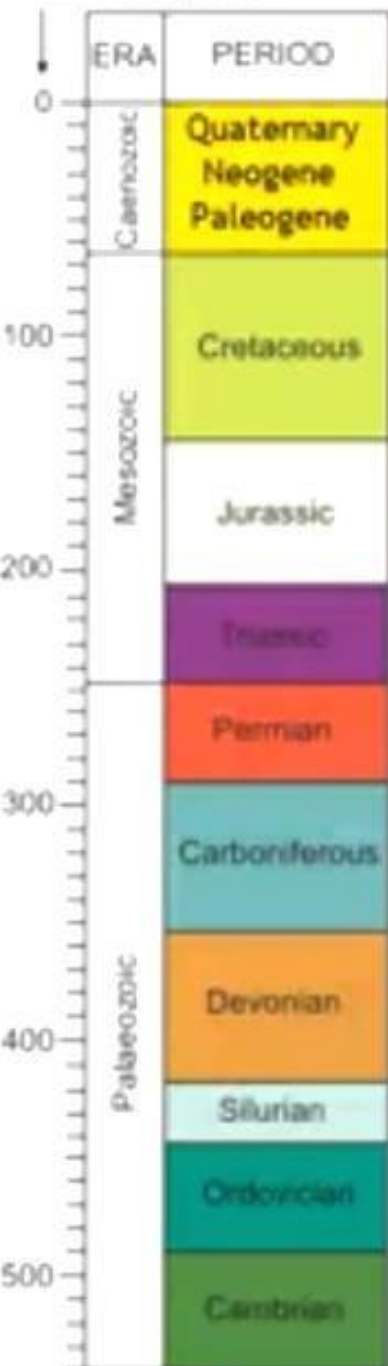
A. Tertiary (Paleogene Period)

1. Paleocene epoch (65-54 m.y.a)

- Social insects achieve ecological dominance.
- Appearance of placental mammals (marsupials, insectivores, creodonts)



Millions of years



4. Phanerozoic eon (600 MYA – present)

3. Cenozoic era (65 MYA to date)

A. Tertiary (Paleogene Period)

2. Eocene Epoch (54-38 mya)

- Ungulates originated.
- The ancestral form of modern horses lived
- The Azolla Event- freshwater fern blooms die at the bottom of Arctic Sea, drawing down large amounts of CO₂ (reduced by 80%) and triggering an ice age

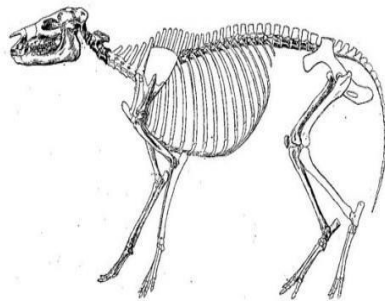
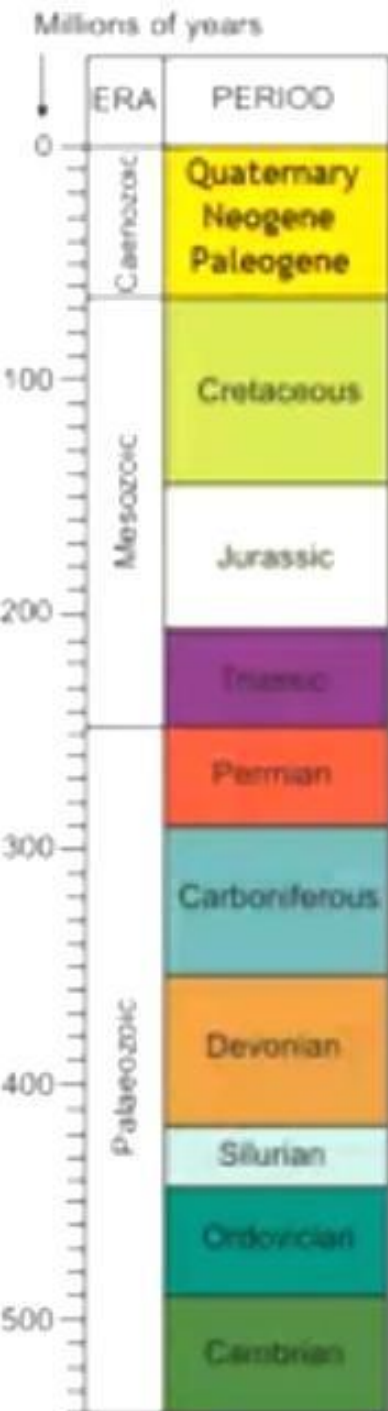


FIG. 94.—The skeleton of Hyracotherium, an ancestor of the modern horse, found in Eocene strata.





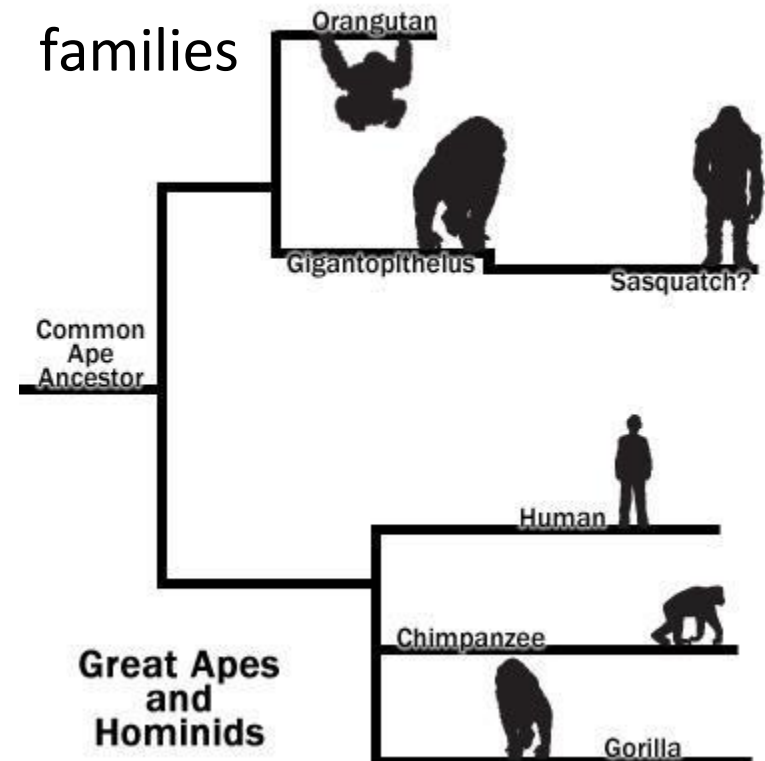
4. Phanerozoic eon (600 MYA – present)

3. Cenozoic era (65 MYA to date)

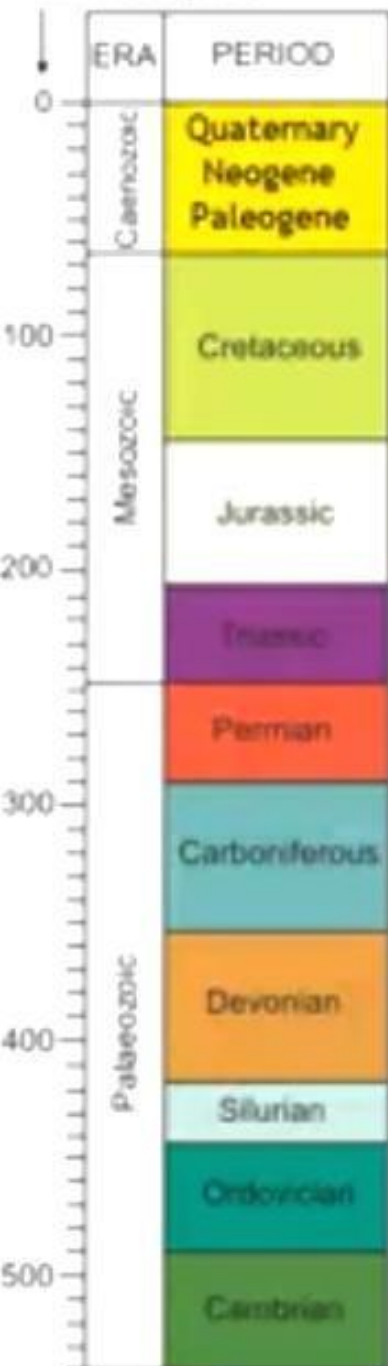
A. Tertiary (Paleogene Period)

3. Oligocene epoch (38-26 mya)

- Several animals with ancient characteristics became extinct.
- Mammals continue to diversify
- Modern mammalian families established.
- Apes originated



Millions of years



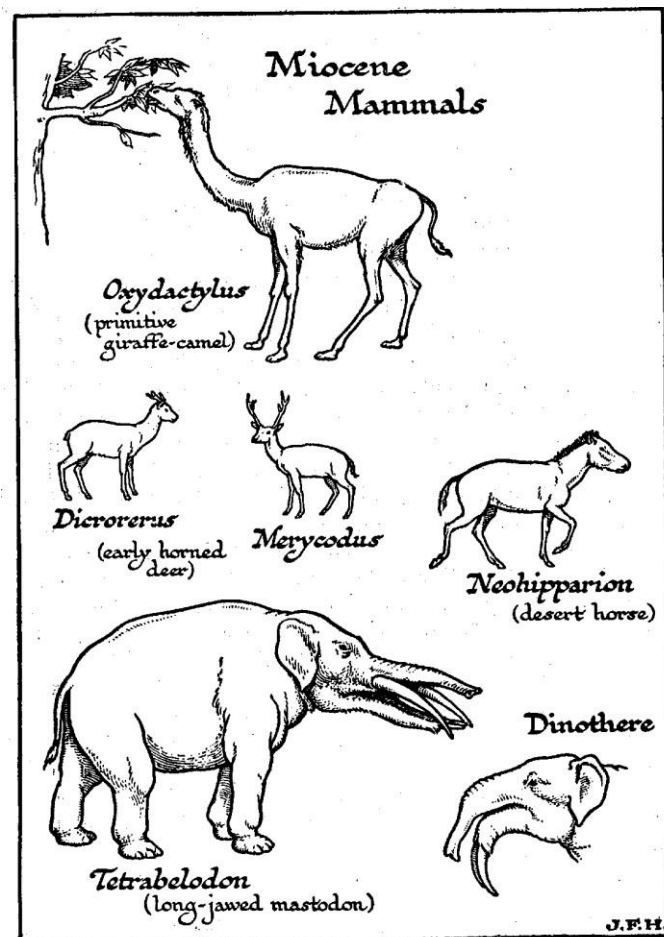
4. Phanerozoic eon (600 MYA – present)

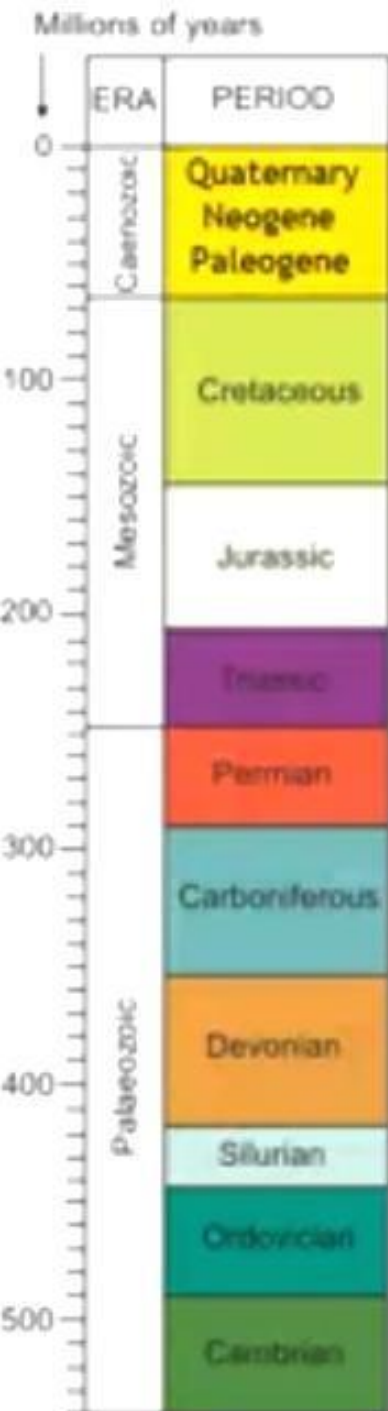
3. Cenozoic era (65 MYA to date)

A. Tertiary (Neogene Period)

1. Miocene epoch - (26-7 m.y.a)

- Several varieties of grasses evolved in Europe and N. America (large prairies formed).
- These changes encouraged the evolution of fast running herbivorous mammals and their predators.





4. Phanerozoic eon (600 MYA – present)

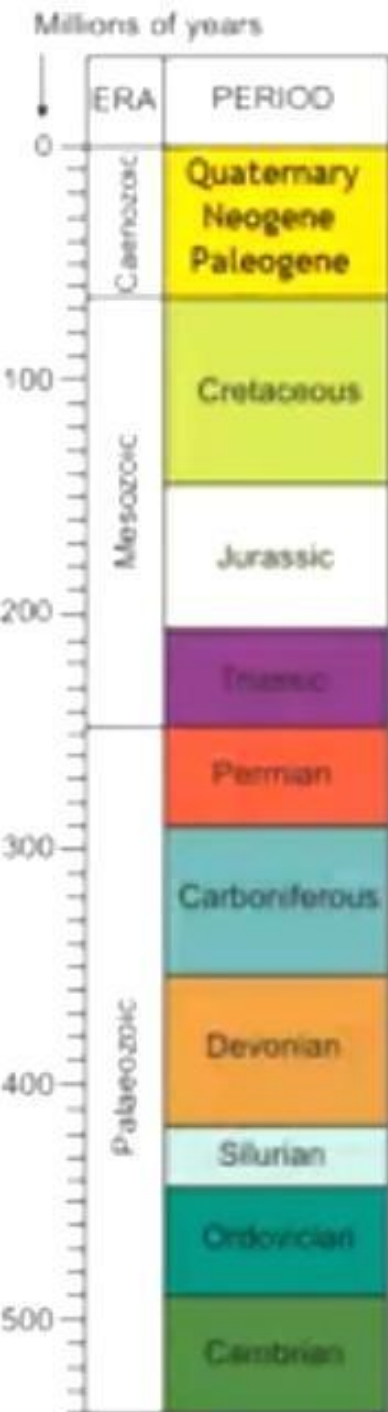
3. Cenozoic era (65 MYA to date)

A. Tertiary (Neogene Period)

2. Pliocene Epoch - (7-2 mya)

- Prairie's enlarged still further in several regions.
- Rodents became more successful.
- mammals increased in number.
- Appearance of *Australopithecus*, genus of hominids.





4. Phanerozoic eon (600 MYA – present)

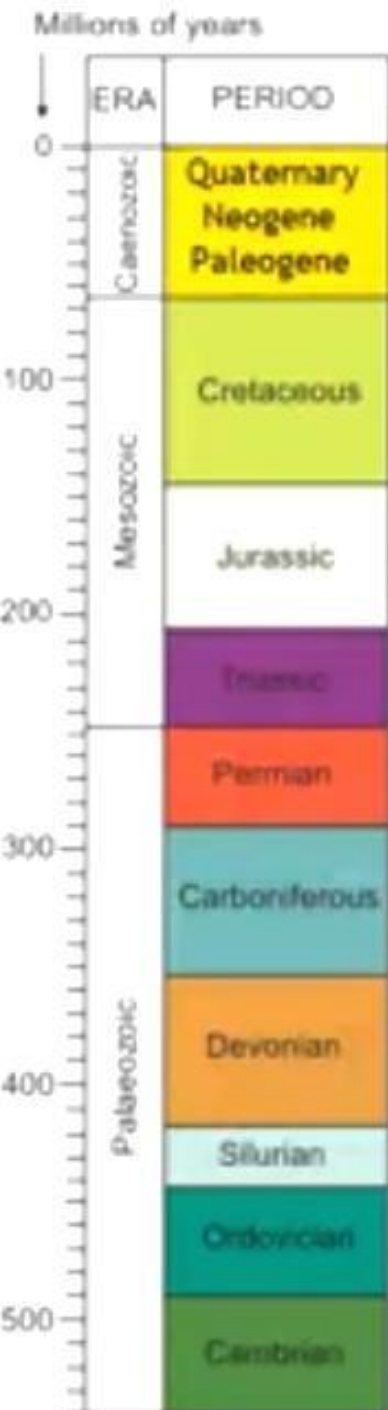
3. Cenozoic era (65 MYA to date)

B. Quaternary Period

1. Pleistocene epoch - (2-1 mya)

- Several glaciations happened
- popularly called the 'modern Ice age'.
- *Homo habilis* appeared
- *Homo erectus* first moves out of Africa
- The evolution of horses and man reached the final stages
- *Homo sapiens* appeared.
- Today we are living in an inter-glacial Period.





4. Phanerozoic eon (600 MYA – present)

3. Cenozoic era (65 MYA to date)

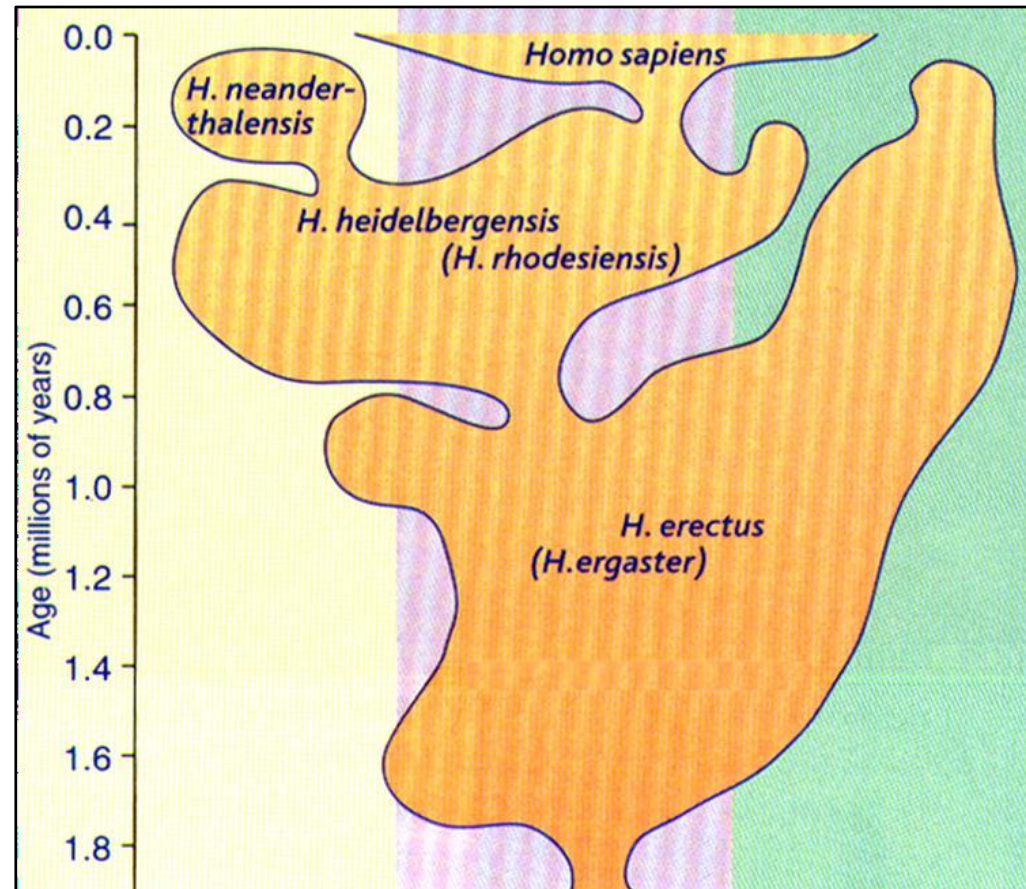
B. Quaternary Period

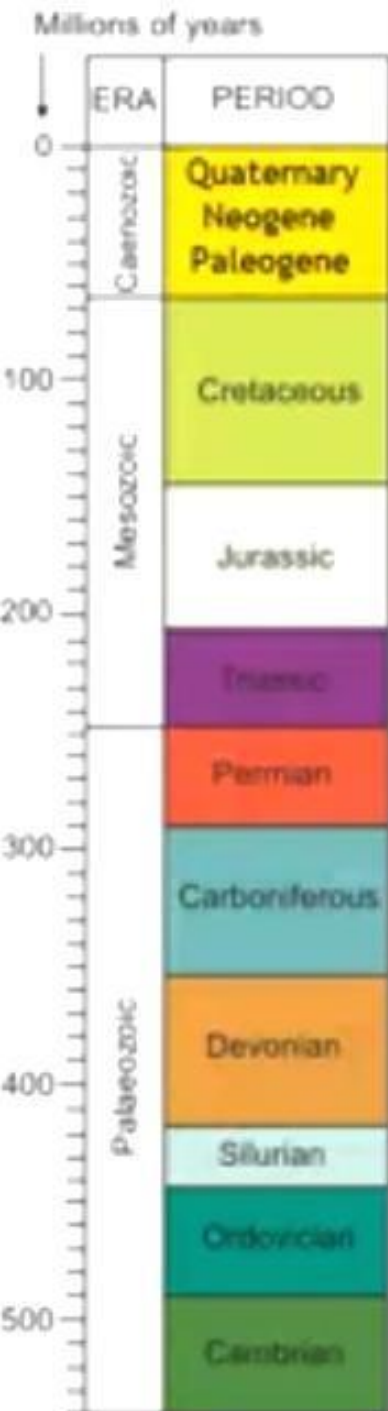
1. Pleistocene epoch - (2-1 mya)

Europe

Africa

Asia





4. Phanerozoic eon (600 MYA – present)

3. Cenozoic era (65 MYA to date)

B. Quaternary Period

1. Holocene epoch : (1 mya-present)

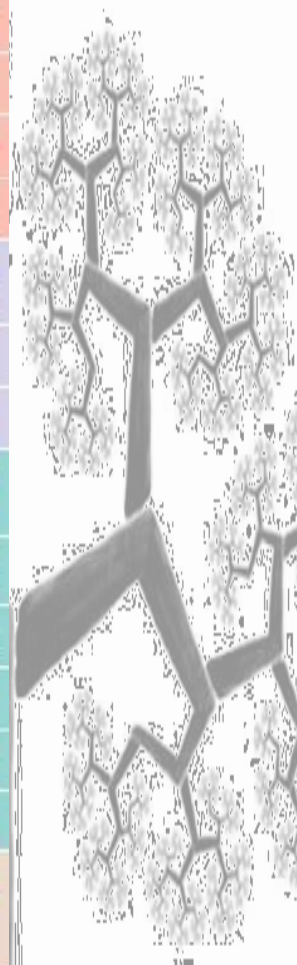
THE MODERN WORLD

- Development of agriculture.
- Domestication of animals.
- 250 yrs ago: Start of the Industrial Revolution
- 50 yrs ago: Space travel
- Humans walk on the surface of the moon (1969).
- Animal cloning (Dolly the sheep)
- Animal and Plant hybridization
- Improved communication
- Health care development
- Biotechnology



Table 26.1 The Geologic Record

Relative Duration of Eons	Era	Period	Epoch	Age (Millions of Years Ago)	Some Important Events in the History of Life
Phanerozoic	Cenozoic	Neogene	Holocene	0.01	Historical time
			Pleistocene	1.8	Ice ages; humans appear
			Pliocene	5.3	Origin of genus <i>Homo</i>
			Miocene	23	Continued radiation of mammals and angiosperms; apelike ancestors of humans appear
Paleogene		Oligocene	33.9	Origins of many primate groups, including apes	
		Eocene	55.8	Angiosperm dominance increases; continued radiation of most modern mammalian orders	
		Paleocene	65.5	Major radiation of mammals, birds, and pollinating insects	
		Mesozoic	Cretaceous	145.5	Flowering plants (angiosperms) appear; many groups of organisms, including dinosaurs, become extinct at end of period (Cretaceous extinctions)
Jurassic			199.6	Gymnosperms continue as dominant plants; dinosaurs abundant and diverse	
Triassic			251	Cone-bearing plants (gymnosperms) dominate landscape; radiation of dinosaurs; origin of mammal-like reptiles	
Paleozoic	Permian	299	Radiation of reptiles; origin of most present-day orders of insects; extinction of many marine and terrestrial organisms at end of period		
	Carboniferous	359.2	Extensive forests of vascular plants; first seed plants; origin of reptiles; amphibians dominant		
	Devonian	416	Diversification of bony fishes; first tetrapods and insects		
	Silurian	443.7	Diversification of early vascular plants		
	Ordovician	488.3	Marine algae abundant; colonization of land by plants and arthropods		
	Cambrian	542	Sudden increase in diversity of many animal phyla (Cambrian explosion)		
		600	Diverse algae and soft-bodied invertebrate animals		
Archaean			2,200	Oldest fossils of eukaryotic cells	
			2,500		
			2,700	Concentration of atmospheric oxygen begins to increase	
			3,500	Oldest fossils of cells (prokaryotes)	
			3,800	Oldest known rocks on Earth's surface	
			Approx. 4,600	Origin of Earth	



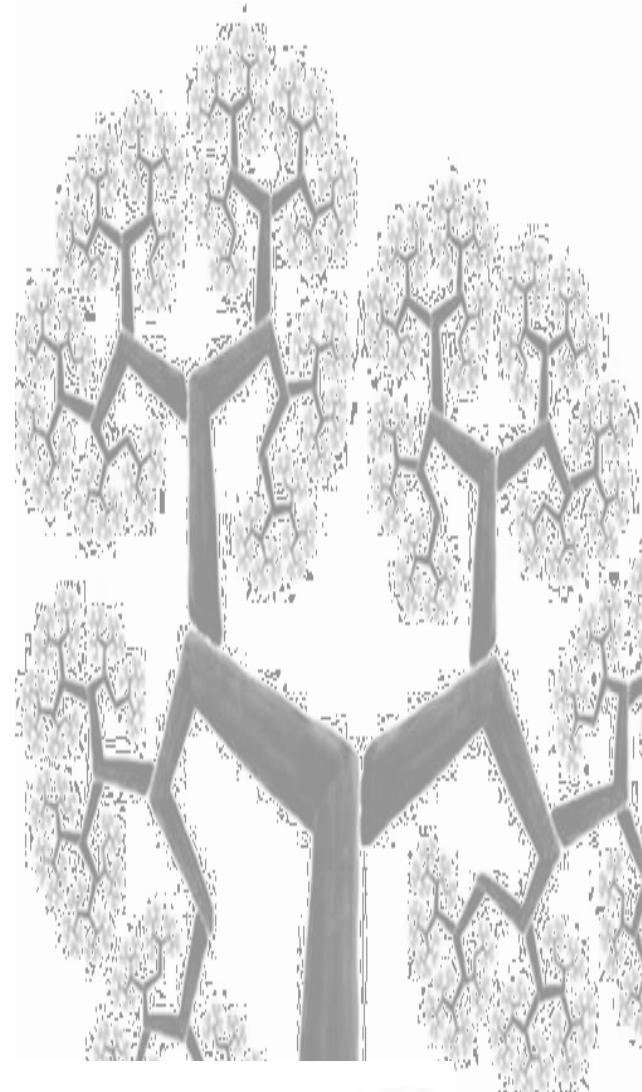
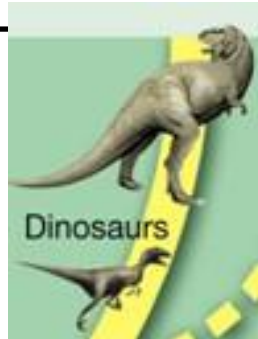
Extinction

- The termination of a lineage without issue or abrupt disappearance of specific groups of organisms without leaving descendents. The death of a species or group of taxa

Types: **True Extinction** and **Pseudoextinction**

1. True Extinctions -particular lineage totally disappears without any progeny or evolutionary descendents.

- E.g. extinction of dinosaurs as a group ; trilobites.

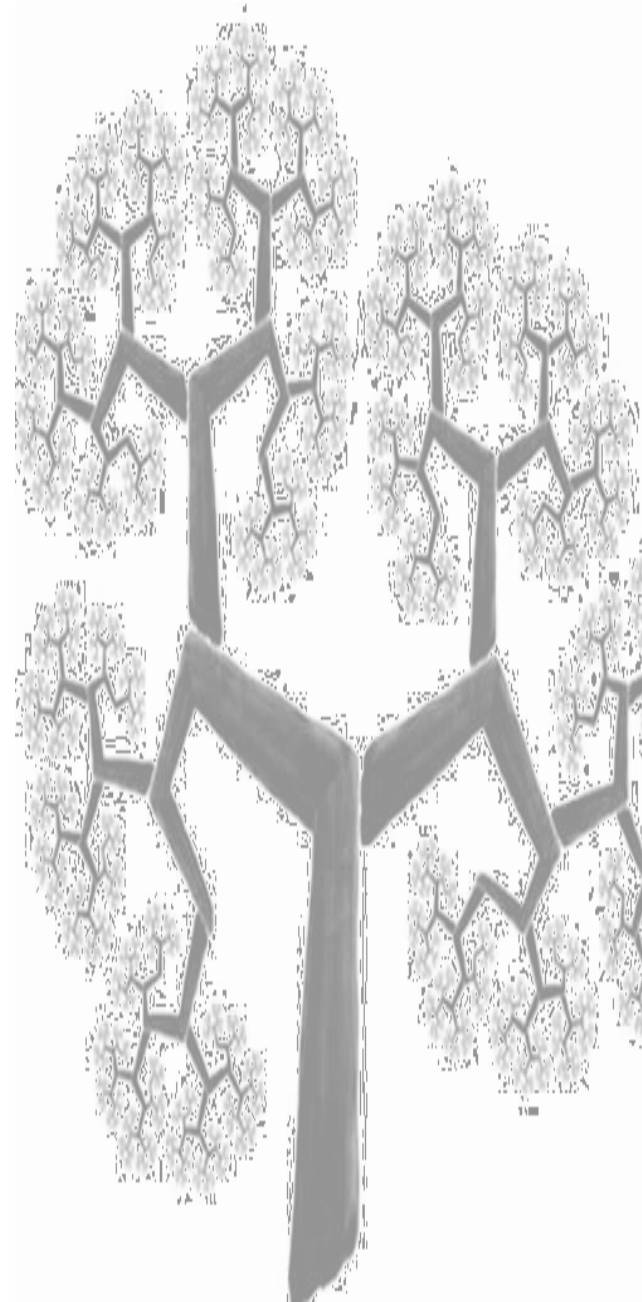
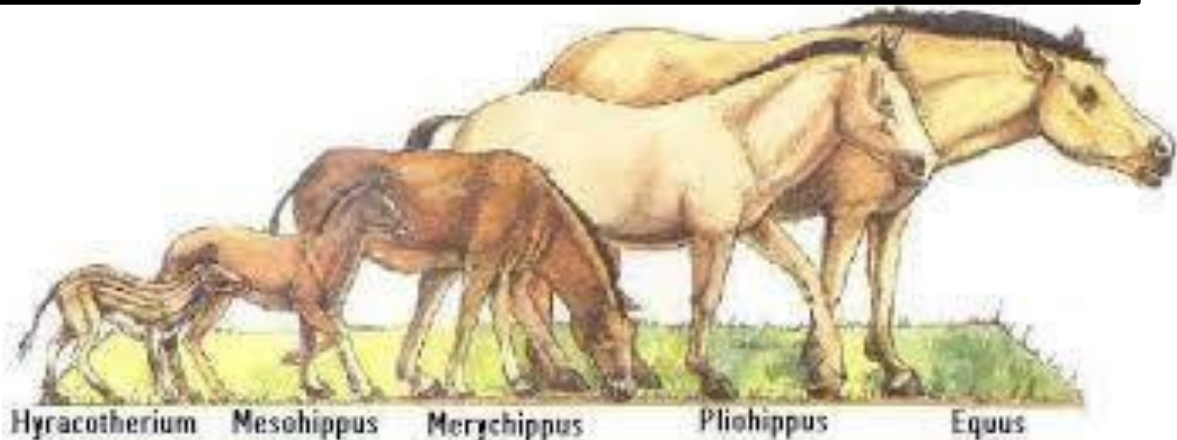


Extinction

2. **Pseudoextinction** (phyletic extinction or phyletic transformation) - a group may disappear leaving descendents with evolutionary modifications.

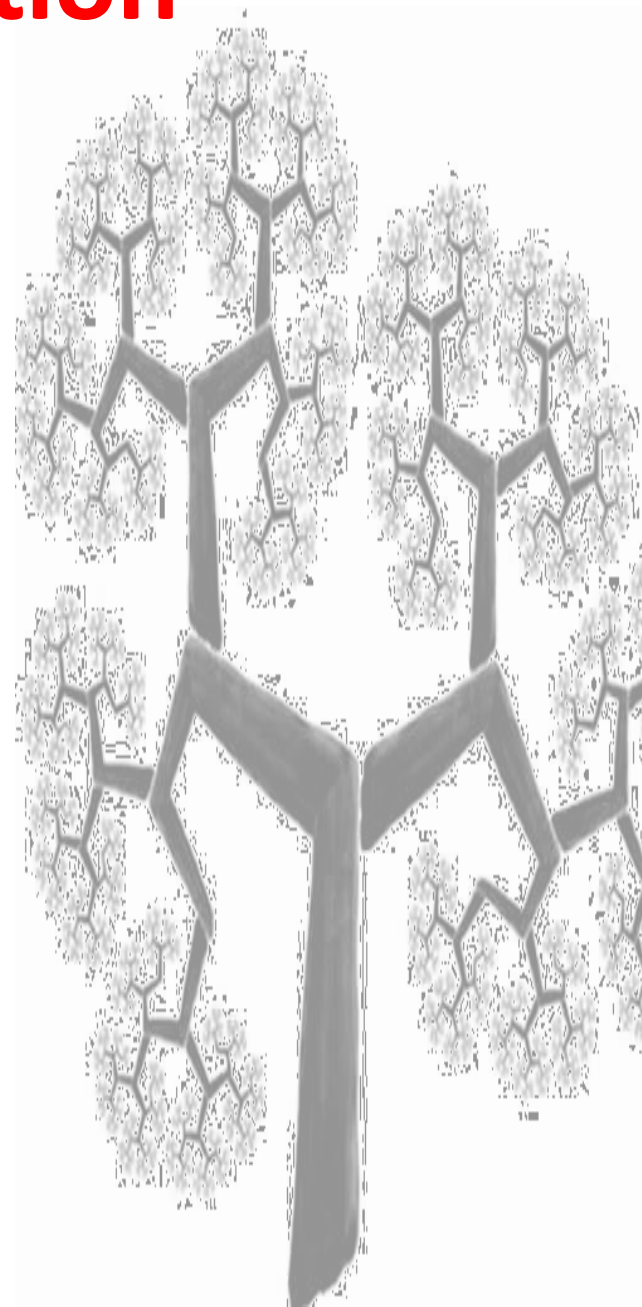
Example:

Horse evolution while the earliest ancestor became extinct its descendant survived to produce the modern '**Equus**'.



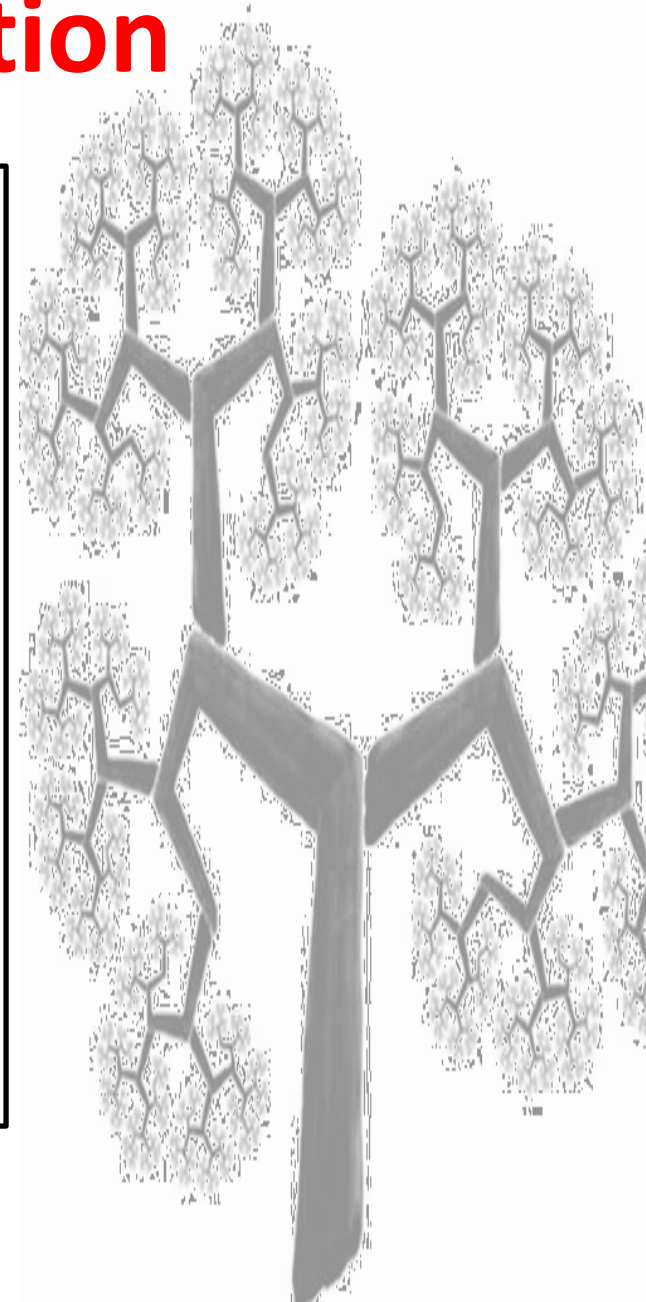
Pattern of extinction

- Major groups of herbivorous vertebrates are more susceptible than the carnivorous vertebrates
- Larger organisms easily became extinct.
- VanValen (1973) recorded a constancy in the rate of extinction in a number of groups.
 - Explained using 'Mac Arthor's law' - "every new adaptation encourages the survival of a possessor it also decreases a fitness of other species of that area".



Causes of extinction

- (1) A mass extinction: due to drastic changes in the environmental conditions.**
 - (2) Any adaptive advance in one species decreases the fitness of all other species.**
- ❖ **Red Queen's hypothesis : you have to keep running pretty fast, just in order to stay in the same place.**

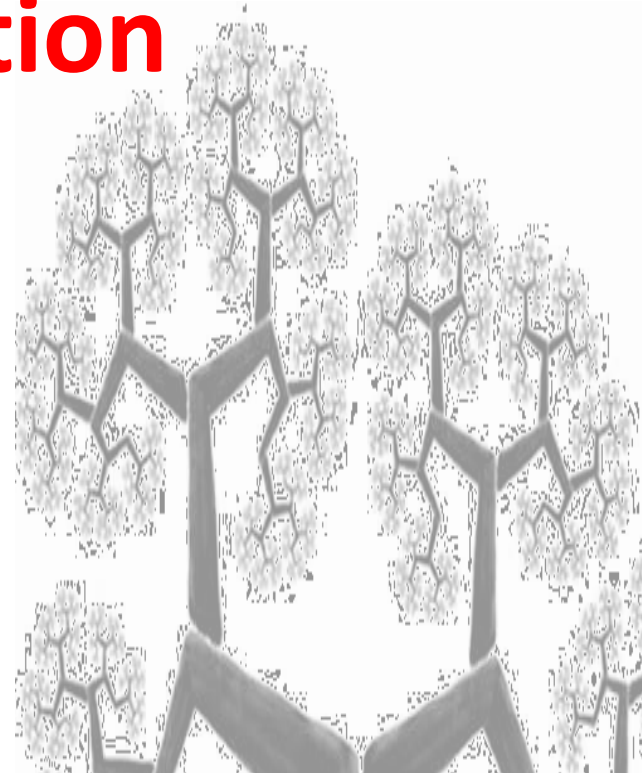


Causes of extinction

(3) Over specialization to a specific situation may cause extinction (ex. Antlers)

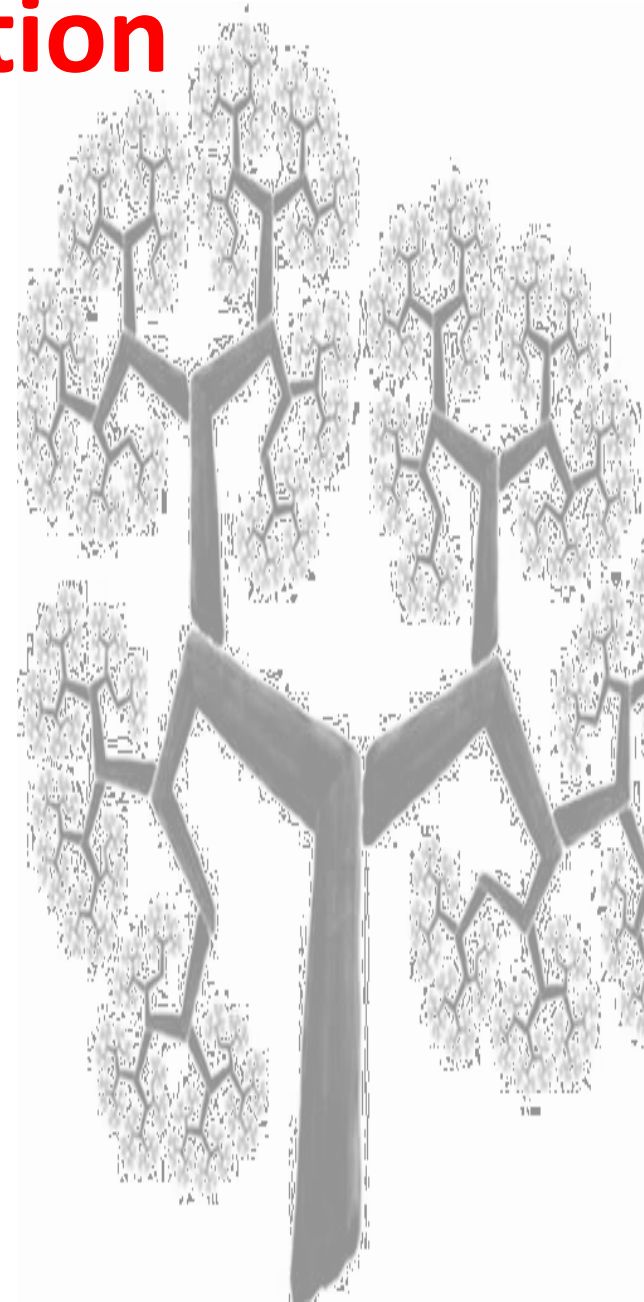
(4) The spread of an epidemic disease without any control can cause extinction.

(5) An increase in the population strength of herbivorous animals cause rapid food shortage and cause extinction for several inter-related groups (Predation, competition)



Causes of extinction

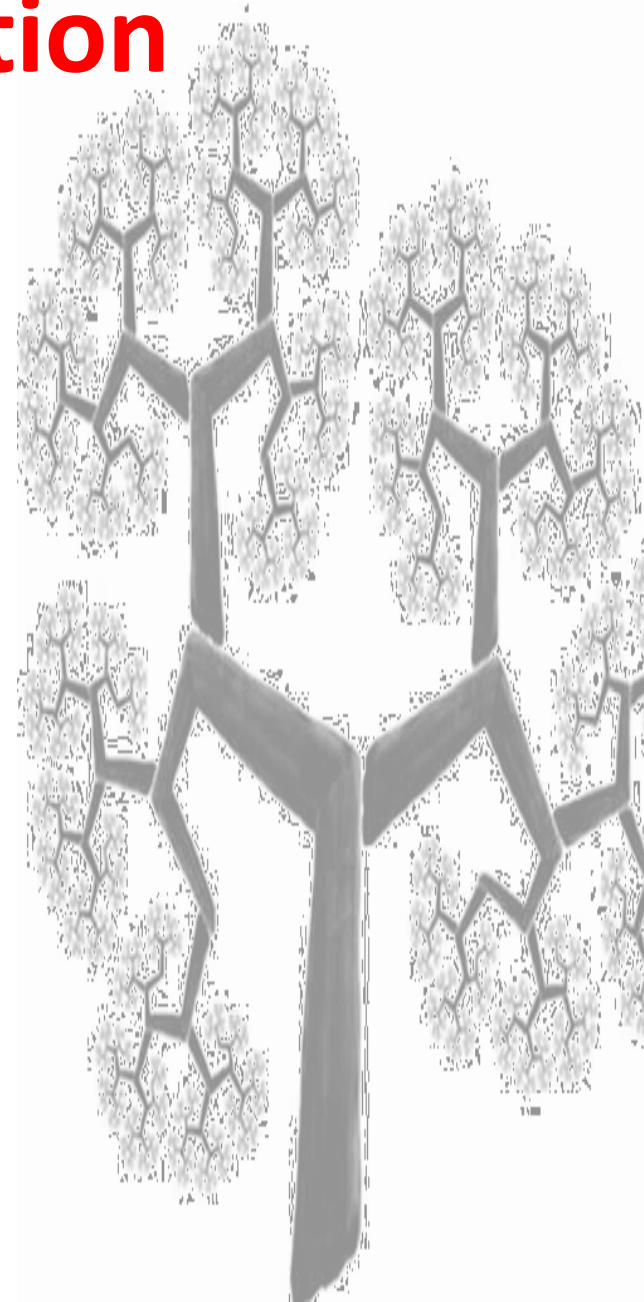
- (6) A sudden cosmic radiation can cause the death of large organisms.
- (7) A dust storm formed due to falling of a meteorite is commonly mentioned as a cause for the disappearance of dinosaurs.
- (8) Habitat degradation: The degradation of a species' habitat may alter the fitness landscape or such an extent that the species is no longer able to survive and becomes extinct.



Causes of extinction

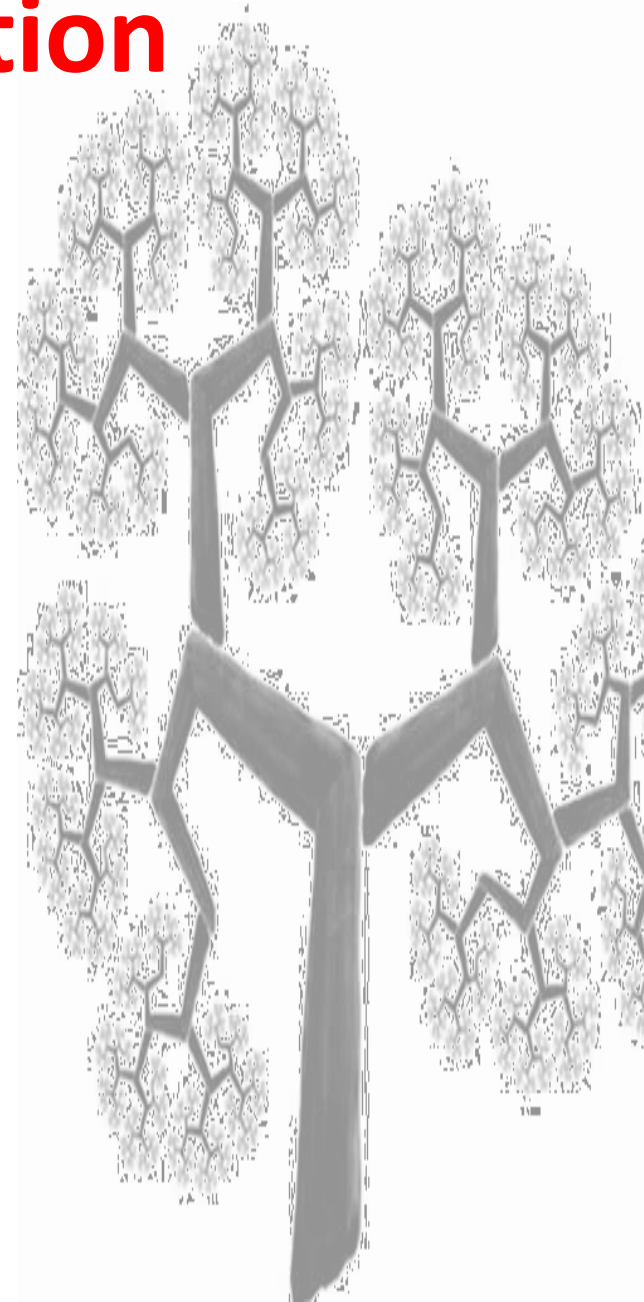
(9) Coextinction: the loss of a species due to the extinction of another; for example, the extinction of parasitic insects following the loss of their hosts

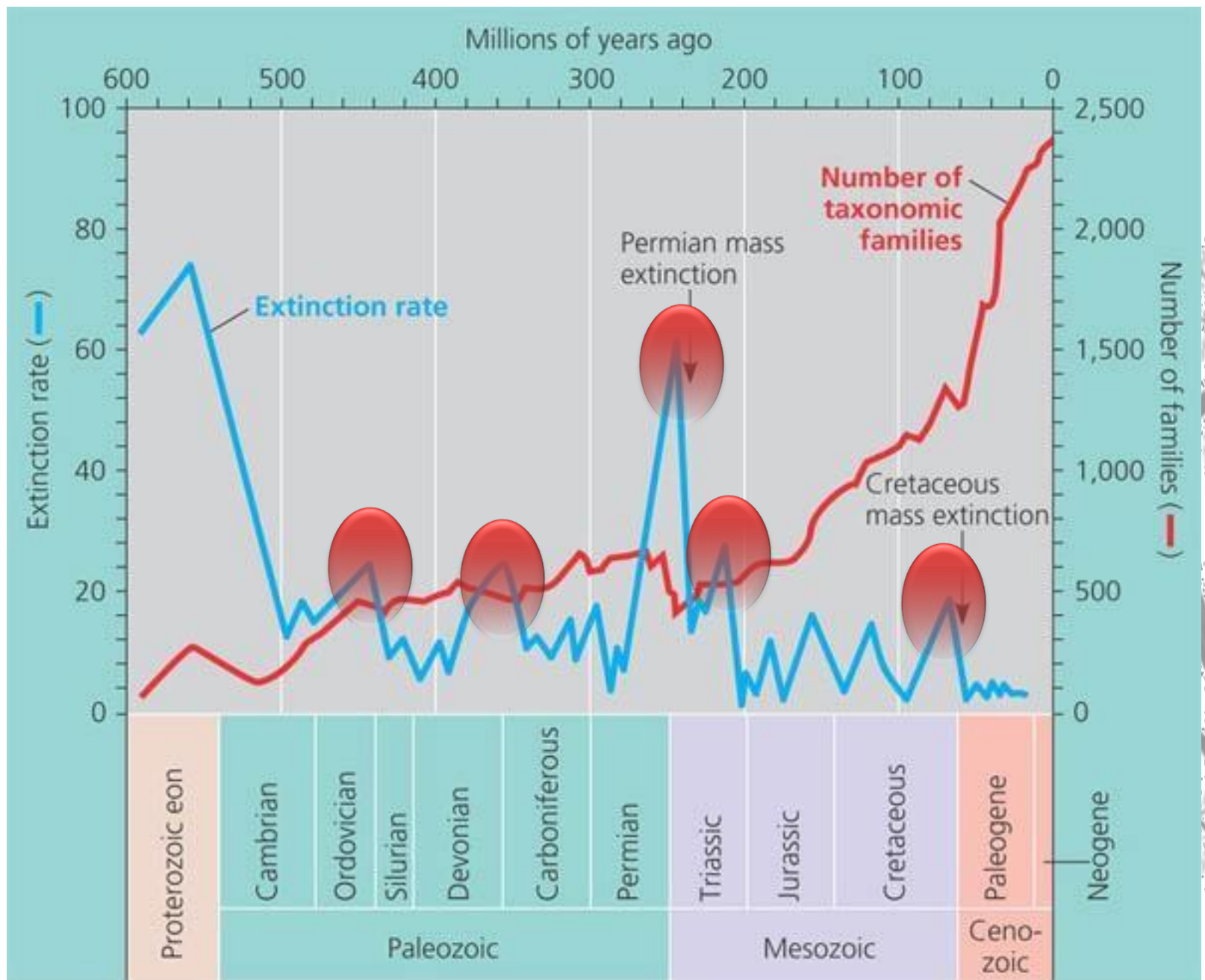
(10) Genetic Pollution: uncontrolled hybridization, introgression genetic swamping which leads to homogenization or replacement of local genotypes as a result of a numerical and/or fitness advantage of the introduced plant or animal



Causes of extinction

- In the recorded history of earth, extinctions of major groups of organisms were due to natural causes.
- By end of Permian period of the Paleozoic Era, nearly 60% of the varieties then existed, became extinct.
- Similar large scale extinctions have been observed by the end of Mesozoic era





Causes of extinction

At present ...

- mostly due to human interference.
- The realization of such a cause lead to starting of several international voluntary agencies to monitor and control extinctions.
- “The red-data book brought out regularly by W. W. F (World Wide Fund for nature, Formerly IUCN - international union for the conservation of nature and natural resources) provides a list of animals and plants that are endangered or have become extinct.



THE IUCN RED LIST
OF THREATENED SPECIES™

